Determining Spatial Distribution and Physical Properties of the Vashon Advance Outwash near Mountlake Terrace, WA

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Executive Summary

This study is aimed at determining the spatial distribution, physical properties, and groundwater conditions of the Vashon advance outwash (Qva) in the Mountlake Terrace, WA area. The Qva is correlative with the Esperance Sand, as defined at its type section; however, local variations in the Qva are not well-characterized (Mullineaux, 1965). While the Qva is a dense glacial unit with low compressibility and high frictional shear strength (Gurtowski and Boirum, 1989), the strength of this unit can be reduced when it becomes saturated (Tubbs, 1974). This can lead to caving or flowing in excavations, and on a larger scale, can lead to slope failures and mass-wasting when intersected by steep slopes. By studying the Qva, we can better predict how it will behave under certain conditions, which will be beneficial to geologists, hydrogeologists, engineers, and environmental scientists during site assessments and early phases of project planning.

In this study, I use data from 27 geotechnical borings from previous field investigations and C-Tech Corporation's EnterVol software to create three-dimensional models of the subsurface geology in the study area. These models made it possible to visualize the spatial distribution of the Qva in relation to other geologic units. I also conducted a comparative study between data from the borings and generalized published data on the spatial distribution, relative density, soil classification, grain-size distribution, moisture content, groundwater conditions, and aquifer properties of the Qva.

I found that the elevation of the top of the Qva ranges from 247 to 477 ft. I found that the Qva is thickest where the modern topography is high, and is thinnest where the topography is low. The thickness of the Qva ranges from absent to 242 ft. Along the northern, east-west trending transect, the Qva thins to the east as it rises above a ridge composed of Pre-Vashon glacial deposits. Along the southern, east-west trending transect, the Qva pinches out against a ridge composed of pre-Vashon interglacial deposits. Two plausible explanations for this ridge are paleotopography and active faulting associated with the Southern Whidbey Fault Zone. Further investigations should be done using geophysical methods and the modeling methods described in this study to determine the nature of this ridge.

The relative density of the Qva in the study area ranges from loose to very dense, with the loose end of the spectrum probably relating to heave in saturated sands. I found subtle correlations between density and depth. Volumetric analysis of the soil groups listed in the boring logs indicate that the Qva in the study area is composed of approximately 9.5% gravel, 89.3% sand, and 1.2% silt and clay. The natural moisture content ranges from 3.0 to 35.4% in select samples from the Qva. The moisture content appears to increase with depth and fines content.

The water table in the study area ranges in elevation from 231.9 to 458 ft, based on observations and measurements recorded in the boring logs. The results from rising-head
and falling-head slug tests done at a single well in the study area indicate that the geometric mean of hydraulic conductivity is 15.93 ft/d \((5.62 \times 10^{-3} \text{ cm/s})\), the storativity is \(3.28 \times 10^{-3}\), and the estimated transmissivity is 738.58 ft²/d in the vicinity of this observation well. At this location, there was 1.73 ft of seasonal variation in groundwater elevation between August 2014 and March 2015.
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Acronyms and Abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
</tr>
<tr>
<td>BGS</td>
<td>Below ground surface</td>
</tr>
<tr>
<td>Brightwater Project</td>
<td>Brightwater Treatment Plant Conveyance System</td>
</tr>
<tr>
<td>CL</td>
<td>Lean clay</td>
</tr>
<tr>
<td>D&amp;M</td>
<td>Dames &amp; Moore</td>
</tr>
<tr>
<td>DEM</td>
<td>Digital Elevation Model</td>
</tr>
<tr>
<td>GeoEngineers</td>
<td>GeoEngineers, Incorporated</td>
</tr>
<tr>
<td>GP</td>
<td>Poorly-graded gravel</td>
</tr>
<tr>
<td>GP-GM</td>
<td>Poorly-graded gravel with silt</td>
</tr>
<tr>
<td>GM</td>
<td>Silty gravel</td>
</tr>
<tr>
<td>GW</td>
<td>Well-graded gravel</td>
</tr>
<tr>
<td>ID</td>
<td>Inner Diameter</td>
</tr>
<tr>
<td>ML</td>
<td>Lean silt</td>
</tr>
<tr>
<td>Mw</td>
<td>Moment magnitude</td>
</tr>
<tr>
<td>Mya</td>
<td>Million years ago</td>
</tr>
<tr>
<td>N-Value</td>
<td>Standard Penetration Resistance</td>
</tr>
<tr>
<td>NAVD</td>
<td>North American Vertical Datum</td>
</tr>
<tr>
<td>OD</td>
<td>Outer Diameter</td>
</tr>
<tr>
<td>Qaf</td>
<td>Quaternary artificial fill</td>
</tr>
<tr>
<td>Qpfnmw</td>
<td>Interglacial mass wasting deposits (pre-Vashon)</td>
</tr>
<tr>
<td>Qpg</td>
<td>Glacial, grouped (pre-Vashon)</td>
</tr>
<tr>
<td>Qpgf</td>
<td>Glacial, fluvial (pre-Vashon)</td>
</tr>
<tr>
<td>Qpgl</td>
<td>Glacial, lacustrine (pre-Vashon)</td>
</tr>
<tr>
<td>Qpn</td>
<td>Interglacial, grouped (pre-Vashon)</td>
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<td>Qpnf</td>
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<tr>
<td>Qpnl</td>
<td>Interglacial lacustrine (pre-Vashon)</td>
</tr>
</tbody>
</table>
Qva Vashon advance outwash
Qvlc Vashon Lawton Clay
Qvr Vashon recessional outwash
Qvt Vashon till
SFZ Seattle Fault Zone
SM Silty sand
SP Poorly-graded sand
SP-SM Poorly-graded sand with silt
SPT Standard Penetration Test
ST-LLE Sound Transit Lynnwood Link Extension
SW Well-graded sand
SWIF Southern Whidbey Island Fault Zone
SW-SM Well-graded sand with silt
USGS United States Geological Survey
UW University of Washington
1.0 Introduction

The purpose of this research project is to characterize the spatial distribution and physical properties of the Vashon advance outwash (Qva) near Mountlake Terrace, WA, and to compare these characteristics to more extensive and generalized properties of the Qva, as defined in previous works. The information and methods provided in this report will be beneficial to geologists, hydrogeologists, engineers, and environmental scientists during site assessments and early phases of project planning.

In general, Qva is a granular, well-sorted, and permeable glaciofluvial unit (Mullineaux et al., 1965). According to Troost et al. (2005), the Qva is equivalent of the Esperance Sand of Mullineaux et al. (1965). Although the Qva has high frictional shear strength and low compressibility as the result of glacial consolidation (Gurtowski and Boirum, 1989), some of the unit’s properties can facilitate increased geologic or environmental risks. For instance, the development of water pressure in the pore space between granular particles may significantly decrease the shear strength of the unit; this is a contributing factor to landslides in western Washington (Tubbs, 1974). The permeable properties of the Qva also pose difficulty to excavations where dewatering, shoring, or other procedures are required to prevent water-bearing sands from caving, flowing, or collapsing (Laprade and Robinson, 1989). Additionally, the Qva forms an extensive, unconfined aquifer that may act as a conduit for chemical pollutants (Bjerg and Christensen, 1993; Golder Associates, 2008). The properties described above make this hydrostratigraphic unit susceptible to contamination, erosion, seepage, and landslides. Understanding of both the spatial distribution and physical properties of Qva in a specific context can aid in developing improved mitigation practices and prediction of slope failures, more informed decisions in building design and practices, improved groundwater modeling, and more accurate mapping of areas susceptible to both geologic hazards and environmental contamination.

1.1 Study Area

The study area is in a mixed residential and commercial area in proximity to the community of Mountlake Terrace. Geographically, it is 12 mi north of Seattle's metropolitan center, 2.5 mi northwest of Lake Washington, and 1.5 mi east of the Puget Sound shoreline. Lake Ballinger is located towards the center of the study site. The topography of this area consists of gently rolling drumlin hills from the last glaciation. The relief at the study site ranges from approximately 289 to 492 ft in elevation. Geologic hazards at this site include landslide-prone areas and erosion/sedimentation hazards as defined by the City of Mountlake Terrace ordinance codes (City of Mountlake Terrace, 2015; GeoEngineers, 2015). The project site is about 2.95 sq mi, and includes 5 transect lines, totaling 8.84 lineal miles (Figure 1). The southern edge of the study area is approximately 75 ft south of the King/Snohomish County...
border. The eastern border of the study area is Interstate-5. The location and boundaries of the study site were determined based on the availability of quality data.

2.0 Scope of Work

This report characterizes and refines the spatial distribution, physical properties, and groundwater conditions of the Qva in the Mountlake Terrace area by:

1) documenting the spatial extent and thickness variations of Qva in cross-sections and three-dimensional models,

2) describing the spatial variation in density using standard penetration test (SPT) data from existing geotechnical boring logs,

3) describing variations in grain size and moisture content, using lab analyses of available soil samples, and

4) describing aquifer properties and groundwater conditions where data is available.

The work described above consisted of the following tasks:

1) obtaining and reviewing existing technical reports, geologic maps, topographic maps, soil survey data, laboratory test results, groundwater data, geospatial imagery, and other publications that aided in characterizing the subsurface conditions of the project site,

2) creating a database that includes the locations of the boreholes and the elevation of every geologic contact within each borehole,

3) generating cross-sections and three-dimensional models, using information in the above described database and C-Tech Corporation’s EnterVol software, to illustrate the lateral and vertical distributions of the advance outwash, and

4) evaluating variations in the unit thickness, elevation, physical properties, and groundwater conditions.

3.0 Background

In this section, I discuss the previous investigations that have been done within the study area and give a general overview of the Qva.

3.1 Previous Investigations

This study incorporates data from 27 existing geotechnical borings, summarized in Table 1, and their corresponding geotechnical reports. These data were collected by local consulting firms and government agencies for various geotechnical investigations. The boring logs and geotechnical reports are publicly available through the Freedom of Information Act, and I
obtained the data by directly contacting the firms and agencies that house the documents. The following paragraphs describe the investigations that were previously conducted in the study area, and the data from them that I used to supplement my research.

A large investigation was conducted in King and Snohomish Counties for the Brightwater Treatment Plant Conveyance System (Brightwater Project), which was completed in 2012. This project consisted of two geotechnical studies, which are discussed in the next two paragraphs.

In 2002, Shannon & Wilson and HWA Geoscience began the initial investigation for the Brightwater Project, which consisted of 27 geotechnical borings and laboratory testing of select soil samples (King County, 2002). The purpose of this investigation was to determine the subsurface conditions for conceptual engineering and environmental impact assessment. Shannon & Wilson used the mud rotary method to drill their borings, while HWA Geosciences used a combination of mud rotary and Becker Hammer methods. Both companies used a 2.42-inch inner diameter (ID), 3.25-inch outer diameter (OD), ring-lined Dames and Moore (D&M) split-barrel sampler with a 300 lb. hammer dropped 30-inches to obtain soil samples. The borings that I used from this study ranged from 352 to 446.5 ft in depth, and include MW-3, MW-4, MW-5, and MW-6 from HWA Geosciences, and BW-4, BW-5, and BW-6 from Shannon & Wilson (Table 1).

The second investigation for the Brightwater Project was completed by CDM Smith and various subconsultants in 2003. The purpose of this investigation was to provide geotechnical services for the design of the wastewater treatment facility. These services included land-based drilling, soil sampling, in-situ testing, hydrogeologic testing, gas monitoring, and geophysical explorations, as well as geologic, index, strength, and deformation testing in the laboratory (King County, 2004). This study included a total of 157 borings. The drilling methods used to complete the borings included hollow-stem auger, mud rotary, rotosonic coring, and wireline coring. Soil samples were collected using a D&M sampler with a 300 lb. or 140 lb. hammer. The borings that I used from this study include E-105, E-106, E-107, E-108, E-109, E110, and E211, which range from 260 to 566 ft in depth (Table 1). Index tests were not completed on any of the soil samples within the Qva from these six borings. However, geologic testing was done on select samples to determine the stratigraphic relationships between the soil units. This testing included radiocarbon dating, optically-stimulated luminescence dating, tephrochronology, x-ray diffraction mineral analysis, bulk geochemistry, and micro- and macro-paleontological analyses (of shells, diatoms, and pollen).

In 2008, Golder Associates conducted a study to provide an overview of the geology and hydrogeology near Mountlake Terrace for OTAK, Inc., and published their findings in a technical memorandum. They used a compilation of existing data, including the Brightwater Environmental Impact Statement, nearby monitoring wells, and city and county data, to
determine the groundwater conditions in their study area. This study was particularly important for the groundwater analysis of my research because not a lot of groundwater data were readily available in my study area; however the Golder Associates (2008) study overlapped with a portion of my study area.

Another large investigation was completed in the Mountlake Terrace area. During the summer of 2014, GeoEngineers, Inc. (GeoEngineers) provided geotechnical consulting services for the Sound Transit Lynnwood Link Extension\(^1\) (ST-LLE), which will extend the Link light rail from Seattle to Lynnwood. This investigation used hollow-stem auger and mud rotary methods to drill 84 boreholes ranging from 40 to 101.5 ft in depth (GeoEngineers, 2015). Samples were collected using a 2-inch OD split-barrel standard penetration test (SPT) sampler in accordance with the American Society for Testing and Materials (ASTM) standard D 1586, or with a 3-inch diameter Shelby tube sampler in accordance with ASTM D 1587. The SPT samples were obtained by driving the sampler 18 inches into the soil with a 140 lb. hammer free-falling 30-inches. The data that I used from this investigation includes: index test results, groundwater measurements, and boring logs from 13 geotechnical borings (Table 1).

### 3.2 Vashon Advance Outwash

In general, glacial advance outwash is a thick unit of fluvial sediments that are deposited by high-energy meltwaters ahead of an advancing glacier (Koloski \textit{et al.}, 1989). These glaciofluvial sediments are then overridden by the glacier, resulting in post-depositional compaction (Easterbrook, 1969). Advance outwash is mostly composed of clean sand, although it often contains a wide range of grain sizes (Tubbs, 1974). As with other fluvial systems, coarser materials are deposited close to the source, and finer materials are sorted and carried away from the source; this process results in a coarsening-up sequence, by which silty sands are deposited farther away from the glacier, and gravel and coarser grained materials are deposited closer to the glacier (Moses, 2008). However, this coarsening up sequence is only a simplified facies model, and in actuality braided streams, point bars, and other fluvial features complicate the stratigraphy of these deposits (Troost and Booth, 2008).

The Qva is described as well-sorted, dense to very dense, fine to medium sand with lenses of gravel, silt, and clay (Mullineaux \textit{et al.}, 1965). The Qva type section is an outcrop in the cliffs at Fort Lawton, in Discovery Park, Seattle, WA (Troost and Booth, 2008). Here, the unit is defined as outwash related to the advance of the Vashon Glacier and includes the transitional zone from the underlying Lawton Clay (Qvlc) (Mullineaux \textit{et al.}, 1965). The transitional zone between the Qva and the Qvlc is typically tens of feet thick, and contains interbedded sand and silt/clay representing the transition from a proglacial lake to a stream environment.

\(^{1}\)I contributed to various aspects of the project while interning at GeoEngineers. Tasks that I helped with included logging borings, taking piezometer and barometer measurements, observing slug tests, surveying, and conducting laboratory analysis of field samples.
(Kathy Troost, University of Washington (UW), personal communication, 2015). In areas where the Qvlc is absent, the onset of the Vashon Stade is marked by the Qva, which may be in contact with pre-Vashon glacial (Qpg) or interglacial deposits (Qpn) (King County, 2002; King County, 2004; Troost and Booth, 2008; GeoEngineers, 2015). About 50% of Qva is capped by Vashon glacial till (Qvt) (Kathy Troost, UW, written communication, 2015). The contact between the Qva and the Qvt varies between sharp and gradational (Laprade and Robinson, 1989; Troost and Booth, 2008). Exposures of Qva can be found bluffs and steep gullies that reach the upland (Kathy Troost, UW, written communication, 2015).

There is some variability in the bedding and depositional setting of the Qva; studies suggest that the Qva was deposited subaerially to subaqueously (Troost and Booth, 2008). Subaerial sedimentation is indicated by remnants of channels, gravel bars, and fine-grained lenses from braided streams, whereas subaqueous sedimentation is recognized by remnants of deltas, turbidites, and horizontal bedding in proglacial lakes, at the terminus of outwash streams (Troost and Booth, 2008). The Qva that is considered to have been subaqueously deposited contains foreset beds and cross-bedding that are steeply dipping at 30-40° (Kathy Troost, UW, personal communication, 2015). Cross-bedding is also common in subaerial deposits, but is generally not as tall as in the deltas (Kathy Troost, UW, written communication, 2015).

3.2.1 Hydrogeology

In the Mountlake Terrace area, the Qva forms an extensive, unconfined aquifer with a saturated thickness of about 100 ft, and an unsaturated thickness ranging from 20 to 100 ft (Golder Associates, 2008). The groundwater in the Qva discharges to surface water, primarily to Hall Creek and Lake Ballinger, via hydraulic connection with recessional outwash or alluvium (Golder Associates, 2008). Golder Associates (2008) states that Lake Ballinger appears to be underlain by Lawton Clay or pre-Fraser deposits, which have low permeability. Additionally, groundwater from the Qva may be recharging deeper aquifers in the area (Golder Associates, 2008). The rate of groundwater recharge ranges from 15 to 20 in/yr in areas where permeable outwash is exposed at the surface, and is less than 10 inches per year in areas that are capped by till or are urbanized (Golder Associates, 2008). Typical hydraulic conductivity data for glacial sediments, and a conceptual hydrogeologic model of geologic units located in the Mountlake Terrace area can be found in Appendix A.

As mentioned above, the basal portion of the Qva is often saturated with groundwater, which is retarded by the underlying less-permeable Qvlc, Qpf, or Qpg geologic units (Tubbs, 1974; Appendix A). If the contact between these units is exposed at the surface, the saturated zone in the Qva can be identified by seeps and springs (Miller, 1989). The contact between these hydrostratigraphic units has been identified as the location of frequent landslides in the Puget Lowland (Tubbs, 1974).
4.0 Geologic Setting

The following sections describe the regional, local, and structural geology in relation to the study area.

4.1 Regional Geology

The study area is located in the Puget Lowland section of the Salish Lowland physiographic province (Haugerud, 2004). The Puget Lowland is a structural and glacially-eroded trough centered between the Cascade Range to the east and the Olympic Mountains and Willapa Hills to the west (Troost and Booth, 2008; Moses, 2013; Figure 2). Major geographic features of the Puget Lowland include the San Juan Islands, the Puget Sound, and the Strait of Juan de Fuca. The Puget Lowland is characterized by a dynamic landscape that has been largely shaped by continental glaciations, tectonic activity, and volcanism (Troost and Booth, 2008). The geomorphic processes that occurred during glacial and interglacial periods have greatly influenced the modern topography of this region (Booth, 1994).

The Cordilleran Ice Sheet was a continental ice sheet that extended from southeastern Alaska, to northern Washington, and across to northwestern Montana during the Quaternary (about 2.59 million years ago (Mya) to present); there were been at least seven glacial advances during this time (Booth et al., 2003; Troost and Booth, 2008). The Cordilleran Ice Sheet included the Puget, Okanogan, Columbia River, Purcell Trench, and Flathead Lobes, which extended into western Washington, north-central Washington, eastern Washington, northern Idaho, and northwestern Montana, respectively (Booth et al., 2003). During the Vashon Stade of the Fraser Glaciation, the Puget Lobe extended farther south than Olympia, WA, and occupied the area between the Cascade Range and the Olympic Mountains (Thorson, 1979; Porter and Swanson, 1998; Troost and Booth, 2008; Figure 2). At its maximum extent, the Puget Lobe was as much as 3,300 ft (1,000 m) thick in the Seattle area, and 6,600 ft (2,000 m) in British Columbia (Porter and Swanson, 1998; Clague and James, 2002).

The surficial geology of the Puget Lowland consists predominantly of Vashon-aged (about 15,000 to 13,000 ya) glacial sediments, with intermittent exposures of Tertiary bedrock of Paleocene (about 66 to 56 Mya) to Oligocene (about 33.9 to 23 Mya) age (Moses, 2013). The generalized Quaternary section in the Puget Lowland consists of pre-Vashon glacial and interglacial deposits overlain by glaciolacustrine clays and silts, advance outwash sands, glacial till, and recessional outwash from the Vashon Stade (Galster and Laprade, 1991; Savage et al., 2000; Figure 3). At least seven glacial advances have been documented in the Puget Lowland (Troost and Booth, 2008). Glacial loading has resulted in the over-consolidation of glacial and interglacial sediments, with the exception of Vashon recessional outwash, which was deposited as the glacier retreated (Galster and Laprade, 1991).
The slopes in the Puget Lowland are prone to landslides and other slope stability issues (Mullineaux et al., 1965; Tubbs, 1975). There are several contributing factors for this, which include geologic and climatic conditions, as well as anthropogenic influences (Tubbs, 1974). The contact between the Qva and the less-permeable underlying units has been identified as the “slip-surface” for several large landslides in the Seattle area (Tubbs, 1974). Sixty-four percent of all historical (between 1909 and 1999) landslides in Seattle occurred within 150 ft of the Qva/Qvlc contact (Coe et al., 2004). During periods of heavy precipitation, water can accumulate above silt and clay lenses within the Qva and above the confining layers that underlie the Qva (Miller, 1989). This occurrence consequently decreases the stability of the soils by elevating the pore fluid pressures between the grains in the Qva (Tubbs, 1974). The stratigraphic placement of the Qva, which is an aquifer, above less-permeable units, which create an aquitard, is a key factor in the landslides in this area (Tubbs, 1974).

4.2 Local Geology

The surficial geology in the vicinity of the project site is predominantly Vashon Stade glacial deposits, as is documented in the boring logs used in this study (King County, 2002; King County, 2004; GeoEngineers, 2015). A conceptual hydrogeologic model of the geologic units in the Mountlake Terrace area can be found in Appendix A (revised from Golder Associates, 2008). Glacial deposits of the Vashon Stade found in the study area include the following units: recessional outwash (Qvr), glacial till (Qvt), advanced outwash (Qva), and proglacial lacustrine deposits, which are formally referred to as the Lawton Clay (Qvlc). Also within the study reach is: Holocene alluvium (Qal), artificial fill (Qaf), and peat (Qp); pre-Fraser interglacial fluvial (Qpfnf), lacustrine (Qpfnl), wetland deposits (Qpfnw), and mass wastage deposits (Qpfnmw); and pre-Olympia glacial outwash (Qpogf), glaciolacustrine deposits (Qpogl), glaciomarine drift (Qpogm), glacial till (Qpogt, Qpogtm), and glacial diamict deposits (Qpogd). For the purposes of this paper, I amalgamated the pre-Fraser interglacial deposits and labeled them as Qpn. Similarly, I grouped the pre-Olympia glacial deposits together and labeled them as Qpg. In summary, the geology documented in the boring logs used in this study exemplify cycles of glacial and interglacial erosion and deposition.

4.3 Structural Geology

Tectonic activity in this area is occurring at both regional and local scales (Atwater et al., 1995; Pratt et al., 1997). At the regional scale, the convergence of the Juan de Fuca plate and the North American plate form the Cascadia Subduction Zone, which is capable of producing up to moment magnitude (Mw) 9.0 earthquakes (Wells et al., 1998; Nedimovic et al., 2003). Additionally, the northward movement of the Pacific plate is causing complex seismic strain (north-south shortening) to accumulate throughout western Washington and Oregon (Pratt et al., 1997; Wells et al., 1998; WA-DNR, 2015). This strain, in combination with glacial isostatic adjustment, has created several large fault systems in western Washington (Figure 2). These faults produce more than 1,000 earthquakes each year (Lasmanis, 1991). Thick
Quaternary deposits of glacial and interglacial sediments conceal many of these faults. Furthermore, dense vegetation and widespread urbanization obscure active fault traces, making it difficult to study faults in this area.

There are two major fault zones in proximity to the study site, the Seattle Fault Zone (SFZ) to the south, and the Southern Whidbey Island Fault Zone (SWIF), which may run through the project site (Blakely et al., 2004; Troost and Booth, 2008; Barnett et al., 2010). Both of these fault zones are poorly located, for reasons described above.

The SFZ is composed of a series of west-trending, south-dipping thrust faults that have resulted from north-south compression due to the convergence of the Pacific, Juan de Fuca, and North American plates (Johnson et al., 2004; Lamb et al., 2012). The Seattle fault is thought to be around 30 Myrs old, and is considered an active fault (Nelson et al., 2014). There is evidence for several significant ruptures in the past 15,000 years, including 20 feet of vertical displacement during an earthquake dated 1,100 years ago (Atwater and Moore, 1992). The SFZ is about 31 mi long and is capable of producing up to Mw 7.0 earthquakes (Blakely et al., 2002; Nelson et al., 2014). The SFZ is recognized by Eocene (about 56 to 33.9 Mya) bedrock juxtaposed against Quaternary (about 2.59 Mya to present) glacial deposits, and large geophysical anomalies (Lasmanis, 1991; Blakely et al., 2002). Three east-trending strands of the fault have been identified, although the exact boundaries of the SFZ are still under investigation (Johnson et al., 1999; Blakely et al., 2002).

The SWIF is another active fault in the Puget Lowland, and is capable of producing up to Mw 7.1 earthquakes (Sherrod et al., 2008). Unlike the Seattle fault, the SWIF has a northwest-trend and a steep northeast-dip (Johnson et al., 1996). The SWIF is thought to have originated in the early Eocene (about 56 to 47.8 Mya) as an arc-parallel strike-slip fault (Liberty and Pape, 2006). The SWIF may be as long as 93 mi long, originating in Victoria and extending to Seattle, where it may merge with the SFZ (Sherrod et al., 2008). It has been identified through the use of seismic-reflection surveys, borehole data, and gravity and magnetic anomalies (Sherrod et al., 2008). The SWIF is composed of several strands across a zone that is 3.75 to 6.8 mi wide (Johnson et al., 1996). The strands have inferred dextral strike-slip, reverse, and thrust displacement (Johnson et al., 1996). The SWIF was conceptualized by Johnson et al., (1996) as an oblique, right-lateral strike-slip fault, that sometimes form transpressional flower structures, and by Brocher et al., (2005) as an advancing wedge bound by roof and floor thrusts. Paleoseismological evidence suggests that the SWIF last ruptured about 2,700 years ago, and has produced at least four significant earthquakes since the retreat of the Vashon Glacier (Sherrod et al., 2008). Evidence for recent activity includes stratigraphic offset and disruption, structural relief, displacement in Quaternary sediments, Quaternary folds, liquefaction features, and minor historical seismicity (Johnson et al., 1996).
5.0 Methods

In this section I describe the methods that I used to obtain and analyze data, and create two- and three-dimensional subsurface models. In addition to studying the Qva in the study area for this project, the modeling methods described in this section can be applied to various other subsurface studies.

5.1 Data Acquisition

I began this study by reviewing existing data about the geology, topography, and hydrogeology of the area. During this stage, I gathered LiDAR images (U.S. Geological Survey, 2001), aerial photographs (Google Earth Pro, 2012), geologic maps (Booth et al., 2004), and technical reports (King County, 2002; King County, 2004; Golder Associates, 2008; GeoEngineers, 2015). I used the Subsurface Geology Information System published by the Washington State Department of Natural Resources (WA-DNR) to view available borehole information. I used the locations of boreholes with sufficient data to determine the boundaries of the study area and to draw the transect lines for the cross-sections. I contacted the appropriate consulting firms and government agencies to obtain the boring logs and geotechnical reports that were pertinent to my study. The boring logs and geotechnical reports that I used in my study were from GeoEngineers for the ST-LLE Project, and from Shannon & Wilson, HWA Geosciences, and CDM Smith for the Brightwater Project. These projects are described in detail in Section 3.1, and a summary of the borings used in this study can be found in Table 1. From the boring logs, I was able to obtain data on stratigraphic unit descriptions, soil classifications, elevations, blow counts, laboratory index test results, and groundwater observations. However, not all boring logs had this complete set of information. The boring logs also identified the geologic units that were observed while drilling, based on visual-manual classifications, laboratory testing, and/or age-determination. I used the labels found in the boring logs as a reference for identifying the Qva in my study.

5.1.1 Unit Thickness

To determine the thickness and variability of the Qva, I created a table of geologic contact elevations (Table 2) based on the information from the boring logs, which can be found in Appendix B. The vertical extent of this study was bound between the ground surface and 100 ft elevation, though not all borings reached this depth and many went deeper. Although the lower limit of the Qva is much shallower than 100 ft elevation, I chose to terminate the vertical extent of the study at this elevation because it provides sufficient context for the paleotopography that might influence the thickness of the Qva. I used Table 2 to develop five cross-sections, a block diagram, and a fence diagram, which are described in Section 5.3.
5.1.2 Relative Density

The soil density values that I used in this study were estimated using field data (N-values\(^3\)) that were recorded at various depths during previous investigations. The N-values recorded for the ST-LLE Project were acquired using a SPT sampler, and were done in accordance with ASTM D 1586. However, the N-values recorded for the Brightwater Project were acquired using a D&M sampler. Although the D&M sampling method is different from the standard test, the blow counts still provide a relative indication of soil density and consistency (King County, 2002). SPT and D&M sampling are considered to be correlative with respect to blow counts, so long as the hammer weight is adjusted to the sampler size, so that the energy delivered to the subsurface is equivalent (Kathy Troost, UW, personal communication, 2015).

There are several variables that affect the integrity of N-value data; this includes drilling method, sampling method, and soil conditions. Different types of drilling methods influence the disturbance in the soil samples in different ways. For the purposes of this study, I analyzed N-value data from samples that were acquired during mud rotary drilling for the following reasons. Soil heave often occurs while drilling in water-bearing sands that are under confining pressures; this compromises the integrity of blow counts and soil samples (Nielsen, 2005). Mud rotary drilling reduces the pressure gradient by adding mud inside the auger, which minimizes heave in water-bearing sands, such as the Qva (Munch and Killey, 1985). Sampling method also effects the N-value. In this study, I use data collected by SPT and D&M sampling methods. Additionally, soil conditions influence the accuracy of blow counts. An inaccurate measure of the soil density can be measured if the soil sampler hits a large gravel or boulder that prevents the sampler from being driven into the soil. Also, if the refusal was met (i.e. the sampler did not penetrate 6-inches into the soil after 50 blows by the hammer), the N-value is recorded as the inches driven per 50 blows (ex: 50 blows for 4-inches), rather than the number of blows taken to drive the sampler the final 12- or 18-inches. For these reasons, I did not include N-values for samples that hit refusal. Only 14 of the 196 SPT and D&M samples were collected during mud rotary drilling, and were not met with refusal. These 14 samples provide the most reliable N-value data.

5.1.3 Laboratory Test Results

I used the information provided in the boring logs from previous investigations and their corresponding geotechnical reports to obtain laboratory test results of select Qva samples (King County, 2002; King County, 2004; GeoEngineers, 2015). The tests on these samples

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\(^3\) Standard penetration resistance (N-value) is the number of blows it takes a 140 pound hammer, free-falling 30 inches, to drive a 2-inch OD SPT sampler the final 12- or 18-inches. The N-values provide a general understanding of the resistance to penetration and is a measure of the relative soil density.
were completed using the following standards: ASTM D 1140, for Percent Fines\textsuperscript{4} Determination; ASTM D 422 for Grain Size Distribution; ASTM D 2216, for Moisture Content Determination; and ASTM D 2487, for Classification of Soils.

5.1.4 Groundwater Conditions

My analysis of the groundwater conditions is limited by the amount of data that were readily available. I used information from the boring logs and geotechnical reports to obtain groundwater elevations. Some of the groundwater data in the boring logs and geotechnical reports were based on observations while drilling, while other data were measured with a vibrating wire piezometer (VWP), pressure transducer, or other measuring instruments. The approximate groundwater elevations, dates of record, and methods of measurement are annotated on the cross-sections (Figures 4-8) where data was available.

Single-well field hydraulic conductivity tests (slug tests) were performed at two wells in the study area, BW-6 and LLE-B11P, by Shannon & Wilson for the Brightwater Project and by GeoEngineers for the ST-LLE Project, respectively. The semi-log plots of water level versus time for the BW-6 slug test were provided in the King County (2002) geotechnical report. However, no interpretation or analysis of the test was provided.

5.2 Data Analysis

I used scatter plots to examine if the density, fines-content, and moisture content directly influenced each other. I plotted the N-values obtained during mud rotary drilling (see Section 5.1.2) against various other variables (percent fines, depth, and elevation) to determine if any of these variables directly influence the density of the soil. As a comparison, I evaluated the N-values obtained during mud rotary, Becker hammer, and hollow-stem auger drilling methods. I also evaluated moisture content and percent fines in relation to each other, to elevation, and to depth from ground surface. In addition, I conducted a volumetric analysis of the soil classifications within the Qva for all 27 borings.

5.3 Modeling

One of the main purposes of this research is to determine the three-dimensional (lateral and vertical) extent of the Qva. To accomplish this, I used ArcGIS and EnterVol to add a third dimension to previously completed two-dimensional studies. The following sections describe the methods that were used to generate a cross-section for each of the five transect lines, a block diagram, a fence diagram, and an isopach map of the Qva thickness. These models help illustrate the spatial variability of the Qva in the study area.

\textsuperscript{4} Fine grained sediments are defined by ASTM D 1140 as material finer than 75 µm, or as particles that can pass through a No. 200 sieve.
5.3.1 Cross-Sections

I used borehole data and various extensions of ArcGIS to create five cross-sections. The purpose of creating the cross-sections is to illustrate the spatial variability in two-dimensions along a transect line. I began this phase of modeling by marking and exporting the location of each borehole and transect line in Google Earth (Figure 1). I then collaborated with Gene Lohrmeyer at GeoEngineers to complete the following steps using ArcGIS. We first imported the locations of the borings and transect lines in ArcGIS. We then created a shapefile for each borehole and transect line, which we projected to the NAD 1983 State Plane Washington North (ft) coordinate system. We used a 10-meter digital elevation model (DEM) from the U.S. Geological Survey as an elevation datum (U.S. Geological Survey, 2001). We then interpolated the lines using their positions along the DEM to create an elevation profile for each of the five transects. I then digitally drew the stratigraphy for each cross-section, using data from the boring logs to infer the subsurface geology. I did this for each of the five cross-sections, shown in Figures 4-8.

5.3.2 Three-Dimensional Models

I collaborated with Gene Lohrmeyer at GeoEngineers to create block and fence diagrams, and an isopach map of the Qva, using EnterVol, which is an extension of ArcGIS.

To create the block diagram, we first georeferenced the borehole locations to the NAD 1983 State Plane Washington North (ft) coordinate system in ArcGIS-ArcScene, ESRI’s three-dimensional viewing platform, and exported the data into our EnterVol map. We then created two new models to define the lateral and vertical extents of the study area. The first model used a shapefile with an xy-grid to define the two-dimensional (lateral) extent of the area to be analyzed. Next, we used elevation data to define the three-dimensional (vertical) extent of the area to be modeled; the top of the borings served as the upper extent and the bottom of the borings as the lower extent. We then added a third model to assign stratigraphic values to the three-dimensional model, based on the borehole data in Table 2. We automated the block diagram in EnterVol using an inverse distance weight algorithm and the three models described above. We then created a fence diagram by making slices of the block diagram along each of the five transect lines.

We also created an isopach map of the unit thickness. We did this by first isolating the Qva in the block diagram. Then we converted this segment of the diagram to a point cloud, and saved it as a shapefile. Next, we opened the shapefile in ArcMap, and added x and y values to the points. We used the natural neighbor interpolation to create a surface from these points based on elevation, using a 10 m grid cell size to match the DEM used in earlier steps. Finally, we converted the interpolated raster surface to 25 ft vector contours to illustrate the thickness of the Qva, as modeled by EnterVol.
6.0 Observations

6.1 Spatial Distribution

The surface of the Qva in the study area is found at a maximum elevation of 477 ft at boring LLE-B17 and at a minimum elevation of 247 ft at boring E-108 (Table 2, Figures 4-8). The depth to the top of the Qva varies from 0 to 109.8 ft below ground surface (bgs). The bottom of the Qva ranges in elevation from 406 ft at boring LLE-B17 to 178.5 ft at boring BW-4. The depth to the bottom of the Qva ranges from 53 to 279 ft bgs. The thickness of this unit varies from 21 to 242 ft in the three-dimensional models (Figures 9-12), and from 0 to 242 ft in the geotechnical boring logs (Table 1). The Qva thins to the east between borings BW-4 and BW-6, along Transect 1 (Figure 4). The thickness and continuity of the Qva is impacted by an apparent ridge at boring E-109, along Transect 2 (Figure 5). At this location the Qva pinches out, and pre-Fraser interglacial deposits (Qpn) are exposed at the surface. Along Transects 3 through 5, the Qva is thickest where the modern topography is high, and is thinnest where the topography is low (Figures 6-8, respectively).

The block diagram in Figure 9A shows the extent of the Qva, as modeled in EnterVol, and Figure 9B shows the block diagram with a vicinity map overlay for reference. There are discrepancies between the three-dimensional models created in EnterVol and the cross-sections (Figures 4-8). Similar to the cross-sections, the block and fence diagrams shows the Qva thinning to the east (Figures 9A and 10). However, there is no surface expression of the ridge that pinches out the Qva in the three-dimensional models. Similar to the cross-sections, the Qva in the block and fence diagrams is thickest where the topography is greatest (Figures 9A and 10). Figures 11A and 11B combine the Qva unit from the block diagram with the fence diagram to help illustrate the extent of the Qva in relation to other geologic units.

The three-dimensional models show that the Qva is thickest at the southwestern extent of the study area, as is illustrated in Figure 12. The Qva appears to thin to the east along Transects 1 and 2, to the north along Transect 3, and to the south along Transects 4 and 5 (Figure 12). The thickness of the Qva appear to decrease as a function of elevation along Transects 3, 4, and 5, which trend north-south. The Qva is thinnest in valleys and other topographic lows, and is thickest at modern topographic highs.

6.2 Physical Properties

6.2.1 Relative Density

The relative density of the Qva in the study area was evaluated based on review of SPT and D&M blow count data collected during the drilling of geotechnical borings. The relative density ranges from dense (N-value range: 30-50) to very dense (N-value: 50+), based on the 14 N-values collected during mud rotary drilling, described in Section 5.2 (Appendix C). As a comparison, the relative density data collected during all drilling methods ranged from loose
(N-values range: 4-10) to very dense (N-values: 50+). There appears to be a slight correlation between density and fines content (Figures 13). I did not find a correlation between density and elevation (Figure 14). However, relative density appears to increase with depth from the ground surface (Figure 15). All N-Values recorded within the Qva can be found in the boring logs (Appendix B). Data regarding fines content, elevation, and depth can be found in the boring logs in Appendix B and in the borehole data summary sheet in Appendix C.

6.2.2 Grain Size

A wide range of grain sizes were recorded for the soil samples that had sieve analyses. The following is a summary of the content of soil samples that were collected from the Qva: gravel content ranged from 0 to 48.2%, the sand content ranged from 40.9 to 97.6%, and the fines content ranged from 1.3 to 36%. Silt and clay lenses are located throughout the Qva. The sample with the highest fines content (36%) was located 40 ft bgs and 7 ft below the top of the Qva, at boring LLE-10S. Results from sieve analyses can be found in Appendix C.

A volumetric analysis of the Qva show that this unit is composed of the following soil groups: 6.6% well-graded gravel (GW), 1.9% poorly-graded gravel (GP), 0.9% poorly-graded gravel with silt (GP-GM), 0.1% silty gravel (GM), 3.5% well-graded sand (SW), 2.7% well-graded sand with silt (SW-SM), 33% poorly-graded sand (SP), 37.3% poorly-graded sand with silt (SP-SM), 12.8% silty sand (SM), 0.9% lean silt (ML), and 0.3% lean clay (CL) (Figure 16A). The soil classifications follow ASTM D 2487, which is summarized in Appendix D. A volumetric analysis of the soil groups within the Qva of each boring is shown in Figure 16B and is summarized in Table 3.

I found a slight correlation between the fines content and the relative soil density (Figure 13). Additionally, all samples with greater than 10% fines content were dense to very dense. I did not find a correlation between fines content and depth nor elevation (Figure 17). Lab test results from sieve analysis and fines content determination can be found in the boring logs (Appendix B), and in the borehole data summary sheet (Appendix C).

6.2.3 Moisture Content

The natural moisture content of select samples from the Qva range from 3.0 to 35.4% natural moisture, by weight. There is a slight trend (exponential, \( R^2 = 0.3226 \)) correlating depth from the ground surface to an increase in moisture content (Figure 18). Likewise, there is a slight linear trend (\( R^2 = 0.2730 \)) correlating elevation and moisture content (Figure 18). The moisture content also appears to increase with an increase in fines content (Figure 19).

6.3 Groundwater Conditions

I found that the top of the water table in the Qva aquifer ranged from 231.9 to 458 ft in elevation, based on the 16 groundwater measurements that were recorded in the
geotechnical boring logs (Appendix B). Rising head and falling head slug tests\(^5\) were done at LLE-B11P on August 04, 2014. The results of the slug tests indicate that the geometric mean of hydraulic conductivity is 15.93 ft/d (5.62 x 10\(^{-03}\) cm/s), the storativity is 3.28 x 10\(^{-03}\), and the estimated transmissivity is 738.58 ft\(^2\)/d in the vicinity of this observation well (GeoEngineers, 2015). The groundwater at LLE-B11P changed from an elevation of 354.83 ft on August 12, 2014 to an elevation of 355.04 on March 13, 2015. During this time period, the lowest groundwater elevation was recorded at 354.74 ft on September 23, 2014, and the peak groundwater elevation was recorded on February 08, 2015 at 356.47 ft, for a difference of 1.73 ft between the summer and winter seasons. The groundwater elevation at LLE-B11P increased after significant precipitation events (Figure 20).

7.0 Analysis & Discussion

In this section I discuss the observations from this study in relation to data found in published literature (Table 4). I will also discuss how and why my findings deviate from published data on the Qva. These comparisons will help geologist, hydrogeologists, engineers, and environmental scientists conceptualize local variations in the Qva that may affect slope stability, groundwater dynamics, engineering properties, and migration of contaminants.

7.1 Spatial Distribution

In a previous study, it was determined that the Qva ranges from 50 to 200 feet in thickness in proximity to Lake Ballinger (Golder Associates, 2008). Additionally, Mullineaux et al. (1965) commented that glacial advance outwash is typically greater than 100 ft thick, and Troost and Booth (2008) found that the Qva ranges from absent to 400 ft thick. I found that the thickness of the Qva in the study area ranges from 0 to 242 ft. This is comparable to findings from published data (Table 4), although the thickness is greater than reported by Golder Associates (2008).

The elevation of the top of the Qva in the study area ranges from 247 to 477 ft. Troost and Booth (2008) found that the top of the Qva was deposited between elevations of 400 and 600 ft, and that the top of this unit is locally lower where subsequent erosion has occurred. At boring E-108, where the top of the Qva is at 247 ft elevation, there is a thick deposit of Qvr overlying the Qva (Figures 5 and 11A). This depression in the Qva may be an erosional feature formed by the advancing glacier, and later filled in with recessional outwash as the glacier retreated. It is also possible that this abnormality was caused by geomorphic or tectonic processes.

The automated three-dimensional models in this study show that the base of the Qva is not flat due to preexisting topography (Figures 4-9A). Troost and Booth (2008) found that the

\(^5\) I observed these tests, which were part of the ST-LLE project, while interning at GeoEngineers.
Qva fills paleotopographic valleys and channels, some of which are below sea level. The bottom elevation of the Qva in the study area ranges from 178 to 406 ft. Figures 11A-11B show the extent of the Qva in relation to other units.

The thickness of the Qva is greatest at topographic highs (Figures 4-8); Troost (2006) found this to be true over much of the Puget Lowland. This is likely due to a combination of pre-existing topography at the time of deposition and preservation from erosional forces. According to the models generated in this study, the topographic highs in the study area are capped by till, which is conceivably shielding the Qva from erosion. However, further explorations are needed to verify the location of the till in the study area.

7.1.1 Variability in Unit Thickness

The thickness of the Qva is impacted by an apparent ridge at boring E-109 on Transect 2 (Figure 5). There are two plausible explanations for the nature of this ridge. The first possibility is that the ridge represents a paleotopographic high, and that the Qva was either eroded or was never deposited at this location. Evidence for erosion includes the contact between Qvr and Qva, and the absence of Qvt at boring E-108 on Transect 2. A second hypothesis is that this ridge represents vertical displacement from a conjugate of the SWIF, which is proximal to the study area. Supporting evidence for this hypothesis includes: indications of off-set and movement recorded in boring logs, differences in stratigraphy between Transects 1 and 2, and geologic mapping of the SWIF close to the study sight. Slickensides, fractures, and other indications of movement are documented in boreholes BW-4, BW-5, and BW-6, on Transect 1, and in E-105, MW-4, E-106, E-107, E-108, MW-5, E-109, E-110, and E-211 on Transect 2. Interglacial mass wasting deposits (Qpfnmw) are also recorded in boring E-108 on Transect 2 (Figure 5, Appendix B). Slickensides represent past shearing displacement between two surfaces, and may indicate faulting, persistent landslide movement, or stress relief from isostatic rebound as the result of glacial ice melting (Miller, 1989). The slickensides found in this area could have formed under any one of the three conditions listed above, or by a combination of those conditions. However, it is also possible that the slickenslides, which were recorded in the Qvlc, Qpn, and Qpg, were created while drilling. The stratigraphic relationships along Transects 1 and 2 are not consistent (Figures 4 and 5, respectively). Transect 1 shows that the bottom of the Qva is in contact with Qvlc and Qpg, and that Qpg overlies Qpn. However, in Transect 2, the bottom of the Qva is in contact with Qvlc and Qpn, which overlie Qpg. The ages of the Qpn and Qpg have not been determined, so it is unclear if the stratigraphic relationship between the Qpn and Qpg in these two transects is undisturbed, or if it represents an unconformity or off-set. Finally, Sherrod et al. (2008) identified lineaments of the SWIF close to the study site using magnetic and gravity anomalies. However, the exact locations of the lineaments are not well-constrained. In summary, there are two possibilities to define the nature of the ridge that the
Qva pinches out against. However, further research is needed to determine the nature of this ridge.

7.2 Physical Properties

The relative density of the 14 Qva samples measured in the study area are consistent with values published by Glaster and Laprade (1991). I found that the density of the Qva generally increases with increasing fines content. Theoretically, this makes sense. “Clean” sands could have a lower blow count than “dirty” sands, because fine-grained sediments can fill void space and give the sands cohesion. However, the sample size that I used in this study was limited, and this correlation may be due to random chance. I also found that the density of the Qva generally increases with depth. This correlation can be explained by the increase in compressive forces on the sediment with depth, making them more compact. However, not all of the very dense (N-value of 50+) soil samples contained a significant percentage of fine-grained material, and some of the samples were located near the surface. Therefore, factors other than fines content and depth influence the density of the Qva. Weathering, bioturbation, stress relief, and downslope movement are a few factors that may reduce soil density, while cobbles and boulders may prevent the sampler from advancing or may increase blow counts.

I found that the Qva in the study area is composed of about 89.3% sand, 9.5% gravel, 0.9% silt, and 0.3% clay. I did not find a correlation between fines content and depth. Despite the coarsening-up facies model of the Qva, I would not expect there to be a correlation between fines content and depth because the depositional environments (high-energy braided streams with subaqueous termini) were dynamic and complex; therefore, the sediments were not uniformly distributed based on grain size.

I found that the natural moisture content of samples collected for the Qva in the study area increase with an increase in fines content and depth, and a decrease in elevation. I would expect these correlations for the following reasons: the fines content likely aids in water retention via adsorption and cohesion, and moisture content probably increases with depth and decreases with elevation as the result of gravity and proximity to groundwater.

7.3 Groundwater Conditions

Variations in the top and bottom elevations of the Qva will influence the flow patterns of groundwater. The thickness of the Qva may also influence the depth to water (see boring E-107, Figure 5). I found that the saturated thickness of the Qva ranges from 0 to 102 ft within the study area. This is comparable to the findings in Golder Associates (2008), which states that the saturated thickness ranges from 10 to 100 ft in the Mountlake Terrace area (Table 4). I found that the depth to the saturated Qva aquifer ranged from 7 to 221 ft bgs in the study area. It was reported in the King County (2002) geotechnical report that the groundwater
elevation varies, although they found that soils 20 to 70 ft bgs were generally saturated (King County, 2002).

Golder Associates (2008) states that the potential for infiltration is good in areas where the Qva is exposed at the surface and a sufficient unsaturated thickness exists. At boring LLE-B11P, the Qva is exposed at the ground surface. However, the groundwater was recorded at 7.4 ft bgs on August 12, 2014. The Qva at this location is 46.5 ft thick; therefore, approximately 84% of the total thickness of the unit is saturated at LLE-B11P. The groundwater elevation at boring LLE-B11P peaked following large precipitation events (Figure 20). This suggests that the aquifer is responding to meteoric water. However, the seasonal variations in water level are less than 2 ft at this location. This low seasonal flux is likely attributed to the aquifer being semi-confined, either by silt lenses within the Qva or by a nearby Qvt cap. The Qva at this location ranges in group classification from SP-SM to SM; the silt content may attribute to the semi-confined aquifer conditions. These data were recorded between August 12, 2014 and February 08, 2015; a longer study may show larger seasonal variation in groundwater flux.

8.0 Conclusions

The characteristics of the Qva make it an important geologic unit. The Qva has high frictional shear strength and low compressibility, which provides good support for foundations and other developments (Gurtowski and Boirum, 1989). The Qva is also an important hydrostratigraphic unit because it forms an extensive, unconfined aquifer (Golder Associates, 2008). However, the Qva is also susceptible to slope instability, erosion, seepage, and contamination. Studying the spatial distribution and physical properties of the Qva will benefit geologists, hydrogeologists, engineers, and environmental scientists with respect to decision making, prediction, and mitigation.

Understanding the spatial distribution of the Qva is significant to geologists, hydrogeologists, engineers, and environmental scientists. The contact between the Qva and the Qvlc is a known “slip-surface” for several large landslides in the Seattle Area (Tubbs, 1974), so documenting the location of this contact is important for geologists working on slope stability issues. Additionally, anomalies in the Qva, such as the one found at boring E-109, may provide insight to other geologic concerns. The top and bottom elevations of the Qva significantly influence the flow patterns of groundwater, and consequently, the migration of any contaminants that leach into the groundwater. Likewise, the variability in thickness of the Qva will directly affect the hydraulic conductivity, storativity, and transmissivity of groundwater in the aquifer. Knowledge of the spatial distribution of the Qva is also significant to engineers for the purposes of construction design and feasibility planning.

The spatial distribution of the Qva in the study area is comparable to generalized published data for the Qva across the Puget Lowland. The top of the Qva ranges in elevation from 247
to 477 ft. This is consistent with Troost and Booth (2008), which states that the top of the Qva ranges from 400 to 600 ft in elevation, and at lower elevations where there has been subsequent erosion. The thickness of the Qva ranges from 0 to 242 ft in the study area, which is within the limits of Qva measured in other studies (Table 4). The three-dimensional models generated using \textit{EnterVol} show that the Qva is not a homogeneous unit in terms of lateral and vertical distribution (Figures 9A-11B). The Qva thins to the east in Transect 1 (Figure 4), and pinches out against a ridge in Transect 2 (Figure 5). In addition to locally affecting groundwater flow patterns and aquifer properties, this apparent anomaly in the Qva on Transect 2 may have broader geologic implications relating to paleotopography or a regional fault system.

The physical properties (density, grain size distribution, and moisture content) of the Qva also have significant implications on the geology, hydrogeology, engineering, and environmental sciences. For example, the hydraulic conductivity of the Qva aquifer will be directly affected by the porosity of the soil it is traveling through. Additionally, silt and clay lenses within the Qva may create perched aquifers or cause seepage, which creates the potential for issues relating to slope stability and erosion. The density and grain size distribution will also affect engineering properties, such as excavatability, angle of repose, and cohesion.

I found that the relative density of samples analyzed in this study ranged from loose to very dense (Appendix C), with the loose end of the range probably resulting from heave. I found that all samples that had greater than 10% fines content were either dense or very dense (Figure 13). Although the Qva is primarily composed of sand, I found that this unit contains an assortment of grain sizes. Individual soil samples contained as much as 48.3% gravel, 97.6% sand, and as much as 36% fine sediment (Appendix C). A volumetric analysis of the soil groups show that the Qva is composed of the following classifications, listed from greatest to least volume: 37.3% SP-SM, 33% SP, 12.8% SM, 6.6% GW, 3.5% SW, 2.7% SW-SM, 1.9% GP, 0.9% GP-GM, 0.9% ML, 0.3% CL, and 0.1% GM (Figures 16A-B). I also found that the natural moisture content from samples collected in the study area range from 3.0 to 35.4%, and increase as a function of depth and fines content (Figures 18-19).

Groundwater dynamics considerably influence the geology and engineering properties of the Qva. Elevated pore-pressures caused by large precipitation events are known to destabilize slopes (Tubbs, 1975). Groundwater also affects the feasibility of developing in the Qva. Although groundwater data were scarce, I found that the elevation of the water table in the Qva ranges from 231.9 to 458 ft. The saturated thickness of the Qva (0-102.13 ft) is comparable to findings from other investigations (Table 4). However, I found that the depth to the saturated aquifer (7.59-221.3 ft bgs) was much greater in the study area than was reported in the King County (2002) geotechnical report, which states that the depth to groundwater is generally 20-70 ft bgs. The results of rising- and falling-head slug tests at
boring LLE-B11P determined the following groundwater characteristics at this location: mean hydraulic conductivity (15.93 ft/d), storativity \(3.28 \times 10^{-3}\), and transmissivity (738.58 ft\(^2\)/d). The seasonal variation in groundwater elevation at boring LLE-B11P was 1.73 ft, as recorded between August 12, 2014 and March 13, 2015. The Qva at this location is silty. The silt content at this location could be partially confining the aquifer, and thus minimizing the seasonal flux. However, data from a pressure transducer installed at this location shows that the aquifer is responding to precipitation events.

Subsurface models can be used to gain a better understanding the relationships between geologic units. In this study, I used EnterVol to try to model the spatial variability of the Qva. While this program has some limitations, I found that it useful for creating three-dimensional models that illustrate the relationships between the Qva and the other geologic units. Overall, EnterVol produced what I needed, and I would recommend it for other subsurface studies.

9.0 Limitations and Assumptions

This study is limited to publicly available data, and the accuracy of those data. The data include, but are not restricted to: geotechnical boring logs, geologic maps, technical reports, memorandums, aerial photographs, and geospatial data.

Although the available subsurface data were sufficient, this study could have benefited from additional borehole data. Transects 1, 2, and 5 are the most reliable, because these transects have a greater concentration of borehole data. Transects 3 and 4 incorporate only 2 boreholes each, leaving much more room for interpretation. Additionally, groundwater data were not as abundant nor as readily available as I had anticipated; my analysis could have been made stronger by additional data in this field.

I assume in my analysis of soil density that the blow counts recorded using SPT and D&M sampling methods are correlative, although the hammer weight, sampler size, and sample depth may affect the consistency of the data.

The final product of this research project will be applicable to the Qva only within the study area, and should not be considered representative of the Qva elsewhere in the Puget Lowland. However, the methods used in this study could be applied to other investigations.

9.1 Software Limitations

While the usability and viability of EnterVol was satisfactory for this study, the software has some limitations. This program automates subsurface models based on borehole data input by the user. However, the ability for the user to make interpretations or add corrections to the models is somewhat limited. This issue was encountered in my models, at boring E-109. Although the data that I input showed that the Qpn was exposed at the surface in boring E-
109, the automated model showed the Qva at the surface instead. Additionally, the isopach map (Figure 12) show “bulls-eye” patterns; this is an unusual geologic pattern that might actually be an artifact of the interpolation algorithm used to make the models. It is possible that the geology was too complex to be modeled in this area. It is also possible that the algorithm used to interpolate the geology did not capture every fine detail. Discrepancies between the actual and modeled values of the thickness of the Qva could have been reduced if more borehole information were available. “Dummy” borings can be used as an aid to increase the user’s ability to make interpretations, or to fill in voids where borehole information is scarce; however, I did not use this approach because I wanted to compare the automated models to the hand-drawn cross-sections. I am uncertain of the complexity of the models that EnterVol is able to produce. I am also uncertain of the full capabilities of this program, which should be explored in future studies.

10.0 Recommended Future Studies

10.1 Local Characterization of the Vashon Advance Outwash

Additional studies should be conducted to compare the engineering properties (bulk density, coefficient of friction, cohesion, etc.) of the Qva locally to that of generalized published data (Table 4). Additional engineering properties that could be tested include: triaxial shear strength, residual strength, dry and wet densities, and stability of cut slopes. It would also be useful to determine the angle of internal friction with relation to fines content. The angle of internal friction is significantly less in silts than it is in sands (Koloski et al., 1989). This information would be useful to engineers who have project designs in the Qva, so that they can determine how the fines content may affect the stability of a slope or excavation.

10.2 Locating Southern Whidbey Island Fault Traces

There is potential evidence for a segment of the Southern Whidbey Island Fault in Transect 2, where the Qva pinches out along a ridge. This hypothesis is supported by the presence of slickensides, brecciated textures, shear zones, and mass wasting deposits along the same transect (Figure 5). However, locating strands of the SWIF was not in the scope of my research, so I did not investigate this in great detail. I recommend that future studies be done using new and existing geotechnical borings, and the ArcGIS/EnterVol modeling methods described above, to locate strands of the SWIF near the King/Snohomish County border or elsewhere. Future research should also incorporate geophysical methods to identify and locate the fault, should it exist here. Ideal locations for the geophysical research would be in the Holyrood Cemetery, which intersects Transect 2, and at the Nile Golf Course, which is located between Lake Ballinger and Transect 5. These areas are minimally developed, and will not have much interference from underground utilities. Since the SWIF has obscure boundaries and is an active fault capable of producing up to Mw 7.1 earthquakes, I think it is in the best interest of the community to locate and constrain the lineaments of this fault.
11.0 References Cited


King County. Dept. of Natural Resources. Wastewater Treatment Division. “CSI Geotechnical Data Report, Brightwater Project Conveyance System.” King County, May 2002. PDF.

King County. Dept. of Natural Resources. Wastewater Treatment Division. “Predesign Geotechnical Data Report, Conveyance System.” King County, February 2004. PDF.


12.0 Figures
Figure 1. Vicinity Map. Transect lines are shown in red and significant borings are represented by a yellow cross in a circle. Borings prefixed with MW- were completed by HWA Geosciences for the Brightwater Project in 2002, with a BW- by Shannon & Wilson for the Brightwater Project in 2002, with an E- by CDM Smith for the Brightwater Project in 2003, and with an LLE-B by GeoEngineers for the Sound Transit-LLE Project in 2014. Lake Ballinger is located near the center of the study area. Interstate-5 is located at the eastern edge of the study area, along Transect 5.
Figure 2, Regional Map. The study area is outlined in red. Highly populated cities are shown in green. The extent of the Puget Lobe of the Cordilleran Ice Sheet is indicated by the dark red, dashed line. Quaternary fault traces and lineaments are labeled and shown as gray lines. Notice the proximity of the Southern Whidbey Island Fault Zone (SWIF) to the study area. Other abbreviations listed on the map are: CS – Chimacum spillway, DMF – Devils Mountain fault zone, HCFZ – Hood Canal Fault Zone, LCBC – Lake Creek-Boundary Creek fault, RP – Restoration Point, SFZ – Seattle fault zone, SMF – Saddle Mountain fault, SPF – Strawberry Point fault, TFZ – Tacoma fault zone, and UPF – Utsalady Point fault. (Image modified from Troost and Booth, 2008)
Figure 3, Generalized Quaternary Geologic Section. (Image from Galster and Laprade, 1991)
Figure 4, Cross-Section 1. Transect 1 is approximately 3.1 mi in length, and includes borings MW-3, BW-4, BW-5, and BW-6. The Qva thins to the east, where there appears to be a paleotopographic ridge composed of pre-Olympia glacial deposits.
Figure 5, Cross-Section 2. Transect 2 is approximately 2.56 mi in length, and includes borings E-105, MW-4, E-106, E-107, E-108, MW-5, E-109, E-110, MW-6, and E-211. The Qva pinches out against a ridge composed of pre-Fraser interglacial deposits. There is significant evidence for soil disturbance along this transect, including slickensides, brecciated textures, shear zones, mass wasting deposits, and fractures. It is unclear whether this ridge is a paleotopographic feature, or whether it was formed from active tectonics. Further research should be done to determine the nature of this ridge.
Figure 6, Cross-Section 3. Transect 3 is approximately 0.88 mi in length, and includes borings MW-3 and MW-4.
Figure 7, Cross-Section 4. Transect 4 is approximately 1.1 mi in length, and includes borings BW-4 and MW-5.
Figure 8, Cross-Section 5. Transect 5 is approximately 1.20 mi in length, and includes borings BW-5, LLE-B19, LLE-B17, LLE-B11, LLE-B09, LLE-B08, and LLE-B06. The apparent bend at boring LLE-B11P may represent a fold.
This block diagram was produced using EnterVol and the geologic contacts database (Table 2) that I constructed using borehole data. The units on the y- and x- axes are northing and easting, respectively. The unit on the z-axis is elevation (ft). The geologic units shown are: pre-Olympia glacial (Qpg) in blue, pre-Fraser interglacial (Qpn) in pink, Lawton clay (Qvlc) in teal, Vashon advance outwash (Qva) in yellow, Vashon till (Qvt) in green, and recessional outwash (Qvr) in orange. This view shows Transect 2 paralleling the x-axis, and Transect 3 paralleling the y-axis.
Figure 9B, Block Diagram with Vicinity Map Overlay. This block diagram was produced using EnterVol and the geologic contacts database (Table 2) that I constructed using borehole data. The units on the y- and x-axes are northing and easting, respectively. The unit on the z-axis is elevation (ft). The geologic units shown are: pre-Olympia glacial (Qpg) in blue, pre-Fraser interglacial (Qpn) in pink, Lawton clay (Qvlc) in teal, Vashon advance outwash (Qva) in yellow, Vashon till (Qvt) in green, and recessional outwash (Qvr) in orange. This view shows Transect 2 paralleling the x-axis, and Transect 3 paralleling the y-axis. Lake Ballinger is located near the center of the map, with Interstate-5 located east of the lake.
Figure 10, Fence Diagram. This fence diagram was produced using EnterVol and the geologic contacts database (Table 2) that I constructed from borehole data. The units on the y- and x- axes are northing and easting, respectively. The unit on the z-axis is elevation (ft). The geologic units shown are: pre-Olympia glacial (Qpg) in blue, pre-Fraser interglacial (Qpn) in pink, Lawton clay (Qvlc) in teal, Vashon advance outwash (Qva) in yellow, Vashon till (Qvt) in green, and recessional outwash (Qvr) in orange. The black bars show the location and depth of each of the boreholes used in this study. This view shows Transect 1 as the northern-most cross-section, Transect 2 paralleling the x-axis, Transect 3 paralleling the y-axis, Transect 4 in the center, and Transect 5 on the far right.
Figure 11A, Qva with Fence Diagram (From Above). This diagram was produced using EnterVol and the geologic contacts database (Table 2) that I constructed from borehole data. The units on the y- and x- axes are northing and easting, respectively. The unit on the z-axis is elevation (ft). The geologic units shown are: pre-Olympia glacial (Qpg) in blue, Vashon advance outwash (Qva) in yellow, Vashon till (Qvt) in green, and recessional outwash (Qvr) in orange. The black bars show the location and depth of each of the boreholes used in this study. This view shows Transect 1 as the northern-most cross-section, Transect 2 paralleling the x-axis, Transect 3 paralleling the y-axis, Transect 4 in the center, and Transect 5 on the far right. This view helps illustrate the extent of the Qva in relation to the Qvr and Qvt.
Figure 11B, Qva with Fence Diagram (From Below). This diagram was produced using EnterVol and the geologic contacts database (Table 2) that I constructed from borehole data. The units on the y- and x- axes are northing and easting, respectively. The unit on the z-axis is elevation (ft). The geologic units shown are: pre-Olympia glacial (Qpg) in blue, pre-Fraser interglacial (Qpn) in pink, Lawton clay (Qvlc) in teal, and Vashon advance outwash (Qva) in yellow. The black bars show the location and depth of each of the boreholes used in this study. This view shows Transect 1 as the northern-most cross-section, Transect 2 paralleling the x-axis, Transect 3 paralleling the y-axis, Transect 4 in the center, and Transect 5 on the far right. This view helps illustrate the extent of the Qva in relation to the Qvlc, Qpn, and Qpg.
Figure 12, Isopach Map of Qva Thickness. The thickness of the Qva is mapped using 25 ft contours, which are based on the model produced in EnterVol. The Qva is thickest in the western corner of the study area, and thins to southeast. There is a steep gradient intersecting Transect 2, between Transects 3 and 4; at this location, there is a thick deposit of Qvr. The Qva is thickest where modern topography is high. The circular contours on the isopach map may indicate topographic highs and lows; however, they could also be artifacts of the model, which would indicate that the EnterVol did not accurately depict the thickness of the Qva.
Figure 13, Density vs. Fines Content. These figures show the relative density of select soil samples as a function of fines content in the soil. Only samples collected using mud rotary drilling methods, which provide the most reliable density data in water-bearing sands, are shown in the top figure. Samples collected using mud rotary, Becker hammer, and hollow stem auger drilling methods are shown in the lower figure. For both of these figures, I used a linear regression line to show the trend in these datasets.
Figure 14, Elevation vs. Density. These figures show the relative density of select soil samples as a function of elevation (NAVD88 datum). Only samples collected using mud rotary drilling methods, which provide the most reliable density data in water-bearing sands, are shown in the top figure. Samples collected using mud rotary, Becker hammer, and hollow stem auger drilling methods are shown in the lower figure.
Figure 15, Depth vs. Density. These figures show the relative density of select soil samples as a function of depth from the surface of the ground. Only samples collected using mud rotary drilling methods, which provide the most reliable density data in water-bearing sands, are shown in the top figure. Samples collected using mud rotary, Becker hammer, and hollow stem auger drilling methods are shown in the lower figure. For both of these figures, I used an exponential regression curve to show the trend in these datasets.
Figure 16A, Summary of Soil Classifications within the Qva. This chart summarizes the percentages of the soil groups found within the Qva, as recorded in the geotechnical boring logs. Gravel comprises about 9.5% of the total volume of the Qva, sand about 89.3%, and silt/clay about 1.2%. The abbreviations are as listed: well-graded gravel (GW), poorly-graded gravel (GP), poorly-graded gravel with silt (GP-GM), silty gravel (GM), well-graded sand (SW), well-graded sand with silt (SW-SM), poorly-graded sand (SP), poorly-graded sand with silt (SP-SM), silty sand (SM), lean silt (ML), and lean clay (CL).
Figure 16B, Summary of Soil Classifications within the Qva. This chart summarizes the percentages of the soil groups found within the Qva, as found in each borehole. Gravel comprises about 9.5% of the total volume of the Qva, sand about 89.3%, and silt/clay about 1.2%. The abbreviations are as listed: well-graded gravel (GW), poorly-graded gravel (GP), poorly-graded gravel with silt (GP-GM), silty gravel (GM), well-graded sand (SW), well-graded sand with silt (SW-SM), poorly-graded sand (SP), poorly-graded sand with silt (SP-SM), silty sand (SM), lean silt (ML), and lean clay (CL).
**Figure 17, Depth and Elevation vs. Fines Content.** These figures show the relationship between depth and fines content (top), and elevation and fines content (bottom), in select samples from within the Qva.
**Figure 18, Depth and Elevation vs. Moisture Content.** These figures show the relationship between depth and moisture content (top), and elevation and moisture content (bottom), in select samples from within the Qva. In the top chart, I used an exponential regression curve to show the relationship between depth and moisture content. In the bottom chart, I used an order-two polynomial line to show the trend.
Figure 19, Fines Content vs Moisture Content. This figure shows the relationship between fines content and moisture content in select samples from within the Qva. This chart is best viewed on a log-log scale. I used a logarithmic trend line to show the subtle relationship between fines content and moisture content.
Figure 20, Groundwater Observations at Boring LLE-B11P. Groundwater observations were recorded using a pressure transducer at a well that was installed at boring LLE-B11P. The well is positioned in the advance outwash, and the top of the screen is 10 ft bgs. The surface elevation is 362.49 ft at this location. The chart shows that the peak groundwater elevation at this location was recorded at 356.47 ft on February 08, 2015, and the minimum groundwater elevation was recorded at 354.74 ft on September 23, 2014. The groundwater elevation appears to increase following large precipitation events. (Image from GeoEngineers, 2015).
13.0 Tables
Table 1, Summary of Geotechnical Borings. This table is a summary of the existing geotechnical borings that were used in this study.

<table>
<thead>
<tr>
<th>Boring ID</th>
<th>Surface Elevation (NAVD88, ft)</th>
<th>Borehole Depth (ft)</th>
<th>Drilling Method</th>
<th>Qva Thickness (ft)</th>
<th>Contractor, Project (Year)</th>
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Table 2, Geologic Contacts Database. This table shows the location of each boring, and the elevation of the bottom of each geologic unit with respect to each boring. I terminated this study at an elevation of 100 ft, although not all borings reached this depth. Blank spaces in the table indicate the absence of a geologic unit within a boring. Notice the anomalous nature of boring E-109, which does not contain any deposits from the Vashon Stade, but instead shows that Qpn is observed in the first 71 ft of the boring.

<p>| Boring ID | Northing  | Easting  | Surface Elevation (ft) | Qvr | Qvt | Qva | Qvlc | Qpg_1 | Qpn_1 | Qpnmw | Qpn_2 | Qpg_2 | Bottom Elevation (ft) |
|-----------|-----------|----------|------------------------|-----|-----|-----|------|-------|-------|-------|-------|-------|-------|-----------------------|
| BW-4      | 292702.53 | 1270571.18 | 368                   |     |     | 177 | 136  | 100   |       |       |       |       | 100               |
| BW-5      | 292558.92 | 1275711.57 | 400                   |     |     | 331 | 100  |       |       |       |       |       | 100               |
| BW-6      | 292329.00 | 1280284.89 | 450                   | 407 | 366 |     | 164  | 100   |       |       |       |       | 100               |
| E-105     | 287350.73 | 1264077.49 | 453                   | 438 | 196 | 193 |     |       | 100   |       |       |       | 100               |
| E-106     | 287281.71 | 1266085.31 | 486                   | 445 | 207 |     |       |       |       |       |       |       | 100               |
| E-107     | 287286.32 | 1268070.00 | 454                   |     |     | 214 |     |       |       |       |       |       | 100               |
| E-108     | 287250.64 | 1270073.56 | 357                   | 247 | 224 |     | 141  | 116  | 101   | 100   |       |       | 100               |
| E-109     | 287168.00 | 1272288.00 | 299                   |     |     |     | 228  |       |       |       |       |       | 100               |
| E-110     | 286963.17 | 1274157.64 | 349                   | 297 | 272 |     | 213  |       |       |       |       |       | 100               |
| E-211     | 286326.37 | 1277098.94 | 317                   | 295 | 274 | 253 |     |       |       |       |       |       | 100               |
| LLE-B08   | 287645.34 | 1275729.20 | 317                   | 279 | 254 | 236 |     |       |       |       |       |       | 236               |
| LLE-B09   | 288336.35 | 1275804.25 | 331                   | 318 | 308 | 256 | 250  |       |       |       |       |       | 250               |
| LLE-B11P  | 289308.55 | 1276263.13 | 363                   |     |     | 310 | 281  |       |       |       |       |       | 281               |
| LLE-B17   | 290943.92 | 1275898.00 | 484                   |     |     | 406 | 382  |       |       |       |       |       | 382               |
| LLE-B19   | 291584.06 | 1275750.55 | 392                   |     |     | 320 | 291  |       |       |       |       |       | 291               |
| MW-3      | 292217.63 | 1264080.88 | 331                   |     |     | 198 | 194  | 181   | 129   |       |       |       | 100               |
| MW-4      | 287602.69 | 1264800.59 | 387                   |     |     | 201 | 197  |       |       |       |       |       | 100               |
| MW-5      | 287165.87 | 1271424.47 | 305                   |     |     | 242 | 201  |       |       |       |       |       | 100               |
| MW-6      | 287239.93 | 1276263.15 | 314                   | 295 | 292 | 260 |     |       |       |       |       |       | 100               |</p>
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<th>Boring ID</th>
<th>Qva Measured in Boring (ft)</th>
<th>GW</th>
<th>GP</th>
<th>GP-GM</th>
<th>GM</th>
<th>SW</th>
<th>SW-SM</th>
<th>SP</th>
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<td><strong>Percent Total:</strong></td>
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<td><strong>6.6%</strong></td>
<td><strong>1.9%</strong></td>
<td><strong>0.9%</strong></td>
<td><strong>0.1%</strong></td>
<td><strong>3.5%</strong></td>
<td><strong>2.7%</strong></td>
<td><strong>33.0%</strong></td>
<td><strong>37.3%</strong></td>
<td><strong>12.8%</strong></td>
<td><strong>0.9%</strong></td>
<td><strong>0.3%</strong></td>
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*Table 3, Summary of the soil groups found within the Qva in each boring. The abbreviations are as follows: well-graded gravel (GW), poorly-graded gravel (GP), poorly-graded gravel with silt (GP-GM), silty gravel (GM), well-graded sand (SW), well-graded sand with silt (SW-SM), poorly-graded sand (SP), poorly-graded sand with silt (SP-SM), silty sand (SM), lean silt (ML), and lean clay (CL).*
Table 4, Comparative Results. This table summarizes the findings from this study, and compares them to published sources.

<table>
<thead>
<tr>
<th>Parameter with Respect to Qva</th>
<th>Findings From This Study</th>
<th>Published Data (Source)</th>
<th>Notes</th>
</tr>
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<tr>
<td>Elevation Range (Qva Surface)</td>
<td>477-247 ft</td>
<td>400-600 ft (Troost and Booth, 2008)</td>
<td>General glacial stratigraphy</td>
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<tr>
<td>Unit Thickness</td>
<td>0 - 242 ft</td>
<td>$&gt;100$ ft (Mullineaux, 1965); 50-200 ft (Golder Associates, 2008); 0-400 ft (Troost and Booth, 2008)</td>
<td>General glacial stratigraphy; As observed in the Mountlake Terrace area: General glacial stratigraphy</td>
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<tr>
<td>Relative Density</td>
<td>dense to very dense</td>
<td>dense to very dense (Galster and Laprade, 1991)</td>
<td>General glacial stratigraphy</td>
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<tr>
<td>Friction Angle</td>
<td>N/A</td>
<td>30-40° (Kolosi, et al, 1989); About 32° (Miller, 1989)</td>
<td>General glacial outwash properties; General glacial outwash properties</td>
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<tr>
<td>Cohesion</td>
<td>N/A</td>
<td>0-1000 psf (Kolosi, et al, 1989)</td>
<td>General glacial outwash properties</td>
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<tr>
<td>Dry Density</td>
<td>N/A</td>
<td>115-130 pcf (Kolosi, et al, 1989); 110 pcf (Miller, 1989)</td>
<td>General glacial outwash properties; General Qva properties</td>
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<td>Wet Density</td>
<td>N/A</td>
<td>120 pcf (Miller, 1989)</td>
<td>General Qva properties</td>
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<td>Relative Erodability</td>
<td>N/A</td>
<td>Low-Medium (Kolosi, et al, 1989)</td>
<td>General glacial outwash properties</td>
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<tr>
<td>Excavation Difficulty</td>
<td>N/A</td>
<td>Low-Medium (Kolosi, et al, 1989); Easy (Laprade and Robinson, 1989)</td>
<td>General glacial outwash properties; General glacial outwash properties</td>
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<td>Moisture Sensitivity</td>
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<td>Foundation Support</td>
<td>N/A</td>
<td>1500-3000 psf (Kolosi, et al, 1989)</td>
<td>General glacial outwash properties</td>
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<td>Cut Slopes</td>
<td>N/A</td>
<td>50-70% (Kolosi, et al, 1989)</td>
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<td>Aquifer Depth</td>
<td>7.59-221.3 ft bgs</td>
<td>20-70 ft bgs (King County, 2002)</td>
<td>General depth to saturated soils along Brightwater alignment</td>
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<td>Saturated Thickness</td>
<td>0-102.13 ft</td>
<td>10-100 ft (Golder Associates, 2008)</td>
<td>Aquifer thickness in the Mountlake Terrace area during a 2008 study</td>
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<tr>
<td>Mean Hydraulic Conductivity</td>
<td>15.93 ft/day</td>
<td>40 ft/d (Golder Associates, 2008); 0.33-328 ft/d (Galster and Laprade, 1991)</td>
<td>As measured in the Mountlake Terrace area; General Qva properties</td>
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<td>Groundwater Recharge Rate</td>
<td>N/A</td>
<td>15-20 in/yr where Qva exposed and &lt;10 in/yr where Qva is capped by till or pavement (Golder Associates, 2008)</td>
<td>Recharge rate in the Mountlake Terrace area during a 2008 study</td>
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<td>Permeability</td>
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<td>0.01-10 ft/min (Kolosi, et al, 1989); 0.0001-0.2 ft/min (Laprade and Robinson, 1989)</td>
<td>General glacial outwash properties</td>
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14.0 Appendices
Appendix A

Summary of Hydraulic Conductivity Data for Glacial Sediments and Conceptual Hydrogeologic Model (Adapted from Golder Associates, 2008)

### Summary of Hydraulic Conductivity Data for Glacial Sediments

<table>
<thead>
<tr>
<th>Aquifer Unit</th>
<th>Hydraulic Conductivity (ft/d)</th>
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<td></td>
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<td>Alluvium</td>
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<tr>
<td>Advance Outwash</td>
<td>0.18</td>
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<td>Pre-Vashon Aquifers</td>
<td>0.22</td>
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### Conceptual Hydrogeologic Model

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<th>Geologic Unit</th>
<th>Hydrostratigraphic Unit</th>
<th>Saturated Thickness (feet)</th>
<th>Groundwater Recharge (in/yr)</th>
<th>Groundwater Discharge</th>
<th>Median Hydraulic Conductivity (ft/d)</th>
<th>Potential for Infiltration</th>
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<td>Alluvium</td>
<td>Alluvia and Recessional Outwash Aquifer</td>
<td>0-40(?)</td>
<td>20-24</td>
<td>To Streams and Lake Ballinger</td>
<td>180</td>
<td>Low - Limited unsaturated thickness and good connection to surface water</td>
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<td>Recessional Outwash</td>
<td></td>
<td>na</td>
<td>&lt;10 where exposed on surface</td>
<td>na</td>
<td>53</td>
<td>Low - Low Permeability</td>
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<tr>
<td>Vashon Till</td>
<td>Aquitard</td>
<td>na</td>
<td>&lt;10 where exposed on surface</td>
<td>na</td>
<td>40</td>
<td>Good where exposed at ground surface and sufficient unsaturated thickness exists. Low where present under till unless till removed.</td>
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<td>Advance Outwash</td>
<td>Aquifer</td>
<td>10-100</td>
<td>15-20 where exposed at surface, &lt;10 when under till</td>
<td>To Streams and to Pre-Vashon Aquifers</td>
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<td>Low - Low Permeability</td>
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<tr>
<td>Lawton Clay</td>
<td>Aquitard</td>
<td>na</td>
<td>na</td>
<td>Puget Sound</td>
<td>31</td>
<td>Low - deep, water supply aquifer</td>
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<tr>
<td>Pre-Vashon</td>
<td>Aquifers and Aquitards</td>
<td>Variable</td>
<td>&lt;10</td>
<td>Puget Sound</td>
<td>31</td>
<td>Low - deep, water supply aquifer</td>
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Appendix B

Geotechnical Boring Logs
### Log of Boring MW-3

**Project:** CSI Brightwater  
**Project Location:** King and Snohomish Counties  
**Contract Number:** E83004E  
**Log Sheet:** Sheet 1 of 7

<table>
<thead>
<tr>
<th>Date(s) Drilled</th>
<th>Drilling Method/ Rig Type</th>
<th>Drilling Contractor</th>
<th>Total Depth of Borehole</th>
<th>Ground Surface Elevation/Datum</th>
<th>Coordinates</th>
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<tr>
<td>1/3/02 - 1/7/02</td>
<td>Becker Hammer/ Truck</td>
<td>Layne Christensen Company</td>
<td>369.0 feet</td>
<td>331 feet / NAVD88</td>
<td>N. 47.79084 W. 122.36443</td>
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**Drill Bit Size/Type:** Dual Wall Reverse Circ.

**Location:** On Edmonds Way.

**Logged By:** BKH, BWT  
**Checked By:** MLR/SEG

---

#### SAMPLES

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<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / in.</th>
<th>Recovery, %</th>
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<td>-320</td>
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<td>S-1</td>
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<td>11 - 15</td>
<td>100</td>
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<td>SM</td>
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#### MATERIAL DESCRIPTION

**Brown, silty, fine to coarse gravelly, slightly silty fine to medium SAND, moist.**

*WEATHERED GLACIAL FLUVIAL, Qva*

**Medium dense to very dense, yellowish brown to olive gray, slightly silty, fine to coarse gravelly, SAND, moist.**

*GLACIAL FLUVIAL, Qva*

**Remarks and Other Tests**

- Prezometer Schematic: M 10.2
- Lab Tests: M 13.3
- Moisture Content: M SA 9.4
- M 5.8
- M 4.7

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*Figure: A-4.1*
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Figure: A-4.2
Project: CSI Brightwater
Project Location: King and Snohomish Counties
Contract Number: E83004E

Log of Boring MW-3
Sheet 3 of 7

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<tr>
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<th>Number</th>
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<th>Recovery, %</th>
<th>Graphic Log</th>
<th>USCS</th>
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<th>Piezometer Schematic</th>
<th>Lab Tests</th>
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<td>S-11</td>
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<td></td>
<td>Dense, brown-gray, fine to medium SAND with lenses of gray CLAY, wet.</td>
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<td>(GLACIOLACUSTRINE, Qvic)</td>
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<td>S-12</td>
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<td>(GLACIAL FLUVIAL, Qpgf)</td>
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<td>S-13</td>
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<td>Dense, gray, slightly silty, fine to medium SAND; wet. Wood fragments noted.</td>
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Figure: A-4.3
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<th>Lab Tests</th>
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<td>M</td>
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<td>SA</td>
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<td>Hard, gray, silty CLAY, wet.</td>
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<td>30.8 26.3</td>
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Figure: A-4.5
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<td>100</td>
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Figure: A-4.6
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<th>Recovery, %</th>
<th>USCS</th>
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<th>Piezometer Schematic</th>
<th>Lab Tests</th>
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<th>REMARKS AND OTHER TESTS</th>
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<td>-20</td>
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<td>medium SAND, wet. Occasional piece of decomposed wood.</td>
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<td>Encountered large piece of wood that appears to be driftwood.</td>
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Bottom of boring at 369 feet.  
2" piezometer installed from 295 to 315 feet.  
Vibrating wire piezometer installed at 250 feet.
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<td>SP-SM gray, poorly graded SAND with silt</td>
</tr>
<tr>
<td>MW-3 S-38</td>
<td>353.0 - 355.0</td>
<td>37.2</td>
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<td>ML olive-gray, SILT</td>
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<td>MW-3 S-39a</td>
<td>355.0 - 355.5</td>
<td>30.4</td>
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<td>ML olive gray, SILT</td>
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<tr>
<td>MW-3 S-39b</td>
<td>355.5 - 356.0</td>
<td>31.0</td>
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<td>ML olive-gray, SILT</td>
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<tr>
<td>MW-3 S-39c</td>
<td>356.0 - 356.5</td>
<td>29.1</td>
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<td>ML olive-gray, SILT</td>
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<td>MW-3 S-40</td>
<td>358.0 - 359.0</td>
<td>25.3</td>
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<td>SP-SM gray, poorly graded SAND with silt</td>
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<td>MW-3 S-41</td>
<td>364.0 - 365.0</td>
<td>32.4</td>
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<td>SP-SM olive gray, poorly graded SAND with silt, wood pieces</td>
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<td>MW-3 S-42</td>
<td>367.5 - 369.0</td>
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</tbody>
</table>

Notes: 1. This table summarizes information presented elsewhere in the report and should be used in conjunction with the report text, other graphs and tables, and the exploration logs.
## Log of Boring MW-4

### Date(s) Drilled
1/25/02 - 2/1/02

### Geotechnical Consultant
HWA GeoSciences Inc.

### Logged By
BKH

### Checked By
MLR/SEG

### Drilling Method/ Rig Type
Becker Hammer/ Truck

### Drilling Contractor
Layne Christensen Company

### Total Depth of Borehole
446.5 feet

### Hammer Weight/Drop (lbs/ft)
30G, 30" Ground Surface Elevation/Datum

### Location
Firdale Village

### Coordinates
N. 47.77823 W. 122.36113

### Elevation Source
Plan

## Samples

<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Graphic Log</th>
<th>USCS</th>
<th>Material Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>380</td>
<td>380</td>
<td>S-1</td>
<td>10 - 12 - 26 (40)</td>
<td>100</td>
<td>SM</td>
<td>Brown, silty, fine to coarse gravelly, fine to medium SAND, moist. Cobbles present and occasional gravel lenses.</td>
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<tr>
<td>370</td>
<td>370</td>
<td>S-2</td>
<td>19 - 24 - 21 (45)</td>
<td>100</td>
<td>SM</td>
<td>Dense, olive brown, slightly silty, fine to coarse gravelly, fine to medium SAND, moist. A lens of coarse sandy gravel is present at the bottom of the sample. (GLACIAL FLUVIAL, Qva)</td>
<td></td>
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<tr>
<td>360</td>
<td>360</td>
<td>S-3</td>
<td>8 - 12 - 22 (34)</td>
<td>100</td>
<td>SP-</td>
<td>Dense, olive brown, clean to slightly silty, fine to coarse gravelly, fine to coarse SAND to fine to coarse sandy, fine to coarse GRAVEL, moist.</td>
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<tr>
<td>350</td>
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<td>S-4</td>
<td>10 - 21 - 26 (47)</td>
<td>100</td>
<td>SW</td>
<td>Dense, olive brown, slightly silty, fine to coarse gravelly, fine to medium SAND, moist. Lenses of silty SAND are present.</td>
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<tr>
<td>340</td>
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<td>13 - 44</td>
<td></td>
<td>SW</td>
<td>Dense, brown, slightly fine gravelly, fine to coarse, clean SAND, moist.</td>
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</table>

**Piezometer Schematic**

**Test Results**

- **Moisture Content, %**
  - S-1: 9.1
  - S-2: 6.0
  - S-3: 10.5
  - S-4: 5.1

**Remarks and Other Tests**

- **Lab Tests**
  - M: Moisture Content
  - SA: Soil Analysis
Project: CSI Brightwater
Project Location: King and Snohomish Counties
Contract Number: E83004E

Log of Boring MW-4
Sheet 2 of 8

<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Graphic Log</th>
<th>MATERIAL DESCRIPTION</th>
<th>Piezometer Schematic</th>
<th>Lab Tests</th>
<th>Moisture Content, %</th>
<th>REMARKS AND OTHER TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td></td>
<td>S-5</td>
<td>28</td>
<td>(72)</td>
<td>100</td>
<td>SW</td>
<td>Very dense, grayish brown, silty, fine to medium SAND, moist. Large gravel/cobble present in middle of sampler.</td>
<td></td>
<td>SA</td>
<td></td>
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<tr>
<td>-330</td>
<td></td>
<td>S-6</td>
<td>22-24</td>
<td>(47)</td>
<td>100</td>
<td>SP</td>
<td>Dense, brownish gray, slightly fine to coarse gravelly, fine to medium SAND, moist. Some coarse sand present. A large fractured cobble is present in the middle of the sampler. The bottom 3 inches of the sample becomes fine sand.</td>
<td></td>
<td>M SA</td>
<td>13.3</td>
<td></td>
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<tr>
<td>-320</td>
<td></td>
<td>S-7</td>
<td>13-26</td>
<td>(63)</td>
<td>100</td>
<td>SP</td>
<td>Very dense, brownish gray, fine to medium SAND, moist.</td>
<td></td>
<td>M SA</td>
<td>4.8</td>
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<tr>
<td>-310</td>
<td></td>
<td>S-8</td>
<td>8-13-8</td>
<td>(21)</td>
<td>100</td>
<td>SP</td>
<td>Medium dense, grayish brown, fine to medium SAND, moist.</td>
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<td>M SA</td>
<td>5.2</td>
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<tr>
<td>-300</td>
<td></td>
<td>S-9</td>
<td>9-19-24</td>
<td>(43)</td>
<td>100</td>
<td>SP</td>
<td>Dense, grayish brown, slightly fine gravelly, fine to medium SAND, moist.</td>
<td></td>
<td>M SA</td>
<td>4.9</td>
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<tr>
<td>-290</td>
<td></td>
<td>S-10</td>
<td>16-36-50</td>
<td>(100+)</td>
<td>100</td>
<td>SP</td>
<td>Very dense, grayish brown, slightly fine gravelly, fine to medium SAND, moist to wet.</td>
<td></td>
<td>M SA</td>
<td>6.6</td>
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</table>

Vibrating Wire Piezometer
3/27/2002 106 8 AM

Figure: A-5.2
<table>
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<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>S-11</th>
<th>Blows / 6 in.</th>
<th>Recovery, %</th>
<th>Graphic Log</th>
<th>USCS</th>
<th>MATERIAL DESCRIPTION</th>
<th>Piezometer Schematic</th>
<th>Lab Tests</th>
<th>Moisture Content, %</th>
<th>REMARKS AND OTHER TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td></td>
<td>S-11</td>
<td>9-30-50-50S</td>
<td>100</td>
<td>SP</td>
<td>SP</td>
<td>Very dense, grayish brown, fine to medium SAND, wet. Bottom 3 inches of sample was fine to coarse SAND, wet.</td>
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<td>M SA</td>
<td>16.8</td>
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<tr>
<td>120</td>
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<td>S-12</td>
<td>4-24-50-50S</td>
<td>100</td>
<td>SP</td>
<td>SP</td>
<td>Very dense, brown, slightly fine gravelly, fine to coarse SAND, wet. 3 feet of heave present at 119 feet.</td>
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<td>M SA</td>
<td>17.3</td>
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<td>130</td>
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<td>S-13</td>
<td></td>
<td></td>
<td>SP</td>
<td>SP</td>
<td>5 feet of heave present at 129 feet. No sample taken.</td>
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<td>M SA</td>
<td>35.4</td>
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<td>140</td>
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<td>S-14</td>
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<td>SP</td>
<td>SP</td>
<td>Brown, slightly fine gravelly, fine to medium SAND, wet.</td>
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<td>M SA</td>
<td>26.1</td>
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<tr>
<td>150</td>
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<td></td>
<td></td>
<td></td>
<td>SP</td>
<td>SP</td>
<td>Cuttings: Brown, slightly fine to coarse gravelly, fine to medium SAND, wet.</td>
<td></td>
<td>M SA</td>
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<tr>
<td>160</td>
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<td></td>
<td></td>
<td></td>
<td>SP</td>
<td>SP</td>
<td>Cuttings: Gray, slightly fine to coarse gravelly, fine to medium SAND, wet. Organics, including wood, and some coarse sand present.</td>
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<td>M SA</td>
<td>23.6</td>
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<td>165</td>
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<td></td>
<td>SP</td>
<td>SP</td>
<td>Cuttings: Gray, slightly fine to coarse gravelly, fine to coarse SAND, wet. Wood pieces present.</td>
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<td>M SA</td>
<td></td>
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<tr>
<td>170</td>
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<td></td>
<td>SP</td>
<td>SP</td>
<td>Cuttings: Same as above - gray SAND, wet.</td>
<td></td>
<td>M SA</td>
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</tbody>
</table>

Figure: A-5.3
Cuttings: Gray, slightly fine to coarse gravelly, fine to medium SAND, wet.

ML: Hard, dark gray, fine sandy, SILT, moist.
(GLACIOLACUSTRINE, Qvlc)

SP, SM: Very dense, dark gray, slightly silty to silty, fine SAND, wet.
(NONGLACIAL FLUVIAL, Qpnf)

Cuttings: Gray, fine to medium SAND, wet. Pieces of wood present.

Cuttings: Dark gray, slightly silty to silty, fine to medium SAND, wet.

Cuttings: Dark gray, slightly silty to silty, fine SAND, wet.

Cuttings: Similar as above - silty fine SAND, wet.

REMARKS AND OTHER TESTS

Lab Tests

Material Content, %

22.9

21.4

23.5

28.3

34.4

Figure: A-5.4.
### Log of Boring MW-4

#### Project: CSI Brightwater
#### Project Location: King and Snohomish Counties
#### Contract Number: E83004E

<table>
<thead>
<tr>
<th>Sample</th>
<th>Elevation, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Graphic Log USCS</th>
<th>Material Description</th>
<th>Piezometer Schematic</th>
<th>Lab Tests</th>
<th>Moisture Content, %</th>
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<tbody>
<tr>
<td>S-20</td>
<td>225</td>
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<td>2-13-28 (41)</td>
<td>100</td>
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<td>ML</td>
<td>Dark gray, slightly silty, fine SAND, wet. Organics, including wood fragments, present.</td>
<td>M SA</td>
<td>26.5</td>
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<td></td>
<td>-160</td>
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<td></td>
<td>(Nonglacial Lacustrine, Qnpl)</td>
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<td>S-21</td>
<td>240</td>
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<td>9-18-30 (48)</td>
<td>100</td>
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<td>CL</td>
<td>Hard, dark gray, fat CLAY, moist.</td>
<td>M SA AL</td>
<td>24.2</td>
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<td></td>
<td>Cuttings: hard, dark gray, CLAY with light gray seams.</td>
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<td>S-22a</td>
<td>250</td>
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<td>9-13-28 (41)</td>
<td>93</td>
<td>100</td>
<td>ML</td>
<td>Dense, dark gray, fine sandy SILT, moist to wet.</td>
<td>M SA AL HA M SA</td>
<td>27.7</td>
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<td>S-22b</td>
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<td>Light gray seams and fine sandy clay lenses present.</td>
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<td>27.5</td>
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<td>S-23</td>
<td>260</td>
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<td>5-10-34 (44)</td>
<td>100</td>
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<td>CL</td>
<td>Cuttings: Clay with sand and silt lenses.</td>
<td>M SA HA</td>
<td>29.7</td>
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<td></td>
<td>Cuttings: Hard, dark gray, lean to fat CLAY, moist. Light gray seams present.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cuttings are silty SAND, wet between 273 and 276 feet.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-25a</td>
<td>280</td>
<td></td>
<td>6-9-12 (20)</td>
<td>100</td>
<td></td>
<td>CL</td>
<td>Very soft, dark CLAY, moist.</td>
<td>M SA AL HA M</td>
<td>31.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Medium dense, dark gray, fine SAND, wet.</td>
<td></td>
<td>27.7</td>
<td></td>
</tr>
<tr>
<td>S-25b</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>Very stiff, dark gray, fine sandy SILT, moist to wet.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SM</td>
<td>Dark gray, SILT, wet.</td>
<td>M SA AL HA M</td>
<td>30.8</td>
<td></td>
</tr>
</tbody>
</table>

**Figure:** A-5.5
Log of Boring MW- 4

Sheet 6 of 8

Project: CSI Brightwater
Project Location: King and Snohomish Counties
Contract Number: E83004E

<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>MATERIAL DESCRIPTION</th>
<th>Piezometer Schematic</th>
<th>Lab Tests</th>
<th>Moisture Content, %</th>
<th>REMARKS AND OTHER TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>285</td>
<td>CL</td>
<td>S-28</td>
<td>8 - 12 - 18 (30)</td>
<td>100</td>
<td>Hard, dark gray, lean CLAY, moist.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>290</td>
<td>CL</td>
<td>S-27</td>
<td>7 - 11 - 21 (32)</td>
<td>100</td>
<td>Dense, dark gray, slightly silty, fine SAND, wet.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cuttings: Dark gray, silty SAND, wet.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>300</td>
<td>CL</td>
<td>S-28</td>
<td>9 - 12 - 18 (30)</td>
<td>100</td>
<td>Hard, dark gray, lean to fat CLAY, moist.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>310</td>
<td>CL</td>
<td>S-29</td>
<td>8 - 10 - 16 (26)</td>
<td>100</td>
<td>Very stiff, dark gray, CLAY, moist. Light gray seams present.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>320</td>
<td>ML</td>
<td>S-30</td>
<td>7 - 12 - 16 (28)</td>
<td>100</td>
<td>Very stiff, dark gray, CLAY, moist. Light gray seams present.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>330</td>
<td>ML</td>
<td>S-31</td>
<td>6 - 18 - 40 (56)</td>
<td>100</td>
<td>Very dense, dark gray, fine sandy SILT to silty fine SAND, wet.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>335</td>
<td>CL</td>
<td>S-32</td>
<td>8 - 11 - 18 (28)</td>
<td>100</td>
<td>Very stiff, dark gray, lean CLAY, moist. Light gray seams present. At the top of the clay was a thin, hard, silt lens. The lens was about 1 mm thick and contained organics.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>340</td>
<td>CL</td>
<td>S-34</td>
<td>8 - 13 - 18 (31)</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

At 315, cuttings contain a thin lens of hard, greenish gray, laminated CLAY, moist. The lens is very brittle.

Very stiff, dark gray, CLAY, moist. Light gray seams present.

Very dense, dark gray, fine sandy SILT to silty fine SAND, wet.

Very stiff, dark gray, lean CLAY, moist. Light gray seams present. At the top of the clay was a thin, hard, silt lens. The lens was about 1 mm thick and contained organics.

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Figure: A-5.6
### Log of Boring MW-4

**Project:** CSI Brightwater  
**Project Location:** King and Snohomish Counties  
**Contract Number:** E83004E

#### Elevation, feet: 345

<table>
<thead>
<tr>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Graphic Log</th>
<th>USCS</th>
<th>Material Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S-35a</td>
<td>4 - 11 - 22</td>
<td>100</td>
<td>100</td>
<td>SP-SM</td>
<td>Dense, dark gray, silty fine SAND, wet.</td>
</tr>
<tr>
<td></td>
<td>S-35b</td>
<td>(33)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>S-36</td>
<td>3 - 11 - 20</td>
<td>100</td>
<td>100</td>
<td>ML</td>
<td>Hard, dark gray, Silt to fine sandy Silt, moist to wet.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(31)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>S-37a</td>
<td>5 - 13 - 23</td>
<td></td>
<td>93</td>
<td>SM</td>
<td>Dense, dark gray, silty fine SAND, wet. Lenses of organics present.</td>
</tr>
<tr>
<td></td>
<td>S-37b</td>
<td>(36)</td>
<td></td>
<td></td>
<td></td>
<td>Hard, dark gray, lean CLAY, moist.</td>
</tr>
<tr>
<td></td>
<td>S-38a</td>
<td>15 - 25 - 27</td>
<td>100</td>
<td>100</td>
<td>CL</td>
<td>Hard, greenish gray, fine sandy Silt, moist to wet.</td>
</tr>
<tr>
<td></td>
<td>S-38b</td>
<td>(72)</td>
<td></td>
<td></td>
<td></td>
<td>Organics present.</td>
</tr>
<tr>
<td></td>
<td>S-39</td>
<td></td>
<td></td>
<td></td>
<td>SP</td>
<td>Dark gray, fine to coarse gravelly, slightly silty, fine to medium SAND, wet. Organics,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>including pieces of wood, present. Lenses of silt/clay present in sand.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(Nonglacial Fluvial, Qpnf)</td>
</tr>
<tr>
<td></td>
<td>S-40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5 feet of heave present at 369 feet. Dark gray, fine to medium SAND, wet. Pieces of</td>
</tr>
<tr>
<td></td>
<td>S-41</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>wood present.</td>
</tr>
<tr>
<td></td>
<td>S-42</td>
<td>7 - 12 - 27</td>
<td>100</td>
<td>100</td>
<td>ML</td>
<td>Cuttings: Light greenish gray, Silt, moist with organics.</td>
</tr>
<tr>
<td></td>
<td>S-43</td>
<td>(39)</td>
<td></td>
<td></td>
<td>SM</td>
<td>Very dense, gray, silty fine SAND, moist. Abundant organics, including pieces of wood,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>present.</td>
</tr>
<tr>
<td></td>
<td>S-44</td>
<td>16 - 50 - 503</td>
<td>100</td>
<td>100</td>
<td>SP</td>
<td>Dense, dark gray with light gray and greenish gray streaks, silty, fine SAND, moist.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(100+)</td>
<td></td>
<td></td>
<td></td>
<td>Abundant organics, including pieces of wood, present.</td>
</tr>
<tr>
<td></td>
<td>S-45</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Heaving sand present. No SPT sample taken. Cuttings consist of dark gray, fine to</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>medium SAND, wet.</td>
</tr>
</tbody>
</table>

#### REMARKS AND OTHER TESTS

<table>
<thead>
<tr>
<th>Piezometer Schematic</th>
<th>Lab Tests</th>
<th>Moisture Content, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>28.8</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>28.1</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>28.1</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>24.3</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>23.4</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>17.1</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>23.4</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>23.8</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>23.8</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>25.0</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>35.9</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>31.0</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>25.3</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>22.1</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>20.8</td>
<td></td>
</tr>
</tbody>
</table>

**Figure:** A-5.7
### Log of Boring MW-4

#### Project: CSI Brightwater
#### Project Location: King and Snohomish Counties
#### Contract Number: E83004E

<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>SAMPLES</th>
<th>MATERIAL DESCRIPTION</th>
<th>Piezometer Schematic</th>
<th>Lab Tests</th>
<th>Moisture Content, %</th>
<th>REMARKS AND OTHER TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>-20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-30</td>
<td>S-49</td>
<td>Cuttings: Gray, SILT, moist.</td>
<td></td>
<td>M</td>
<td>28.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(NONGLACUSTRINE, Qnfl)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hard, gray, organic SILT, moist. Abundant compressed peat layers present. Compressed peat is platey and breaks into sheets.</td>
<td></td>
<td>M</td>
<td>32.7</td>
<td></td>
</tr>
<tr>
<td>-35</td>
<td>S-50</td>
<td>Cuttings: Gray, SILT, moist.</td>
<td></td>
<td>M</td>
<td>28.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11 - 35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>50/5</td>
<td>(100+)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>100</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>-40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-50</td>
<td>S-52</td>
<td>Cuttings: Brown, compressed peat.</td>
<td></td>
<td>M</td>
<td>47.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>S-51b</td>
<td>Cuttings: Brown, compressed peat.</td>
<td></td>
<td>M</td>
<td>47.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>S51c</td>
<td>Cuttings: Brown, compressed peat.</td>
<td></td>
<td>M</td>
<td>47.5</td>
<td></td>
</tr>
<tr>
<td>-60</td>
<td>S-53</td>
<td>Cuttings: Brown, compressed peat.</td>
<td></td>
<td>M</td>
<td>47.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>35 - 50/2</td>
<td>Cuttings: Brown, compressed peat.</td>
<td></td>
<td>M</td>
<td>47.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(100+)</td>
<td>Cuttings: Brown, compressed peat.</td>
<td></td>
<td>M</td>
<td>47.5</td>
<td></td>
</tr>
<tr>
<td>-65</td>
<td>S-54</td>
<td>Cuttings: Brown, compressed peat.</td>
<td></td>
<td>M</td>
<td>47.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>S-55</td>
<td>Cuttings: Brown, compressed peat.</td>
<td></td>
<td>M</td>
<td>47.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>S-56</td>
<td>Cuttings: Brown, compressed peat.</td>
<td></td>
<td>M</td>
<td>47.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30 - 50/3</td>
<td>Cuttings: Brown, compressed peat.</td>
<td></td>
<td>M</td>
<td>47.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(100+)</td>
<td>Cuttings: Brown, compressed peat.</td>
<td></td>
<td>M</td>
<td>47.5</td>
<td></td>
</tr>
<tr>
<td>-70</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>400</td>
<td>S-48</td>
<td>Heaving sand present. No SPT sample taken. Cuttings consist of dark gray, fine to medium SAND, wet.</td>
<td></td>
<td>SA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>S-47</td>
<td>Cuttings: Brown to gray, CLAY, moist. According to the driller, this clay lens is only 1.5 to 2 feet thick.</td>
<td></td>
<td>M, SA</td>
<td>32.9</td>
<td></td>
</tr>
<tr>
<td>405</td>
<td>S-48</td>
<td>35 feet of heave present at 405 feet. No SPT sample taken. Cuttings: Gray, gravelly, fine to coarse SAND, wet. Gravel is fine.</td>
<td></td>
<td>M, SA</td>
<td>14.8</td>
<td></td>
</tr>
<tr>
<td>410</td>
<td>S-49</td>
<td>Cuttings: Gray, SILT, moist.</td>
<td></td>
<td>M</td>
<td>28.9</td>
<td></td>
</tr>
<tr>
<td>415</td>
<td>S-50</td>
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<td></td>
<td>M</td>
<td>28.9</td>
<td></td>
</tr>
<tr>
<td>420</td>
<td>S-51</td>
<td>Cuttings: Gray, SILT, moist.</td>
<td></td>
<td>M</td>
<td>28.9</td>
<td></td>
</tr>
<tr>
<td>425</td>
<td>S-51a</td>
<td>Cuttings: Gray, SILT, moist.</td>
<td></td>
<td>M</td>
<td>28.9</td>
<td></td>
</tr>
<tr>
<td>430</td>
<td>S-52</td>
<td>Cuttings: Gray, SILT, moist.</td>
<td></td>
<td>M</td>
<td>28.9</td>
<td></td>
</tr>
<tr>
<td>435</td>
<td>S-53</td>
<td>Cuttings: Gray, SILT, moist.</td>
<td></td>
<td>M</td>
<td>28.9</td>
<td></td>
</tr>
<tr>
<td>440</td>
<td>S-54</td>
<td>Cuttings: Dark gray, fine to coarse sandy, GRAVEL, wet.</td>
<td></td>
<td>M</td>
<td>7.7</td>
<td></td>
</tr>
<tr>
<td>445</td>
<td>S-55</td>
<td>Cuttings: Dark gray, fine to coarse sandy, GRAVEL, wet.</td>
<td></td>
<td>M</td>
<td>8.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>S-56</td>
<td>Cuttings: Dark gray, fine to coarse sandy, GRAVEL, wet.</td>
<td></td>
<td>M</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td>450</td>
<td>S-57</td>
<td>Very dense, gray, fine sandy GRAVEL, moist.</td>
<td></td>
<td>M</td>
<td>5.1</td>
<td></td>
</tr>
<tr>
<td>455</td>
<td>S-58</td>
<td>Bottom of hole at 446.5 feet. 2&quot; piezometer installed from 404 to 424 feet. Vibrating wire piezometer installed at 226 feet.</td>
<td></td>
<td>M</td>
<td>13.3</td>
<td></td>
</tr>
<tr>
<td>460</td>
<td>S-59</td>
<td>Bottom of hole at 446.5 feet. 2&quot; piezometer installed from 404 to 424 feet. Vibrating wire piezometer installed at 226 feet.</td>
<td></td>
<td>M, SA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EXPLORATION DESIGNATION</td>
<td>SAMPLE NUMBER</td>
<td>DEPTH (ft)</td>
<td>WATER CONTENT (%)</td>
<td>WET DENSITY (pcf)</td>
<td>DRY DENSITY (pcf)</td>
<td>SODIUM CONTENT (mg/l)</td>
</tr>
<tr>
<td>-------------------------</td>
<td>---------------</td>
<td>-----------</td>
<td>-------------------</td>
<td>-------------------</td>
<td>-------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>MW-4</td>
<td>S-1</td>
<td>9.0 - 10.5</td>
<td>9.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MW-4</td>
<td>S-2</td>
<td>19.0 - 20.5</td>
<td>6.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MW-4</td>
<td>S-3</td>
<td>29.0 - 30.5</td>
<td>10.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MW-4</td>
<td>S-4</td>
<td>39.0 - 40.5</td>
<td>5.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MW-4</td>
<td>S-5</td>
<td>49.0 - 50.5</td>
<td>5.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MW-4</td>
<td>S-6</td>
<td>59.0 - 60.5</td>
<td>13.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MW-4</td>
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<td></td>
<td>NP</td>
<td>gray, poorly graded SAND with silt</td>
</tr>
<tr>
<td>MW-4</td>
<td>S51c</td>
<td>429.0 - 429.5</td>
<td>32.7</td>
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<td></td>
<td></td>
<td></td>
<td>ML</td>
<td>dk. olive-gray, SILT with sand, thin interbedded organics</td>
</tr>
<tr>
<td>MW-4</td>
<td>S-52</td>
<td>430.0 - 430.5</td>
<td>32.7</td>
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<td>6.7 93.3</td>
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<td></td>
<td></td>
<td>ML</td>
<td>dk. olive-gray, SILT, thin interbedded organic layers</td>
</tr>
</tbody>
</table>

Notes: 1. This table summarizes information presented elsewhere in the report and should be used in conjunction with the report text, other graphs and tables, and the exploration logs.
<table>
<thead>
<tr>
<th>EXPLORATION DESIGNATION</th>
<th>SAMPLE NUMBER</th>
<th>DEPTH (ft)</th>
<th>WATER CONTENT (%)</th>
<th>DRY DENSITY (pcf)</th>
<th>SODIUM CONTENT (mpa, dry)</th>
<th>UNCONF. COMP. STRENGTH (kPa)</th>
<th>COHESION (psi)</th>
<th>PHIL ANGLE (degrees)</th>
<th>LIQUID LIMIT</th>
<th>PLASTIC LIMIT</th>
<th>% GRAVEL</th>
<th>% SAND</th>
<th>% FINES</th>
<th>ORGANIC CONTENT (%)</th>
<th>ASTM SOIL CLASSIFICATION</th>
<th>SAMPLE CLASSIFICATION</th>
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<tr>
<td>MW-4</td>
<td>S-52</td>
<td>432.0 - 433.0</td>
<td>47.5</td>
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<td></td>
<td>ML</td>
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<tr>
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<td>S-53</td>
<td>435.0 - 435.7</td>
<td>7.7</td>
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<td>444.0 - 444.5</td>
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<td>445.0 - 446.5</td>
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<td></td>
<td></td>
<td>GP</td>
<td>olive-gray, poorly graded GRAVEL with silt and sand</td>
</tr>
</tbody>
</table>

Notes: 1. This table summarizes information presented elsewhere in the report and should be used in conjunction with the report text, other graphs and tables, and the exploration logs.
### Log of Boring MW-5

**Report Title:**
CSI Brightwater

**Project Location:**
King and Snohomish Counties

**Contract Number:**
E83004E

<table>
<thead>
<tr>
<th>Date(s) Drilled</th>
<th>Geotechnical Consultant</th>
<th>HWA GeoSciences Inc.</th>
<th>Logged By</th>
<th>SEG, BKH</th>
<th>Checked By</th>
<th>MLR/SEG</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/27/01 - 12/7/01</td>
<td>Layne Christensen Company</td>
<td>Total Depth of Borehole 352.0 feet</td>
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<tr>
<td>Drilling Method/Rig Type</td>
<td>Drilling Contractor</td>
<td>Hammer Weight/Drop (lbs/in.)</td>
<td>Ground Surface Elevation/Datum 305 feet / NAVD88</td>
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<tr>
<td>Becker Hammer/ Truck</td>
<td>Dual Wall Reverse Circ.</td>
<td>300#, 30&quot;</td>
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</tr>
</tbody>
</table>

**Location**
Lake Ballinger Pump Station

**Coordinates**
N. 47.77739, W. 122.33416

**Elevation Source**
Plan

---

### SAMPLES

<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Graphic Log</th>
<th>USCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>-300</td>
<td>0</td>
<td>S-1</td>
<td>8 - 8 - 8 (16)</td>
<td>100</td>
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<td>SP</td>
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<tr>
<td>-280</td>
<td>10</td>
<td>S-2</td>
<td>7 - 8 - 8 (16)</td>
<td>100</td>
<td></td>
<td>SP</td>
<td>SP</td>
</tr>
<tr>
<td>-270</td>
<td>15</td>
<td>S-3</td>
<td>8 - 14 - 15 (29)</td>
<td>100</td>
<td></td>
<td>SP</td>
<td>SP</td>
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<tr>
<td>-260</td>
<td>20</td>
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<td></td>
</tr>
<tr>
<td>-250</td>
<td>25</td>
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<td></td>
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<tr>
<td>-240</td>
<td>30</td>
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<tr>
<td>-230</td>
<td>35</td>
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<tr>
<td>-220</td>
<td>40</td>
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<td>-210</td>
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<tr>
<td>-200</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

---

### MATERIAL DESCRIPTION

- **Asphalt**
  - Sandy Fill, (FILL, f)
  - Medium dense, grayish brown, fine SAND with trace silt and gravel, moist.

- **GLACIAL FLUVIAL, Qva**
  - Occasional gravel and minor silt seams present.

- **SP**
  - Medium dense, grayish brown, fine to medium SAND with occasional gravels, dry. Contains minor silt seams.

- **SP**
  - Medium dense, grayish brown, medium SAND, with gravel, moist.

- **SP**
  - Medium dense, grayish brown, medium SAND, trace gravel, moist.

- **SP**
  - Becomes gray to brownish gray, medium SAND.

- **SP**
  - 1 foot of heave present at 29 feet.

- **SP**
  - Medium dense, dark gray, fine to medium SAND, wet. Trace fine gravel.

- **ML**
  - Stiff, grayish brown, fine sandy, SILT to SILT, moist. Laminated, non-plastic.

- **SP**
  - Easy push of casing to 63 feet. Medium dense, gray, medium SAND, wet. Clean.

---

### REMARKS AND OTHER TESTS

- **Piezometer Schematic**
- **Lab Tests**
- **Moisture Content, %**
- **Remarks and Other Tests**

---

**Figure:** A-6.1
<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>SAMPLES</th>
<th>MATERIAL DESCRIPTION</th>
<th>Piezometer Schematic</th>
<th>Lab Tests</th>
<th>Soil Type %</th>
<th>REMARKS AND OTHER TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td></td>
<td>S-6</td>
<td>1' of heave present at 50 feet.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-250</td>
<td>55</td>
<td>S-8</td>
<td>5' of heave present at 60 feet. No sample taken.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-240</td>
<td>65</td>
<td>ML</td>
<td>Stiff to hard, dark gray, massive to laminated, low plastic Silt, dry.</td>
<td>(GLACIOLAGUSTRINE, Qvc)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-230</td>
<td>75</td>
<td>S-7</td>
<td>Hard, dark gray, slightly sandy Silt, moist. Laminated, non to slightly plastic.</td>
<td></td>
<td>M</td>
<td>28.4</td>
<td></td>
</tr>
<tr>
<td>-220</td>
<td>85</td>
<td>ML</td>
<td>Becomes drier, massive, more clayey with slightly wavy laminae.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-210</td>
<td>95</td>
<td>S-8</td>
<td>Hard, dark gray, lean Clay, laminated, moist. Low plastic.</td>
<td></td>
<td>M</td>
<td>25.3</td>
<td></td>
</tr>
<tr>
<td>-205</td>
<td>105</td>
<td>CL</td>
<td>A few gravels present at 86 feet.</td>
<td></td>
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</tr>
<tr>
<td>-200</td>
<td>110</td>
<td>M</td>
<td>Hard, dark gray, Silt, moist. Laminated and minor slickensides present. Low plasticity.</td>
<td></td>
<td>MSA AL HA</td>
<td>26.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>S-9</td>
<td>Hard, dark gray, massive to laminated, lean Clay, dry.</td>
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<tr>
<td></td>
<td></td>
<td>CL</td>
<td>Very dense, gray, silty sand with gravel (diamict) with beds of interlaminated silty sand and sandy Silt, wet.</td>
<td>(GLACIAL TILL, Qpqt)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure: A-6.2
Project: CSI Brightwater
Project Location: King and Snohomish Counties
Contract Number: E83004E

Log of Boring MW-5
Sheet 3 of 7

SAMPLING

<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Graphic Log</th>
<th>USCS</th>
<th>MATERIAL DESCRIPTION</th>
<th>Piezometer Schematic</th>
<th>Lab Tests</th>
<th>Moisture Content, %</th>
<th>REMARKS AND OTHER TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td></td>
<td>S-11</td>
<td>8</td>
<td>20 - 15 (35)</td>
<td>100</td>
<td></td>
<td>SM</td>
<td>Very dense, dark gray, very silty, SAND with gravel, dry.</td>
<td>MSA</td>
<td>12.0</td>
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<tr>
<td></td>
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<td></td>
<td>Boulder encountered at 115 feet.</td>
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<td>115</td>
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<td></td>
<td></td>
<td></td>
<td>Dense, dark gray to brownish gray, interbedded medium SAND with gravel to silty fine SAND, wet. Encountered water at 118 feet.</td>
<td>MSA</td>
<td>13.3</td>
<td></td>
<td>GLACIAL FLUVIAL, Qpgr</td>
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<td>120</td>
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<td>S-12</td>
<td>5</td>
<td>18 - 18 (35)</td>
<td>100</td>
<td></td>
<td>SP-SM</td>
<td></td>
<td></td>
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<td>125</td>
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<td></td>
<td>5 feet of heave present at 129 feet. No sample taken. Cuttings are silty SAND.</td>
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<td>130</td>
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<tr>
<td>150</td>
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<td>S-14</td>
<td>71</td>
<td></td>
<td>100</td>
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<td>SP-SM</td>
<td>Very dense, dark gray, silty SAND to sandy SILT with gravel, moist to wet. TILL-LIKE.</td>
<td>MSA</td>
<td>15.2</td>
<td></td>
<td>GLACIAL TILL, Qpgr</td>
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<td>155</td>
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<td>160</td>
<td></td>
<td>S-15</td>
<td>81</td>
<td></td>
<td>100</td>
<td></td>
<td>GP</td>
<td>Becomes sandy gravel and wet at 152 feet.</td>
<td>M</td>
<td>9.7</td>
<td></td>
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<td>165</td>
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<tr>
<td>170</td>
<td></td>
<td>S-16</td>
<td>5</td>
<td>19 - 30 (49)</td>
<td>44</td>
<td></td>
<td>SM</td>
<td>Dense, dark gray, silty medium SAND to fine sandy SILT interbeds. Mostly massive with silty laminae. 6 feet of heave present at 158 feet.</td>
<td>MSA</td>
<td>22.4</td>
<td></td>
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Figure: A-6.3
## Log of Boring MW-5

**Project:** CSI Brightwater  
**Project Location:** King and Snohomish Counties  
**Contract Number:** E83004E

### Samples

<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Material Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>170</td>
<td>S-17</td>
<td></td>
<td>90</td>
<td>83</td>
<td></td>
<td>dark draped laminations present. A few drop stones present. (GLACIALACUSTRINE, Qpgl)</td>
</tr>
</tbody>
</table>

Becomes more clayey at 175 feet.

<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Material Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>180</td>
<td>S-18</td>
<td>6-14-17</td>
<td>31</td>
<td>100</td>
<td></td>
<td>Hard, dark gray, slightly sandy SILT, moist. Faintly laminated to massive. Low plasticity. Sand is fine to medium.</td>
</tr>
</tbody>
</table>

Becomes cobbly at 185 feet.

<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Material Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>190</td>
<td>S-19</td>
<td></td>
<td>70</td>
<td>100</td>
<td></td>
<td>Hard, dark gray, SILT, with trace fine sand, dry. Faintly laminated to massive.</td>
</tr>
</tbody>
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<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Material Description</th>
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<tbody>
<tr>
<td>195</td>
<td>S-20</td>
<td>10-18-27</td>
<td>45</td>
<td>100</td>
<td></td>
<td>Between 194 and 196 feet, silty sand interbeds present.</td>
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<table>
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<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Material Description</th>
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<td>200</td>
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<td>83</td>
<td></td>
<td></td>
<td>Hard, dark gray, fat CLAY with trace fine sand, dry. Laminations are contorted. Moderate plasticity when wet. Appears carbonaceous.</td>
</tr>
</tbody>
</table>

<table>
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<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Material Description</th>
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<td>210</td>
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<td></td>
<td>87</td>
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<td></td>
<td>Very dense, dark gray, silty, fine to coarse SAND, moist. Some cobbles present. Till-like. (GLACIAL TILL, Qpgl)</td>
</tr>
</tbody>
</table>

### Remarks and Other Tests

- 1/30/2002 166.79 ft
- M 16.5
- M 26.8
- M 23.8
- M 19.2
- M 8.2
- M 10.2

---

Figure: A-6.4
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<th>Depth, feet</th>
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<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>USCS</th>
<th>MATERIAL DESCRIPTION</th>
<th>Piezometer Schematic</th>
<th>Lab Tests</th>
<th>Moisture Content, %</th>
<th>Remarks and Other Tests</th>
</tr>
</thead>
<tbody>
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<td>-20</td>
<td>285</td>
<td>S-33</td>
<td>50</td>
<td>83</td>
<td></td>
<td>SP-SM</td>
<td>Very dense, dark gray, slightly silty to silty, fine to coarse gravelly, fine to coarse SAND, wet. (Drift-like)</td>
<td>M</td>
<td>SA</td>
<td>13.2</td>
<td>12 feet of heave present at 289 feet. No sample taken.</td>
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<td>S-34</td>
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<td>S-35</td>
<td>Very dense, dark gray, slightly silty, fine to coarse gravelly, fine to medium SAND, wet.</td>
<td>M</td>
<td></td>
<td>20.2</td>
<td>4 feet of heave present. Driller pulled back casing and heave fell out, therefore, a sample was taken.</td>
</tr>
<tr>
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<td></td>
<td>S-35b</td>
<td>83</td>
<td>117</td>
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<td>SP-SM</td>
<td>Very dense, dark gray, slightly silty, fine to coarse sandy, silty, fine to coarse GRAVEL, wet.</td>
<td>M</td>
<td>SA</td>
<td>8.8</td>
<td>Very dense, dark gray, slightly silty, fine to coarse gravelly, fine to medium SAND, wet.</td>
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<tr>
<td>-10</td>
<td>305</td>
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<td>72</td>
<td>83</td>
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<td>GP</td>
<td>Very dense, dark gray, slightly silty, fine to coarse gravelly, fine to coarse SAND, wet.</td>
<td>M</td>
<td></td>
<td>9.1</td>
<td>Ground water at 169.9 feet below ground surface at start of drilling the next day.</td>
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<tr>
<td></td>
<td></td>
<td>S-37</td>
<td>66</td>
<td>83</td>
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<td>SW</td>
<td>Very dense, dark gray, slightly silty, fine to medium gravelly, fine to coarse SAND, wet.</td>
<td>M</td>
<td></td>
<td>7.9</td>
<td>Very dense, dark gray, silty, fine to coarse gravelly, fine to coarse GRAVEL, wet.</td>
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<td>S-38</td>
<td>72</td>
<td>100</td>
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<td>SW</td>
<td>Very dense, dark gray, slightly silty, fine to coarse gravelly, fine to coarse SAND, wet.</td>
<td>M</td>
<td></td>
<td>7.8</td>
<td>No recovery. Cuttings are silty, sandy gravel and cobbles.</td>
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<td>S-39</td>
<td>68</td>
<td>83</td>
<td></td>
<td>SW</td>
<td>Very dense, dark gray, silty, fine to course sandy, fine to coarse GRAVEL, wet.</td>
<td>M</td>
<td>SA</td>
<td>10.3</td>
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<td>0.5</td>
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<td>GP</td>
<td>Very dense, dark gray, slightly silty to clean, fine to coarse sandy, fine to coarse GRAVEL with cobbles, wet.</td>
<td>M</td>
<td></td>
<td>7.5</td>
<td>22 feet of heave present at 329 feet. No sample taken.</td>
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<td>S-42</td>
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<td>M</td>
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<td></td>
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<td>S-43</td>
<td></td>
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<td>M</td>
<td></td>
<td></td>
<td>10 feet of heave present. Cuttings are sandy GRAVEL, wet.</td>
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</tbody>
</table>

Figure: A-6.6
### Log of Boring MW-5

**Project:** CSI Brightwater  
**Project Location:** King and Snohomish Counties  
**Contract Number:** E83004E

<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in.</th>
<th>Recovery, %</th>
<th>Graphic Log</th>
<th>USCS</th>
<th>MATERIAL DESCRIPTION</th>
<th>Pluvimeter Schematic</th>
<th>Lab Tests</th>
<th>Moisture Content, %</th>
<th>REMARKS AND OTHER TESTS</th>
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<tbody>
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<td></td>
<td></td>
<td>Hard, dark gray, Silt, moist. Laminated and plastic. (GLACIALACUSTRINE, Qppi)</td>
<td></td>
<td>M</td>
<td>26.3</td>
<td>Bottom of boring at 352'. 2&quot; piezometer installed to 352'. Vibrating wire piezometer installed to 240'.</td>
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<tr>
<td></td>
<td>350</td>
<td>GM</td>
<td>S-45</td>
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<td></td>
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<td></td>
<td>Cuttings become gravelly and wet. Lenses of silt and gravel.</td>
<td></td>
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**Remarks and Other Tests:**
- Bottom of boring at 352'. 2" piezometer installed to 352'. Vibrating wire piezometer installed to 240'.
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<th>SAMPLE NUMBER</th>
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<th>WATER CONTENT (%)</th>
<th>DRY DENSITY (pcf)</th>
<th>SODIUM CONTENT (mg/kg dry)</th>
<th>UNCONFINED COMPR. STRENGTH (ksi)</th>
<th>COHESION (psi)</th>
<th>PHI ANGLE (degrees)</th>
<th>LIQUID LIMIT</th>
<th>PLASTIC LIMIT</th>
<th>% GRAVEL</th>
<th>% SAND</th>
<th>% FINES</th>
<th>ORGANIC CONTENT (%)</th>
<th>ASTM SOIL CLASSIFICATION</th>
<th>SAMPLE CLASSIFICATION</th>
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<td>9.0 - 10.5</td>
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<td></td>
<td>ML</td>
<td>I. olive-brown, poorly graded sandy SILT</td>
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<tr>
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<td>I. olive-gray, poorly graded SAND</td>
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<td>93.9</td>
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Notes: 1. This table summarizes information presented elsewhere in the report and should be used in conjunction with the report text, other graphs and tables, and the exploration logs.
<table>
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<th>EXPLORATION DESIGNATION</th>
<th>SAMPLE NUMBER</th>
<th>DEPTH (%)</th>
<th>WATER CONTENT (%)</th>
<th>DRY DENSITY (pcf)</th>
<th>SODIUM CONTENT (mg/kg dry)</th>
<th>UNCONF. COMPR. STRENGTH (kPa)</th>
<th>COHESION (psi)</th>
<th>PHI ANGLE (degrees)</th>
<th>LIQUID LIMIT</th>
<th>PLASTIC LIMIT</th>
<th>% GRAVEL</th>
<th>% SAND</th>
<th>% FINES</th>
<th>ORGANIC CONTENT (%)</th>
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<th>SAMPLE CLASSIFICATION</th>
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Notes: 1. This table summarizes information presented elsewhere in the report and should be used in conjunction with the report text, other graphs and tables, and the exploration logs.

SUMMARY OF MATERIAL PROPERTIES
PAGE: 2 of 3
PROJECT NO.: 99153-490 FIGURE: A-6.15
<table>
<thead>
<tr>
<th>EXPLORATION DESIGNATION</th>
<th>SAMPLE NUMBER</th>
<th>DEPTH (ft)</th>
<th>WATER CONTENT (%)</th>
<th>DRY DENSITY (pcf)</th>
<th>SODIUM CONTENT (mg/kg dry)</th>
<th>UNCONF COMPR. STRENGTH (psi)</th>
<th>COHESION (psi)</th>
<th>PHIL ANGLE (degrees)</th>
<th>LIQUID LIMIT</th>
<th>PLASTIC LIMIT</th>
<th>% GRAVEL</th>
<th>% SAND</th>
<th>% FINES</th>
<th>ORGANIC CONTENT (%)</th>
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<th>SAMPLE CLASSIFICATION</th>
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</table>

Notes: 1. This table summarizes information presented elsewhere in the report and should be used in conjunction with the report text, other graphs and tables, and the exploration logs.
## Log of Boring MW-6

**Date(s) Drilled:** 1/11/02 - 1/23/02  
**Geotechnical Consultant:** HWA GeoSciences Inc.  
**Logged By:** BKH, MBB  
**Checked By:** MLR/SEG  
**Total Depth of Borehole:** 360.5 feet  
**Ground Surface Elevation/Datum:** 314 feet / NAVD88

**Drilling Method/Rig Type:** Becker Hammer Drill/Truck  
**Drill Bit Size/Type:** Dual Wall Reverse Circ.  
**Coordinates:** N. 47.77785 W. 122.31449  
**Location:** North east of 1-5/SR 1-4 I/C

### SAMPLES

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<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Graphic Log</th>
<th>USCS</th>
<th>Material Description</th>
<th>Piezometer Schematic</th>
<th>Lab Tests</th>
<th>Moisture Content, %</th>
<th>REMARKS AND OTHER TESTS</th>
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<tr>
<td>-310</td>
<td>5</td>
<td>SP</td>
<td>S-1</td>
<td>4 - 6 - 7</td>
<td>(13)</td>
<td>100</td>
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<td>Medium dense, brown, fine to coarse gravelly, fine to coarse SAND, moist. (RECESSIONAL FLUVIAL, Qvr)</td>
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<td>M</td>
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<td>SM</td>
<td>S-2</td>
<td>50 / 5</td>
<td>(100+)</td>
<td>100</td>
<td>SM</td>
<td>Very dense, olive gray, fine to coarse gravelly, silty, fine to medium SAND, moist. (GLACIAL TILL, Qrt)</td>
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<td>M</td>
<td>SA</td>
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**Figure:** A-7.1
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<td>50</td>
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<td>10</td>
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<td>Very dense, gray, interbedded fine to medium SAND and SILT, moist to wet.</td>
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<td>(NONGLACIAL FLUVIAL, Qpnl) Abundant wood chunks present.</td>
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<td>55</td>
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<td>11 - 22 - 36 (60)</td>
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<td>Dense, rust mottled gray, very fine gravelly, slightly silty, coarse SAND, wet.</td>
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<td>6 - 9 - 12 (21)</td>
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<td>Very stiff, green gray and dark gray, lean CLAY, moist. Laminated with many interbedded thin light gray, fine sand and silt lenses.</td>
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<td>75</td>
<td>CL</td>
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<td>(NONGLACIAL LACUSTRINE, Qpnl) Hard, dark gray to green gray, fine sandy, lean CLAY, moist to wet. Organics present.</td>
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<td>5 - 9 - 13 (22)</td>
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<td>Hard, green gray, fine sandy, Lean CLAY, moist. Organics, wood and charcoal fragments present.</td>
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**Remarks and Other Tests**

- MSA 20.2 Vibrating Wire Piezometer 3/27/2002 61 ft daughters 1/30/2002 69.4 ft daughters
- MSA AL HA
- MSA 28.2
- MSA AL HA
- MSA 26.7
### Log of Boring MW-6

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<td>Hard, fine to coarse gravelly, fine to coarse sandy, Silt, moist. Some cobbles present. (GLACIAL TILL, Qpgt)</td>
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<td>Standpipe Piezometer 3/27/2002 160.4 ft 3/30/2002 160.59 ft</td>
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### Log of Boring MW-6

**Sheet 4 of 7**

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<th>Recovery, %</th>
<th>USCS</th>
<th>Material Description</th>
<th>Piezometer Schematic</th>
<th>Lab Tests</th>
<th>Moisture Content, %</th>
<th>Remarks and Other Tests</th>
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Remarks and Other Tests:

- Dense, dark gray, sandy, fine to coarse gravel, moist. Gravel is sub-rounded to sub-angular.
- Very dense, dark gray, fine to medium SAND, wet. Trace fine sub-rounded gravel and coarse sand.

Figure: A-7.6
### Log of Boring MW-6

#### Sheet 7 of 7

<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>MATERIAL DESCRIPTION</th>
<th>Piezometer Schematic</th>
<th>Moisture Content, %</th>
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Bottom of boring at 360.5 feet. 2" piezometer installed from 340 to 360 feet bgs. Vibrating wire piezometer installed at 180 feet.
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<th>DEPTH (ft)</th>
<th>WATER CONTENT (%)</th>
<th>DRY DENSITY (pcf)</th>
<th>WET DENSITY (pcf)</th>
<th>SODIUM CONTENT (mg/100g dry)</th>
<th>UNCONF. COMPR. STRENGTH (psi)</th>
<th>COHESION (psi)</th>
<th>PHI ANGLE (degrees)</th>
<th>LIQUID LIMIT</th>
<th>PLASTIC LIMIT</th>
<th>% GRANULAR MATERIAL</th>
<th>% SAND</th>
<th>% FINES</th>
<th>ORGANIC CONTENT (%)</th>
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Notes: 1. This table summarizes information presented elsewhere in the report and should be used in conjunction with the report text, other graphs and tables, and the exploration logs.
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<td></td>
<td>dark olive-gray, SILT</td>
</tr>
</tbody>
</table>

Notes: 1. This table summarizes information presented elsewhere in the report and should be used in conjunction with the report text, other graphs and tables, and the exploration logs.
### Log of Boring BW-4

**Date(s) Drilled:** 12/28/01 - 1/11/02  
**Geotechnical Consultant:** SHANNON & WILSON  
**Logged By:** XDH/BMP  
**Checked By:** TWH  

**Drilling Method/Rig Type:** mud rotary/ Mobile B-59  
**Drilling Contractor:** Geo-Tech Explorations, Inc.  
**Total Depth of Borehole:** 366.4 feet  
**Ground Surface Elevation/Datum:** 358 feet / NAVD88  

**Location:** 228th St/Hwy 99  
**Coordinates:** N 292703.0 E 1270572.0  
**Elevation Source:** Topo

### MATERIAL DESCRIPTION

**Type Number** | **Blows / 6 in. (N)** | **Recovery, %** | **USCS** | **Remarks and Other Tests** | **Density Test** | **Moisture Content, %** | **Remarks and Other Tests**  
--- | --- | --- | --- | --- | --- | --- | ---  
1 | 50/5' | 0 | SP-SM | Very dense, gray-brown, slightly silty, fine to medium SAND, trace of gravel, moist to wet; scattered gravelly layers; SP-SM. (Qve) | | |  
2 | 99/10.5' | 89 | | | | |  
3 | 58/6’ | 100 | | | | |  
4 | 50/5’ | 74 | | | | |  
5 | 57/6’ | 98 | | | | |  
6 | 87/6’ | 100 | | | | |  
7 | 65/6’ | 0 | | | | |  
8 | 54/6’ | 100 | | | | |  
9 | 65/6’ | 0 | | | | |  

**Figure:** B-3.1
<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>USCS</th>
<th>Material Description</th>
<th>Lab Tests</th>
<th>Moisture Content, %</th>
<th>Remarks and Other Tests</th>
</tr>
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<tbody>
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<td>100</td>
<td>260</td>
<td>11</td>
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<td></td>
<td>SM</td>
<td>Very dense SAND; SP-SM (cont.) (Qva)</td>
<td>M</td>
<td>18.0</td>
<td></td>
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<tr>
<td>110</td>
<td>240</td>
<td>12</td>
<td>50/3&quot;</td>
<td>42</td>
<td></td>
<td></td>
<td>Very dense, gray-brown to gray, silty, fine SAND; wet, grades finer with depth, abundant wood fragments at bottom; SM. (Qva)</td>
<td>M</td>
<td>23.0</td>
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<tr>
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<td>M</td>
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<td></td>
<td>ML</td>
<td>Very dense, gray, fine sandy SILT grading to SILT, trace of clay and fine sand; moist to wet; abundant fine organic fragments; ML. (Qva)</td>
<td>M SA</td>
<td>25.6</td>
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<tr>
<td>190</td>
<td>180</td>
<td>19</td>
<td>46</td>
<td>133</td>
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<td>CL</td>
<td>Hard, gray, silty CLAY and clayey SILT, trace of fine sand; moist; interbedded, scattered seams of slightly clayey silt; CL/ML. (Qve)</td>
<td>M</td>
<td>32.0</td>
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<tr>
<td>200</td>
<td>160</td>
<td>20</td>
<td>33</td>
<td>133</td>
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<td></td>
<td>Very dense, gray, fine sandy SILT to slightly fine</td>
<td>M AL</td>
<td>25.5</td>
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<tr>
<td>210</td>
<td>160</td>
<td>21</td>
<td>77/11*</td>
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<td>31.3</td>
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**Log of Boring BW-4**

**SAMPLES**

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<th>Elevation, feet</th>
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<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery</th>
<th>USCS</th>
<th>Graphic Log</th>
<th>MATERIAL DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>220</td>
<td>140</td>
<td>22</td>
<td>50/3&quot;</td>
<td>100</td>
<td>ML</td>
<td></td>
<td></td>
<td>sandy SILT, trace of clay; moist; interbedded; scattered seams of silty clay and seams of silty, fine sand; ML (Qvic)</td>
</tr>
<tr>
<td>230</td>
<td>120</td>
<td>23</td>
<td>90/9&quot;</td>
<td>100</td>
<td>CH</td>
<td></td>
<td></td>
<td>Hard, gray, silty CLAY and clayey SILT; moist; interbedded, abundant seams of fine sandy silt; CH/CL/ML (Qpgr)</td>
</tr>
<tr>
<td>240</td>
<td>100</td>
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<td>42</td>
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<td>91/9&quot;</td>
<td>110</td>
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<td>27</td>
<td>50/5.5&quot;</td>
<td>162</td>
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<td></td>
<td></td>
<td>Very dense, gray, silty, fine SAND and fine sandy SILT to slightly clayey, fine sandy SILT; moist to wet; interbedded, scattered to abundant fine organic fragments; SM/ML (Qpgr)</td>
</tr>
<tr>
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<td>50/6&quot;</td>
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<td>29</td>
<td>50/5&quot;</td>
<td>1001</td>
<td>CL</td>
<td></td>
<td></td>
<td>Hard, blue-gray, fine sandy, silty CLAY to silty CLAY, trace of fine sand, moist, massive, oxidizes to green-gray, scattered white specks, scattered organics; CL (Qpgr)</td>
</tr>
<tr>
<td>300</td>
<td>-80</td>
<td>30</td>
<td>53</td>
<td>400</td>
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<td>360</td>
<td>20</td>
<td>36</td>
<td>73/11&quot;</td>
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<td>CH</td>
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<td>Hard, blue-gray to green-gray, silty CLAY, trace of gravel; moist; scattered gravelly zones; CH (Qpgr)</td>
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<td>370</td>
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<td>150/2.5&quot;</td>
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**REMARKS AND OTHER TESTS**

- M 22.8
- M 24.6
- M AL 34.4
- M 25.8
- M 21.9
- M 26.2
- M 20.8
- M 24.2
- M AL 19.0
- M 22.1 % Passing #200 Selve
- M 24.1
- M 18.6
- M 16.4
- M 30.2

Figure: B-3.3
### Log of Boring BW-4

**Sheet 4 of 4**

<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>SAMPLES</th>
<th>Blows / in. (N)</th>
<th>Recovery, %</th>
<th>MATERIAL DESCRIPTION</th>
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<tr>
<td>38</td>
<td>340</td>
<td>200/2.5&quot;</td>
<td>0</td>
<td>CL</td>
<td>Hard, silty CLAY; CH (cont.) (Qpgm)</td>
</tr>
<tr>
<td>39</td>
<td>350</td>
<td>93/11&quot;</td>
<td>115</td>
<td>CL</td>
<td>Hard, gray to blue-gray, slightly fine sandy, silty CLAY to fine sandy, silty CLAY; moist; abundant sandy seams, trace of gravel locally; CL. (Qpgl)</td>
</tr>
<tr>
<td>40</td>
<td>360</td>
<td>50/5&quot;</td>
<td>200</td>
<td>CL</td>
<td>Hard, gray, silty CLAY, trace of sand; moist; massive, trace of gravel locally, scattered streaks of green-gray mottling; CL. (Qpgl)</td>
</tr>
<tr>
<td>41</td>
<td>370</td>
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</tr>
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<td>380</td>
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<td>M</td>
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<td>107</td>
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**Remarks and Other Tests**

BOTTOM OF BORING
COMPLETED 1/11/2002

---

Figure: B-3.4
### FIGURE B-3.7
LABORATORY TESTING SUMMARY FOR BW-4

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<th>SAMPLE DATA</th>
<th>GRAIN-SIZE ANALYSES</th>
<th>ATTERBERG LIMITS&lt;sup&gt;de&lt;/sup&gt;</th>
<th>INTERPRETED GEOLOGIC UNIT</th>
<th>SOIL DESCRIPTION&lt;sup&gt;f&lt;/sup&gt;</th>
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</thead>
<tbody>
<tr>
<td>Boring No.</td>
<td>Sample No.</td>
<td>Top Depth (feet)</td>
<td>Natural Water Content&lt;sup&gt;a&lt;/sup&gt; (%)</td>
<td>% Clay</td>
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<tr>
<td>BW-4</td>
<td>S-3</td>
<td>30.0</td>
<td>16.4</td>
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<td>S-5</td>
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</tr>
<tr>
<td>S-14</td>
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<td>23.7</td>
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<td>4.5</td>
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</tr>
<tr>
<td>S-21</td>
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<td>210.0</td>
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<td>S-24</td>
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</tr>
<tr>
<td>S-31</td>
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<td>350.0</td>
<td>19.3</td>
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</tbody>
</table>

Notes:

a. Natural water content conducted on all samples and appears on boring logs.
b. Particle size smaller than 0.075 mm.
c. 1 mm = 1000 μm
d. The numbers shown have been rounded (LL, PL, and PI)
e. NP = non-plastic
f. Soil descriptions have been abbreviated and simplified. For complete descriptions, see the boring logs in Appendix A.1.
**Log of Boring BW-5**

**Sheet 1 of 3**

<table>
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<tr>
<th>Date(s) Drilled</th>
<th>Drilling Method/ Rig Type</th>
<th>Geotechnical Consultant</th>
<th>Drilling Contractor</th>
<th>Total Depth of Borehole</th>
<th>Ground Surface Datum</th>
<th>Elevation Source</th>
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</thead>
<tbody>
<tr>
<td>12/6/01 - 12/20/01</td>
<td>mud rotary/ Mobile B-59</td>
<td>SHANNON &amp; WILSON</td>
<td>Geo-Tech Explorations, Inc.</td>
<td>391.2 feet</td>
<td>400 feet / NAVD88</td>
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<table>
<thead>
<tr>
<th>Drill Bit Size/Type</th>
<th>Hammer Weight/Drop (lbs/in.)</th>
<th>Coordinates</th>
<th>Elevation Source</th>
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<tr>
<td>6-inch Tricone</td>
<td>300#/30&quot;</td>
<td>N 292560.0 E 1275712.0</td>
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**MATERIAL DESCRIPTION**

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<th>Elevation, Feet</th>
<th>Depth, Feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Graphic Log</th>
<th>USCS</th>
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<td>3</td>
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<td>73/11.8&quot;</td>
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<td>13</td>
<td>50/3&quot;</td>
<td>119</td>
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</tr>
</tbody>
</table>

**REMARKS AND OTHER TESTS**

- Very dense, gray-brown, slightly silty, fine to medium SAND; moist to wet; massive, scattered gravelly layers inferred from drill action; SP-SM. (Qva)
- gravelly sand between 3 and 41 feet
- light gray below 45 feet
- Hard, gray-brown to gray, silty CLAY to clayey SILT; trace of fine sand; moist to wet; massive, scattered seams of fine sandy silt, abundant organic; CL/ML. (Qqgl)
- Hard, green-gray to brown and gray, silty CLAY to clayey SILT; moist; massive to bedded, trace of sand locally, weathered at top; CH/ML/CL. (Qnp)
- Hard, light brown, silty CLAY grading to clayey SILT; moist; massive to bedded, abundant seams of silty, fine sand to fine sandy SILT, scattered gravel inferred from drill action; ML/CL. (Qqgl)
<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>USGS</th>
<th>MATERIAL DESCRIPTION</th>
<th>Rem.</th>
<th>Lab Tests</th>
<th>Moisture Content, %</th>
<th>Remarks and Other Tests</th>
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<tbody>
<tr>
<td>260</td>
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<td>14</td>
<td>82/9'</td>
<td></td>
<td>100</td>
<td>CL</td>
<td>Hard, light gray-brown, sandy, gravelly, silty CLAY to very dense, silty, sandy GRAVEL, trace of clay; massive; scattered cobbles inferred from drill action; CL/GM. (Gpgm)</td>
<td>M</td>
<td>M</td>
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<td>97</td>
<td>SM</td>
<td>Very dense, brown, silty, fine to medium SAND, trace of gravel; moist to wet; massive, scattered gravelly layers inferred from drill action; SM. (Gpgf)</td>
<td>M</td>
<td>SA</td>
<td>17.6</td>
<td></td>
</tr>
<tr>
<td>170</td>
<td>180</td>
<td>17</td>
<td>100/5'</td>
<td></td>
<td>98</td>
<td>SM</td>
<td>Very dense, brown to gray-brown, silty, gravelly SAND; moist to wet; scattered slightly clayey layers, scattered layers of silty, fine sand; SM. (Gpgf)</td>
<td>M</td>
<td>M</td>
<td>12.8</td>
<td></td>
</tr>
<tr>
<td>190</td>
<td>200</td>
<td>19</td>
<td>100/4'</td>
<td></td>
<td>33</td>
<td>SM</td>
<td>Very dense, brown to gray-brown, silty, gravelly SAND; moist to wet; scattered slightly clayey layers, scattered layers of silty, fine sand; SM. (Gpgf)</td>
<td>M</td>
<td>M</td>
<td>15.9</td>
<td></td>
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<tr>
<td>200</td>
<td>200</td>
<td>20</td>
<td>200/4.5'</td>
<td></td>
<td>31</td>
<td>SC</td>
<td>Very dense, gray, fine gravelly, silty, clayey SAND and hard, fine sandy, silty CLAY to clayey SILT.</td>
<td>M</td>
<td>SA</td>
<td>8.8</td>
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<tr>
<td>210</td>
<td>220</td>
<td>21</td>
<td>200/4'</td>
<td></td>
<td>101</td>
<td>SM</td>
<td>Very dense, brown to gray-brown, silty, gravelly SAND; moist to wet; scattered slightly clayey layers, scattered layers of silty, fine sand; SM. (Gpgf)</td>
<td>M</td>
<td>M</td>
<td>11.2</td>
<td></td>
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<td>180</td>
<td>220</td>
<td>22</td>
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<td>Very dense, brown to gray-brown, silty, gravelly SAND; moist to wet; scattered slightly clayey layers, scattered layers of silty, fine sand; SM. (Gpgf)</td>
<td>M</td>
<td>SA</td>
<td>11.0</td>
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<td>230</td>
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<td>M</td>
<td>M</td>
<td>14.4</td>
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<td>240</td>
<td>24</td>
<td>150/4'</td>
<td></td>
<td>78</td>
<td>SM</td>
<td>Very dense, brown to gray-brown, silty, gravelly SAND; moist to wet; scattered slightly clayey layers, scattered layers of silty, fine sand; SM. (Gpgf)</td>
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<td>M</td>
<td>11.5</td>
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<td>25</td>
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<td>M</td>
<td>17.4</td>
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<td>260</td>
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<td>150/4'</td>
<td></td>
<td>33</td>
<td>SM</td>
<td>Very dense, brown to gray-brown, silty, gravelly SAND; moist to wet; scattered slightly clayey layers, scattered layers of silty, fine sand; SM. (Gpgf)</td>
<td>M</td>
<td>M</td>
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<tr>
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<td>270</td>
<td>27</td>
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<td></td>
<td>125</td>
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<td>SA</td>
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<tr>
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<td></td>
<td>100</td>
<td>SC</td>
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<td>SA</td>
<td>12.4</td>
<td></td>
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<td>Elevation, feet</td>
<td>Depth, feet</td>
<td>Type</td>
<td>Number</td>
<td>Blows / 6 in. (N)</td>
<td>Recovery, %</td>
<td>Graphic Log</td>
<td>USCS</td>
<td>Material Description</td>
<td>Parameter Systematic</td>
<td>Lab Tests</td>
<td>Moisture Content, %</td>
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<td>40</td>
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<td></td>
<td>M SA</td>
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<tr>
<td>370</td>
<td>390</td>
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<td>43</td>
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<td>116</td>
<td></td>
<td></td>
<td>Hard, gray, silty CLAY; massive to bedded, trace of sand above 375 feet, scattered silt pockets and partings; CH/CL. (Qpgf)</td>
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<td>M AL</td>
<td>15.7</td>
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<tr>
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<td></td>
<td>45</td>
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<td>M AL</td>
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<td>M</td>
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Bottom of Boring Completed 12/20/2001

Figure: B-4.3
**FIGURE B-4.6**
LABORATORY TESTING SUMMARY FOR BW-5

<table>
<thead>
<tr>
<th>SAMPLE DATA</th>
<th>GRAIN-SIZE ANALYSES</th>
<th>ATTERBERG LIMITS</th>
<th>Interpreted Geologic Unit</th>
<th>Soil Description^f</th>
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</thead>
<tbody>
<tr>
<td>Boring No.</td>
<td>Sample No.</td>
<td>Top Depth (feet)</td>
<td>Natural Water Content^a (%)</td>
<td>% Gravel</td>
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<td>S-3</td>
<td>30.0</td>
<td>11.3</td>
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<td>71.0</td>
<td>23.7</td>
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<td>S-8</td>
<td>81.0</td>
<td>23.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-9</td>
<td>90.0</td>
<td>32.2</td>
<td></td>
<td></td>
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<tr>
<td>S-12</td>
<td>120.0</td>
<td>34.2</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>20.9</td>
<td>2.2</td>
<td>83.6</td>
</tr>
<tr>
<td>S-22</td>
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<td>11.0</td>
<td>15.7</td>
<td>58.5</td>
</tr>
<tr>
<td>S-28</td>
<td>280.0</td>
<td>12.4</td>
<td>13.7</td>
<td>41.8</td>
</tr>
<tr>
<td>S-29</td>
<td>290.0</td>
<td>17.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-34</td>
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<td></td>
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<tr>
<td>S-35</td>
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<td>12.7</td>
<td>5.5</td>
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<td>370.0</td>
<td>15.7</td>
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</tbody>
</table>

Notes:

a Natural water content conducted on all samples and appears on boring logs.
b Particle size smaller than 0.075 mm.
c 1 mm = 1000 µm
d The numbers shown have been rounded (LL, PL, and PI)
e NP = non-plastic
f Soil descriptions have been abbreviated and simplified. For complete descriptions, see the boring logs in Appendix A.1.
## Log of Boring BW-6

### Samples

<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Bows / 6 in.</th>
<th>Recovery, %</th>
<th>Graphic Log</th>
<th>USCS</th>
<th>Material Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>100</td>
<td>T</td>
<td>10</td>
<td>50/3</td>
<td>83</td>
<td></td>
<td></td>
<td>Very dense, silty CLAY to sandy GRAVEL; GM/CL (cont.) (Qpgm)</td>
</tr>
<tr>
<td>240</td>
<td>110</td>
<td>T</td>
<td>11</td>
<td>50/5*</td>
<td>83</td>
<td></td>
<td>ML</td>
<td>Hard, gray-brown to gray, clayey SILT, trace of sand and gravel, sandy, silty CLAY, trace of gravel; moist to wet; massive to slightly bedded; ML/CL. (Qpgm)</td>
</tr>
<tr>
<td>320</td>
<td>130</td>
<td>T</td>
<td>13</td>
<td>50/5*</td>
<td>83</td>
<td></td>
<td></td>
<td>Gray below 130 feet.</td>
</tr>
<tr>
<td>140</td>
<td>140</td>
<td>T</td>
<td>14</td>
<td>50/5*</td>
<td>83</td>
<td></td>
<td>SM</td>
<td>Very dense, gray, silty, fine SAND; wet; massive; scattered organic fragments; SM. (Qpgf)</td>
</tr>
<tr>
<td>300</td>
<td>150</td>
<td>T</td>
<td>15</td>
<td>75/9*</td>
<td>120</td>
<td></td>
<td>CH</td>
<td>Hard, gray, silty CLAY, trace of sand, to slightly sandy, silty CLAY, trace of gravel; moist; CH. (Qpgm)</td>
</tr>
<tr>
<td>160</td>
<td>160</td>
<td>T</td>
<td>16</td>
<td>50/5*</td>
<td>83</td>
<td></td>
<td></td>
<td>Layer of slightly clayey, fine sandy silt at 160 feet.</td>
</tr>
<tr>
<td>280</td>
<td>170</td>
<td>T</td>
<td>17</td>
<td>74/11*</td>
<td>100</td>
<td></td>
<td></td>
<td>Gravelly layer inferred from drill action at 175 feet.</td>
</tr>
<tr>
<td>180</td>
<td>180</td>
<td>T</td>
<td>18</td>
<td>67/8*</td>
<td>136</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>260</td>
<td>190</td>
<td>T</td>
<td>19</td>
<td>65/6*</td>
<td>136</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>240</td>
<td>210</td>
<td>T</td>
<td>21</td>
<td>50/6*</td>
<td>0</td>
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### Remarks and Other Tests

- WWP 1/29/2002 124.63 ft
- CW 1/29/2002 126.6 ft

---

**Figure: B-5.2**
<table>
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<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery %</th>
<th>USCS</th>
<th>MATERIAL DESCRIPTION</th>
<th>Piezometer, Schematic</th>
<th>Lab Tests</th>
<th>Moisture Content, %</th>
<th>REMARKS AND OTHER TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>220</td>
<td>22</td>
<td>70/3*</td>
<td>100</td>
<td>SM</td>
<td>Very dense, gray, clayey, silty, gravelly SAND; moist; SM (Gppm)</td>
<td></td>
<td>M</td>
<td>9.7</td>
<td></td>
</tr>
<tr>
<td>-220 230</td>
<td>23</td>
<td>67/4*</td>
<td>101</td>
<td>SP-SM</td>
<td>Very dense, gray, slightly silty, fine to medium SAND, trace of gravel, to fine to medium SAND, trace of silt; wet; scattered seams and layers of silty, fine sand to fine sandy, clayey silt; SP-SM/SP (Qpgf)</td>
<td></td>
<td>M</td>
<td>16.0</td>
<td></td>
</tr>
<tr>
<td>240</td>
<td>24</td>
<td>65/4*</td>
<td>69</td>
<td></td>
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<td></td>
<td>M</td>
<td>17.9</td>
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</tr>
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<td>100</td>
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<td>M</td>
<td>18.5</td>
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<td>260</td>
<td>26</td>
<td>50/5*</td>
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<td>Gravelly layer inferred from drill action at 265 feet.</td>
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<td>M</td>
<td>19.2</td>
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<tr>
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<td>27</td>
<td>50/5*</td>
<td>83</td>
<td>GW-GM</td>
<td>Very dense, gray, slightly silty, sandy GRAVEL; wet, scattered to abundant cobbles inferred from drill action; GW-GM (Qpgf)</td>
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<td>M</td>
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<td>SM</td>
<td>Very dense, gray SILT, trace of fine sand and clay, to silty, fine SAND; moist; scattered to abundant organic and wood fragments, scattered slightly silty layers; SM/ML (Qpni)</td>
<td></td>
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<td>30</td>
<td>69/5*</td>
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<td>M SA</td>
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<td>71/11*</td>
<td>95</td>
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<td>Hard, gray, clayey SILT to silty CLAY, trace of sand; moist; bedded, abundant organic to peaty seams and wood fragments; CL/ML (Qpni)</td>
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<td>M M</td>
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Figure: B-5.3
### Samples

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<td>37</td>
<td>50/5.5*</td>
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<td>50</td>
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<td>39</td>
<td>65/8*</td>
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<td>silty CLAY, trace</td>
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<td>scattered peaty</td>
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<td></td>
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<td>particles; scattered</td>
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<td>to abundant organic</td>
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<tr>
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<td></td>
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<td>fragments; ML/CL.</td>
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<td>(Qpf)</td>
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<tr>
<td>420</td>
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<td></td>
<td>40</td>
<td>50/3*</td>
<td>95</td>
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<tr>
<td>440</td>
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<td>41</td>
<td>50/3*</td>
<td>100</td>
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</tr>
<tr>
<td>460</td>
<td>0</td>
<td></td>
<td>42</td>
<td>65/10*</td>
<td>100</td>
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<td></td>
</tr>
</tbody>
</table>

---

**Remarks and Other Tests**

- **Parameter Schematic:**
- **Lab Tests:**
- **Moisture Content %:**

**Bottom of Boring: Completed 12/28/2001**

---

Figure: B-5.4
### Log of Boring E-105

**Project:** King County WTD / Brightwater Conveyance System  
**Project Location:** King & Snohomish Counties, Washington  
**Contract Number:** E23007E  
**Date(s) Drilled:** 3/3/03 - 4/3/03  
**Geotechnical Consultant:** Camp Dresser & McKee Inc.  
**Logged by:**  
**TCB:**  
**Checked By:** VJP 02-03-04

<table>
<thead>
<tr>
<th>Drilling Method/Rig Type</th>
<th>Drilling Contractor</th>
<th>Total Depth of Borehole</th>
<th>Ground Surface Elevation/Datum</th>
<th>Elevation Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roto-Sonic</td>
<td>Cascade/Boart-Longyear</td>
<td>535.0 feet</td>
<td>549.0 feet / Metro</td>
<td>Survey</td>
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</tbody>
</table>

#### Casing
- **Size/Type:** 8"/6"/4"/Telescop Casing
- **Hammer Weight/Drop:** N/A

#### Location
- **5th Ave SW, Shoreline**
- **Coordinates:** N 287349 E 1264077

#### SAMPLES

<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Graphic Log</th>
<th>USCS</th>
<th>MATERIAL DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>-545</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-540</td>
<td>1</td>
<td>SM</td>
<td></td>
<td>93</td>
<td></td>
<td></td>
<td></td>
<td>Medium dense, red brown, wet, slightly gravelly SILTY SAND (SM), fine to coarse sand, fine to coarse gravel, subrounded to round, numerous organics, wood debris, homogeneous (af)</td>
</tr>
<tr>
<td>-535</td>
<td>2</td>
<td>SM</td>
<td></td>
<td></td>
<td>97</td>
<td></td>
<td></td>
<td>Medium dense, yellow red, gravelly silty SAND (SM), fine to medium sand, fine to coarse gravel, trace cobbles, subrounded to rounded, poorly-graded, matrix supported, scattered organics (Qvt)</td>
</tr>
<tr>
<td>-530</td>
<td></td>
<td>SW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Dense, brown-olive-gray, moist, gravelly SAND (SW), well-graded, fine to coarse sand, fine to coarse gravel, subrounded to round, homogeneous (Qva)</td>
</tr>
<tr>
<td>-526</td>
<td></td>
<td>SP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Dense, brown-light gray, moist, gravelly SAND (SP), poorly-graded, trace silt, trace fine sand, medium to coarse sand, fine gravel, subrounded to round, homogeneous (Qva)</td>
</tr>
</tbody>
</table>

#### REMARKS AND OTHER TESTS
- 0 to 6 feet excavated with vacuum truck, not sampled
- Starting with 9-inch casing

### Groundwater Observation Data:
- **OW (FT BGS):**  
- **VWP1 (FT BGS):**  
- **VWP2 (FT BGS):**

**Remarks:** Negative Groundwater Data indicates measurements above Ground Surface  
**Recovery values > 100 indicate sample expansion during sampling.**
### Log of Boring E-105

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

<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Graphic Log</th>
<th>Material Description</th>
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<tbody>
<tr>
<td>25</td>
<td>3</td>
<td>SW</td>
<td>100</td>
<td>Dense, brown to light gray, moist, gravelly SAND (SW), well-graded, trace silt, fine to coarse sand, fine gravel, subrounded to rounded, homogeneous (Q_v)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-520</td>
<td>1</td>
<td>SP-SM</td>
<td></td>
<td>Dense, light gray, moist, slightly silty gravelly SAND (SP-SM), poorly-graded, trace coarse sand, fine to medium sand, subrounded to round (Q_v)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>SP</td>
<td>91</td>
<td>Dense, red brown, moist to wet, slightly gravelly SAND (SP), poorly-graded, trace coarse sand, fine to medium sand, fine to coarse gravel, subrounded to round, homogeneous, trace silt (Q_v)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-515</td>
<td>5</td>
<td>SW</td>
<td>100</td>
<td>Dense, red brown, moist, gravelly SAND (SW), well-graded, fine to coarse sand, fine gravel, subrounded to round, homogeneous (Q_v)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-510</td>
<td>6</td>
<td>SP</td>
<td>100</td>
<td>Dense, red brown, moist, slightly gravelly SAND (SP), poorly-graded, trace silt, trace coarse sand, fine to medium sand, subrounded to round, homogeneous (Q_v)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>-505</td>
<td>7</td>
<td>SP-SM</td>
<td>100</td>
<td>Dense, red brown, moist, slightly gravelly SAND (SP-SM), poorly-graded, trace silt, trace coarse sand, fine to medium sand, subrounded to round, homogeneous (Q_v)</td>
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<tr>
<td></td>
<td></td>
<td>GM</td>
<td></td>
<td>Dense, gray, wet, silty sandy GRAVEL (GM), fine to coarse sand, fine to coarse gravel, subrounded to round, scattered weathered silt nodulels, brown yellow, homogeneous (Q_v)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>-500</td>
<td>8</td>
<td>SM</td>
<td>88</td>
<td>Dense, brown/grey, wet, slightly silty gravelly SAND (SM), trace coarse sand, fine to medium sand, subrounded to round, homogeneous, trace Fe(II) staining, weathered yellow brown silt clasts-scattered (Q_v)</td>
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<tr>
<td>-495</td>
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<td></td>
<td></td>
<td>Becomes very dense, trace fine sand, medium to coarse sand</td>
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<tr>
<td>-490</td>
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<td></td>
<td></td>
<td>Decreasing silt with depth</td>
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**REMARKS AND OTHER TESTS**

- (Add any additional remarks or tests related to the material descriptions.)

---

**Piezometer Schematic**

**Lab Tests**

**Packer Peneterometer (ft)**

---

**CDM**
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<th>Number</th>
<th>Blows / 6 in.</th>
<th>Recovery</th>
<th>Graphic Log</th>
<th>MATERIAL DESCRIPTION</th>
<th>Piezometer Schematic</th>
<th>Lab Tests</th>
<th>Pocket</th>
<th>Penetrometer (ft)</th>
<th>REMARKS AND OTHER TESTS</th>
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<tr>
<td>-485</td>
<td>65</td>
<td>SW</td>
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<td>Dense, red brown, wet, gravelly SAND (SW), well-graded, trace silt, fine to coarse sand, fine to coarse gravel, subround to round, homogeneous (Qva)</td>
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<tr>
<td>-480</td>
<td>70</td>
<td>GM</td>
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<td></td>
<td>Very dense, light gray, wet, silty GRAVEL (GM), trace medium to coarse sand, fine sand, fine to coarse gravel (2-3 in. diameter), subround to round (Qva)</td>
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<tr>
<td>-480</td>
<td>75</td>
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<td>Dense to very dense, red brown, slightly silty, gravelly SAND (SP-SM), poorly-graded, layers of fine to coarse gravel, subrounded to rounded, homogeneous, fine to coarse sand (Qva)</td>
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<td></td>
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<tr>
<td>-475</td>
<td>70</td>
<td>SP</td>
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<td>Very dense, red brown, wet, gravelly SAND (SP), poorly-graded, trace silt, trace fine sand, medium to coarse sand, subround to round, homogeneous, scattered oxidation (Qva)</td>
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<tr>
<td>-470</td>
<td>80</td>
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<td>Very dense, red brown, wet, sandy GRAVEL (GW), well-graded, fine to coarse sand, fine to coarse gravel, subround to round, homogeneous, trace silt (Qva)</td>
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<td>Dense, brown, wet SAND (SP), poorly-graded, trace silt, trace medium to coarse sand, trace fine to coarse gravel, fine sand, subround to round, homogeneous (Qva)</td>
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<td>Increasing medium to coarse sand</td>
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<td>95</td>
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<td></td>
<td>Grades slightly gravelly, fine sand, fine to coarse gravel, subrounded to rounded</td>
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<td>12</td>
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<td>Grades trace coarse sand, fine to medium sand</td>
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<tr>
<td>Depth, feet</td>
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<td>Recovery %</td>
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<td>Lab Tests</td>
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<td>REMARKS AND OTHER TESTS</td>
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<tr>
<td>95</td>
<td>SW</td>
<td>13</td>
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<td>Dense, brown, wet, slightly gravelly SAND (SW), well-graded, fine to coarse sand, fine to coarse gravel, rounded to subrounded, homogeneous (Qva)</td>
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<tr>
<td>-450</td>
<td>SP</td>
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<td></td>
<td>Dense, brown, wet, slightly gravelly SAND (SP), poorly-graded, trace coarse and, fine to medium sand, fine to coarse gravel, subrounded to rounded, homogeneous (Qva)</td>
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<td>Dense, brown, moist, slightly gravelly SAND (SW), well-graded, fine to coarse sand, fine to coarse gravel, subrounded to round, homogeneous (Qva)</td>
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<tr>
<td>-450</td>
<td>SP</td>
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<td></td>
<td></td>
<td></td>
<td>Dense, brown, slightly gravelly SAND (SP), poorly-graded, trace silt, trace medium to coarse sand, trace fine gravel, fine sand, subrounded to round, homogeneous (Qva)</td>
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<tr>
<td>110</td>
<td>SP</td>
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<td></td>
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<td>Dense, brown, wet SAND (SP), poorly-graded, trace silt, trace medium to coarse sand, trace fine gravel, fine sand, subrounded to rounded (Qva)</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>-450</td>
<td>SP</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Dense, brown, moist, slightly gravelly SAND (SP), poorly-graded, trace silt, trace medium to coarse sand, trace fine gravel, fine sand, subrounded to rounded, homogeneous (Qva)</td>
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<td>120</td>
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<td>Dense, brown, wet SAND (SP), poorly-graded, trace silt, trace medium to coarse sand, trace fine gravel, fine sand, subrounded to round, homogeneous (Qva)</td>
<td></td>
<td></td>
<td></td>
<td>Scattered clasts of gray sandy SILT</td>
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</tr>
<tr>
<td>-450</td>
<td>SP</td>
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<td>Dense, brown, moist, gravely SAND (SW), well-graded, trace silt, fine to coarse sand, fine to coarse gravel, subrounded to round, homogeneous (Qva)</td>
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<tr>
<td>125</td>
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<td></td>
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</tr>
<tr>
<td>-450</td>
<td>GW</td>
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<td>Dense, brown, wet SAND (SP), poorly-graded, trace silt, trace medium to coarse sand, trace fine gravel, fine sand, subrounded to round, homogeneous (Qva)</td>
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<td></td>
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<td>130</td>
<td>SW</td>
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<td>96</td>
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<td>Dense, brown, moist, gravelly SAND (SW), well-graded, trace silt, fine to coarse sand, fine to coarse gravel, subrounded to round, homogeneous (Qva)</td>
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<td>Number</td>
<td>Blows / 6 ft. (N)</td>
<td>Recovery %</td>
<td>Graphic Log</td>
<td>MATERIAL DESCRIPTION</td>
<td>Remarks and Other Tests</td>
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<td>130</td>
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<td>SP</td>
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<td>Dense, brown, moist, slightly gravelly SAND (SP), poorly-graded, trace silt, trace coarse sand, fine to medium sand, fine to coarse gravel, subrounded to rounded, homogeneous, numerous silt/sand clasts. (Qva)</td>
<td>With numerous 1-2-inch rip-up clast of sandy Silt</td>
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<td>21</td>
<td>100</td>
<td>SP</td>
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<td>Dense, brown, moist SAND (SP), poorly-graded, trace silt, trace fine gravel, trace coarse sand, fine to medium sand, subrounded to rounded, homogeneous (Qva)</td>
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<td>-410</td>
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<td>140</td>
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<td>23</td>
<td>100</td>
<td>SP</td>
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<td></td>
<td>Dense, brown, moist SAND (SP), poorly-graded, trace fine gravel, trace medium to coarse sand, fine sand, subrounded to rounded, homogeneous (Qva)</td>
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<td>Numerous 1/2-inch to 3/4-inch laminated sand/silt clasts</td>
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<td>100</td>
<td>SP</td>
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<td>Slightly gravelly from 145 to 146 feet bgs</td>
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<td>Sand grades fine, trace fine gravel</td>
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<td>Scattered laminated clasts of sand/silt</td>
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<td>-390</td>
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<td>Grades to slightly gravelly, fine to coarse gravel</td>
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<td>160</td>
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<td>12-inch-thick, well-graded slightly gravelly SAND layer</td>
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<td>Elevation, feet</td>
<td>Depth, feet</td>
<td>Type</td>
<td>Number</td>
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<td>Recovery, %</td>
<td>Graphic Log</td>
<td>USCS</td>
<td>MATERIAL DESCRIPTION</td>
<td>Piezometer Schematic</td>
<td>Lab Tests</td>
<td>Pocket Penetrometer (ft)</td>
<td>REMARKS AND OTHER TESTS</td>
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<td>+6 inch cobble</td>
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<td>Scattered laminated clasts of sand/silt</td>
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<td>32</td>
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<td>SW Very dense, brown gray, wet, slightly silty, gravelly SAND (SW), well-graded, fine to coarse sand, fine to coarse gravel, subrounded to rounded, homogeneous (Qva) 3-inch interbed of fine to medium sand</td>
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<td>-370</td>
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<td>33</td>
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<td>93</td>
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<td>SP Dense, brown, moist SAND (SP), poorly-graded, trace coarse sand, trace fine to coarse gravel, trace silt, fine to medium sand, subrounded to rounded, homogeneous (Qva) Grades slightly gravelly SAND (SP)</td>
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<td>-365</td>
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<td>Grades trace fine to coarse gravel 187 to 190 feet bgs</td>
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<td>-360</td>
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<td></td>
<td>Becomes wet</td>
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**Project:** King County WTD / Brightwater Conveyance System  
**Project Location:** King & Snohomish Counties, Washington  
**Contract Number:** E23007E  
**Log of Boring E-105**  
Sheet 6 of 16
<table>
<thead>
<tr>
<th>Elevation, feet</th>
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<th>Recovery %</th>
<th>MATERIAL DESCRIPTION</th>
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<tr>
<td>-345</td>
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<td>125</td>
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<td>Becomes very dense</td>
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<td>-340</td>
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<td>36</td>
<td>100</td>
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<td>Becomes dense, brown gray, moist to wet</td>
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<td>-335</td>
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<td>Layers of very dense, fine sand (SP)</td>
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<td>-320</td>
<td>230</td>
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<td>40</td>
<td>83</td>
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<td>Grades dark gray, slightly silty</td>
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**Remarks and Other Tests**

- **Piezometer Schematic**
- **Lab Tests**
- **Pocket Penetrometer (lb)**
<table>
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<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Graphic Log</th>
<th>USCS</th>
<th>MATERIAL DESCRIPTION</th>
<th>Piezometer Schematic</th>
<th>Lab Tests</th>
<th>Pocket Penetrometer (ft)</th>
<th>REMARKS AND OTHER TESTS</th>
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<td>-310</td>
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<td>Grades moist, fine sand, trace medium sand, fine sand</td>
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<td></td>
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<tr>
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<td>-295</td>
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<td>ML Hard, dark gray, moist, clayey SILT (ML), trace fine sand, subrounded to rounded, medium plasticity, medium strength, massive (Qvcl)</td>
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<td>-290</td>
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<td>SP- SM Very dense, dark gray, moist, slightly silty SAND (SP-SM), poorly-graded, trace medium sand, fine sand, homogeneous, micaceous, occasional organic fragments (Qpifn)</td>
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<td>-285</td>
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<td>SM Dense, dark brown, wet, silty SAND (SM), fine sand, subrounded to rounded, homogeneous, rapid dilatancy, occasional organic fragments (Qpifn)</td>
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<td>-280</td>
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<td>Rapid dilatancy</td>
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<td>Elevation, feet</td>
<td>Depth, feet</td>
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<td>Blows / 6 in. (N)</td>
<td>Recovery %</td>
<td>Material Description</td>
<td>Piezometer Schematic</td>
<td>Lab Tests</td>
<td>Pocket Penetrometer (sf)</td>
<td>Remarks and Other Tests</td>
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<td>300-304</td>
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<tr>
<td>295</td>
<td>295-294</td>
<td>48</td>
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<td>ML Very stiff, dark gray, wet, clayey SILT (ML), trace fine sand, low plasticity, rapid dilatancy, massive, trace organics (Qpfl)</td>
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<td>Grades to sandy SILT</td>
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<td>Grades to silty SAND</td>
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295-305 foot sample was drilled on 3/11/03 end of day. Sample was lost while pulling rods. Redrilled and left rods in hole overnight to attempt retrieval.
### MATERIAL DESCRIPTION

<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
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<th>USCS</th>
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<td>50</td>
<td>100</td>
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<td></td>
<td></td>
<td>Increased plasticity, slow dilatancy</td>
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<tr>
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<td></td>
<td><strong>CL</strong> Hard, gray, moist, very silty CLAY (CL), low to moderate plasticity, medium dry strength, massive, slow dilatancy, occasional organics (Qpfin)</td>
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<td></td>
<td></td>
<td>51</td>
<td>95</td>
<td></td>
<td></td>
<td></td>
<td>Laminated with light gray silt and fine sand partings/seams, slow to rapid dilatancy</td>
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<td>Grades moderate to highly plastic</td>
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<td>3-foot stratum grades very stiff, wet, slightly sandy to trace sand, fine sand, subrounded to rounded, low plasticity, massive to scattered interbeds of fine sand</td>
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<td><strong>SP-SM</strong> Dense, dark gray, moist, slightly silty SAND (SP-SM), poorly-graded, fine to medium sand, subrounded to rounded, homogeneous, scattered (ML) layers (Qpfin)</td>
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**REMARKS AND OTHER TESTS**

- Termination of 8-inch casing
- Petroleum hydrocarbon odor and apparent oil-like coating on sample probably due to decaying organics
- Sample loss occurred approximately 320 to 322 feet. Driller required 250 to 300 psi to extrude sample
- Slickensides
- Begin with 6-inch casing and 4-inch core
## Log of Boring E-105

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

### Samples

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<th>Number</th>
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<th>Recovery %</th>
<th>Graphic Log</th>
<th>USCS</th>
<th>Material Description</th>
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<td>100</td>
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<td></td>
<td>ML</td>
<td>Hard, dark gray, moist, clayey SILT (ML), low plasticity, non-dilatant, massive (Qpfni)</td>
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<td>-205</td>
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<td>Dense, gray green, moist, slightly silty SAND (SM), poorly-graded, fine to medium, trace organics (Qpfni)</td>
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<td>142</td>
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<td>ML</td>
<td>Very stiff to hard, gray, moist, clayey SILT (ML), low plasticity, laminated, rapid dilatancy, organic odor (Qpfni)</td>
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<td>Rapid dilatancy, low strength</td>
</tr>
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<td></td>
<td></td>
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<td>Slow dilatancy, medium strength</td>
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<td></td>
<td>Hard, dark gray, silty CLAY (CL), trace fine gravel, low plasticity, medium strength, massive, occasional partings of light gray fine sand (Qpfni)</td>
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### Remarks and Other Tests

- 354 to 360 foot sample fell out of core barrel during extraction
- Conventional radiocarbon date 28,600 ± 250 years B.P.
- Occasional brown organic nodules

(CDM)
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<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Graphic Log</th>
<th>USCS</th>
<th>MATERIAL DESCRIPTION</th>
<th>Piezometer Schematic</th>
<th>Lab Tests</th>
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CDM
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<th>Number</th>
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<th>Recovery</th>
<th>Graphic Log</th>
<th>MATERIAL DESCRIPTION</th>
<th>Piezometer Schematic</th>
<th>Lab Tests</th>
<th>Pedestal</th>
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<td>Run 65 drilled/sampled 3 times before brought up, TCB starts logging</td>
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<td>Grades slightly clayey, trace fine sand, nonplastic, slow to rapid dilatancy, massive</td>
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<td>Grades silty, trace clay, low toughness, nonplastic, fine sand</td>
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<td>Increasing silt</td>
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<td>ML</td>
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<td>Stiff, dark gray, moist, slightly sandy to sandy SILT (ML), trace medium sand, fine sand, subrounded to rounded, nonplastic, slow to rapid dilatancy, homogeneous (Qpfm)</td>
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<tr>
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</table>

Sample discovered to have slid out at 1615. 1 foot run lost. Drilling done for 3/15 at 1830.
Log of Boring E-105

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

Sheet 14 of 16

Elevation, feet
Depth, feet
Type
Number
Blows / in. (N)
Recovery, %
Graphic Log

USCS

MATERIAL DESCRIPTION

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<td>445</td>
<td>ML</td>
<td>Hard, dark gray, moist, slightly clayey SILT (ML), nonplastic, medium strength, numerous organic nodules, massive (Qpfnl)</td>
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<tr>
<td>450</td>
<td>SM</td>
<td>Dense, dark gray, wet, silty to slightly silty SAND (SM), fine to medium sand, subround to round, homogeneous, scattered silt clasts (Qpfnl)</td>
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<td>455</td>
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<td>Recovery of Run 70 attempted approximately 6 times</td>
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<tr>
<td>460</td>
<td>ML</td>
<td>Hard, gray, moist, slightly clayey SILT (ML), low plasticity, low strength, massive, numerous black organic nodules (Qpfnl)</td>
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<tr>
<td>465</td>
<td>OL</td>
<td>Hard, dark brown, moist, organic SILT (OL), nonplastic to low plasticity, medium strength, numerous brown-black organic (Qpfnw)</td>
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<tr>
<td>470</td>
<td>ML</td>
<td>Hard, brown gray to gray, moist, clayey SILT (ML), low plasticity, medium strength, massive, numerous organic nodules (Qpfnl) becomes sandy</td>
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<td>475</td>
<td>OL</td>
<td>Hard, dark brown, moist, organic SILT (OL), nonplastic to low plasticity, medium strength, numerous brown-black organic (Qpfnw)</td>
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<tr>
<td>480</td>
<td>ML</td>
<td>Stiff, gray, wet, slightly clayey SILT (ML), trace fine sand, low plasticity, low strength, massive, scattered organic, slow dilatancy (Qpfnl)</td>
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</table>

Remarks and Other Tests:
- 459 to 465 feet sample appears to be intact and not reworked/drilled
<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>SAMPLES</th>
<th>MATERIAL DESCRIPTION</th>
<th>USCS</th>
<th>Piezometer Schematic</th>
<th>Lab Tests</th>
<th>Penetrometer (ls)</th>
<th>REMARKS AND OTHER TESTS</th>
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<td>480</td>
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<td>MSA</td>
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<td>Grades silty, occasional organics</td>
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<td>485</td>
<td>73</td>
<td>Grades to very stiff, brown gray, mottled, silt (ML), trace fine sand, nonplastic to low plasticity, medium strength, numerous organics, slow to rapid dilatancy</td>
<td>ML</td>
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<td>Layer rapid dilatancy at 484 ft bgs (Qpfnf)</td>
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<td>Grades trace fine sand, nonplastic</td>
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<td>Grades very stiff, moist, slightly clayey, trace fine sand, numerous organic nodules</td>
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<td>Very stiff, dark brown, wet PEAT (PT), numerous partings of ash, fibrous, wood debris, 2 to 4-inch layers of gray SILT (ML) (Qpfnw)</td>
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<td>-50</td>
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<td>Type</td>
<td>Number</td>
<td>Blows / 6 in. (N)</td>
<td>Recovery, %</td>
<td>Graphic Log</td>
<td>USCS</td>
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**Log of Boring E-106**

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

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<th>Date(s) Drilled</th>
<th>Geotechnical Consultant</th>
<th>Camp Dresser &amp; McKee Inc.</th>
<th>Logged By</th>
<th>RW</th>
<th>Checked By</th>
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<td>4/11/03 - 4/22/03</td>
<td>Cascade Drilling, Inc.</td>
<td>Total Depth of Borehole</td>
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<td>566.0 feet</td>
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**Drilling Method/Rig Type:** Wireline/T3  
**Hammer Weight/Drop (lbs/in.):** 300#/30"  
**Ground Surface Elevation/Datum:** 581.9 feet/Metro  
**Location:** 20357 Greenwood Ave  
**Coordinates:** N 287281, E 1266085  
**Elevation Source:** Survey

### SAMPLES

<table>
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<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
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**MATERIAL DESCRIPTION:**

- **GW-GM:** Dense, yellow-brown, moist, slightly silty, sandy gravel (GW-GM), trace cobbles, well-graded, fine to coarse subangular gravel (Qvtn)

### REMARKS AND OTHER TESTS

- 0 to 6 ft bgs excavated with vacuum truck, not sampled
- Drive 6-inch diameter casing to 18 feet bgs
- Soil description inferred from drill action and cuttings
- Driller reports hard drilling in cobbles and boulders
- No recovery, stone in sampling shoe
- Drillers use tri cone bit for drilling through formation from 21 to 37 feet bgs

**Groundwater Observation Data:**

- **OW (FT BGS):** 390.0 (Low) 388.9 (High)
- **VWP1 (FT BGS):**
- **VWP2 (FT BGS):**

**Remarks:** Negative Groundwater Data indicates measurements above Ground Surface  
Recovery values > 100 indicate sample expansion during sampling.
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- **GW**
  - 2 19 - 60/5 (100+): Very dense, brown, moist, sandy GRAVEL (GW), well-graded, fine to coarse subangular gravel (Qva)
  - Hard drilling

- **SW-SM**
  - 3 55/5 (100+): Very dense, brown, moist, slightly silty, gravelly SAND (SW-SM), well-graded, fine to coarse sand, fine to coarse subangular gravel (Qva)
  - Drilling smoother
  - Soil description inferred from drill action and cuttings
**Log of Boring E-106**

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

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*Note: The diagram and table are not fully transcribed due to the complexity and illegibility of the handwritten or printed text.*
Log of Boring E-106

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**REMARKS AND OTHER TESTS**

- Cobbles noticed by drillers
- Soil description inferred from drill action and cuttings
- Drill action suggests some gravel
## Log of Boring E-106

**SAMPLING**

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**Remarks:**
- Drill action suggests gravelly sand.
- Soil description inferred from drill action and cuttings.

---

**Project:** King County WTD / Brightwater Conveyance System  
**Project Location:** King & Snohomish Counties, Washington  
**Contract Number:** E23007E
### Log of Boring E-106

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

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**Remarks**: Soil description inferred from drill action and cuttings.
### Log of Boring E-106

**Project:** King County WTD / Brightwater Conveyance System  
**Project Location:** King & Snohomish Counties, Washington  
**Contract Number:** E23007E  
**Sheet:** 7 of 17

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**Contract Number:** E23007E

**Project Location:** King & Snohomish Counties, Washington

**Project:** King County WTD / Brightwater Conveyance System

**Log of Boring E-106**
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<td>Stiff, olive gray, moist, slightly clayey, sandy SILT (ML), medium plasticity, scattered organics (Qpfnl)</td>
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<tr>
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**REMARKS AND OTHER TESTS**
- Gravel inferred by drill action and cuttings
- Soil description inferred from drill action and cuttings
- Switch to wire-line
- Slough, outwashed sand
- Organic odor
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<th>Type</th>
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1-foot fine sand layer
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### Log of Boring E-106

#### Sheet 12 of 17

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<th>USCS</th>
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<td>Hard, dark gray, moist, silty CLAY (CL), medium plasticity, slickensided, homogeneous, fine sand layers (Qpfnl)</td>
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<td>Interbedded fine sand has strong organic odor</td>
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<td>Hard, dark gray, moist, clayey SILT (MH), medium to high plasticity (Qpfnl)</td>
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<td>Dense, dark gray, moist SAND (SP), trace silt, poorly-graded sand, scattered organics (Qpfnf)</td>
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<td>Strong organic odor in fine sand</td>
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**CDM**
Log of Boring E-106

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

Sheet 13 of 17

**Elevation, feet**

- 445
- 440
- 435
- 430
- 425
- 420
- 415
- 410
- 405
- 400
- 395
- 390
- 385
- 380
- 375
- 370
- 365
- 360
- 355
- 350
- 345
- 340
- 335
- 330
- 325
- 320
- 315
- 310
- 305
- 300
- 295
- 290
- 285
- 280
- 275
- 270
- 265
- 260
- 255
- 250
- 245
- 240
- 235
- 230
- 225
- 220
- 215
- 210
- 205
- 200
- 195
- 190
- 185
- 180
- 175
- 170
- 165
- 160
- 155
- 150
- 145
- 140

**Depth, feet**

- 445
- 440
- 435
- 430
- 425
- 420
- 415
- 410
- 405
- 400
- 395
- 390
- 385
- 380
- 375
- 370
- 365
- 360
- 355
- 350
- 345
- 340
- 335
- 330
- 325
- 320
- 315
- 310
- 305
- 300
- 295
- 290
- 285
- 280
- 275
- 270
- 265
- 260
- 255
- 250
- 245
- 240
- 235
- 230
- 225
- 220
- 215
- 210
- 205
- 200
- 195
- 190
- 185
- 180
- 175
- 170
- 165
- 160
- 155
- 150
- 145
- 140

**Type**

- CL
- ML
- SP
- PT

**Samples**

- **USCS**
  - CL: Hard, dark gray, moist, silty CLAY (CL), medium plasticity, slickensided, homogeneous, fine sand layers (Qpfni)
  - ML: Stiff, dark gray to gray green, moist, SILT (ML), trace sand, trace clay, low plasticity, scattered organics (Qpfni)
  - SP: Very dense, dark gray, moist, SAND (SP), trace silt, poorly-graded fine sand, scattered organics (Qpfni)
  - PT: Brown PEAT (Qpfnw)

**Remarks and Other Tests**

- Grades dense, fine to medium sand
- Grades fine to medium sand
- Wood pieces
- Organic odor
- Outwashed gravel
- Very stiff, dark gray, moist, silty CLAY (CL), medium plasticity
- Hard, gray olive, slightly clayey, sandy SILT (ML), low plasticity, occasional organics
<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Graphic Log</th>
<th>MATERIAL DESCRIPTION</th>
<th>Piezometer Schematic</th>
<th>Lab Tests</th>
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**Remarks and Other Tests:**
- Coarse subrounded gravel inferred by drill action and cuttings
- Soil description inferred from drill action and cuttings
- Gravely drilling
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Terminated boring at 586 feet below ground surface.
# Log of Boring E-107

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

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<th>Geotechnical Consultant</th>
<th>Camp Dresser &amp; McKee Inc.</th>
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<th>RW</th>
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### SAMPLES

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**MATERIAL DESCRIPTION**

- **GP:** Very dense, brown, wet, sandy GRAVEL (GP), trace silt, poorly-graded fine to coarse sand, poorly-graded fine subangular gravel (Qva)

**REMARKS AND OTHER TESTS**

- 0-8 feet excavated with vacuum truck, not sampled
- Drilling Mud Rotary 8 to 180 feet below ground surface (bgs)
- Soil description inferred from drill action and cuttings
- Irregular drilling resistance in gravel

---

**Groundwater Observation Data:**

- **OW (FT BGS):**
  - VWP1 (FT BGS) 223.8 (Low) 221.3 (High)
  - VWP2 (FT BGS) 223.9 (Low) 220.8 (High)

**Remarks:** Negative Groundwater Data indicates measurements above Ground Surface. Recovery values > 100 indicate sample expansion during sampling.
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Log of Boring E-107

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Sample collected from cuttings of circulation mud (crushed gravel)

Hard drilling in gravel and cobbles

Drilling smooth

Soil description inferred from drill action and cuttings
Log of Boring E-107

MATERIAL DESCRIPTION

GW - Sandy GRAVEL (GW), well-graded to sandy GRAVEL (GP), poorly-graded, fine to coarse gravel, fine to coarse sand, subangular gravel (Qva)

REMARS AND OTHER TESTS

Soil description inferred from drill action and cuttings
<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery</th>
<th>Graphic Log</th>
<th>USCS</th>
<th>MATERIAL DESCRIPTION</th>
<th>Plazometer Schematic</th>
<th>Lab Tests</th>
<th>Pocket Penetrometer (lbf)</th>
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## Log of Boring E-107

**Project:** King County WTD / Brightwater Conveyance System  
**Project Location:** King & Snohomish Counties, Washington  
**Contract Number:** E23007E  
**Sheet 8 of 16**

### SAMPLES

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### MATERIAL DESCRIPTION

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<td>Transitions hard, gray, clayey silt, low plasticity</td>
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<td>Transitions stiff, wet, trace clay</td>
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### REMARKS AND OTHER TESTS

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### Log of Boring E-107

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

#### SAMPLES

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<th>Recovery, %</th>
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<td>(Qpfnf)</td>
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**CDM**
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<th>Lab. Tests</th>
<th>Pocket</th>
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</table>

Organic odor

Transitions gray olive, occasional organics

2-foot slightly silty stratum

Silty sand layer

Organic odor when cutting core from 495 to 520 feet bgs
<table>
<thead>
<tr>
<th>Depth, feet</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Material Description</th>
<th>Remarks and Other Tests</th>
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<td>525</td>
<td>79</td>
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<td>550</td>
<td>84</td>
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<td>Terminated boring at 548 feet below ground surface</td>
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</table>

**Log of Boring E-107**

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

Sheet 16 of 16
Project: King County WTD / Brightwater Conveyance System  
Project Location: King & Snohomish Counties, Washington  
Contract Number: E23007E

Log of Boring E-108  
Sheet 1 of 11

Date(s) Drilled: 7/7/03 - 7/7/03  
Geotechnical Consultant: Camp Dresser & McKee Inc.  
Camp Dresser & McKee Inc.  
Logged By: SHE  
Checked By: RWS 2/03/04  
Drilling Contractor: Gregory Drilling, Inc.  
Total Depth of Borehole: 346.0 feet  
Hammer Weight/Drop (lbs/in.):  
Ground Surface Elevation/Datum: 453.1 feet / Metro  
Location: 1621 N. 205th St  
Coordinates: N 287249  E 1270073  
Elevation Source: Survey

Elevation, feet  | Depth, feet  | SAMPLES  | MATERIAL DESCRIPTION  | REMARKS AND OTHER TESTS
--- | --- | --- | --- | ---
-450  | 0  |  |  | 0 to 8 ft bgs excavated with vacuum truck, not sampled
-445  | 5  | SP  | Wet, brown, gravelly SAND (SP), poorly graded (af)  | 70% to 80% quartz, gravel 60% to 70% dark gray volcanics  
-440  | 10  |  |  | Soil description inferred from drill action and cuttings
-435  | 15  |  |  |  
-430  | 20  |  |  |  
| 25  | 1  | 0  |  |  

Groundwater Observation Data:  
OW (FT BGS): 139.9 (Low) 137.8 (High)  
VWP1 (FT BGS):  
VWP2 (FT BGS):  

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).
### Log of Boring E-108

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

#### SAMPLES

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<th>Elevation (feet)</th>
<th>Depth, feet</th>
<th>Type</th>
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<th>Blows / 6 in (N)</th>
<th>Recovery %</th>
<th>Graphic Log</th>
<th>USCS</th>
<th>MATERIAL DESCRIPTION</th>
<th>Piezometer Schematic</th>
<th>Lab Tests</th>
<th>Pocket penetrometer (ts)</th>
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<td>Drilled out to 36 ft bgs</td>
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<td>Driller report: &quot;loose&quot; sand and gravel</td>
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Intermittent heavy rattling (gravel or dense sand)
Silt sample fell out of core barrel
### Log of Boring E-108

**Sheet 4 of 11**

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<td>Change in drill action infers increase in soil density</td>
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**Contract Number:** E23007E

**Project:** King County WTD / Brightwater Conveyance System

**Project Location:** King & Snohomish Counties, Washington
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### Remarks and Other Tests

Slight organic odor

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**Project:** King County WTD / Brightwater Conveyance System  
**Project Location:** King & Snohomish Counties, Washington  
**Contract Number:** E23007E
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Samples:
- **SP**: Dense, dark gray, wet, SAND (SP), poorly-graded fine sand, homogeneous, shell fragments (Qpogm)
- **ML**: Hard, olive gray, moist, very gravelly, sandy SILT (ML), trace clay, low to medium plasticity, matrix supported (Qpogd)
- **CL-ML**: Very stiff, olive gray, moist, clayey SILT (ML) homogeneous (Qpogi)

MATERIAL DESCRIPTION:
- Grades trace fine gravel
- Abundant clam shells
- Grading silt, trace fine sand, low plasticity, slow dilatancy
- Hard, olive gray, moist clayey SILT (ML) (Qpogi)
- Sand layer
- 2-foot sand stratum

REMARKS AND OTHER TESTS:
- Hydrogen sulfide odor
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<th>Recovery, %</th>
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<td>Terminated boring at 346 feet below ground surface</td>
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Log of Boring E-109

Date(s) Drilled: 7/29/03 - 7/30/03

Drilling Method/Rig Type: Wireline/ T3
Casing Size/Type: PQ (7" O.D.)
Location: NE 205th St and 1st Ave

Geotechnical Consultant: Camp Dresser & McKee Inc
Udrilling Contractor: Cascade Drilling, Inc.
Total Depth of Borehole: 260.0 feet
Ground Surface Elevation/Datum: 395.0 feet / Metro
Coordinates: N 287168 E 1272288
Elevation Source: Survey

SAMPLES

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<tr>
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MATERIAL DESCRIPTION

GM: Medium dense, brown, moist to wet, slightly silty, sandy GRAVEL (GM), poorly-graded fine to coarse sand, fine to coarse subangular to subrounded gravel (af)

GM: Loose, gray, wet, silty, sandy GRAVEL (GM), fine to coarse sand, fine to coarse subangular to subrounded gravel (af)

SM: Hard, brown yellow to yellow red, gravelly, silty SAND (SM), scattered cobbles (Qpfnf)

SW: Loose, brown, wet, gravelly, SAND (SW), well-graded fine to coarse sand, fine to coarse subangular gravel (Qpfnf)

EXPANDED MAXER DATA:

Groundwater Observation Data:

OW (FT BGS): 130.6 (Low) 115.0 (High)

VWP1 (FT BGS):

VWP2 (FT BGS):

REMARKS AND OTHER TESTS

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).

0 to 6 feet excavated with vacuum truck, not sampled
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<th>Blows / 6 in. (N)</th>
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REMARKS AND OTHER TESTS: 
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- SW: Medium dense, dark gray, wet, gravelly SAND (SW), well graded sand (Qpogf)
- GM: Dense, gray, wet, sandy, silty GRAVEL (GM), fine to coarse subrounded gravel (Qpogf)
- GM: Medium dense, dark gray, wet, silty SAND (SM), fine sand (Qpogf)
- GM: Grades dense, moist, slightly gravelly
- GM: Dense, dark gray, moist, silty, sandy GRAVEL (GM) (Qpogd)
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</tbody>
</table>

ML: Hard, dark gray, moist, sandy Silt (ML), nonplastic to low plasticity, frequent shell fragments (Qpogm)

Grades wet, slow to rapid dilatancy

Scattered gravel cobbles
### Log of Boring E-109

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

#### Sheet 6 of 8

<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>USCS</th>
<th>MATERIAL DESCRIPTION</th>
<th>Pluviosmeter Schematic</th>
<th>Lab Tests</th>
<th>Pocket Penetrometer (lb)</th>
<th>REMARKS AND OTHER TESTS</th>
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<td>230</td>
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<td>Grades slightly gravel</td>
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<td>High angle fracture at 70 degrees</td>
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<td>Hard, dark gray, moist, silty CLAY (CL), low plasticity (Qpogi)</td>
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<td>Scattered slickensides 30 to 40 degrees</td>
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<td>Grades trace fine to coarse sand and fine gravel</td>
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<td>220</td>
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<td>210</td>
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<td>ML</td>
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<td>Hard, dark gray, moist, slightly clayey SILT (ML), trace sand, low plasticity (Qpogi)</td>
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<td>Dropstones 195.5 to 196 ft bgs, vertical planar fracture</td>
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**CDM**
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<th>Recovery %</th>
<th>Graphic Log</th>
<th>USCS</th>
<th>MATERIAL DESCRIPTION</th>
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<td>Grades soft to medium stiff, wet, sandy, clayey silt, medium plasticity</td>
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<td>Grades fine to coarse subrounded gravel, occasional cobbles</td>
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REMARKS AND OTHER TESTS

MAL

CDM
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<th>Recovery, %</th>
<th>Graphic Log</th>
<th>USCS</th>
<th>MATERIAL DESCRIPTION</th>
<th>Piezometer Schematic</th>
<th>Lab Tests</th>
<th>Pocket Penetrometer (ft)</th>
<th>REMARKS AND OTHER TESTS</th>
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<td>Steel liners in core barrel.</td>
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<td>Scattered some gravel dropstones</td>
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<td>Dense, dark gray, moist to wet, slightly silty SAND (SP-SM), poorly-graded (Qpogl)</td>
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<td>253 to 260 ft bgs, high angle fractures 50 to 70 degrees</td>
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<td>Hard, dark gray, moist, silty CLAY (CL), trace sand, medium plasticity, homogeneous (Qpogl)</td>
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<td>-135</td>
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<td>Terminated boring at 260 feet below ground surface</td>
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### Log of Boring E-110

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

<table>
<thead>
<tr>
<th>Date(s) Drilled</th>
<th>Geotechnical Consultant</th>
<th>Camp Dresser &amp; McKee Inc.</th>
<th>Logged By</th>
<th>RW</th>
<th>Checked By</th>
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<td>3/28/03 - 4/4/03</td>
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<td>VJP 02-03-04</td>
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<th>Drilling Method/Rig Type</th>
<th>Drilling Contractor</th>
<th>Total Depth of Borehole</th>
<th>Ground Surface Elevation/Datum</th>
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<tr>
<td>Wireline/ T3</td>
<td>Cascade Drilling, Inc.</td>
<td>438.0 feet</td>
<td>444.7 feet / Metro</td>
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<table>
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<tr>
<th>Casing Size/Type</th>
<th>Hammer Weight/Drop (lbs/ft)</th>
<th>Ground Elevation/Datum</th>
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<tr>
<td>PQ (7&quot; O.D.)</td>
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<tr>
<th>Location</th>
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<td>603 NE 204th St</td>
<td>N 286964 E 1274158</td>
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**SAMPLING**

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<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
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<td>USCS</td>
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</tbody>
</table>

**MATERIAL DESCRIPTION**

- **SM**: Very dense, brown, moist, silty, gravelly SAND (SM), poorly-grade coarse sand, poorly-graded fine to coarse angular gravel (Qvt)

**REMARKS AND OTHER TESTS**

- Vacuum out to 5.9 ft bgs. not sampled. Drive 7-inch casing to 8 feet.
- Soil description partially inferred from drill action and cuttings.

**Groundwater Observation Data**

- **OW (FT BGS)**: 109.4 (Low) 98.4 (High)
- **VWP1 (FT BGS)**: 144.8 (Low) 143.4 (High)
- **VWP2 (FT BGS)**: 170.1 (Low) 167.6 (High)

**Remarks**:
- Negative Groundwater Data indicates measurements above Ground Surface Recovery values > 100 indicate sample expansion during sampling.
- Pocket Penetrometer shown as 4.8 indicates unconfined compressive strength > 4.5 tsf (penetrometer upper limit).
<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Graphic Log USCS</th>
<th>MATERIAL DESCRIPTION</th>
<th>Piezometer Schematic</th>
<th>Lab Tests</th>
<th>Pocket Penetrometer (ft)</th>
<th>REMARKS AND OTHER TESTS</th>
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<td>-415</td>
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<td>Very dense, brown, moist, slightly silty, sandy GRAVEL (GW-GM), well-graded fine to coarse sand, well-graded fine to coarse angular gravel (Qvtm)</td>
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<td>Soil description partially inferred from drill action and cuttings</td>
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<td>-410</td>
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<td>SM Silty, gravelly SAND (SM), fine to coarse sand, fine angular gravel (Qvtm)</td>
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<td>Drillers note hard drilling</td>
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<td>Irregular drilling resistance suggest gravel and cobbles</td>
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**Project:** King County WTD / Brightwater Conveyance System  
**Project Location:** King & Snohomish Counties, Washington  
**Contract Number:** E23007E
Log of Boring E-110

SAMPLES

<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / ft. (N)</th>
<th>Recovery, %</th>
<th>USCS</th>
<th>MATERIAL DESCRIPTION</th>
<th>Pneumometer Schematic</th>
<th>Lab Tests</th>
<th>Pedestal</th>
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<td>Driller’s note interbedded gravel and cobbles</td>
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<td>-370</td>
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<td>SP</td>
<td>4</td>
<td>50/5&quot; (100+)</td>
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<td>Very dense, gray green, moist SAND (SP), trace silt, poorly-graded fine to medium sand, occasional organics (Qpfmi)</td>
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<td>-365</td>
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## Log of Boring E-110

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

### SAMPLES

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<tr>
<th>Elevation, feet</th>
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<th>Number</th>
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<td>95</td>
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<td>25 - 50/6&quot; (100+)</td>
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<td>Transitions to gravelly, gravel and cobbles in clayey silt matrix, subrounded</td>
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<td>Very stiff, dark gray Silt (ML), nonplastic, numerous organics (Qpfnl)</td>
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<td>94</td>
<td>Very stiff, gray olive, moist Silt (ML), trace sand, low plasticity, scattered organics (Qpfnl)</td>
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<td>125</td>
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<tr>
<td>-315</td>
<td>130</td>
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<td>Medium stiff Silt at 118 ft bgs</td>
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</table>

### REMARKS AND OTHER TESTS
- 0 to 98' mud-rotary, switch to wire-line at 98', drilling from 95'
- Conventional radiocarbon date >47,930 yrs B.P.

---

*Note: The diagram shows the material description at each elevation and depth, with specific details for each sample.*
<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>MATERIAL DESCRIPTION</th>
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<td><strong>CL</strong> Stiff, gray green, moist, silty CLAY (CL), medium plasticity, slickensides (Qpogl)</td>
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<td>100</td>
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<td>Transitions to gray</td>
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<td>Transitions to very stiff, gray green to green, silty clay</td>
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<td>Transitions to gray, sandy, silty clay</td>
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<td>30</td>
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<td></td>
<td><strong>SM</strong> Very dense, gray green to gray olive, moist, silty, gravely SAND (SM), fine to coarse subrounded gravel, occasional organics (Qpogtm)</td>
</tr>
<tr>
<td>-290</td>
<td>155</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Transitions to slightly silty and gravely sand</td>
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<tr>
<td>-285</td>
<td>160</td>
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<td><strong>GW</strong> Very dense, gray green, moist GRAVEL (GW), well-graded fine to coarse, subrounded gravel, layers of gravelly sand (Qpogl)</td>
</tr>
<tr>
<td>-280</td>
<td>165</td>
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<td></td>
<td><strong>GM</strong> Very dense, gray green, moist, silty, sandy GRAVEL (GM), fine to coarse sand, fine to</td>
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<tr>
<td>Elevation, feet</td>
<td>Depth, feet</td>
<td>Type</td>
<td>Number</td>
<td>Blows / 6 in. (N)</td>
<td>Recovery, %</td>
<td>MATERIAL DESCRIPTION</td>
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</tr>
<tr>
<td>165</td>
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<td>coarse gravel, subrounded (Qpogtm)</td>
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<tr>
<td>-275</td>
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<td>SM</td>
<td>13</td>
<td>50</td>
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<td>Very dense, gray green to olive gray, moist, slightly silty, gravelly SAND (SM), fine to coarse sand, fine to coarse subrounded gravel, strong cementation (Qpogtm)</td>
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<tr>
<td>-270</td>
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<td>GW</td>
<td>14</td>
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<td>Dense, gray green, moist GRAVEL (GW), well-graded fine to coarse, subrounded gravel (Qpogf)</td>
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<tr>
<td>-265</td>
<td>180</td>
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<td></td>
<td></td>
<td>Hard, olive gray, moist, gravelly, sandy SILT (ML), nonplastic stratum</td>
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<tr>
<td>-260</td>
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<td></td>
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<td>Stratum of very stiff to hard, gray, moist, slightly clayey, slightly sandy silt, low plasticity, occasional organics, homogeneous, slow to rapid dilatancy</td>
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<tr>
<td>-255</td>
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<td>Transitions to gravel and cobbles, subrounded</td>
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CDM
**Log of Boring E-110**

**SAMPLES**

<table>
<thead>
<tr>
<th>Elev., feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Graphic Log</th>
<th>USCS</th>
<th>MATERIAL DESCRIPTION</th>
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<tr>
<td>200</td>
<td></td>
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<td>17</td>
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<td>67</td>
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<td>Transitions to very stiff, clayey silt, trace fine sand and fine gravel as dropstones, homogeneous</td>
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<td>-235</td>
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<td>19</td>
<td></td>
<td>93</td>
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<td>Dense, dark gray, wet, silty SAND (SM), rapid dilatancy (Qpogi)</td>
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<tr>
<td>-225</td>
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<td>-220</td>
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<td>CH</td>
<td>Very stiff, dark gray, moist, slightly sandy CLAY (CH), high plasticity (Qpogi)</td>
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**REMARKS AND OTHER TESTS**

- Sand-filled high angle fractures
- 209 to 216.5 ft bgs, slickensides
- Slickensides at 45 degree angle
- 225 to 230 ft bgs, scattered slickensides
- 230 to 240 ft bgs, slickensides, shearing, fracturing
### SAMPLES

<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Type</th>
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<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
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<td></td>
<td></td>
<td>26</td>
<td></td>
<td>100</td>
<td></td>
<td>CL</td>
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</table>

### MATERIAL DESCRIPTION

- **CL**: Very stiff, dark gray, moist slightly sandy CLAY (CL), medium plasticity (Qpogi)
- **Layer of sand**: M
- **Decrease in clay content**: M
- **Transitions to sandy and gravelly**: M
- **SM**: Very dense, gray, dry to moist, very gravelly, silty, clayey SAND (SM), fine to coarse sand, fine subrounded gravel (Qpogd)
- **CL**: Hard, dark gray, moist, silty CLAY (CL), low to medium plasticity, scattered partings of fine sand

### REMARKS AND OTHER TESTS

- 240 to 259 ft bgs, scattered slickensides, high angle silt-filled fractures
- Sand-filled fracture at 20 degree angle
- Scattered slickensides, high angle 70 degrees, block structure
<table>
<thead>
<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery %</th>
<th>Graphic Log</th>
<th>USCS</th>
<th>MATERIAL DESCRIPTION</th>
<th>Piezometer Schematic</th>
<th>Lab Tests</th>
<th>Pock</th>
<th>Penetrometer (lb)</th>
<th>REMARKS AND OTHER TESTS</th>
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<td>275</td>
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<td>28</td>
<td>90</td>
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<td>SM Very dense, gray, moist, very gravelly, very silty SAND (SM), trace gravel, subrounded to rounded (Qpogd)</td>
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<td>-165</td>
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<td>15</td>
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<td>CL Hard, dark gray, moist, slightly sandy, silty CLAY (CL), low to medium plasticity, slickensided, homogeneous (Qpogm)</td>
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<td>Scattered slickensides 20 to 40 degrees</td>
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<td>Elevation, feet</td>
<td>Depth, feet</td>
<td>Type</td>
<td>Blows / 6 in (N)</td>
<td>Recovery, %</td>
<td>Graphic Log</td>
<td>USCS</td>
<td>MATERIAL DESCRIPTION</td>
<td>Piezometer Schematic</td>
<td>Lab Tests</td>
<td>Pocket Penetrometer (tlf)</td>
<td>REMARKS AND OTHER TESTS</td>
<td></td>
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</tr>
</tbody>
</table>

**MATERIAL DESCRIPTION**

- **32**: Interbeds of olive gray and gray green, fine sand from 317 to 320 ft bgs, occasional organics
- **33**: Shell fragments at 322 ft bgs
- **34**: 1-foot layer of sandy clay occasionally organics and shell fragments
- **SP-SM**: Very dense, dark gray, wet, slightly silty SAND (SP-SM), poorly-graded, occasional organics (Qpogf)

**REMARKS AND OTHER TESTS**

- Horizontal breaks along fine sand seam
- Paleosol
- Strong HCL reaction at 322 ft bgs
- Organic odor
- Strong HCL reaction
- Strong organic odor
- Sheared sand layer; sand injection
<table>
<thead>
<tr>
<th>Depth, feet</th>
<th>Type</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Graphic Log</th>
<th>USCS</th>
<th>MATERIAL DESCRIPTION</th>
<th>Piezometer Schematic</th>
<th>Lab Tests</th>
<th>Pocket Penetrometer (ft)</th>
<th>REMARKS AND OTHER TESTS</th>
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<td>375-380</td>
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<td>CL</td>
<td>Hard, dark gray, sandy, silty CLAY (CL), trace gravel, medium plasticity, slickensided, homogeneous, occasional organics (Qpfnl)</td>
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<td>380-385</td>
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<td>Very fine sand layer</td>
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<tr>
<td>385-390</td>
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<td>Layer of silty fine sand, trace gravel, occasional organics</td>
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<td>390-395</td>
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<td>Sandy gravel layer</td>
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</table>

4 High angle slickensides, near vertical
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<th>Depth, feet</th>
<th>Type</th>
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<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
<th>Graphic Log</th>
<th>USCS</th>
<th>MATERIAL DESCRIPTION</th>
<th>Peizometer Schematic</th>
<th>Lab Tests</th>
<th>Pocket Penetrometer (lb)</th>
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<td>Sandy gravel with partings and sand layers</td>
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<td>-30</td>
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<td>Piece of wood, occasional mussel, Shells and shell fragments</td>
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<td>Terminated boring at 438 feet bgs</td>
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**Log of Boring E-211**

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

<table>
<thead>
<tr>
<th>Date(s) Drilled</th>
<th>6/9/03 - 6/12/03</th>
<th>Geotechnical Consultant</th>
<th>Camp Dresser &amp; McKee Inc.</th>
<th>Logged By</th>
<th>SHE</th>
<th>Checked By</th>
<th>RWS 2/02/04</th>
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</thead>
<tbody>
<tr>
<td>Drilling Method/Rig Type</td>
<td>Wireline/ Porta-drill</td>
<td>Drilling Contractor</td>
<td>Gregory Drilling, Inc.</td>
<td>Total Depth of Borehole</td>
<td>280.0 feet</td>
<td>Ground Surface Elevation/Datum</td>
<td>413.4 feet / Metro</td>
</tr>
<tr>
<td>Casing Size/Type</td>
<td>PQ (7&quot; O.D.)</td>
<td>Hammer Weight/Drop (lbs/in.)</td>
<td>300# / 30&quot;</td>
<td>Location</td>
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<td>Coordinates</td>
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**SAMPLING**

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<tr>
<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
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<th>USCS</th>
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<td></td>
<td>2 - 30  - 50/8 (100+)</td>
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</table>

**MATERIAL DESCRIPTION**

- **SM**: Medium dense, brown, silty, slightly gravelly to gravelly SAND (SM), fine to medium, gravelly Sands (Qvr)
- **SM**: Very dense, yellow red, moist, silty, gravelly SAND (SM), non-plastic, fine to medium, gravelly Sands (Qvt)

**REMARKS AND OTHER TESTS**

- 0 to 6 feet excavated with vacuum truck, not sampled
- Inferred from drill action and cuttings
- Some grinding and bucking while drilling (gravel, possible cobbles)

**Groundwater Observation Data:**

- **QW (FT BGS):** 49.2 (Low) 30.0 (High)
- **VWP1 (FT BGS):** 66.1 (Low) 60.5 (High)
- **VWP2 (FT BGS):**

**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).
<table>
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<th>Elevation, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
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<th>Recovery, %</th>
<th>Graphic Log</th>
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<th>Plazometer Schematic</th>
<th>Lab Tests</th>
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Heave/slough in hole -3'
Drove sampler through slough - no counts, slough suggests lack of matrix fines, artesian pressure.
<table>
<thead>
<tr>
<th>Elevation</th>
<th>Depth, feet</th>
<th>Type</th>
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<th>Blows / 6 in. (N)</th>
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<td>18-28-40 (68)</td>
<td>89</td>
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<td>Very dense, gray olive and gray blue, moist SAND (SP), trace silt, gravel, yellow orange laminae, organic material along scattered bedding planes (Qpfnf)</td>
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<td>2 feet slough, washing hole; slough cleaned, smooth, even sample, bedding inclined 5 to 10 degrees</td>
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<td>Drilling quiet at 67 ft bgs</td>
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<td>Driller reports interbedded salty CLAY and SAND, 3-foot beds</td>
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<td>4</td>
<td>9-19-17 (36)</td>
<td>83</td>
<td>CL-ML</td>
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<td>Hard, dark brown, moist, clayey SILT CL-ML, numerous disseminated organics, trace fine sand in scattered layers, slightly plastic, slow dilatancy, mottled brown and green (Qpfnl)</td>
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<td>Very stiff, olive gray, moist, silty CLAY (CL) high plasticity, homogeneous, scattered bedding plane partings (Qpfl)</td>
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**Remarks:**
- 4.5 Sheared zone, top of core
- Smooth, even drive
<table>
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**Assessment:**
- **SM:** Very dense, olive gray, very silty, gravelly SAND (SM), cobbles, gravel rounded to subangular, sand fine grained, poorly graded, clayey slough (Opogt)

**Remarks:**
- Even drive
- Driller reported change at 150 ft bgs, drill chattering and bucking
**Log of Boring E-211**

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

### SAMPLES

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<th>Depth, feet</th>
<th>Type</th>
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### MATERIAL DESCRIPTION

- Scattered gravel layers, approximately 6 inches to 1 foot thick
- 6-inch gravelly beds, with 6-inch sand/silt layers
- Silt content decreases
- Hard, olive gray, moist, silty CLAY (CL), trace gravel and sand dropstones, medium plasticity, no dilatancy, laminae of light gray silt (Qpogi)
- 6-inch silt layer
- Frequent slickensides and fractures, becciated texture

**REMARKS AND OTHER TESTS**

- Pressure meter test 175 to 180 ft bgs
- Slow drilling
- Frequent slickensides and fractures, becciated texture

**Plazometer Schematic**

**Lab Tests**

**Pocket Penetrometer (bs)**

---

**Note:** The image contains a detailed log of core samples and their descriptions, along with notes on drilling conditions and other tests performed at specific depths.
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<th>Elevator, feet</th>
<th>Depth, feet</th>
<th>Type</th>
<th>Number</th>
<th>Blows / 6 in. (N)</th>
<th>Recovery, %</th>
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<td>Laminated silt layer from 210 to 211 ft bgs</td>
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<td>Scattered shiny black and small white grains (glass and ash?), volcanics and quartz</td>
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<td>Gravelly from 232 to 234 ft bgs</td>
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</table>

**Remarks and Other Tests:**
- Rotary 220.5 to 225 ft bgs: Drilled out to clean borehole for in situ test, drilling rocky at top, less gravel and cobbles toward 225 ft bgs.
- Difficult drilling - formation choking off circulation - mainly clay and silt, few gravel.
- Pressure meter test 225 to 230 ft bgs.
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Remarks:
- Bedding inclined to 5 degrees
- Sheared and brecciated
- Pressure meter test 269 to 280 ft bgs
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<th>Material Description</th>
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<th>Remarks</th>
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**Log of Boring LLE-B06**

- **Project:** Sound Transit - Lynnwood Link Extension
- **Project Location:** Shoreline, Washington
- **Project Number:** 4082-026-02

Figure A-54

Sheet 1 of 3

---

Note: See Figure A-0 for explanation of symbols.
### Field Data

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### Material Description

- **Gray silty fine to medium sand with gravel (dense, moist)**
- **Brown silty fine to medium sand with occasional gravel (dense, moist)**
- **Brownish gray with oxidation staining fine to medium sand with silt (dense, wet) (advance outwash) (ESU 6B)**
- **Brownish gray silty fine to medium sand (very dense, wet)**
- **Brownish gray fine to medium sand with silt (very dense, wet)**
- **Brownish gray fine to medium sand with silt (very dense, wet)**
- **Gray fine sand with silt (very dense, wet)**

### Remarks

- Groundwater observed at 50 feet during drilling
- Rough drilling at 66 feet

---

#### Log of Boring LLE-B06 (continued)

**Project:** Sound Transit - Lynnwood Link Extension  
**Project Location:** Shoreline, Washington  
**Project Number:** 4082-026-02  
**Figure A-54**
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<th>Blows/foot</th>
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<td>Gray silty fine sand (very dense, wet)</td>
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**Note:** See Figure A-0 for explanation of symbols.

---

**Log of Boring LLE-B06 (continued)**

- **Project:** Sound Transit - Lynnwood Link Extension
- **Project Location:** Shoreline, Washington
- **Project Number:** 4082-026-02

Figure A-54
Brown silty fine to medium sand with gravel, occasional cobbles and boulders (medium dense, moist) (fill) (ESU 1B)

With decreasing cobbles and boulder content

Gray fine to coarse sand with silt and gravel (dense, moist)

Gray silty fine to medium sand with occasional gravel (dense to very dense, moist) (glacial till) (ESU 5B)

Grades to with gravel

Grades to brown

Grayish brown silty fine to medium sand (medium dense, moist)

Gray silty fine to medium sand with occasional gravel and trace organics (dense, wet)

Water knife/vactor to 5 feet.

Soil description based on visual observation.

Rough drilling

Rough drilling

Rough drilling

Note: See Figure A-0 for explanation of symbols.

Log of Boring LLE-B08

Project: Sound Transit - Lynnwood Link Extension
Project Location: Mountlake Terrace, Washington
Project Number: 4082-026-02

Figure A-55
Sheet 1 of 3
Groundwater observed at 36 feet during drilling.

No recovery.

AL (LL = 34%; PI = 11%)

Log of Boring LLE-B08 (continued)

Project: Sound Transit - Lynnwood Link Extension
Project Location: Mountlake Terrace, Washington
Project Number: 4082-026-02

Figure A-55
Sheet 2 of 3
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Note: See Figure A-0 for explanation of symbols.

Log of Boring LLE-B08 (continued)

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### MATERIAL DESCRIPTION

- **SM**: Brown silty fine to medium sand with gravel, occasional cobbles and trace roots (loose, moist) (fill) (ESU 1A)
- **SP-SM**: Brown fine to medium sand with gravel and occasional cobbles (dense, moist)
- **SM**: Brown silty fine to medium sand with gravel (medium dense, moist) (recessional outwash) (ESU 4)
- **SP**: Brown fine to medium sand with silt, gravel and occasional cobbles (dense, moist)
- **SM**: Brown fine to medium sand with silt, gravel, occasional cobbles and trace roots (loose, moist) (fill) (ESU 1A)
- **SP**: Brown fine to medium sand with occasional gravel and trace silt (very dense, wet) (advance outwash) (ESU 6B)
- **SP-SM**: Brown fine to coarse sand with silt and gravel (very dense, wet)
- **SM**: Brown fine to medium sand with silt, gravel and occasional cobbles (dense, moist)
- **SM**: Brown fine to medium sand with silt, gravel and occasional cobbles (dense, moist)
- **SM**: Brown fine to medium sand with gravel (medium dense, moist) (recessional outwash) (ESU 4)

### Log of Boring LLE-B09

**Project:** Sound Transit - Lynnwood Link Extension  
**Project Location:** Shoreline, Washington  
**Project Number:** 4082-026-02
Log of Boring LLE-B09 (continued)

Note: See Figure A-0 for explanation of symbols.
### Field Data

- **Surface Elevation (ft):** 354
- **Vertical Datum:** Project
- **Easting (X):** 1376055.124
- **Northing (Y):** 388777.7713
- **Data System:** DTM
- **Datum:** Project
- **System:** Datum
- **Driller:** CRW
- **Logged By:** DRW
- **Checked By:** CRW
- **Start:** 6/19/2014
- **End:** 6/19/2014
- **Total Depth (ft):** 81.5
- **Autohammer:** 140 (lbs) / 30 (in) Drop
- **Hammer Data:** Autohammer
- **Drilled:** Surface Elevation (ft)
- **Groundwater:** Depth to Water (ft)

### Material Description

- **Level:**
  - **Depth (feet):** 0
  - **Elevation (feet):** 350
  - **Sample Name:** Testing
  - **Recovered (in):** Graphic Log
  - **Collected Sample:** Collected Sample

#### Group Classification

- **MATERIAL DESCRIPTION**
  - **SM:** Grayish brown silty fine to medium sand with occasional gravel
  - **AC:** 3 inches asphalt concrete
  - **SP-SP:** Grayish brown silt fine to medium sand with gravel

### Remarks

- Water knife/vactor to 5 feet.
- Soil description based on visual observation.
- Autohammer efficiency = 87% (measured 11/1/2013)
- 3 (in) solid well installed at 80 (ft), decommissioned after seismic testing.

---

**Log of Boring LLE-B10S**

- **Project:** Sound Transit - Lynnwood Link Extension
- **Project Location:** Mountlake Terrace, Washington
- **Project Number:** 4082-026-02

Figure A-57
Sheet 1 of 3
Grayish brown silty fine to medium sand with gravel (very dense, moist to wet)

Grayish brown lean clay with sand (hard, moist)

Brown silty fine to medium sand (very dense, moist)

Gray silty fine to medium sand with silt interbeds (very dense, wet)

Groundwater observed at 70 feet during drilling

Note: See Figure A-0 for explanation of symbols.
### Field Data

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<th>Depth (feet)</th>
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### Material Description

- **Group:** SM
- **Classification:** Gray silty fine sand (very dense, wet)

**Remarks:**

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A 2 ft well was installed on 6/20/2014 to a depth of 30.25 ft.

**Notes:**
- Autohammer efficiency = 87% (measured 11/1/2013)

**Log of Boring LLE-B11P**

**Project:** Sound Transit - Lynnwood Link Extension

**Project Location:** Shoreline, Washington

**Project Number:** 4082-026-02

**Figure A-58**

**Sheet 1 of 3**
<table>
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<th>Interval</th>
<th>Blows/foot</th>
<th>Collected Sample</th>
<th>Elevation (feet)</th>
<th>Water Level</th>
<th>Graphic Log</th>
<th>Group</th>
<th>Classification</th>
<th>Moisture Content (%)</th>
<th>Fine Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>15</td>
<td>59</td>
<td>Sils</td>
<td>81.5</td>
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</table>

Note: See Figure A-0 for explanation of symbols.
Log of Boring LLE-B12

Project: Sound Transit - Lynnwood Link Extension
Project Location: Mountlake Terrace, Washington
Project Number: 4082-026-02

FIELD DATA

<table>
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<tr>
<th>Interval (feet)</th>
<th>Elevation (feet)</th>
<th>Recovered (in)</th>
<th>Blow Count</th>
<th>Collected Sample</th>
<th>Water Level</th>
<th>Graphic Log</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>390</td>
<td>15</td>
<td>10</td>
<td>CR</td>
<td>AC</td>
<td>7 inches asphalt concrete</td>
</tr>
<tr>
<td>5</td>
<td>385</td>
<td>15</td>
<td>10</td>
<td>SP-SM</td>
<td>2 inches base course</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>380</td>
<td>13</td>
<td>30</td>
<td>SP-SM</td>
<td>Brown fine sand with silt, gravel and occasional cobbles (medium dense, moist) (fill) (ESU 1B)</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>375</td>
<td>18</td>
<td>21</td>
<td>SP-SM</td>
<td>Brown with oxidation staining fine to medium sand with silt (medium dense, moist)</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>370</td>
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<td>33</td>
<td>SP-SM</td>
<td>Brown fine to medium sand with silt and occasional gravel (medium dense, moist)</td>
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<tr>
<td>25</td>
<td>365</td>
<td>18</td>
<td>31</td>
<td>SP-SM</td>
<td>Gray fine to medium sand with silt and occasional gravel (medium dense, moist)</td>
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<tr>
<td>30</td>
<td>360</td>
<td>18</td>
<td>31</td>
<td>SM</td>
<td>Gray silty fine to medium sand with occasional gravel and lenses of wood/peat and silt (dense, moist) (advance outwash) (ESU 6A)</td>
<td></td>
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<td>Brown with oxidation staining silty fine to medium sand with occasional gravel and silt interbeds (dense, moist) (ESU 6B)</td>
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</tr>
<tr>
<td>40</td>
<td>350</td>
<td>18</td>
<td>31</td>
<td>SM</td>
<td>Brown with oxidation staining silty fine to medium sand with occasional gravel and silt interbeds (dense, moist) (ESU 6B)</td>
<td></td>
</tr>
</tbody>
</table>

MATERIAL DESCRIPTION

- **AC**: 7 inches asphalt concrete
- **CR**: 2 inches base course
- **SP-SM**: Brown fine sand with silt, gravel and occasional cobbles (medium dense, moist) (fill) (ESU 1B)
- **SM**: Gray silty fine to medium sand with occasional gravel and lenses of wood/peat and silt (dense, moist) (advance outwash) (ESU 6A)

REMARKS

- Water knife/vactor to 5.5 feet.
- Soil description based on visual observation.
- Water level to 5.5 feet.
- Hard drilling
- No recovery

Note: See Figure A-0 for explanation of symbols.
Brown fine to medium sand with trace silt and occasional gravel (dense, wet)

Brown fine to medium sand with silt (dense to very dense, wet)

Brown with oxidation staining fine to medium sand with silt and silt interbeds (very dense, wet)

Brown with oxidation staining fine to medium sand with silt (very dense, wet)

Groundwater observed at 38 feet during drilling

Driller added mud to control heave

Poor recovery

Note: See Figure A-0 for explanation of symbols.
<table>
<thead>
<tr>
<th>Depth (feet)</th>
<th>Interval</th>
<th>Recovered (in)</th>
<th>Blows/foot</th>
<th>Collected Sample</th>
<th>Sample Name</th>
<th>Testing</th>
<th>Water Level</th>
<th>Group</th>
<th>Classification</th>
<th>MATERIAL DESCRIPTION</th>
<th>Moisture Content (%)</th>
<th>Remains</th>
<th>Fines Content (%)</th>
<th>REMARKS</th>
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<tbody>
<tr>
<td>50/5&quot;</td>
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Note: See Figure A-0 for explanation of symbols.
FIELD DATA

MATERIAL DESCRIPTION

3 inches base course
Gray fine to coarse gravel with silt and sand (medium dense, wet) (fill) (ESU 1A)

Brown silty fine to medium sand with gravel, trace roots and wood fragments (loose to medium dense, moist)

With trace wood fragments

With occasional asphalt and debris

Gray fine to coarse sand (medium dense, moist) (advance outwash) (ESU 6A)

Gray fine to medium sand with silt (medium dense, moist)

Gray fine to medium sand with silt and gravel (dense, wet) (ESU 6B)

4 inches asphalt concrete

Remarks:
- Water knife/vactor to 5 feet. Soil description based on visual observation.
- Groundwater observed at 32 feet during drilling.
### FIELD DATA

<table>
<thead>
<tr>
<th>Elevation (feet)</th>
<th>Depth (feet)</th>
<th>Interval</th>
<th>Recovered (in)</th>
<th>Blows/foot</th>
<th>Collected Sample</th>
<th>Testing</th>
<th>Water Level</th>
<th>Graphic Log</th>
<th>Group</th>
<th>Classification</th>
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### MATERIAL DESCRIPTION

<table>
<thead>
<tr>
<th>Material Description</th>
<th>Moisture Content (%)</th>
<th>Fines Content (%)</th>
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</thead>
<tbody>
<tr>
<td>Gray fine to medium sand with silt (dense to very dense, wet)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gray silty fine to medium sand (very dense, wet)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brown with oxidation staining fine to medium sand with silt (very dense, wet)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**REMARKS**

Driller added mud to auger to prevent heave

---

**Log of Boring LLE-B13 (continued)**

*Project:* Sound Transit - Lynnwood Link Extension  
*Project Location:* Mountlake Terrace, Washington  
*Project Number:* 4082-026-02  
*Figure A-60*  
*Sheet 2 of 3*  

Note: See Figure A-0 for explanation of symbols.
### Field Data

<table>
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<th>Depth (feet)</th>
<th>Interval</th>
<th>Recovered (in)</th>
<th>Blows/foot</th>
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<tbody>
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<td>18.00</td>
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### Material Description

<table>
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<th>Classification</th>
<th>Water Level</th>
<th>Sample Name Testing</th>
<th>Collected Sample</th>
<th>Blows/foot</th>
<th>Fines Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Redmond</td>
<td>Sand &amp; Gravel</td>
<td>315</td>
<td>Testing</td>
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<td>SM</td>
<td>Silty Fine Sand</td>
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### Remarks

Note: See Figure A-0 for explanation of symbols.
Notes: Autohammer efficiency = 87% (measured 11/1/2013)

Log of Boring LLE-B14

Project: Sound Transit - Lynnwood Link Extension
Project Location: Mountlake Terrace, Washington
Project Number: 4082-026-02

Figure A-61 Sheet 1 of 2
<table>
<thead>
<tr>
<th>Depth (feet)</th>
<th>Interval</th>
<th>Blows/foot</th>
<th>Collected Sample</th>
<th>Sample Name Testing</th>
<th>Water Level</th>
<th>Group Classification</th>
<th>Fines Content (%)</th>
<th>Moisture Content (%)</th>
<th>REMARKS</th>
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<td>71</td>
<td>±</td>
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<td>Grades to wet</td>
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<td>Groundwater observed at 35 feet during drilling</td>
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<tr>
<td>40</td>
<td>12</td>
<td>50/6'</td>
<td>±</td>
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<td>Brownish gray fine to medium sand with trace silt (very dense, wet)</td>
<td>30</td>
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Log of Boring LLE-B15

Project: Sound Transit - Lynnwood Link Extension
Project Location: Mountlake Terrace, Washington
Project Number: 4082-026-02

FIELD DATA

<table>
<thead>
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<th>Elevation (feet)</th>
<th>Depth (feet)</th>
<th>Interval</th>
<th>Recovered (in)</th>
<th>Collected Sample</th>
<th>Group</th>
<th>Classification</th>
<th>Water Level</th>
<th>Graphic Log</th>
<th>Sample Name</th>
<th>Testing</th>
<th>Recovered (in)</th>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MATERIAL DESCRIPTION

- AC: 8 inches asphalt concrete
- CR: 9 inches base course
- SP-SM: Grayish brown fine to medium sand with silt and occasional gravel (medium dense, moist) (advance outwash) (ESU 6A)
- SP-SM: Grayish brown fine to medium sand with silt (dense to very dense, moist) (ESU 6B)
- SP-SM: Gray fine to medium sand with trace silt (very dense, moist)
- SP-SM: Brownish gray fine to medium sand with silt (very dense, moist)
- SP-SM: Brownish gray fine to medium sand with silt and occasional gravel (very dense, wet)

REMARKS

- Water knife/vactor to 5.5 feet.
- Soil description based on visual observation.

Note: See Figure A-0 for explanation of symbols.
<table>
<thead>
<tr>
<th>Depth (feet)</th>
<th>Interval</th>
<th>Recov. (in)</th>
<th>Collected Sample</th>
<th>Water Level</th>
<th>Elevation (feet)</th>
<th>Sample Name</th>
<th>Testing</th>
<th>Graphic Log</th>
<th>Group</th>
<th>Classification</th>
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<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>14</td>
<td>81/8&quot;</td>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Brownish gray fine to medium sand with occasional gravel and trace silt (very dense, wet)</td>
</tr>
</tbody>
</table>

**REMARKS**

12 7
Groundwater observed at 35 feet during drilling

16 4

---

Note: See Figure A-0 for explanation of symbols.
LOG OF BORING LLE-B17

PROJECT: Sound Transit - Lynnwood Link Extension

PROJECT LOCATION: Shoreline, Washington

PROJECT NUMBER: 4082-026-02

LOGGED BY: ERH

CHECKED BY: CRW

DRILLED: 6/18/2014

END: 6/18/2014

TOTAL Depth: 101.5 ft

DRILLING METHOD: Hollow-Stem Auger

Driller: Holocene

Hammer: Autohammer

Data: 140 (lbs) / 30 (in) Drop

SELECTED MATERIAL DESCRIPTION:

0 - 5 ft

Crushed rock

Gray fine to coarse gravel with silt, sand and cobbles (loose, moist) (fill) (ESU 1A)

15 - 20 ft

Brown fine to medium sand with trace gravel and trace organics (loose, moist)

30 - 35 ft

Gray fine to medium sand with silt and occasional gravel (dense to very dense, wet) (ESU 6B)

REMARKS:

Water knife/vactor to 5 feet.

Soil description based on visual observation.

Groundwater observed at 26 feet during drilling.

Notes: Autohammer efficiency = 87% (measured 11/1/2013)

Note: See Figure A-0 for explanation of symbols.
### Field Data

<table>
<thead>
<tr>
<th>Depth (feet)</th>
<th>Interval</th>
<th>Blows/foot</th>
<th>Collection Name</th>
<th>Testing</th>
<th>Water Level</th>
<th>Graphic Log</th>
<th>Group Classification</th>
<th>Material Description</th>
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</table>

### Material Description

- **Brown fine to medium sand** (very dense, wet)
- **Gray fine to medium sand with silt** (very dense, wet)
- **Brown fine to medium sand with silt** (dense to very dense, wet)
- **Brown fine sand with silt** (very dense, wet)
- **Brown silty fine sand** (very dense, wet)
- **Brown with oxidation staining lean clay** (hard, moist to wet)
- **Gray fine sand with silt** (very dense, moist)

---

**Note:** See Figure A-0 for explanation of symbols.
<table>
<thead>
<tr>
<th>Depth (feet)</th>
<th>Interval</th>
<th>Recovered (in)</th>
<th>Blows/foot</th>
<th>Sample Name</th>
<th>Testing</th>
<th>Water Level</th>
<th>Graphic Log</th>
<th>Group</th>
<th>Classification</th>
<th>Material Description</th>
<th>Moisture Content (%)</th>
<th>Fines Content (%)</th>
<th>REMARKS</th>
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<td>25</td>
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<td>Gray sandy silt (hard, moist) (transitional beds) (ESU 7)</td>
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<td>Gray lean clay (hard, moist)</td>
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<td>Gray sandy silt (hard, moist) (transitional beds) (ESU 7)</td>
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Note: See Figure A-0 for explanation of symbols.
Log of Boring LLE-B18

Project: Sound Transit - Lynnwood Link Extension
Project Location: Mountlake Terrace, Washington
Project Number: 4082-026-02

Note: See Figure A-0 for explanation of symbols.
### Field Data

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### Remarks

- With occasional gravel
- Gravel zone at 45 feet

**MATERIAL DESCRIPTION**

- Gray fine sand with silt (micaceous) (very dense, moist)
- Wet fine sand

Note: See Figure A-0 for explanation of symbols.
### Log of Boring LLE-B19

**Project:** Sound Transit - Lynnwood Link Extension  
**Project Location:** Mountlake Terrace, Washington  
**Project Number:** 4082-026-02  

---

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<th>Fines Content (%)</th>
<th>REMARKS</th>
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<td>Grades to wet</td>
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<td>7</td>
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**Note:** See Figure A-0 for explanation of symbols.
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<th>Group Classification</th>
<th>MATERIAL DESCRIPTION</th>
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<th>Fines Content (%)</th>
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<td>76</td>
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<td>8</td>
<td>Driller added mud to auger to control heave</td>
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<td>18</td>
<td>43</td>
<td>8</td>
<td></td>
<td></td>
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<td></td>
<td>Grades to grayish brown</td>
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<td>7</td>
<td></td>
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<td>Grayish brown silty fine to medium sand (very dense, wet)</td>
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<td>18</td>
<td>77</td>
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<td></td>
<td></td>
<td>Gray fine to medium sand with silt (very dense, wet)</td>
<td>23</td>
<td>9</td>
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<td>8</td>
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<tr>
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<td>50/8&quot;</td>
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<td></td>
<td>Gray fat clay (hard, moist) (transitional beds) (ESU 7)</td>
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<td>7</td>
<td>AL (LL = 53%; PI = 28%)</td>
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<tr>
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<td>17</td>
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**Note:** See Figure A-0 for explanation of symbols.

---

**Log of Boring LLE-B19 (continued)**

**Project:** Sound Transit - Lynnwood Link Extension  
**Project Location:** Mountlake Terrace, Washington  
**Project Number:** 4082-026-02  
**Figure A-65**  
**Sheet 2 of 3**
### Field Data

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<th>Depth (feet)</th>
<th>Interval</th>
<th>Recovered (in)</th>
<th>Sample Name</th>
<th>Testing</th>
<th>Water Level</th>
<th>Group</th>
<th>Classification</th>
<th>Moisture Content (%)</th>
<th>Fines Content (%)</th>
<th>Remarks</th>
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<td>80</td>
<td>18</td>
<td>31</td>
<td>AL</td>
<td>MC</td>
<td></td>
<td>CL</td>
<td>Gray with oxidation staining lean clay with sand interbeds (hard, moist)</td>
<td>18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>18</td>
<td>56</td>
<td>AL</td>
<td>MC</td>
<td></td>
<td>CL</td>
<td>Brown with oxidation staining elastic silt (hard, moist)</td>
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<td></td>
<td></td>
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<td>90</td>
<td>18</td>
<td>34</td>
<td>AL</td>
<td>MC</td>
<td></td>
<td>CL</td>
<td>Brownish gray fat clay (hard, moist)</td>
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<td>AL (LL = 53%; PI = 23%)</td>
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<td>18</td>
<td>29</td>
<td>AL</td>
<td>MC</td>
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<td>CL</td>
<td>Brownish gray fat clay (hard, moist)</td>
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<td>18</td>
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Note: See Figure A-0 for explanation of symbols.
Log of Boring LLE-B20

Project: Sound Transit - Lynnwood Link Extension
Project Location: Mountlake Terrace, Washington
Project Number: 4082-026-02

Field Data

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<th>Testing</th>
<th>Group</th>
<th>Classification</th>
<th>Moisture Content (%)</th>
<th>Fines Content (%)</th>
<th>Remarks</th>
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<td></td>
<td>GP</td>
<td>3 inches gravel base course</td>
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<tr>
<td>10</td>
<td>420</td>
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<td>Brown silty sand with gravel and occasional boulders (medium dense, moist) (fill) (ESU 1B)</td>
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<td></td>
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<td>15</td>
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<td>Brown fine to medium sand with silt and gravel (medium dense, moist)</td>
<td></td>
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<tr>
<td>20</td>
<td>410</td>
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<td></td>
<td>ML</td>
<td>Gray silt with occasional sand and gravel (very stiff, moist)</td>
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<td>Brown silty fine to medium sand with gravel (medium dense to dense, moist)</td>
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<td>400</td>
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<td>F</td>
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<td>SP-SM</td>
<td>Gray fine to medium sand with silt and occasional gravel (medium dense, moist)</td>
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Notes: Autohammer efficiency = 87% (measured 11/1/2013)

Water knife/vactor to 5.5 feet. Soil description based on visual observation.
Note: See Figure A for explanation of symbols.

FIELD DATA

MATERIAL DESCRIPTION

- **Wood (SP-SM)**
  - 25 yd 2-inch wood layer
  - Underlying soil fine to medium sand with silt and gravel (medium dense, moist) (advance outwash) (ESU 6A)

FIELD DATA

- **Depth (feet)**
- **Interval**
- **Recovered (in)**
- **Blows/foot**
- **Collected Sample**
- **Sample Name Testing**
- **Water Level**
- **Graphic Log**

REMARKS

- **Fines Content (%)**
- **Moisture Content (%)**

FIELD DATA

- **Elevation (feet)**
- **Interval**
- **Recovered (in)**
- **Blows/foot**
- **Collected Sample**
- **Sample Name Testing**
- **Water Level**
- **Graphic Log**

REMARKS

- **Fines Content (%)**
- **Moisture Content (%)**
Appendix C

Borehole Data Summary Sheet
Appendix C, Borehole Data Summary Sheet. Expansions of the abbreviations listed in this table are as follows – Drilling Methods: Hollow Stem Auger (HAS), Mud Rotary (MR), and Becher Hammer (BH); Samplers: Standard Penetration Test (SPT), and Dames and Moore (D&M); Methods of Water Measurement: Vibrating Wire Piezometer (VWP), Observations while Drilling (drilling obs.), and electric tape (e-tape).

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<th>Sampler</th>
<th>Depth (ft)</th>
<th>Elevation (ft)</th>
<th>N-Value</th>
<th>Density</th>
<th>Water Elevation (ft)</th>
<th>Method and Date of Water Measurements</th>
<th>Percent Moisture</th>
<th>Percent Gravel</th>
<th>Percent Sand</th>
<th>Percent Fines</th>
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<td>B06</td>
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<td>50</td>
<td>279</td>
<td>37</td>
<td>dense</td>
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Appendix D

Unified Soil Classification Guide (Adapted from Zhou, 2006)
Figure 4-1: Flow chart to determine the group symbol and group name for coarse-grained soils (ASTM D 2487).
Figure 4-4a. Flow chart to determine the group symbol and group name for fine-grained soils (ASTM D 2487).
Figure 4-4b. Flow chart to determine the group symbol and group name for organic soils (ASTM D 2487).