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GEOTECHNICAL REPORT

4th Avenue Storm Drainage Project

PUYALLUP, WASHINGTON

January 12, 2021

Shannon & Wilson No: 105692-004

Submitted To: Brown and Caldwell
701 Pike Street, Suite 1200
Seattle, WA 98101
Attn: Ms. Abbi Dorn

Subject: DRAFT GEOTECHNICAL REPORT, 4TH AVENUE STORM DRAINAGE PROJECT, PUYALLUP, WASHINGTON

Shannon & Wilson prepared this report and participated in this project as a subconsultant to Brown and Caldwell. Our scope of services was specified in Purchase Order #35553 dated October 12, 2020. This report presents the results of our subsurface explorations, geotechnical analyses, and recommendations and was prepared by the undersigned.

We appreciate the opportunity to be of service to you on this project. If you have questions concerning this report, or we may be of further service, please contact us.

Sincerely,

SHANNON & WILSON

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ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
AREMA	American Railway Engineering and Maintenance-of-Way Association
bgs	below ground surface
City	City of Puyallup
DNR	Washington State Department of Natural Resources
Ecology	Washington State Department of Ecology
F_{pga}, F_a, and F_v	spectral acceleration site coefficients
MH	maintenance hole
MTBM	microtunnel boring machine
pcf	pounds per cubic foot
PGA	peak ground acceleration
psf	pounds per square foot
ROW	right-of-way
S_1	spectral acceleration at period of one second
S_s	short-period spectral acceleration
USGS	U.S. Geological Survey
WSDOT	Washington State Department of Transportation

1 INTRODUCTION

This draft geotechnical report presents the results of our geotechnical engineering studies completed for the 4th Avenue Storm Drain project (Project) located in Puyallup, Washington (Figure 1). This report was prepared for the exclusive use of the City of Puyallup (City) and the Brown and Caldwell design team and their representatives to assist with advancing design of the Project. Included in this report are a site and Project description, an overview of existing geotechnical explorations, results of the completed Project geotechnical explorations and laboratory testing, the interpreted subsurface soil and groundwater conditions, engineering recommendations, construction considerations, and recommendations for geotechnical instrumentation.

This report was prepared during development of the 60% design of the Project. This report should not be used for construction and should not be used without our approval if any of the following occurs:

- Conditions change due to natural forces or human activity under, at, or adjacent to the site.
- Assumptions stated in this report have changed.
- Project details change or new information becomes available such that our recommendations may be affected.
- If the site ownership or land use has changed.
- More than ten years has passed since the date of this report.

If any of these occur, we should be retained to review the applicability of our recommendations.

2 SITE AND PROJECT DESCRIPTION

The Project site is in the downtown area of the City of Puyallup in Pierce County, as shown in Figure 1. The Project consists of designing and constructing a new north-alignment storm drain to connect the Sound Transit redevelopment area to the existing 54-inch system that discharges to the Puyallup River. The new storm drain alignment is proposed to be constructed along 5th Street NW between 3rd Avenue NW and W. Stewart Avenue and along 4th Street NW between W. Stewart Avenue and the existing 54-inch system that begins just north of River Road.

The depth of the new storm drain ranges from about 10 to 20 feet below ground surface (bgs). The primary construction method for the pipeline is anticipated to be open-cut trenching but will also include trenchless crossings at the BNSF Railroad right-of-way (ROW) and potentially at River Road. Based on the 30% drawings, we understand that the storm drain may cross below or be constructed next to existing utilities and that the new storm drain is generally deeper than the adjacent existing utilities. In addition to the construction of the new storm drain pipe, the Project will include five new maintenance holes (MHs) and four relocated MHs.

3 SUBSURFACE EXPLORATIONS

Shannon & Wilson completed a geotechnical exploration program to characterize the soil and groundwater conditions present along the Project alignment. The geotechnical exploration program included collecting existing subsurface exploration data near the Project alignment and completing subsurface explorations and testing.

3.1 Existing Subsurface Explorations

The collected existing subsurface exploration data include four exploration logs from borings and groundwater wells from previously completed projects. We did not review the samples from these explorations and cannot confirm that they are representative of the site conditions. The exploration logs were collected from the Washington State Department of Natural Resources (WA DNR) Division of Geology and from Sound Transit development documents. A location map showing the approximate locations of the explorations and logs of the explorations are included in Appendix A.

3.1.1 Washington State Department of Natural Resources (WA DNR) Subsurface Database

According to the WA DNR subsurface database, two groundwater wells are located near the north end of the Project alignment. The first well, H-1-00, was a geotechnical boring and well installation that was completed approximately one-half mile north of the Project alignment by the Washington State Department of Transportation (WSDOT) in June 2000 (WSDOT, 2002). The second well, designated as Well ID ABY244 by the Washington State Department of Ecology (Ecology), was a domestic water well installed approximately 1 mile east of the Project alignment in November 1995 (Ecology, 1995). While the wells are located near the Project alignment, they are on the opposite side of the Puyallup River as the Project site.

3.1.2 Sound Transit Explorations

We understand that subsurface explorations were completed in the vicinity of the Project alignment in 1999 and 2015 for Sound Transit development projects. These previous explorations were completed in the vicinities east and west of 5th Street NW and south of W. Stewart Avenue.

We reviewed the draft geotechnical report for the 2015 subsurface exploration, which included information on both the 1999 and 2015 explorations (HWA Geosciences, 2016). Based on the report, six borings performed by HWA Geosciences are located near the portion of the Project alignment that is along 5th Street NW. The borings are designated BH-2 (1999) and BH-1 through BH-5 (2015).

3.2 Project Subsurface Explorations

Shannon & Wilson performed four geotechnical borings that were drilled and sampled to characterize the subsurface conditions at the site. The borings were drilled by Holocene Drilling of Puyallup, Washington, under subcontract to Shannon & Wilson. Standard penetration tests were completed in the borings during drilling. Geotechnical laboratory tests of soil samples collected during drilling included performing visual classification and testing to determine the natural water content, grain-size distribution, and Atterberg Limits. A summary of the geotechnical explorations and logs of the borings is included in Appendix B. A summary and results of geotechnical laboratory testing are included in Appendix C.

4 SUBSURFACE CONDITIONS

The geology and subsurface conditions along the Project alignment were inferred from soil samples and information obtained from borings and observation wells, from data gathered from existing projects in the vicinity, from geologic maps of the area, from field reconnaissance, and from our experience on other projects in the area. Our observations are specific to the locations and depths noted on the logs and profiles and may not be applicable to all areas of the site. No number of explorations or testing can precisely predict the characteristics, quality, or distribution of subsurface and site conditions. Potential variation includes, but is not limited to:

- The conditions between and below explorations may be different.
- The passage of time or intervening causes (natural and man-made) may result in changes to site and subsurface conditions.
- Groundwater levels and flow directions may fluctuate due to seasonal variations.

- Groundwater flow between different aquifers can occur. No soil layer should be assumed to be continuous and/or watertight.
- Penetration test results in gravelly soils may be unrealistic. Actual soil density may be lower than estimated if the test was performed on a gravel or cobble.
- Obstructions such as wood, boulders, piles, foundations, rubble, etc., may be present in the subsurface.

If conditions different from those described herein are encountered, we should be advised so we can review our description of the subsurface conditions and reconsider our conclusions and recommendations.

The following sections include a description of the site geology, subsurface soil and groundwater conditions encountered at the site, geologic hazards, and soil properties.

4.1 Geologic Setting

The Project is in the central portion of the Puget Lowland, an elongated, north-south depression situated between the Olympic Mountains and the Cascade Range. Repeated glaciation (glacial events) in this region strongly influenced the present-day topography, geology, and groundwater conditions in the Project area.

Geologists generally agree that the Puget Sound area was subjected to six or more major glacial events, five of which may have overridden the Tacoma/Puyallup area. Glacial ice for these glaciations originated in the Coast Range and Canadian Rockies and generally flowed southward into the Puget Lowland. Each glaciation deposited new sediment and partially eroded previous sediments. During the intervening periods when glacial ice was not present, normal river processes, sediment-laden floods from Mount Rainer eruptions (lahars), wave action, and landsliding eroded, reworked, and deposited new sediment. In the Project area, the glacial and interglacial deposits (non-glacial soils deposited in between glacial events) are estimated to be thicker than 1,900 feet (Buchanan-Banks and Collins, 1994).

During the most recent glaciation that covered the central Puget Lowland (termed Vashon), glacial ice is estimated to have been about 2,300 feet thick in the Project area (Thorson, 1989). The weight of the glacial ice resulted in compaction (overconsolidation) of the glacial and nonglacial soils. Sub-glacial meltwater streams eroded into overconsolidated soil forming north-trending valleys.

In Puyallup, glacial deposits are overlain by younger (Holocene epoch), relatively loose and soft, post-glacial soils that include alluvial, beach, and estuarine sediment deposited as the Puyallup River delta advanced into Commencement Bay.

4.2 Tectonic Conditions

Tectonically, the Puget Lowland is located in the forearc of the Cascadia Subduction Zone. The tectonics and seismicity of the region are the result of the relative northeastward subduction of the Juan de Fuca Plate beneath the North American Plate. North-south compression is accommodated beneath the Puget Lowland by a series of west- and northwest-trending faults that extend to depths of about 12 miles. The nearest active fault to the Project is the Tacoma Fault, a collective term for a series of several east-trending, north-dipping fault splays beneath Tacoma. The nearest fault splay may extend through Commencement Bay and the Puyallup River. Geologic evidence indicates that Holocene movement occurred on this fault zone (Sherrod and others, 2004).

4.3 Geologic Units

The soil types interpreted from the existing and current geotechnical data along the Project alignment include:

- Fill (Hf): Fill placed by humans, both engineered and non-engineered. The deposits consist of various compositions of clay, silt, sand, and gravel and may contain other materials, including construction debris, cobbles, boulders, wood, and pockets of peat. Typically, engineered fill is dense or stiff and non-engineered fill is very loose to medium dense or very soft to stiff.
- Alluvium Deposits (Ha): Silt, elastic silt, lean clay, sand, and gravel deposited in streambeds and as overbank deposits. Cobbles, and less likely boulders, may be present with the alluvium deposits. Wood, peat, and organic debris may also be present with the alluvium deposits.

4.4 Subsurface Conditions

As discussed, our understanding of the subsurface soil conditions along the alignment is based on our review of existing subsurface explorations, current Project subsurface explorations, and our general understanding of the geologic history and stratigraphy of the region. In general, the soils at the Project site are the result of post-glacial geologic processes and human modification of the ground surface.

A profile showing the anticipated soil and groundwater conditions at the boring locations along the Project alignment is presented in Figure 3 (Sheets 1 through 4). This subsurface profile is interpreted from materials observed in explorations and descriptions from existing subsurface exploration logs. The subsurface profile provides one of many possible interpretations of the subsurface conditions. The actual subsurface conditions along the alignment are only known at the depths and locations of samples obtained from the subsurface explorations specifically performed for this Project. Variations between the interpretation shown and actual conditions will exist. The legend and notes for the profile, including a listing and description of the interpreted geologic units encountered in the borings, are presented in Figure 2.

4.4.1 Soil Conditions

The soil conditions along the Project alignment consist of approximately 6 feet of fill (Hf) overlying alluvial (Ha) deposits. The alluvial deposits along the south end of the alignment consist of interbedded, very loose to dense silty sand and very soft to medium stiff silt, elastic silt, and lean clay to a depth of approximately 26 feet. Alluvial deposits consisting of medium dense to dense clean to silty sand underlie the interbedded deposits. Along the north end of the alignment south of River Road, the alluvial deposits consist of interbedded loose to dense silty sand and silt and medium stiff silt and lean clay. North of River Road, the alluvial deposits consist of very loose to dense clean to silty sand.

4.4.2 Groundwater Conditions

Groundwater was encountered during the drilling of borings SWB-1-20, SWB-2-20, and SWB-4-20 between November 30 and December 2, 2020. The groundwater was observed in the borings between approximate depths of 7 and 12 feet bgs. A groundwater well was installed in boring SWB-4-20 after the boring was complete; however, subsequent water measurements in the well on December 4 and 30, 2020, indicated that groundwater was below the bottom of the well screen or below approximately 13 feet bgs.

The magnitude of potential seasonal groundwater fluctuation is not known. However, in our opinion, the site groundwater level may be related to the Puyallup River gauge elevation due to the river’s proximity to the site. Additionally, the previous explorations discussed in Section 3.1 include groundwater data from different seasons. The log for BH-4 (2015) indicates groundwater was encountered during drilling at approximately 7 feet bgs in October 2015 and measured after well completion at approximately 4 feet bgs. The log for H-1-00 indicates groundwater was encountered during drilling at approximately 14 feet bgs in June 2000 and measured after well completion at approximately 9 feet bgs (Appendix A). The groundwater measurements reported during drilling at BH-4 (2015) and H-1-00 are generally within range of the observations we made during drilling of the Project borings. While we did not verify the groundwater measurements in wells from previous explorations, the reported data may be helpful in understanding the potential groundwater fluctuation at the site. We estimated that the depth to groundwater varies from about 4 to 15 feet bgs along the pipeline alignment.

The well log for the domestic well (Ecology Well ID ABY244) installed east of the Project alignment indicates it is installed deeper than the other wells in the site vicinity with a bottom-of-screen depth at approximately 226 feet bgs. The well log indicates an artesian groundwater level approximately 8 feet above ground surface (Appendix A). In our opinion, this well is located within a deep regional aquifer and likely does not represent the shallow groundwater conditions at the site. Although the deep regional aquifer is not anticipated to have a direct impact on the Project, the data from the deep aquifer suggests there is a general upward groundwater gradient in the vicinity of the Project.

4.5 Geologic Hazards

Although not observed in the borings, cobbles and boulders should be expected in both the fill (Hf) and alluvium (Ha) deposits along the Project alignment. Based on our experience, cobbles and boulders associated with glacial deposits are generally igneous or metamorphic rock with relatively high unconfined compressive strengths. Cobbles and boulders in the alluvial deposits were likely weathered out from glacial deposits and have similar compressive strengths. Cobbles and boulders in the fill could be imported from other areas and likely have a wider range of unconfined compressive strengths.

Although not observed in the borings, the fill (Hf) and alluvium (Ha) deposits should be expected to contain wood and other debris that could be difficult to penetrate and could cause other problems for excavation, trenchless construction, and shoring installation. In addition, peat or other soft, organic soils may be present in the alluvium (Ha). Peat and organic soils are differentiated from other soft, fine-grained soils because of their potential for high moisture contents and to significantly compress under new loads. Wood, debris, peat, and organics encountered during the excavation are considered unsuitable material for construction. Construction recommendations for unsuitable soil encountered during construction are discussed in Section 5.6.

4.5.1 Seismic Hazard Areas

According to the WA DNR Geologic Information Portal, the Project site is located within a seismic hazard area (Washington Geological Survey, 2021). As discussed in Section 4.2, the nearest active faults to the Project are collectively termed the Tacoma Fault Zone, which is located approximately 5 miles north and northeast of the Project area. Consequently, ground surface rupture from movement on these fault zones is not anticipated to occur within the Project area. However, the Project area is located within an area of high liquefaction susceptibility according to WA DNR mapping. Based on our understanding of the subsurface soil and groundwater conditions at the site, there is also potential for seismic-induced lateral spreading.

We understand that the City does not require seismic design of the storm drain pipeline. Therefore, per our scope of work, we did not perform an evaluation of potential liquefaction-induced settlement or lateral spreading at the site.

4.6 Soil Properties

For design purposes, soil engineering properties are presented in Exhibit 4-1 for the geologic units encountered during our geotechnical investigations. The values in this exhibit are based on relationships with laboratory test results and our experience with these soil units on similar projects.

Exhibit 4-1: Soil Engineering Properties

Geologic Unit	Total Unit Weight (pcf)	Drained Shear Strength		Hydraulic Conductivity K (cm/sec)
		c' (psf)	φ' (degrees)	
Hf	125	0	32	10^{-5} to 10^{-3}
Ha	115	0	30	

NOTES:
cm/sec = centimeters per second; pcf = pounds per cubic foot; psf = pounds per square foot

5 ENGINEERING RECOMMENDATIONS AND CONSTRUCTION CONSIDERATIONS

This section provides our geotechnical recommendations related to the proposed storm drain pipeline construction. Included in this section are geotechnical recommendations related to excavation and temporary shoring, groundwater control, foundation support, trenchless construction, backfill and compaction, geotechnical instrumentation, and wet weather work.

We understand that the information contained in this report will be used by the designers to develop the final design. The recommendations included herein are not intended for construction.

We have identified considerations for excavation, shoring, and trenchless construction to assist you in developing geotechnical and dewatering-related plans, specifications, and designs but not to dictate methods or sequences used by contractors. We recommended that the contract specifications require that prospective contractors undertake their own independent review and evaluation of all information to arrive at decisions concerning the planning of the work; the selection of equipment, means and methods, techniques, and sequences of construction; establishment of safety precautions; and evaluation of the influence of construction on adjacent sites.

5.1 Groundwater Control

Based on the proposed pipe elevation and groundwater conditions observed or measured in the previous and current subsurface explorations, we anticipate that the pipeline and MHs along most of the alignment will be constructed beneath the groundwater table or will be influenced by perched groundwater. Consequently, some form of groundwater control will be necessary to complete the work.

Numerous factors influence the type of dewatering approach that would be appropriate for excavations along the Project alignment. These include soil properties, aquifer thickness, the relationship of the maximum excavation depth to the base of the aquifer, drawdown requirements, shoring and excavation approaches, the amount of dewatering flow anticipated, and the experience of the Contractor. We anticipate that the Contractor's dewatering approach and system design will include some combination of sump pumping and vacuum well points. We anticipate that the Contractor's dewatering approach and system design would use vacuum well points for the deepest excavations, such as for the manhole installations and deeper trench excavations. Where 3 feet or less of drawdown is needed, we anticipate the Contractor would control groundwater using sump pumping. These methods are discussed in the following sections.

Dewatering-induced settlement of the Hf and Ha deposits could cause downdrag loading and settlement of nearby structures. Settlements due to dewatering can be reduced by limiting the amount of groundwater drawdown outside the excavation. We recommend that deep, large-diameter dewatering wells not be allowed, because they may result in larger groundwater drawdowns farther from the proposed excavations.

5.1.1 Sumps

Sumps consist of a shallow hole or trench in the excavation subgrade with a slotted casing containing a pump and surrounded by filter sand or gravel to prevent the pumping of formation material. Sumps are the most common method of dewatering and, where practical, are generally the least costly. Sump pumping is typically limited to locations where less than 2 to 3 feet of drawdown is required. If not properly designed, dewatering with sumps can cause substantial pumping of finer-grained formation material, which can undermine excavations. Loss of fines by pumping in some instances can cause large ground losses. Regardless of potential ground loss, reducing suspended fines produced from sump pumping commonly requires treatment of the dewatering discharge prior to disposal.

"Open sumping," defined as the use of sump pumps to remove surface water without using a slotted casing surrounded with filter material, should not be allowed.

5.1.2 Vacuum Well Points

Well points typically consist of small-diameter wells that are connected to a common vacuum header and operated using a single vacuum pump for the whole system. Well points can be effective in fine- and coarse-grained soils. They are generally up to 23 feet deep and are constrained by the limits of the vacuum pump to pull water out of the ground (a limitation of about 18 to 20 feet at sea level). This depth is measured relative to the vacuum header location for the system. For areas on the Project where dewatering could be required to about 25 feet bgs, constructing the dewatering system and placing the header within a trench can increase the effective depth of the dewatering system. The well points typically have a 3-foot-long section of slotted well screen at the bottom and are spaced 3 to 10 feet apart, with the closer spacing for finer-grained soils. Frequent maintenance of the well points and control of the vacuum system is required to maintain the effectiveness of this system. The treatment requirements for disposal of groundwater generated from vacuum well points are typical lower than for groundwater generated from sumps.

5.2 Excavation

Excavations for the proposed pipeline are anticipated to encounter fill (Hf) and alluvium (Ha). The following descriptions are generalized. Refer to the boring logs in Appendix A for a more complete understanding of the variations in soil constituents, relative densities, and relative consistencies.

The geologic units anticipated to be excavated include very loose to medium dense fill (Hf) and alluvium (Ha) deposits. Based on these subsurface soil conditions, we anticipate that the pipeline excavations can be accomplished using conventional excavating equipment such as rubber-tired backhoes or tracked hydraulic excavators. Temporary excavation slopes may be possible where there are sufficient working limits and the excavations are either above the groundwater table or the groundwater is adequately controlled. Consistent with conventional practice, temporary excavation slopes should be made the responsibility of the Contractor since the Contractor is able to observe full time the nature and conditions of the subsurface materials encountered, including groundwater, and has the responsibility for methods, sequence, and schedule of construction. All temporary excavation slopes should be accomplished in accordance with local, state, and federal safety regulations. For planning purposes, we recommend assuming temporary excavation slopes in the fill (Hf) and alluvium (Ha) be no steeper than 2 Horizontal to 1 Vertical (2H:1V).

The excavations for the pipeline will encounter fill (Hf) and alluvium (Ha) deposits in the pipeline subgrade. These soils are considered to be moisture-sensitive and easily disturbed. Therefore, the last 2 feet of the excavation should be made using an excavating bucket equipped with a cleanup or ditch-cleaning bucket (i.e., a bucket without digging teeth) to reduce construction disturbance of the subgrade soil and thus reduce post-construction settlements.

5.3 Trenching and Shoring

The proposed pipeline will require excavation depths ranging from about 10 to 25 feet bgs. Temporary shoring will be required to support the soils and provide protection for the workers. The type and location of the shoring will depend upon many factors, including site constraints, excavation depths, soil and groundwater conditions, and the presence of existing structures and utilities near the pipeline alignment. It is our understanding that the design and method of construction of the shoring will be the responsibility of the Contractor. The shoring system should provide adequate protection for workers and should prevent damage to adjacent structures, utilities, streets, and other facilities.

5.3.1 Trenching

In our opinion, excavation for the pipeline can be accomplished using trenching and conventional excavation equipment. We anticipate that trench boxes would be used along most of the alignment where the bottom of the proposed trench is not more than 1 to 2 feet below the groundwater table and existing utilities can be protected from settlement and lateral movement. Trench boxes are typically used in areas where settlement behind the shoring is not a concern and sumps and pumps can be used to control the groundwater without resulting in groundwater-drawdown-induced settlement. Because trench boxes provided passive protection for workers in the trench, movement of the ground adjacent to the trench is likely.

Where the bottom of the trench will be more than 2 feet below groundwater, unless the trench is excavated and constructed in the wet, groundwater must be lowered to at least 2 feet below the pipe invert. Adjacent pile-support structures, if present, could experience downdrag loading and settlement associated with dewatering-induced settlement of the fill (Hf) and alluvium (Ha) deposits. Adjacent utilities, structures, and improvements founded above these deposits could also experience settlement.

Settlements due to dewatering can be reduced by limiting the amount of groundwater drawdown outside the excavation. This can be accomplished by using watertight shoring with dewatering from inside the excavation, using conventional non-watertight shoring with recharge wells adjacent to the excavation, and/or limiting the allowable methods of dewatering. Recharge wells are only partially effective in the fine-grained portions of the alluvium (Ha). Consequently, we recommend that watertight shoring be used to reduce dewatering discharge volumes and potential settlements outside the excavation.

5.3.2 Shoring

Shoring will be required where sloped excavation sides and trench boxes are not suitable. In areas where the trench will extend beneath existing utilities, it may be difficult to install watertight shoring. In our experience, the Contractor may use a combination of steel sheets, soldier piles with steel or wood lagging, and other combinations of shoring for trench support. Sheet pile shoring installation could be difficult if subsurface obstructions are present. If sheet pile shoring is used, pre-excavation along the sheet pile alignment may be required to check for and remove obstructions. Alternatively, predrilling could be performed along the sheet pile alignment. However, predrilling may not be effective where timber obstructions are present.

We recommend the Contractor be responsible for the design of temporary shoring for the trench. The design of the shoring should be performed in conjunction with the Contractor's temporary construction dewatering design. Temporary shoring should be designed for lateral earth, unbalanced water, and surcharge pressures. The total design pressure acting on the temporary shoring is the sum of these pressures. Typically, contractors use active earth pressures for shoring design. If active earth pressure conditions are assumed, lateral movement at the top of the shoring could range from about 0.1 to 0.15% of the shored height. If waterline thrust blocks are present, the associated thrust loads must be considered in the design of the shoring. Because horizontal movement at the thrust block locations must be limited, we recommend that the shoring be designed for at-rest earth pressure conditions in these areas. At-rest earth pressures may also be applicable adjacent to settlement sensitive structures.

5.4 Trenchless Construction

Trenchless construction is being considered to install the casing beneath the BNSF ROW and also River Road. Based on the borings, we anticipate that the trenchless casing would be installed in alluvial (Ha) deposits. Cobbles and boulders may be present within the alluvium (Ha). Wood and soft, organic soils such as peat may also be present in these soils.

The proposed trenchless crossings are estimated to be below the groundwater level. Localized perched layers and lenses of water-bearing soils should also be anticipated.

While it is our opinion that the methods discussed in the report are generally applicable for the anticipated subsurface conditions, there are inherent risks associated with these construction methods. Risks are primarily derived from the site groundwater conditions. Therefore, installation is recommended to be performed during the summer months when groundwater levels are anticipated to be at their lowest and construction of the jacking and receiving shafts and trenchless crossings could be performed with reduced risk. We recommend that the Contractor be contractually responsible for selecting the means and methods used to install the casing pipe, with means and methods based on the City's risk tolerance and the Contractor's interpretation of the subsurface conditions.

The following sections provide railroad crossing considerations, general descriptions of likely trenchless construction methods, jacking and receiving shaft recommendations, recommendations relative to jacking loads, and potential for ground settlement and heave.

5.4.1 Railroad Crossing Considerations

This section includes a description of our understanding of some of the typical railroad crossing considerations as they relate to geotechnical and geometric issues. The casing pipe should have a minimum of 3 feet cover at the flow line of a ditch or ground surface and be 5.5 feet from the base of rail, whichever is deeper. The natural ground surface at the toe of fill slopes is to be considered the ditch grade.

The casing pipe will need to consider the Cooper E80 Railroad live loading with diesel impact. Although the Contractor should be responsible for selecting the casing size and wall thickness, their selection must also consider American Railway Engineering and Maintenance-of-Way Association (AREMA) requirements. Assuming non-coated and no cathodic protection, the AREMA minimum casing wall thickness is 0.781-inch-thick for 54-inch-diameter steel casing.

Leakproof joints, typically welded, are required. The ends of the casing pipes should be sealed around the carrier pipe to mitigate the loss of ground into the annular gap between the two pipes.

Casing spacers, if used, must permit the removal of the carrier pipe without disturbing the casing pipe. Deflections of the casing pipe must not result in the transmission of roadbed, track, or railroad traffic loading onto the carrier pipe.

Monitoring of track movements during trenchless construction is required. Movements of more than ¼ inch vertically must be immediately reported to the BNSF Roadmaster. The maximum allowable overcut, based on the outside diameter of the casing, is 2 inches. The trenchless methods described in this report can typically accommodate this requirement.

5.4.2 Trenchless Methods

We evaluated two trenchless methods, guided boring and microtunneling, that could potentially be used to construct the trenchless crossings. We did not evaluate other methods, such as auger boring or pipe ramming, due to the likely presence of groundwater at the site and the need to maintain the required grade of the gravity pipeline. On two recent projects in the Puget Sound area where groundwater was present and auger boring was used, sinkholes and settlement above the casing alignment resulted from the inability of the method to control flowing ground. While dewatering could have potentially mitigated the risk of flowing ground, construction claims associated with construction dewatering are relatively common. To reduce risk to the Project, we recommend requiring a trenchless method that does not rely on dewatering.

While in our opinion the contract specifications should allow the Contractor to select the trenchless method, we recommend assuming that guided boring would likely be the preferred method if dewatering is not permitted.

5.4.2.1 Guided (Pilot Tube) Boring

The guided boring process, also sometimes referred to as pilot tube, uses a small-diameter steerable pilot tube that displaces the ground to steer and establish the line and grade from the jacking to the receiving shafts. After the steerable assembly reaches the receiving shaft, the initial bore is enlarged by jacking sections of larger-diameter auger tube from the jacking to the receiving shaft along the completed bore path. As each section of auger tube is jacked into the borehole, a section of the pilot tube or smaller-diameter auger tube is removed from the receiving shaft. This process is repeated until all sections of the pilot tube are removed. The auger tube acts as a casing to support the borehole from collapse. A pipe adapter is attached to the last section of auger tube, and the pipe is thrust into place as sections of the auger tube are removed from the receiving shaft. Guided borings in soil are generally limited to about 200 feet, but longer drives of up to about 600 feet have been constructed in favorable conditions. The guided bore method can generally accommodate about 10 feet of groundwater head above the casing.

As discussed above, the subsurface ground conditions along the proposed alignment consist primarily of sandy and silt alluvial (Ha) soils, and less than 10 feet of groundwater head is anticipated above the casing. These conditions are generally considered to be suitable for casing installation using guided bore. Line and grade tolerance for a guided boring installation may be within 0.1% vertically and 1% horizontally of the length of the installation (ASCE, 2017).

5.4.2.2 Microtunneling

Microtunneling uses a remote-controlled microtunnel boring machine (MTBM) operated from a control panel located at the ground surface. The MTBM system is equipped with a guidance system to maintain required line and grade as it is advanced from the jacking shaft. Continuous pressure is applied at the face of the MTBM to balance groundwater and earth pressures. The jacking and receiving shafts for microtunneling are generally larger than for guided boring. In addition, the slurry separation plant and related microtunneling equipment requires a larger staging area than for a guided boring system.

Microtunneling typically requires a larger staging area at the jacking shaft compared to other methods. Microtunneling is typically less cost-effective than other trenchless construction methods for relatively short run lengths such as those planned for this Project.

5.4.3 Jacking and Receiving Shafts

Trenchless methods discussed in this report will require dry, relatively flat jacking and receiving areas at the ends of the trenchless alignments. Jacking shafts will be sized by the Contractor to allow sufficient room for their selected means and methods. For guided boring and microtunneling methods, the design of the jacking shafts needs to consider the anticipated jacking loads and be designed to limit jacking-induced deflections, which could cause problems with maintaining line and grade. The shoring design also needs to meet Occupational Safety and Health Administration standards. In general, jacking shafts for guided boring will tend to be smaller than for microtunneling. For planning purposes, jacking shafts for microtunneling could be 20 feet wide and 40 feet long; jacking shafts for guided boring could be potentially as short as about 15 feet. In addition, microtunneling would require significantly more ground surface staging area at the jacking shaft compared to guided boring.

Receiving shafts are usually smaller and are sized for the removal of a cutting shoe, guide bore tooling, or shield. Typical minimum receiving shafts are 10 to 15 feet wide and about 10 to 15 feet long.

5.4.4 Shoring for Trenchless Construction

The method of shoring for the jacking and receiving shafts will depend on many factors, including, but not limited to, depth, soil types, groundwater, vicinity to existing utilities and structures, and the selected method of trenchless construction. We anticipate that the shoring method used for the trenchless shafts at the BNSF ROW and River Road crossings will be like those described above for the trench. Specifically, we anticipate that the shafts will consist of watertight shoring with internal dewatering or trench boxes or slide-rail shoring systems with dewatering and recharge wells.

If microtunneling is used, dewatering outside of the shafts has the potential to negatively impact the ability to maintain positive face pressure.

5.4.5 Jacking Loads

The jacking loads required to advance a guided bore casing or a microtunneling MTBM are a function of the friction between the soil and pipe. Injecting bentonite slurry or synthetic polymers will decrease the frictional resistance. With bentonite injection that completely encapsulates the perimeter of the pipe, the frictional resistance can be reduced from about 300 to 800 pounds per square foot (psf) to between about 25 and 300 psf. The Contractor should determine the anticipated jacking loads and provide ample jacking capacity to provide for a margin of safety.

The jacking system design is outside the scope of this study and should be the responsibility of the Contractor. For preliminary design purposes only, the available thrust reaction can be calculated using an allowable passive pressure, as shown in Figure 4. For allowable passive pressure, we recommend using an equivalent fluid density of 265 pcf if the ground outside of the jacking shaft is not dewatered and an equivalent fluid density of 400 pcf if the ground outside the jacking shaft is dewatered. These passive pressures include a factor of safety of 1.5. For the dewatered condition, the allowable passive pressure value assumes that groundwater is lowered and maintained below the depth of the shoring providing resistance.

If the shoring consists of soldier piles, the passive pressures should be distributed over three times the pile diameter or the pile spacing, whichever is less. If sheet piles are used for shoring, the passive pressure should be distributed over the entire width of the wall. If a single steel sheet is used, the passive pressure should be distributed over the width of the steel sheet.

5.4.6 Settlement and Heave

Settlement and heave on trenchless projects are largely a function of the Contractor's means and methods, as well as workmanship. Some settlement can result from the inevitable response of the soil due to excavation and overexcavation required to install the casing. Excessive settlement largely results from overexcavation or insufficient support of soil at the heading. Heave generally occurs when the casing installation rate or cased excavation volume exceeds the spoils excavation rate or spoils excavation volume. For planning purposes, we estimate that the settlement associated with trenchless construction under the

BNSF tracks and River Road would be about ⅛ inch assuming 1% volume loss occurs during trenchless construction. While for planning purposes we recommend assuming 1% volume loss, because settlement is linearly related to volume loss, a 2% volume loss would result in about ¼ inch of settlement and a 0.5% volume loss about 1/16 inch of settlement.

5.5 Seismic Parameters

We developed seismic parameters for the Project as requested by the design team. We understand that the Project does not require seismic design of the storm drain pipeline. As such, we did not perform analyses or evaluate the potential for liquefaction.

We assessed the soil profile along the Project alignment by assigning a site class definition. It is our opinion that based on the Project explorations, the site can be classified as Site Class E.

Since there is no specified seismic design code for the sewer pipelines, we elected to use seismic parameters that are representative of a 2,475-year return period ground motion. This is consistent with how seismic parameters are selected in the International Building Code 2018 and American Association of State Highway and Transportation Officials (AASHTO) 2020. Seismic inputs are the peak ground acceleration (PGA), short-period maximum spectral acceleration, S_s, and spectral acceleration at a period of one second, S_1. Using the map provided by U.S. Geological Survey (USGS)/AASHTO Seismic Hazard Maps produced by the USGS, which corresponds to Site Class B sites, the mapped values of PGA, S_s and S_1, are approximately 0.580 g, 1.353 g, and 0.366 g, respectively. The site coefficients for the given spectral acceleration values and Site Class E are approximately 1.12, 0.90, and 2.54 for F_{pga}, F_a, and F_v, respectively.

5.6 Foundation Support

The pipe and MHs will be founded in a variety of soils. Except for the very soft to soft and very loose alluvium (Ha) deposits, most of the soils along the alignment are considered to be suitable foundation soils for the pipe and MHs.

In areas where very soft to soft and very loose alluvium (Ha) deposits are encountered in the subgrade, these soils should be overexcavated and replaced. Where the depth of overexcavation is less than 2 feet, the overexcavated subgrade soils should be replaced with compacted bedding materials meeting the requirements of Section 9-03.12(3) of the WSDOT Standard Specifications for Gravel Backfill for Pipe Zone Bedding. Where the depth of overexcavation is 2 feet or more, the overexcavated subgrade soils should be replaced with geosynthetic-wrapped backfill. Geosynthetic-wrapped backfill should consist of a geosynthetic filter fabric (Mirafi 500X or equivalent) placed across the bottom of the overexcavated area and up the sidewalls of the shoring. The filter fabric should then be backfilled up to the design trench base elevation using ballast material meeting the gradational requirements specified in 9-03.9(2), Permeable Ballast of the WSDOT Standard Specifications (WSDOT, 2021). After the filter fabric is wrapped and overlapped over the backfill, the trench would be ready for bedding and pipe or manhole placement.

Assuming unsuitable foundation soils are overexcavated and replaced, settlement due to construction disturbance of subgrade soils and placement of the pipes, MHs, and backfill is expected to be about ½ inch or less. For the 60% design, we recommend assuming an allowable bearing capacity of 1,500 psf for the MHs.

5.7 Loads on Maintenance Holes (MHs) and Buried Pipes

We understand that concrete MHs and appurtenant structures will be installed along the pipe alignment. An unyielding, precast manhole or structure above the groundwater level should be designed to resist an at-rest lateral earth pressure using an equivalent fluid density of 55 pounds per cubic foot (pcf). Unyielding precast MHs or structures below the groundwater level should be designed to resist an at-rest lateral earth pressure using an equivalent fluid density of 90 pcf. In our experience, unyielding, precast MHs that extend both above and below the groundwater level are typically designed using an equivalent fluid density of 90 pcf. The recommended at-rest lateral earth pressures assume that a well-compacted structural fill, meeting the gradational requirements specified in Section 9-03.14(1) of the WSDOT Standard Specifications for Gravel Borrow, will be placed around the MHs.

General recommendations regarding backfill and surcharge loading on buried pipes are presented in Figure 5. We anticipate that trenching would be used to install the proposed pipe; therefore, Case (b) for a conduit in a trench would likely apply. We recommend that the effect of backfill loads, as shown in Figure 6 from Case (b) and the H-20 live load shown in Case (c), be added (where appropriate) to obtain the total load on the pipe under vehicular traffic. We recommend using a unit weight for trench backfill of 125 pcf.

5.8 Uplift Resistance

Watertight, permanent buried pipe, MHs, and appurtenant structures may be subjected to hydrostatic uplift pressures. As discussed in Section 4.4.2, the depth to groundwater is estimated to vary from about 4 to 15 feet bgs along the pipeline alignment. We recommend assuming a groundwater elevation of 40 feet to account for potential changes in the groundwater level.

The recommended values for use in calculating uplift resistance for the pipe, MHs, and appurtenant structures are presented in Figures 7 through 9. Figure 7 is included for buried MHs and appurtenant structures. It is presented in a general form so that it can be used for structures with and without an extended base. Figures 8 and 9 are included for buried pipes with and without extended bases or pipe sleds, respectively.

5.9 Ground Movement and Settlement

Based on the anticipated subsurface conditions, ground movements and settlement could result from three major construction-related sources: dewatering, vibration, and lateral deformation of the temporary shoring systems. The ground settlement estimates presented below should be reviewed relative to the proximity and condition of adjacent structures, improvements, utilities, pavements, and facilities. If the settlements appear to be excessive and could pose a risk of unacceptable damage, the Contractor would generally be required to alter their construction means and methods to limit ground movements. In all cases, a monitoring program should be established to evaluate performance during construction.

We estimated that dewatering-induced settlement could range from ⅛ inch to 1.5 inches or more, based on the anticipated 5 to 15 feet of required dewatering, respectively. To limit groundwater-drawdown-induced settlements to less than ½ inch, the construction dewatering design and shoring design should be coordinated so that drawdown does not exceed 2 feet at nearby structures, utilities, and pavements. There are several methods to reduce settlements induced by dewatering. These include excavation and installation in the wet (i.e., without dewatering), using watertight shoring with dewatering from inside the excavation and potentially recharge wells outside the excavation, using conventional non-watertight shoring with recharge wells outside of the excavation and using ground freezing to stabilize the ground and eliminate dewatering.

Shoring elements installed using vibratory or impact hammers, such as sheet piles, could cause vibration-induced consolidation of the soils beneath nearby pavements, utilities, and structures. Settlement due to vibration-induced densification of the underlying soils could extend approximately as far as the piling is long. We recommend that vibratory or impact methods are not used to install shoring elements. If sheet piles are installed, we recommend using the press-in method to install the sheet piles.

In addition to vibration-induced consolidation, lateral deformations of the temporary shoring system during excavation will likely result in settlement behind the support systems. The magnitude of lateral deformation and the resulting settlement is a function of the soil and groundwater conditions, the stiffness of the temporary shoring system, and the means and methods selected by the Contractor. Based on work performed by Clough and

O'Rourke (1990), the maximum anticipated settlement resulting from ground movements could range between about 0.15 and 0.5% of the height of the excavation, depending on the type of support. The typical model for the settlement trough behind temporary shoring supporting granular materials is linear from the point of maximum settlement located immediately behind the shoring to less than ⅛ inch of settlement at a horizontal distance equal to one to 1.5 times the height of the excavation. Based on an average of 0.3% of the excavation depth and an excavation depth of 25 feet, settlements caused by shoring deformations are estimated to about ⅛ inch immediately behind the shoring.

5.10 Backfill Placement and Compaction

Although portions of the excavated material along the alignment may be suitable for reuse as backfill, we recommend that imported fill be used to backfill the excavations. This is primarily due to the relatively high fines content of some of the soils; potential for peat deposits in the alluvium (Hf) deposit; and difficulty in segregating, transporting, and storing the excavated soils.

5.10.1 Pipe Bedding

We recommend that the pipe bedding consist of imported granular bedding material meeting the gradational requirements specified in Section 9-03.12(3) of the WSDOT Standard Specifications (WSDOT and American Public Works Association, 2021) or 5/8-inch minus crushed material. The bedding should extend a minimum of 4 inches below the bottom of the pipe and up to the pipe springline.

5.10.2 Subsequent Backfill

In areas where future surface improvements are planned, we recommend that the trench backfill, above the pipe backfill materials, meets the gradational requirements specified in Section 9-03.14(1) of the WSDOT Standard Specifications for Gravel Borrow. The backfill should be placed in uniform lifts and compacted to 95% of its Modified Proctor maximum dry density (ASTM Designation D1557, Method C or D) (ASTM, 2012).

5.10.3 Structural Fill

In our opinion, backfill materials for permanent structures should meet the gradational requirements specified in Section 9-03.14(1) of the WSDOT Standard Specifications for Gravel Borrow.

5.10.4 Compaction

The pipe bedding and subsequent backfill should be placed in a maximum loose backfill lift thickness of 6 inches. The pipe bedding backfill should be carefully worked under the pipe by means of slicing with a shovel, vibration, tamping, or other approved method. Heavy mechanical compaction equipment should not be allowed within 2 feet of the pipe. The pipe bedding and subsequent backfill should be placed in uniform lifts and compacted to a dense and unyielding condition and to 95% of its Modified Proctor maximum dry density (ASTM International Designation D1557, Method C or D).

Imported structural fill should be at a moisture content near optimum (±2%) to allow proper compaction. We recommend that the material be compacted to a dense, unyielding condition. To avoid overstressing, heavy compaction equipment should not be used in the immediate vicinity of structural walls. For compaction within 3 feet of walls, smaller, vibrating-plate compactors should be used. We recommend a maximum loose backfill lift thickness of 9 inches for heavy compaction equipment or 6 inches for hand-operated equipment. If a backhoe-mounted plate compactor is used, the maximum loose lift thickness could be increased to 18 inches. Whatever equipment and lift thicknesses are used, all soil within the lift should be compacted to the applicable WSDOT Standard Specifications. We recommend that the above limitations on compaction equipment use be incorporated into the Project specifications. All compacted surfaces should be sloped to drain to prevent ponding

5.11 Wet Weather Considerations

In the Project area, wet weather work generally begins about mid-October and continues through May, although rainy periods may occur at any time of year. It would be advisable to schedule the earthwork during the drier weather months; however, the following recommendations would apply if wet weather earthwork was unavoidable.

- The ground surface in the construction area should be sloped to promote rapid runoff of precipitation away from open excavation and to prevent ponding of water.
- Covering work areas or slopes with plastic, sloping, ditching, using sumps, dewatering, and other measures should be employed as necessary to permit proper completion of the work.
- Earthwork should be accomplished in small sections to minimize exposure to wet weather. That is, each section should be small enough so that the removal of unsuitable soils and placement and compaction of clean structural fill can be accomplished on the same day.
- The size and type of construction equipment and its mode of mobility (wheels or track) should be selected to prevent soil disturbance. It may be necessary to excavate soils

with a backhoe, Gradall, or equivalent, located so that the equipment does not traffic over the excavated area; thus, subgrade disturbance caused by equipment traffic will be reduced.

- Fill material to be placed should consist of clean, granular soil of which no more than 5% by dry weight passes the No. 200 sieve based on wet sieving the fraction passing the ¾-inch sieve. The fines should be nonplastic.
- No soil should be left uncompacted and exposed to water. A smooth-drum vibratory roller, or equivalent, should roll the fill surface to seal out as much water as possible and promote rapid runoff of surface water.
- Soils that become too wet for compaction should be removed and replaced with clean, imported structural fill.
- Excavation and placement of structural fill should be observed on a full-time basis by a geotechnical engineer or engineer's representative experienced in earthwork to determine that all work is being accomplished in accordance with the intent of the specifications.
- Grading and earthwork should not be accomplished during periods of heavy, continuous rainfall.

The above recommendations for wet weather earthwork should be incorporated into the contract specifications.

6 GEOTECHNICAL INSTRUMENTATION

Geotechnical instrumentation should be installed to monitor the response of the ground and adjacent structures, utilities, and pavement to the construction of the pipeline, MHs, and appurtenant structures. Data collected from the monitoring program would be used to assess:

- The validity of any claims.
- Effectiveness of remedial measures.
- Performance of the shoring.
- Performance of the dewatering system.

The construction of the Project will require relatively deep-shored trenches and manhole excavations, dewatering, trenchless construction, and a railroad ROW crossing. Each of these construction activities could result in excessive deformations or ground losses that may lead to vertical settlements adjacent to excavations, which may affect adjacent structures, utilities, and pavements. In addition, we anticipate that BNSF ROW crossing will require geotechnical instrumentation to monitor movement of the railroad track because of trenchless construction. Each of these and other related elements should be monitored prior to construction and during construction, as required. For 60% design, we recommend assuming the following geotechnical instrumentation systems:

- For the Project alignment, we recommend structure settlement points on any structures within 100 feet of the trench excavation where dewatering is required.
- Utility settlement points should be established on settlement-sensitive utilities such as water lines without restrained joints that cross above and/or parallel the pipe excavations within 50 feet. We recommend that utility settlement points be installed and monitored on settlement-sensitive utilities within 100 feet of the trench excavation.
- Pre- and post-construction closed-circuit television inspection of gravity sewer and storm drains that cross above and or parallel the pipe excavations within 50 feet.
- Piezometers for monitoring groundwater levels where dewatering-induced settlement could occur. We anticipate that piezometers would be located at property lines adjacent to dewatering activity to monitor drawdown.
- Vibration monitors for measuring vibration levels at adjacent structures and utilities within 100 feet of where impact or vibratory methods are used.
- Optical or digital survey of targets attached to the rail and railroad ties. The targets could consist of bonded survey targets or PK nails installed in railroad ties. The targets should be installed and monitored prior to the start of construction to develop baseline elevations. We recommend survey targets on each rail and tie along casing centerline and at 5-foot spacing to either side of the centerline for a total distance of 20 feet to either side of centerline.
- During construction, the settlement and vibration points for trenchless crossings should be monitored daily during trenchless construction. The monitoring results should be provided to the City within 24 hours of being obtained.

The proposed instrument locations and details should be developed and included in the Contractor drawings, and the installation and monitoring requirements should be included in the specifications.

7 CLOSURE

The recommendations and conclusions in this draft geotechnical report are based on:

- The limitations of our approved scope, schedule, and budget described in our subcontractor task order agreement with Brown and Caldwell dated October 12, 2020.
- Our understanding of the Project and information provided by Brown and Caldwell.
- Subsurface conditions we observed in the borings as they existed during drilling.

- The results of testing performed in the explorations and on samples we collected from the explorations.
- Information reported in previous subsurface explorations at the site.
- Assumed construction methods for the pipeline.

We have prepared an appendix, "Important Information About Your Geotechnical Report," to assist you and others in understanding the use and limitations of this report. Please read this document to learn how you can lower your risks for this Project.

8 REFERENCES

American Society of Civil Engineers, 2017, Pilot tube and other guided boring methods: Reston, Va., American Society of Civil Engineers Manuals and Reports on Engineering Practice no. 133, 173 p.

Buchanan-Banks, J. M. and Collins, D. S., 1994, Map showing depth to bedrock of the Tacoma and part of the Centralia 30' x 60 quadrangles, Washington: U.S. Geological Survey Miscellaneous Field Studies Map MF-2265, scale 1:100,000.

Clough, G.W., and O'Rourke, T.D., 1990, Construction induced movements of in situ walls, in Labe, P.C., and Hansen, L.A., eds., Design and performance of earth retaining structures, Ithaca, N.Y., 1990, Proceedings: New York, American Society of Civil Engineers, Special Publication No. 25, p.439-470.

HWA Geosciences, 2016, Preliminary geotechnical data report, Sound Transit – Puyallup Station access improvements, Puyallup, Washington [Draft]: Report prepared by HWA Geosciences, Bothell, Wash., project no. 2013-075-21, for Sound Transit, Seattle, Wash. and Parametrix, Inc., Puyallup, Wash., January 8.

Sherrod, B. L.; Brocher, T. M.; Weaver, C. S.; and others, 2004, Holocene fault scarps near Tacoma, Washington, USA: Geology, v. 32, no. 1, p. 9-12.

Thorson, R.M., 1989, Glacio-isostatic response of the Puget Sound area, Washington: Geological Society of America Bulletin, v. 101, no. 9, p. 1163 1174

Washington Geological Survey, 2021, Geologic information portal, subsurface data: Available: https://geologyportal.dnr.wa.gov/#subsurface, accessed January.

Washington State Department of Ecology (Ecology), 1995, Water well report for Well ABY244: Washington State Department of Ecology start card no. W16453, 1 p., October 19.

Washington State Department of Transportation (WSDOT), 2002, Preliminary geotechnical expertise report, SR-167 Puyallup (SR-161) to Port of Tacoma (SR-509): Olympia, Wash., WSDOT Environmental and Engineering Programs Division, OL-3432, March 27.

Washington State Department of Transportation (WSDOT), 2021, Standard specifications for road, bridge, and municipal construction: Olympia, Wash., WSDOT, Manual 41-10, 1 v., available: https://www.wsdot.wa.gov/Publications/Manuals/M41-10.htm.

Approximate Scale in Feet

City of Puyallup
4th Avenue Storm Drainage Project
Puyallup, Washington

VICINITY MAP

January 2021 105692-004

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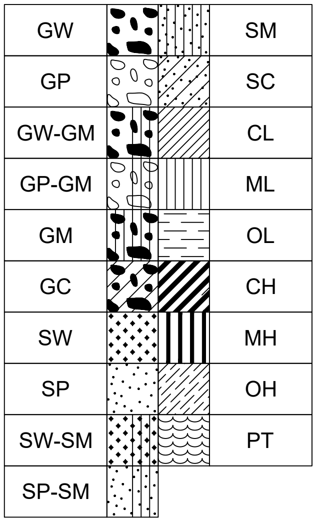
FIG. 1

Filename: E:\J_SEA\105692\001\105692-001 Fig 1 - Vicinity Map.dwg Date: 12-30-2020 Login: SAC

UNIFIED SOIL CLASSIFICATION SYSTEM

(From USACE Tech Memo 3-357)



SAMPLE TYPES

*	Sample Not Recovered
⌶	2" O.D. Split Spoon Sample with 140 lb. Hammer (standard penetration test - SPT)
Ⅱ	3" O.D. Shelby Tube Sample (Thin Wall Sample)
G	Grab Sample

1. Dual Symbols (symbols separated by a hyphen, i.e., SP-SM, slightly silty fine SAND) are used for soils with between 5% and 12% fines or when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.
2. Borderline symbols (symbols separated by a slash, i.e., CL/ML, silty CLAY/clayey SILT; GW/SW, sandy GRAVEL/gravelly SAND) indicate that the soil may fall into one of two possible basic groups, based on ASTM D 2488-93 Visual Manual Classification System. The graphic symbol of only the first group symbol is shown on the profile.

GEOLOGIC UNIT DESCRIPTION

HOLOCENE DEPOSITS

Hf FILL: Fill placed by humans, both engineered and nonengineered.
Various materials, including debris; cobbles and boulders common; commonly dense or stiff if engineered, but very loose to dense or very soft to stiff if nonengineered.

Ha ALLUVIUM: River or creek deposits, normally associated with historic streams, including overbank deposits. Very loose to dense *Sand, Silty Sand, Gravelly Sand, Silt, Silt with Sand and Sandy Silt*, and very soft to medium stiff *Silt, Silt with Sand, Elastic Silt and Lean Clay*.

RELATIVE DENSITY / CONSISTENCY

COARSE-GRAINED SOILS		**FINE-GRAINED/COHESIVE SOILS**	
N, SPT, BLOWS/FT.	RELATIVE DENSITY	N, SPT, BLOWS/FT.	RELATIVE CONSISTENCY
0 - 4	Very loose	<2	Very soft
4 - 10	Loose	2 - 4	Soft
10 - 30	Medium dense	4 - 8	Medium stiff
30 - 50	Dense	8 - 15	Stiff
Over 50	Very dense	15 - 30	Very stiff
		Over 30	Hard

NOTES

1. Plan and profile adapted from 30 percent Stormwater Piping Plan and Profile, Drawings *153448-C-01 through 153448-C-04, Puyallup4thAve StormDrain_FinalTM_dwg*. prepared by Brown & Caldwell, dated 2-3-20.
2. This subsurface profile is generalized from materials observed in soil borings. Variations may exist between profile and actual conditions.
3. Detailed logs of the current project explorations are presented in Appendix A of the report.

City of Puyallup
4th Avenue Storm Drainage Project
Puyallup, Washington

PROFILE LEGEND AND NOTES

January 2021 105692-004

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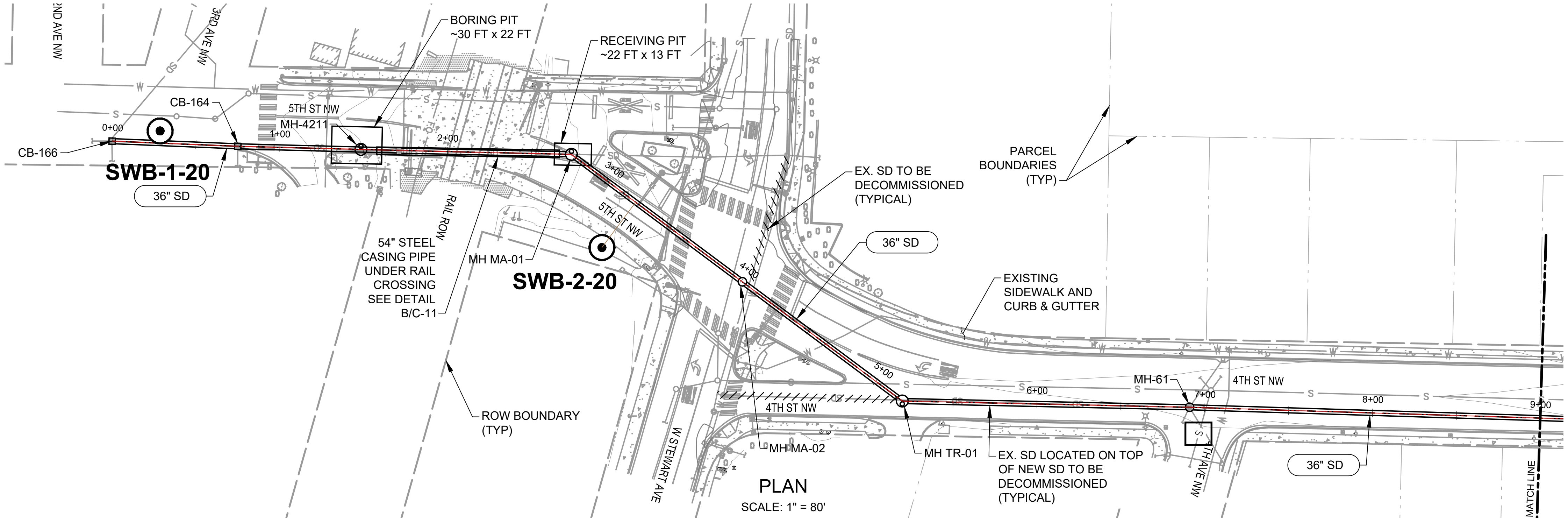
FIG. 2

Filename: E:\J_SEA\105692\001\105692-001 Fig 2 - Profile Legend.dwg Layout: Layout Date: 12-31-2020 Login: SAC



PLAN

SCALE: 1" = 80'

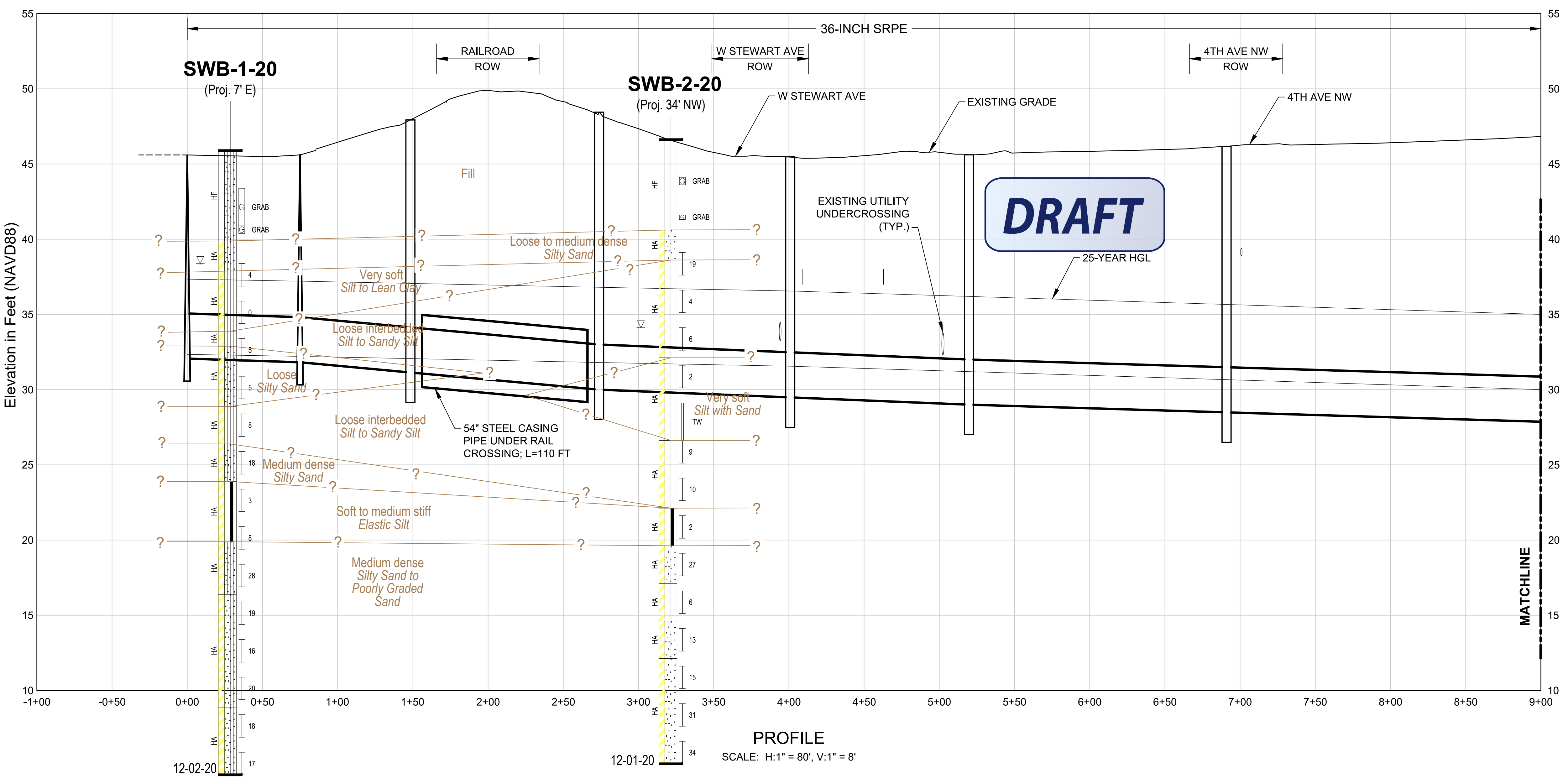
N

0 80 160

Scale in Feet

PLAN LEGEND

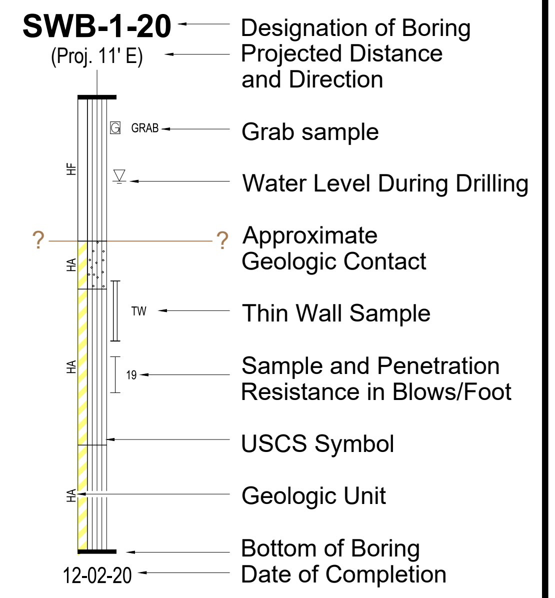
SWB-1-20 ⦿ Boring Designation and Approximate Location



PROFILE

SCALE: H:1" = 80', V:1" = 8'

BORING LOG LEGEND



SWB-1-20	Designation of Boring
(Proj. 11' E)	Projected Distance and Direction
GRAB	Grab sample
▽	Water Level During Drilling
? ---- ?	Approximate Geologic Contact
TW	Thin Wall Sample
19	Sample and Penetration Resistance in Blows/Foot
HF	USCS Symbol
HA	Geologic Unit
	Bottom of Boring
12-02-20	Date of Completion

NOTE

See Figure 2 for additional profile legend and notes.

City of Puyallup
4th Avenue Storm Drainage Project
Puyallup, Washington

PLAN AND PROFILE

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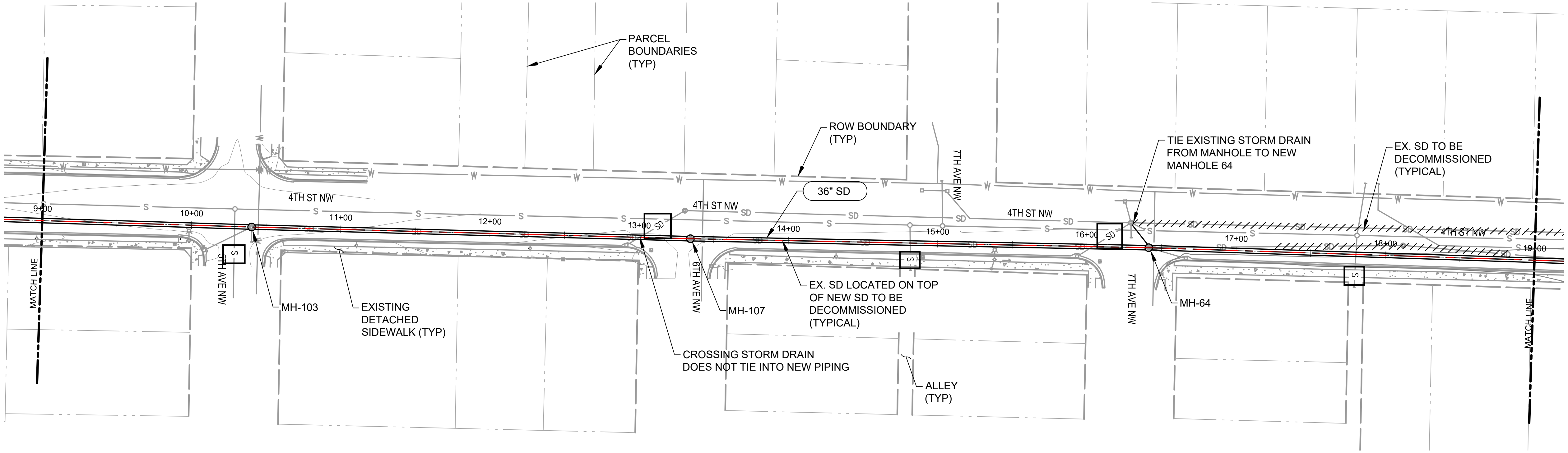
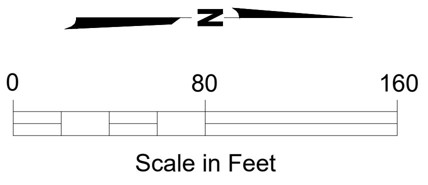
FIG. 3
Sheet 1 of 4

Filename: E:\J_SEA\105692\001\153448-C-01_SW.dwg Layout: SW Sheet 1 of 4 Date: 12-30-2020 Login: SAC



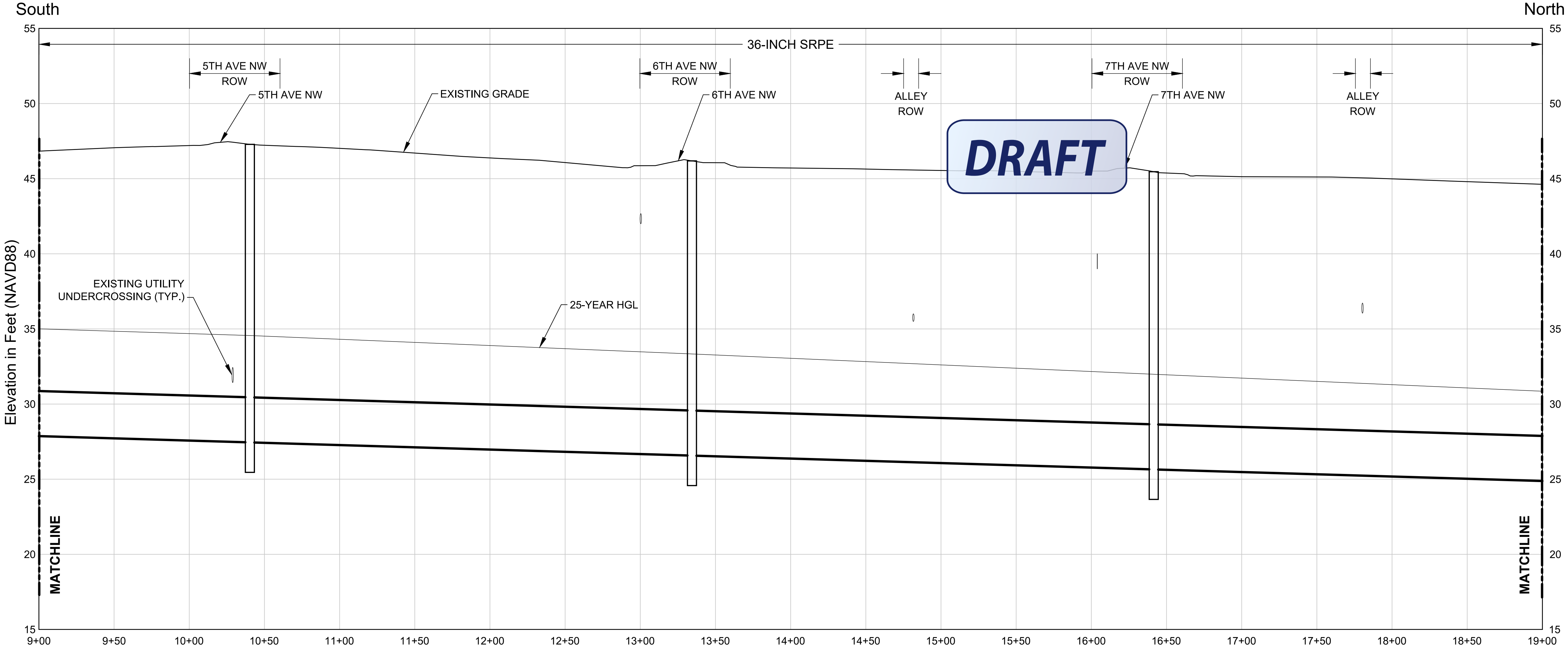
PLAN

SCALE: 1" = 80'



PLAN LEGEND

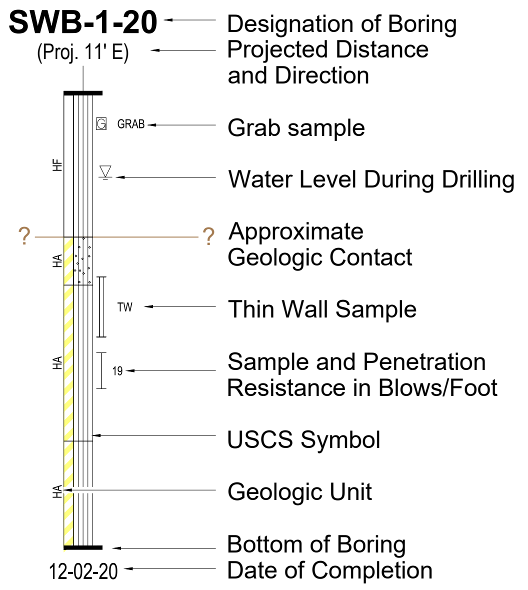
SWB-1-20 ⊙ Boring Designation and Approximate Location



PROFILE

SCALE: H:1" = 80', V:1" = 8'

BORING LOG LEGEND



NOTE

See Figure 2 for additional profile legend and notes.

City of Puyallup
4th Avenue Storm Drainage Project
Puyallup, Washington

PLAN AND PROFILE

January 2021

105692-004

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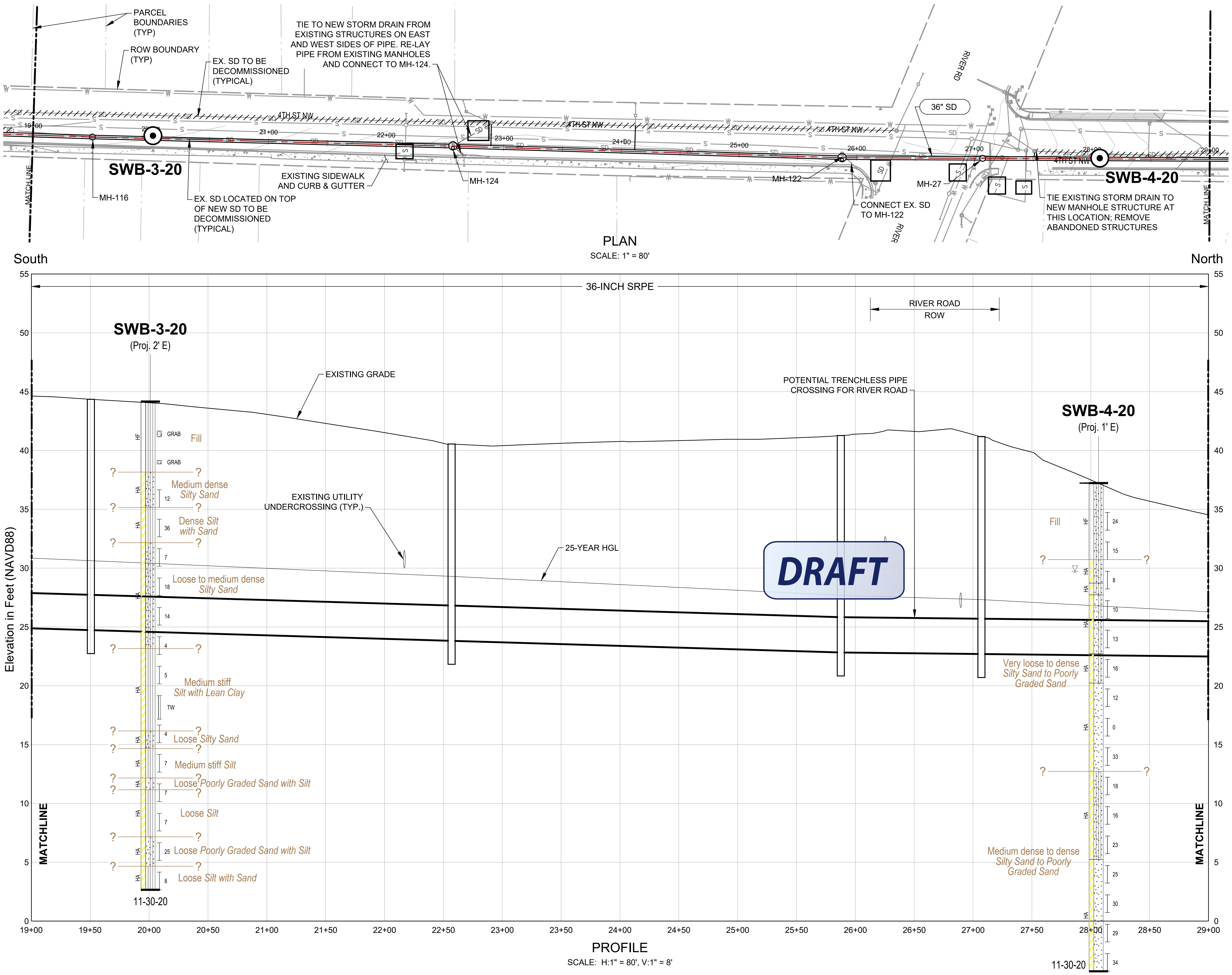
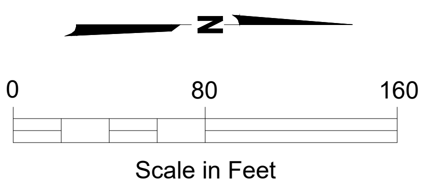
FIG. 3
Sheet 2 of 4

Filename: E:\J_SEA\105692\001\153448-C-02_SW.dwg Layout: SW-Sheet 2 of 4 Date: 12-30-2020 Login: SAC

Filename: E:\J_SEA\105692\001\153448-C-03_SW.dwg   Layout: SW-Sheet 3 of 4   Date: 12-31-2020   Login: SAC



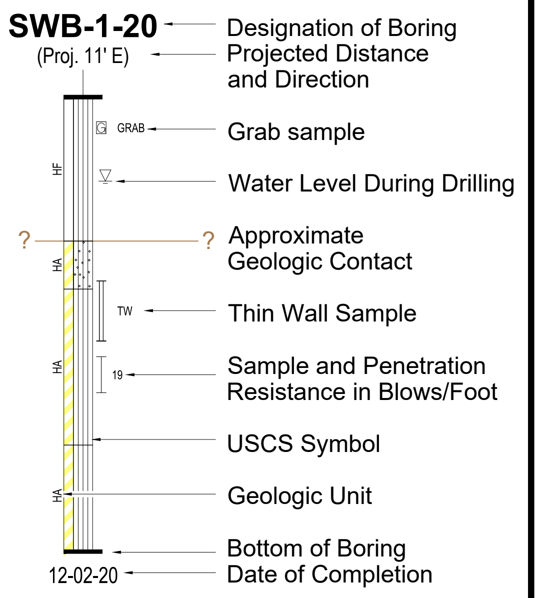


Scale in Feet

PLAN LEGEND

SWB-1-20 ⊙ Boring Designation and Approximate Location

BORING LOG LEGEND



NOTE

See Figure 2 for additional profile legend and notes.

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Puyallup, Washington

PLAN AND PROFILE

January 2021   105692-004

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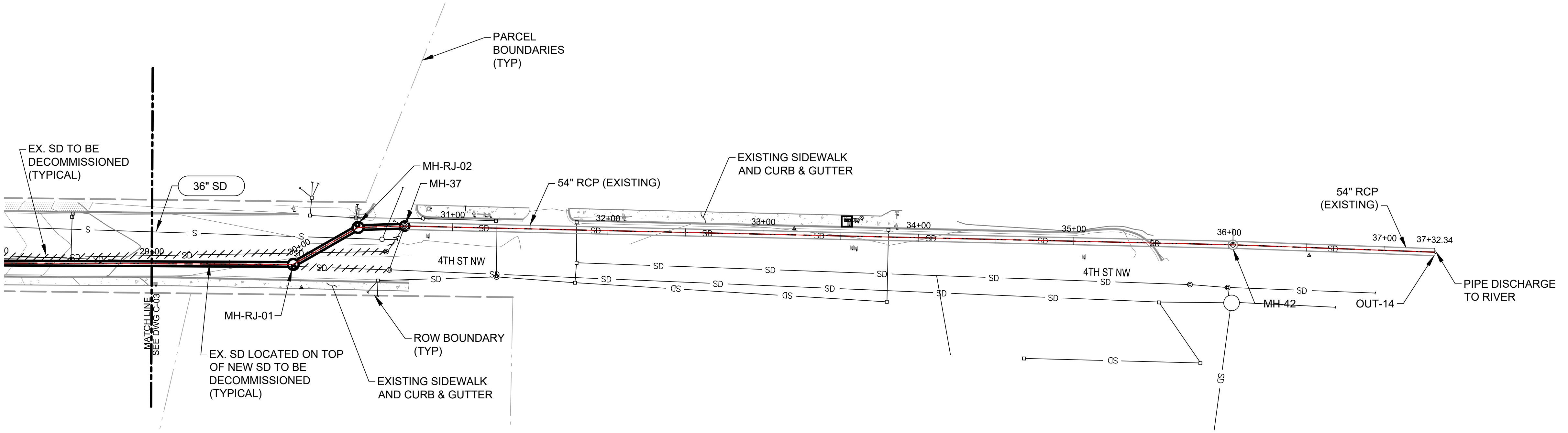
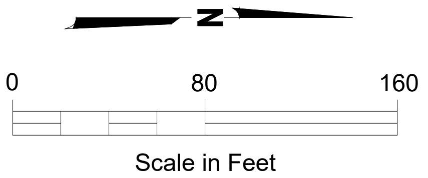
FIG. 3
Sheet 3 of 4



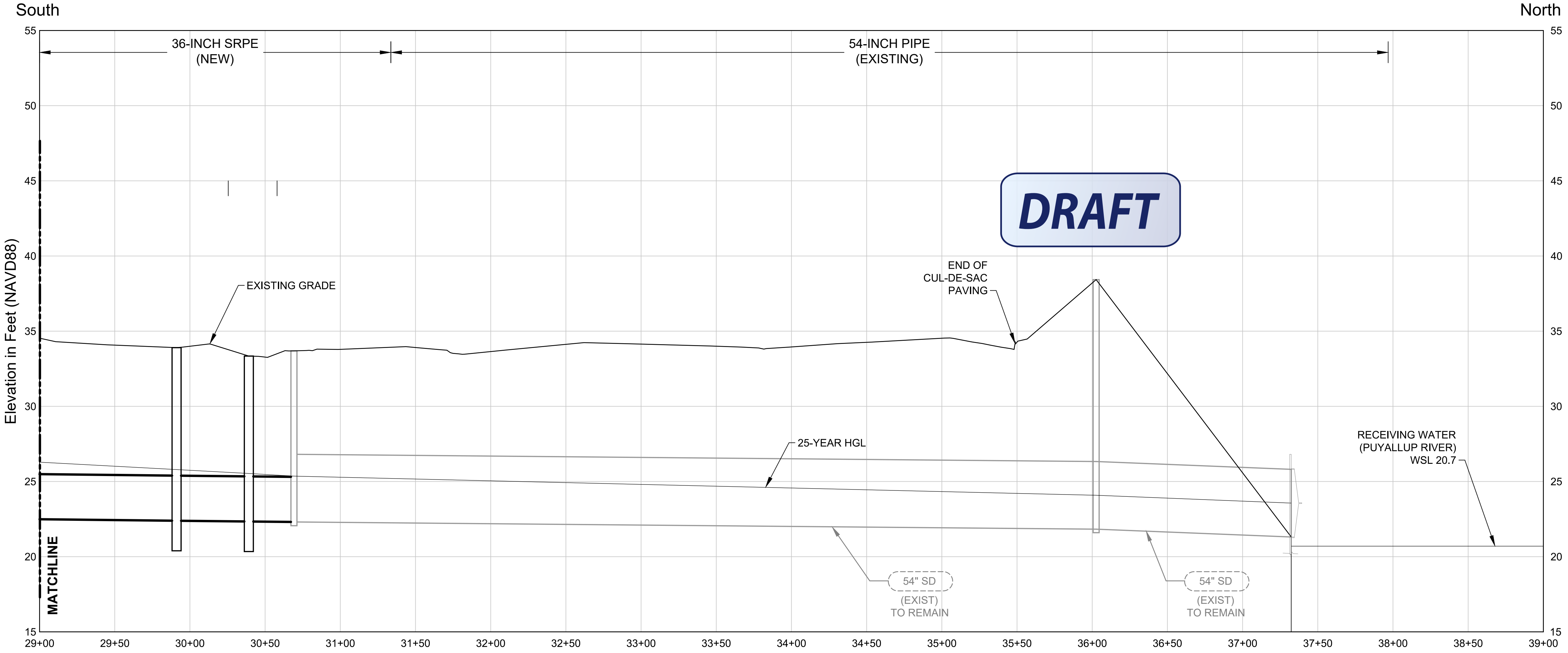
PLAN

SCALE: 1" = 80'



PLAN LEGEND

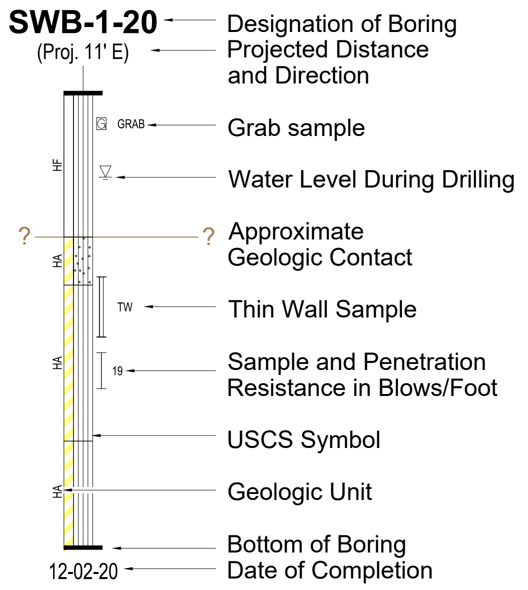
SWB-1-20 ⦿ Boring Designation and Approximate Location



PROFILE

SCALE: H:1" = 80', V:1" = 8'

BORING LOG LEGEND



SWB-1-20	Designation of Boring
(Proj. 11' E)	Projected Distance and Direction
GRAB	Grab sample
▽	Water Level During Drilling
? ?	Approximate Geologic Contact
TW	Thin Wall Sample
19	Sample and Penetration Resistance in Blows/Foot
	USCS Symbol
	Geologic Unit
	Bottom of Boring
12-02-20	Date of Completion

NOTE

See Figure 2 for additional profile legend and notes.

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Puyallup, Washington

PLAN AND PROFILE

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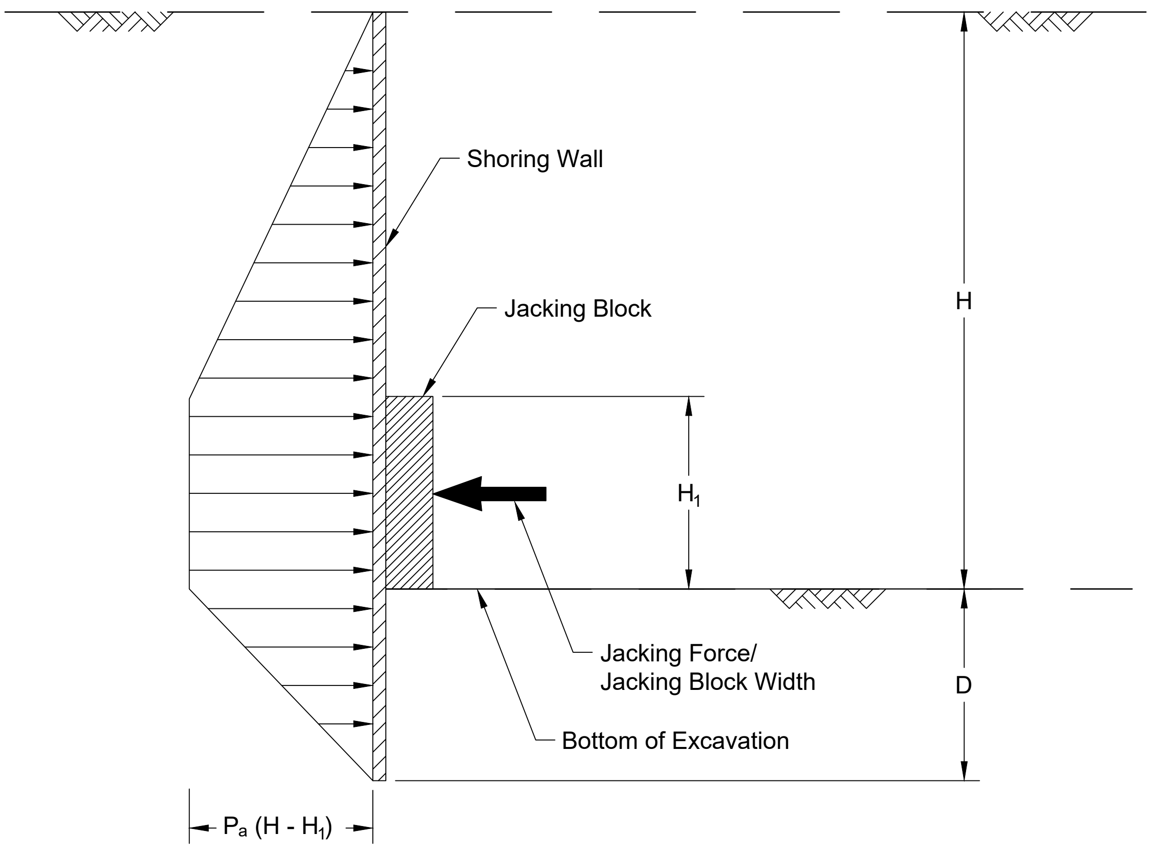
FIG. 3
Sheet 4 of 4



NOTES

1. Refer to Geotechnical Report for recommended values for the passive pressure, P_a.
2. Pressures are in pounds per square foot (psf).
3. Passive pressures include a factor of safety of 1.5.

LEGEND

H = Depth of Excavation Below Present Ground Surface, Including Overexcavation Depth, if Required, (feet)

D = Depth of Pile Embedment Below Bottom of Excavation, (feet)

H_1 = Jacking Block Height, (feet)

City of Puyallup
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Puyallup, Washington

MAXIMUM ALLOWABLE PASSIVE PRESSURE TO RESIST JACKING FORCE

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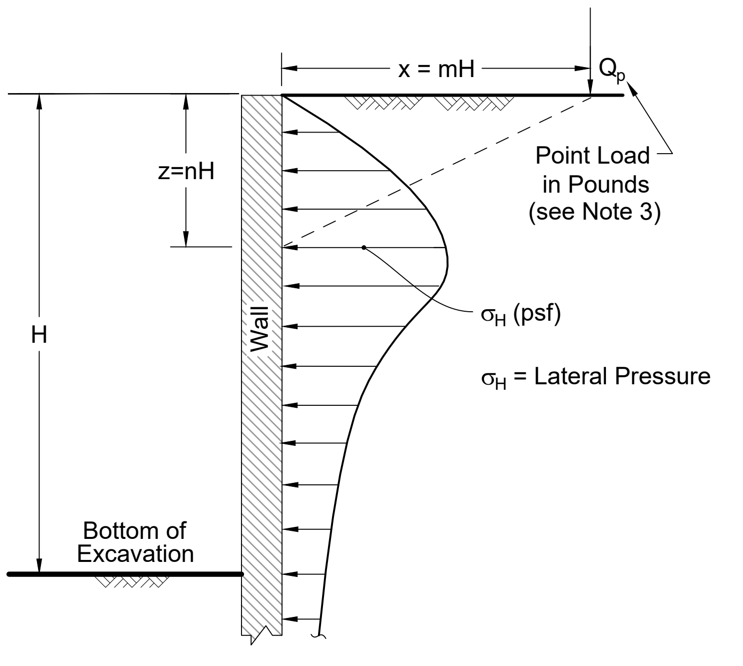
FIG. 4

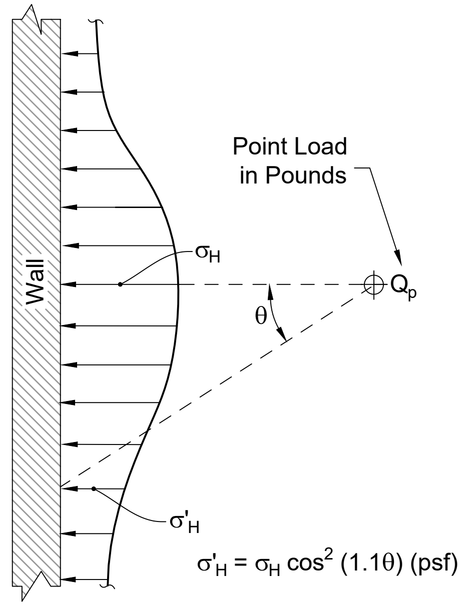
Filename: E:\J_SEA\105692\004\105692-004 Fig 4 - Passive Pressure to Resist Jacking Force.dwg Layout: Layout Date: 01-12-2021 Login: SAC



ELEVATION VIEW

For m ≤ 0.4: $\sigma_H = 0.28\ \dfrac{Q_p}{H^2}\ \dfrac{n^2}{(0.16 + n^2)^3}$ (psf) (see Note 3)

For m > 0.4: $\sigma_H = 1.77\ \dfrac{Q_p}{H^2}\ \dfrac{m^2n^2}{(m^2 + n^2)^3}$ (psf)

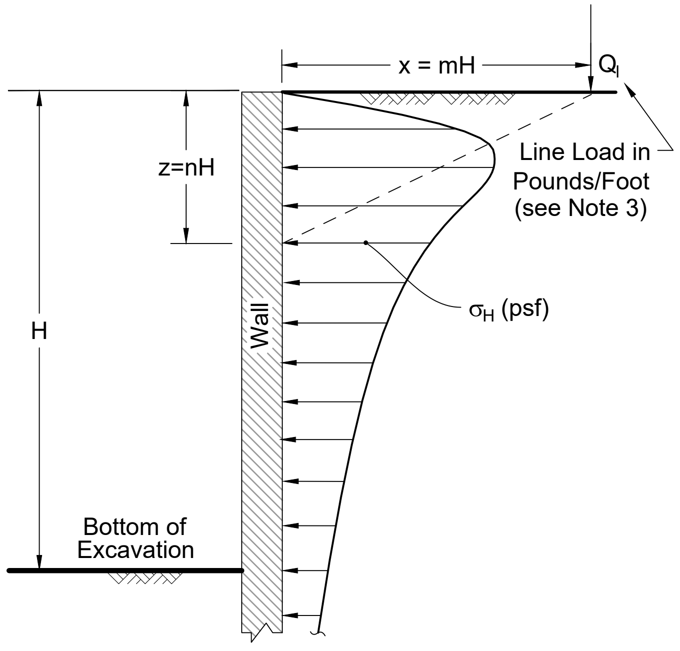


$\sigma'_H = \sigma_H \cos^2 (1.1\theta)$ (psf)

PLAN VIEW

A) LATERAL PRESSURE DUE TO POINT LOAD i.e. SMALL ISOLATED FOOTING OR WHEEL LOAD

(NAVFAC DM 7.02, 1986)



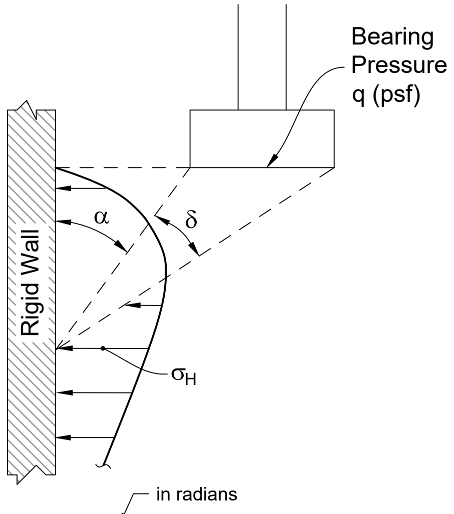
ELEVATION VIEW

For m ≤ 0.4: $\sigma_H = 0.20\ \dfrac{Q_l}{H}\ \dfrac{n}{(0.16 + n^2)^2}$ (psf) (see Note 3)

For m > 0.4: $\sigma_H = 1.28\ \dfrac{Q_l}{H}\ \dfrac{m^2n}{(m^2 + n^2)^2}$ (psf)

B) LATERAL PRESSURE DUE TO LINE LOAD i.e. NARROW CONTINUOUS FOOTING PARALLEL TO WALL

(NAVFAC DM 7.02, 1986)

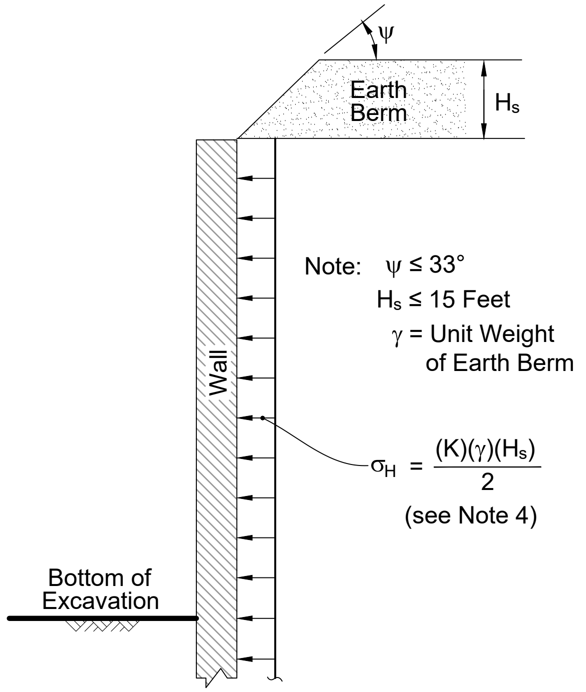


in radians

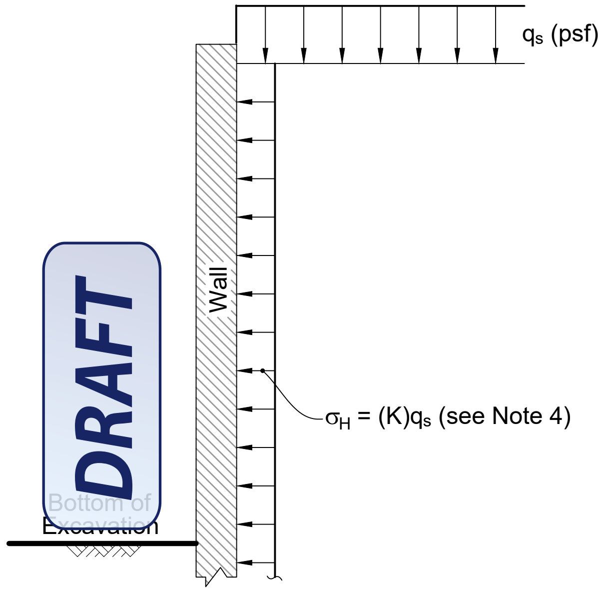
$\sigma_H = \dfrac{2q}{\pi}\ [\delta - \sin \delta \cos (\delta + 2\alpha)]$ (psf)

C) LATERAL PRESSURE DUE TO STRIP LOAD

(AASHTO LRFD Bridge Design Specifications, 2020)



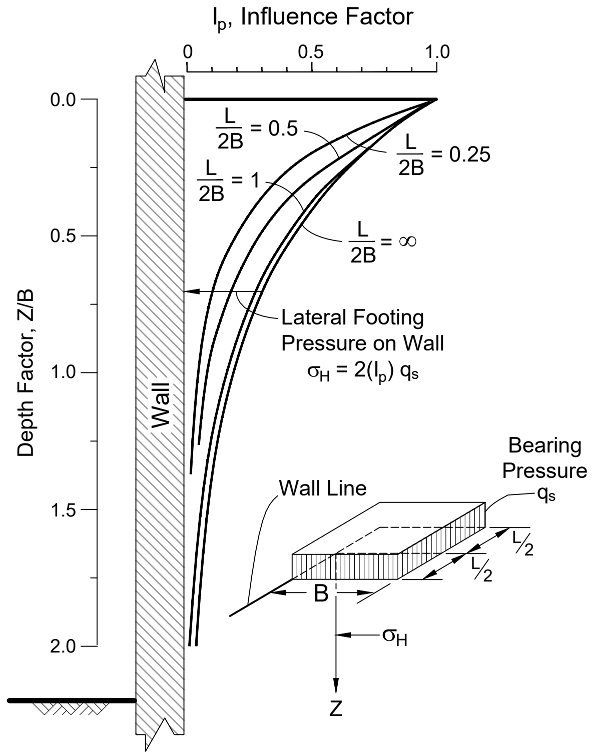
EARTH BERM



UNIFORM SURCHARGE

D) LATERAL PRESSURE DUE TO EARTH BERM OR UNIFORM SURCHARGE

(derived from Poulos and Davis, *Elastic Solutions for Soil and Rock Mechanics*, 1974; and Terzaghi and Peck, *Soil Mechanics in Engineering Practice*, 1967)



E) LATERAL PRESSURE DUE TO ADJACENT FOOTING

(see Notes 5 and 6)

(derived from NAVFAC DM 7.02, 1986; and Sandhu, *Earth Pressure on Walls Due to Surcharge*, 1974)

NOTES

1. Figures are not drawn to scale.
2. Applicable surcharge pressures should be added to appropriate permanent wall lateral earth and water pressure.
3. If point or line loads are close to the back of the wall such that m ≤ 0.4, it may be more appropriate to model the actual load distribution (i.e., Detail E) or use more rigorous analysis methods.
4. See text for recommended K values.
5. The stress is estimated on the back of the wall at the center of the length, L, of loading.
6. The estimated stress is based on a Poisson's ratio of 0.5.

City of Puyallup
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Puyallup, Washington

RECOMMENDED SURCHARGE LOADING FOR WALLS

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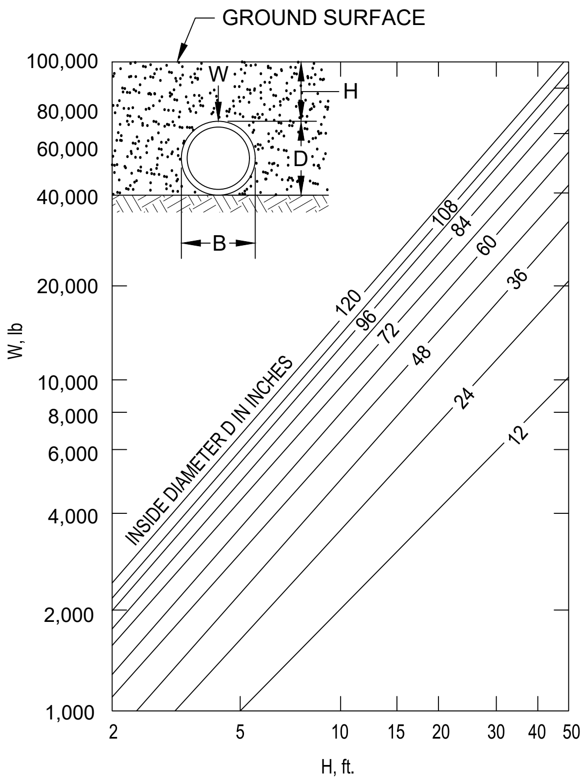
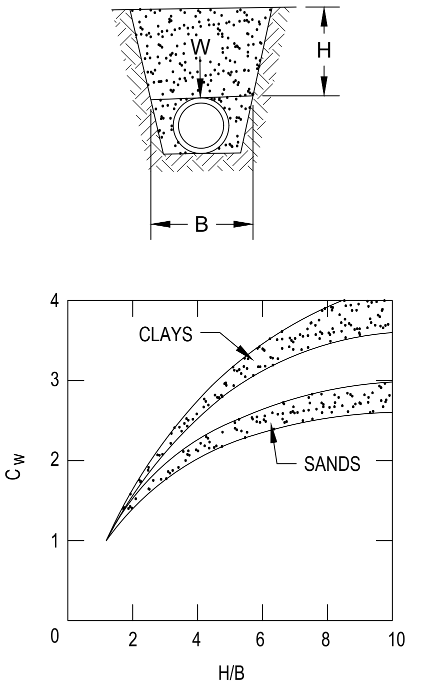
FIG. 5

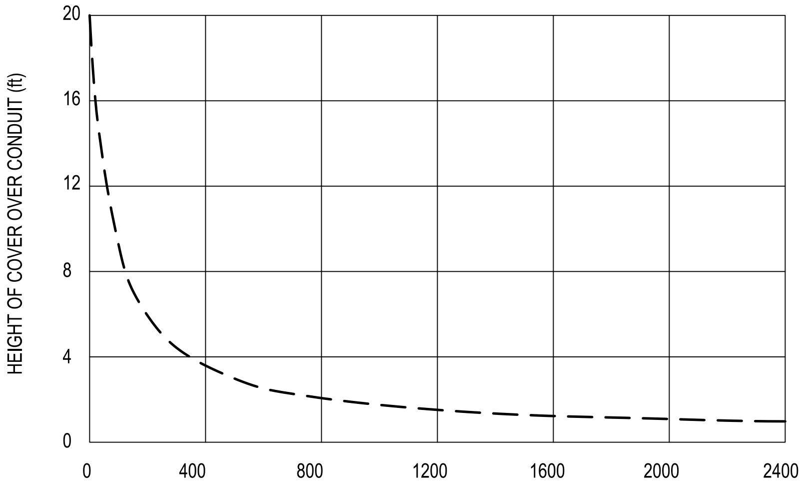
File: E:\J_SEA\105692\001\105692-001 Fig 5 - Surcharge Loading.dwg Date: 12-30-2020 Author: SAC



(a) EMBANKMENT DEAD LOAD W ON A
CONDUIT BURIED IN A SOIL EMBANKMENT.



(b) C_W FOR CONDUIT IN A TRENCH



(c) VERTICAL PRESSURE DUE TO H-20 LIVE LOAD ON CONDUIT (PSF)

NOTES

1. W = total dead load per unit length.

2. Embankment dead loads shown in (a) are based on soil unit weight of 100 pcf.
For different soil unit weights, adjust the loads proportionately.

3. For trench backfill shown in (b): $W = C_W (\gamma)(B)^2$

where: γ = soil unit weight.
B = trench width at top of pipe level.

If backfill compacted adequately, a unit weight of 125 pcf is recommended for evaluation.

4. Live loads shown in (c) include effect of impact.

5. This figure was adapted from NAVFAC DM7.

City of Puyallup
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LOADS ON BURIED UTILITIES

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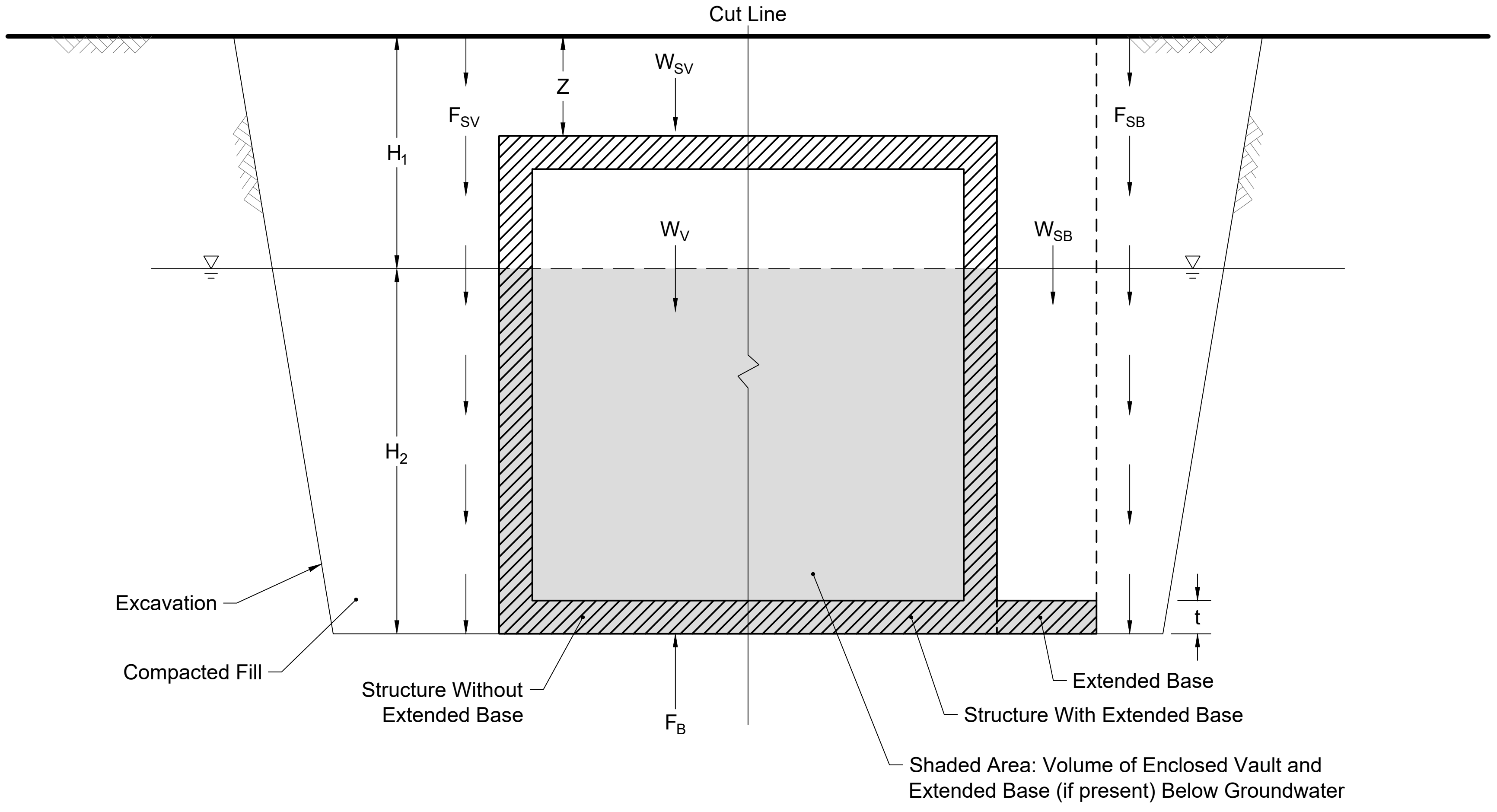
FIG. 6



Not to Scale

NOTATION

γ_T = Total Unit Weight of Soil Above Groundwater Level, γ_T = 125 pcf

γ_B = Buoyant Unit Weight of Soil Below Groundwater Level, γ_B = 62.6 pcf

γ_W = Unit Weight of Water, γ_W = 62.4 pcf (Fresh Water)

ϕ = Soil Effective Stress Friction Angle, ϕ = 30°

δ = Soil - Structure Interface Friction Angle, $\delta = \frac{2}{3}\phi$ (Precast Concrete)

K = K_o for Unshored Excavations, K = K_a otherwise

- K_o = At-Rest Earth Pressure Coefficient, $K_o = 1 - \sin\phi$
- K_a = Active Earth Pressure Coefficient, $K_a = \frac{1-\sin\phi}{1+\sin\phi}$

A_{Top} = Area of Top of Vault, Ft^2

A_{EB} = Area of Extended Base, Ft^2

P = Perimeter Distance Around Base of Vault and Extended Base (if present), Ft. May Not Be Same Shape as Shown

t = Thickness of Extended Base, Ft.

V = Volume of Enclosed Vault and Extended Base (if present) Below Groundwater, Ft^3. May Not Be Same Shape as Shown

Z = Depth to Top of Vault

H_1 = Depth to Groundwater (See Figure 3)

H_2 = Depth from Groundwater to Base of Vault

$\bar{\nabla}$ = Groundwater Level

DRAFT

EQUATIONS

$$\text{Factor of Safety without Extended Base} = \frac{W_V + W_{SV} + F_{SV}\,(P)}{F_B}$$

$$\text{Factor of Safety with Extended Base} = \frac{W_V + W_{SV} + W_{SB} + F_{SB}\,(P)}{F_B}$$

W_V = Weight of Vault and Extended Base (if present), lb

W_{SV} = Weight of Soil Above Vault (if present), lb

Buried Vault with Groundwater Below Top of Vault: $W_{SV} = \gamma_T\, Z\, A_{Top}$ (lb)

Buried Vault with Groundwater Above Top of Vault: $W_{SV} = [\gamma_T H_1 + \gamma_B (Z - H_1)]\, A_{Top}$ (lb)

W_{SB} = Weight of Soil Above Extended Base (if present), lb

$= [\gamma_T H_1 + \gamma_B (H_2 - t)]\, A_{EB}$

F_{SV} = Shearing Resistance of Soil to Vault Wall, lb/Ft

$= (\frac{1}{2})(\tan\delta)(K)(2\,\gamma_T H_1 H_2 + \gamma_T H_1^2 + \gamma_B H_2^2)$

F_{SB} = Shearing Resistance of Soil, lb/Ft

$= (\frac{1}{2})(\tan\phi)(K)(2\,\gamma_T H_1 H_2 + \gamma_T H_1^2 + \gamma_B H_2^2)$

F_B = Buoyant Force, lb

$= V\,\gamma_W$

NOTES

1. Uplift could result in high moments in bottom slab.
2. If temporary or permanent shoring is left in place adjacent to vault, F_{SV} and F_{SB} should be ignored.

City of Puyallup
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Puyallup, Washington

UPLIFT RESISTANCE FOR BURIED MANHOLES AND STRUCTURES

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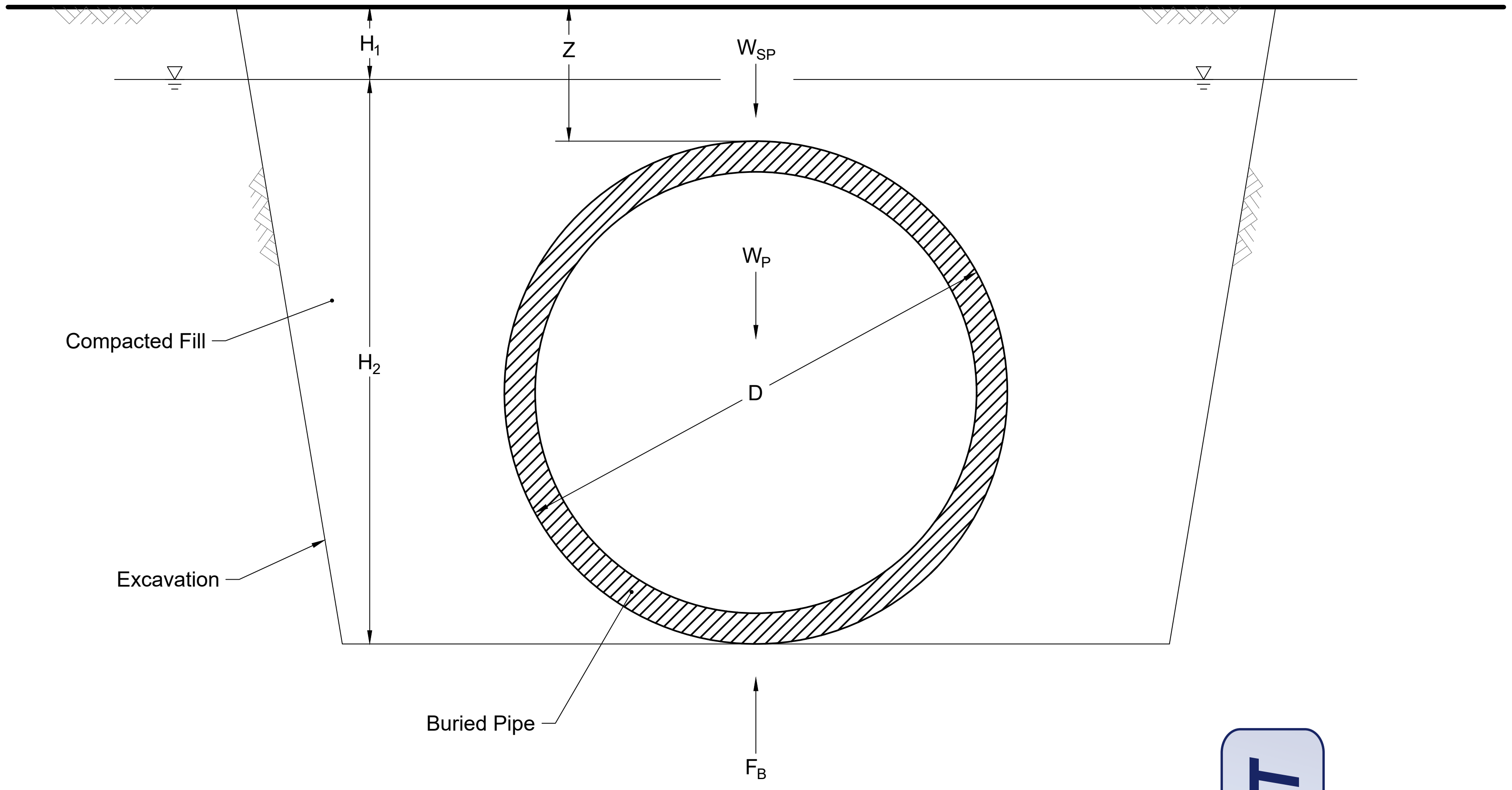
FIG. 7

File: E:\J_SEA\105692\001\105692-001 Uplift Resistance.dwg   Date: 12-30-2020   Author: SAC



Not to Scale

EQUATIONS

$$\text{Factor of Safety} = \frac{W_P + W_{SP}}{F_B}$$

W_P = Weight of Pipe, lb/lft

W_{SP} = Weight of Soil Above Pipe, lb/lft

$= [\gamma_T H_1 + \gamma_B (Z - H_1)] A_{Top}$

F_B = Buoyant Force, lb/lft

$= A \gamma_W$

NOTATION

γ_T = Total Unit Weight of Soil Above Groundwater Level, $\gamma_T = 125$ pcf

γ_B = Buoyant Unit Weight of Soil Below Groundwater Level, $\gamma_B = 62.6$ pcf

γ_W = Unit Weight of Water, $\gamma_W = 62.4$ pcf (Fresh Water)

D = Outside Diameter of Pipe, Ft.

A = Area of Enclosed Pipe Below Groundwater, Ft^2. May Not Be Same Shape as Shown

A_{TOP} = Plan View Area of Pipe, DUnit Length Ft^2

Z = Depth to Top of Pipe

H_1 = Depth to Groundwater (See Figure 3)

H_2 = Depth from Groundwater to Base of Pipe

▽ = Groundwater Level

NOTE

Permanent tiedowns could also be used to resist uplift.

City of Puyallup
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Puyallup, Washington

BURIED PIPE
UPLIFT RESISTANCE

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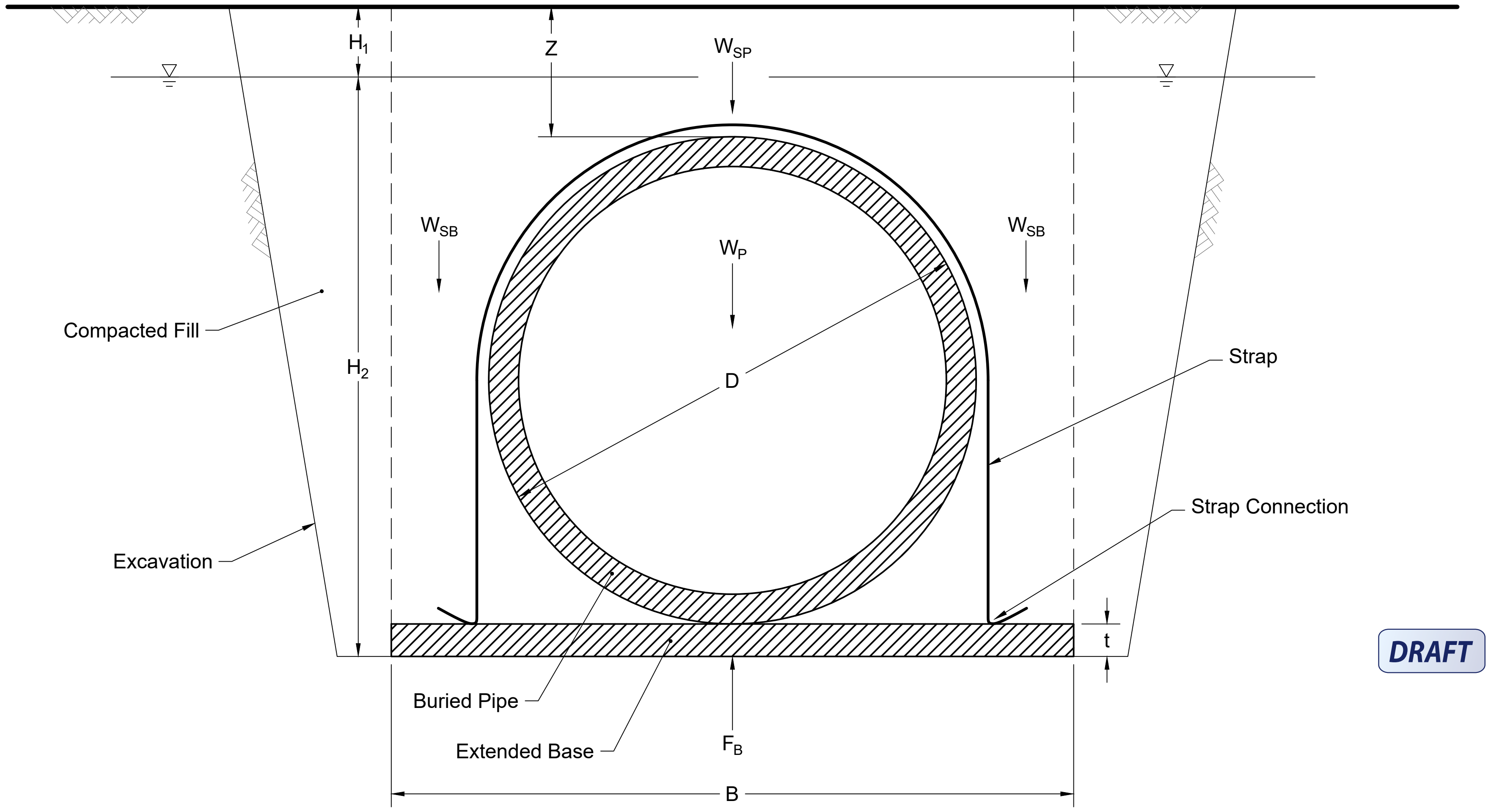
FIG. 8

File: E:\J_SEA\105692\001\105692-001 Uplift Resistance.dwg Date: 12-30-2020 Author: SAC



Not to Scale

EQUATIONS

$$\text{Factor of Safety with Extended Base} = \frac{W_P + W_{SP} + W_{SB}}{F_B}$$

W_P = Weight of Pipe and Extended Base, lb/lft

W_{SP} = Weight of Soil Above Pipe, lb/lft

$= [\gamma_T H_1 + \gamma_B (Z - H_1)] A_{Top}$

W_{SB} = Weight of Soil Above Extended Base, lb/lft

$= [\gamma_T H_1 + \gamma_B (Z - t)] (B-D)$

F_B = Buoyant Force, lb/lft

$= A \gamma_W$

NOTATION

γ_T = Total Unit Weight of Soil Above Groundwater Level, $\gamma_T = 125$ pcf

γ_B = Buoyant Unit Weight of Soil Below Groundwater Level, $\gamma_B = 62.6$ pcf

γ_W = Unit Weight of Water, $\gamma_W = 62.4$ pcf (Fresh Water)

t = Thickness of Extended Base, Ft.

A = Area of Enclosed Pipe and Extended Base Below Groundwater, Ft^3.
May Not Be Same Shape as Shown

Z = Depth to Top of Pipe

H_1 = Depth to Groundwater (See Figure 3)

H_2 = Depth from Groundwater to Base of Pipe

D = Outside Diameter of Pipe, Ft.

B = Length of Extended Base

NOTES

1. Uplift could result in high moments in bottom slab.
2. Strap, strap connection, and strap spacing should be structurally designed.

File: E:\J_SEA\105692\001\105692-001 Uplift Resistance.dwg Date: 12-30-2020 Author: SAC

City of Puyallup
4th Avenue Storm Drainage Project
Puyallup, Washington

BURIED PIPE UPLIFT RESISTANCE WITH EXTENDED BASE

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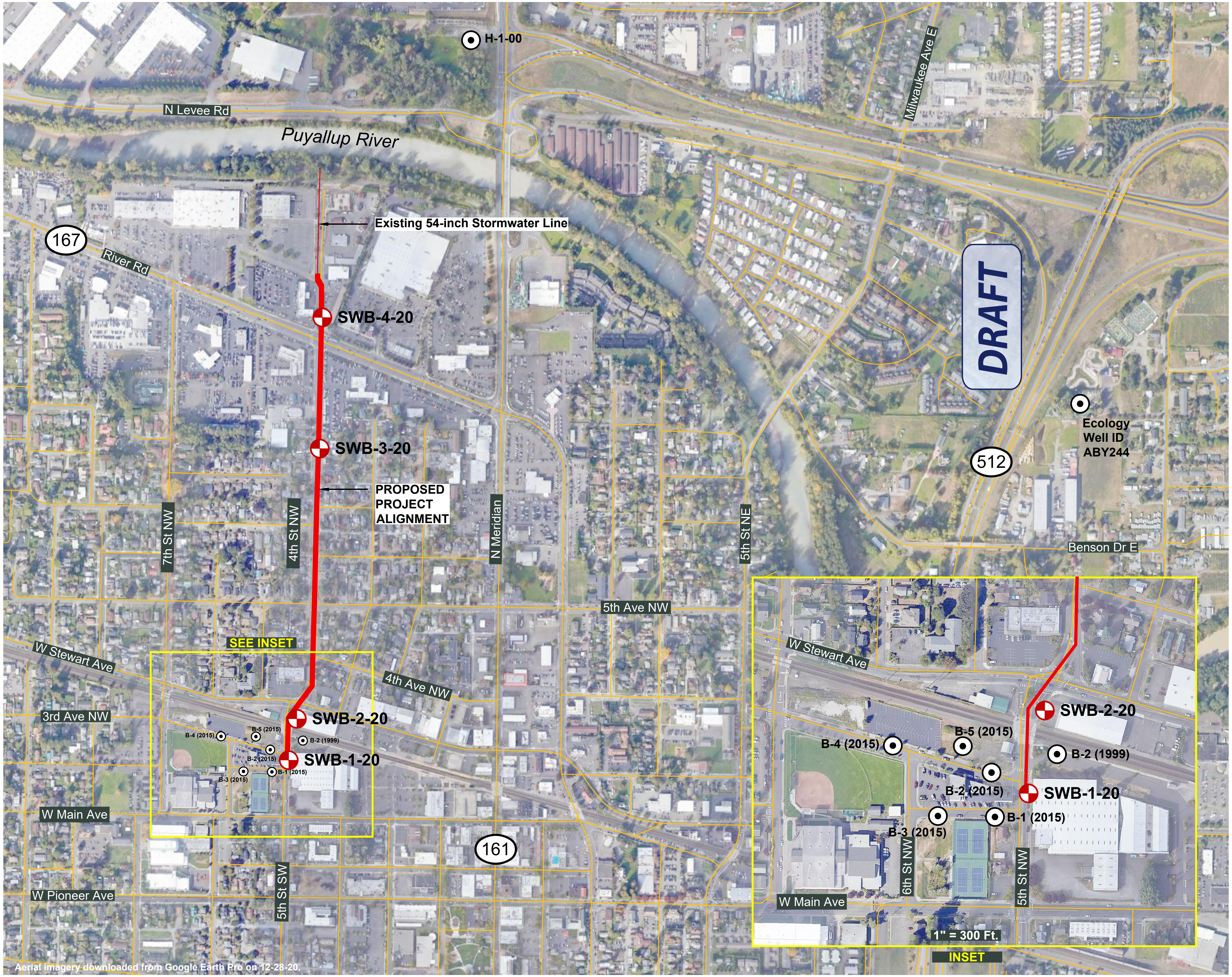
FIG. 9

Appendix A

Existing Explorations

CONTENTS



LEGEND

SWB-1-20 ⊕	Project Boring Designation and Approximate Location
BH-1 (2015) ⊙	Existing Boring or Groundwater Well Installation Designation and Approximate Location

NOTES

Approximate locations of existing borings and well installation based on information from *Washington State DNR Division of Geology Subsurface Database*, accessed January 2021 and *Draft Preliminary Geotechnical Data Report, Sound Transit - Puyallup Station Access Improvements*, prepared by HWA Geosciences, dated January 2016.

City of Puyallup
4th Avenue Storm Drainage Project
Puyallup, Washington

APPROXIMATE LOCATIONS OF EXISTING EXPLORATIONS

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FIG. A-1

Filename: E:\J_SEA\105692\004\105692-004 Fig A-1 - Existing Explorations.dwg Layout: Layout Date: 01-08-2021 Login: SAC

RELATIVE DENSITY OR CONSISTENCY VERSUS SPT N-VALUE

COHESIONLESS SOILS			COHESIVE SOILS		
Density	N (blows/ft)	Approximate Relative Density(%)	Consistency	N (blows/ft)	Approximate Undrained Shear Strength (psf)
Very Loose	0 to 4	0 - 15	Very Soft	0 to 2	<250
Loose	4 to 10	15 - 35	Soft	2 to 4	250 - 500
Medium Dense	10 to 30	35 - 65	Medium Stiff	4 to 8	500 - 1000
Dense	30 to 50	65 - 85	Stiff	8 to 15	1000 - 2000
Very Dense	over 50	85 - 100	Very Stiff	15 to 30	2000 - 4000
			Hard	over 30	>4000

TEST SYMBOLS

GS	Grain Size Distribution
%F	Percent Fines
CN	Consolidation
TX	Triaxial Compression
UC	Unconfined Compression
DS	Direct Shear
M	Resilient Modulus
PP	Pocket Penetrometer Approx. Compressive Strength (tsf)
TV	Torvane Approximate Shear Strength (tsf)
CBR	California Bearing Ratio
MD	Moisture/Density Relationship
PID	Photoionization Device Reading
AL	Atterberg Limits: PL Plastic Limit LL Liquid Limit

ASTM SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GROUP DESCRIPTIONS		
Coarse Grained Soils More than 50% Retained on No. 200 Sieve Size	Gravel and Gravelly Soils More than 50% of Coarse Fraction Retained on No. 4 Sieve	Clean Gravel (little or no fines)	▨	GW	Well-graded GRAVEL
			▨	GP	Poorly-graded GRAVEL
		Gravel with Fines (appreciable amount of fines)	▨	GM	Silty GRAVEL
			▨	GC	Clayey GRAVEL
	Sand and Sandy Soils 50% or More of Coarse Fraction Passing No. 4 Sieve	Clean Sand (little or no fines)	▨	SW	Well-graded SAND
			▨	SP	Poorly-graded SAND
		Sand with Fines (appreciable amount of fines)	▨	SM	Silty SAND
			▨	SC	Clayey SAND
Fine Grained Soils 50% or More Passing No. 200 Sieve Size	Silt and Clay	Liquid Limit Less than 50%	▨	ML	SILT
			▨	CL	Lean CLAY
			▨	OL	Organic SILT/Organic CLAY
	Silt and Clay	Liquid Limit 50% or More	▨	MH	Elastic SILT
			▨	CH	Fat CLAY
			▨	OH	Organic SILT/Organic CLAY
Highly Organic Soils			▨	PT	PEAT

SAMPLE TYPE SYMBOLS

⊠	2.0" OD Split Spoon (SPT) (140 lb. hammer with 30 in. drop)
⌶	Shelby Tube
▣	3.0" OD Split Spoon with Brass Rings
○	Small Bag Sample
▚	Large Bag (Bulk) Sample
▮	Core Run
⧄	Non-standard Penetration Test (with split spoon sampler)

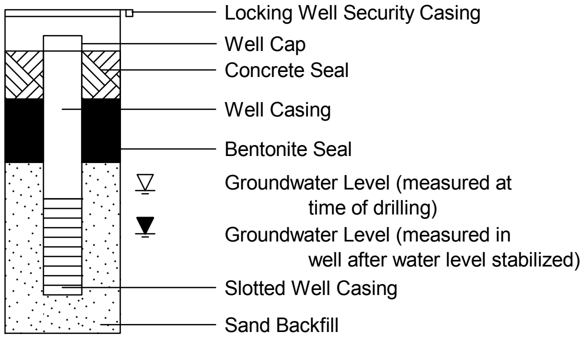
COMPONENT PROPORTIONS

DESCRIPTIVE TERMS	RANGE OF PROPORTION
Clean	< 5%
Slightly (Clayey, Silty, Sandy)	5 - 12%
Clayey, Silty, Sandy, Gravelly	12 - 30%
Very (Clayey, Silty, Sandy, Gravelly)	30 - 50%

COMPONENT DEFINITIONS

COMPONENT	SIZE RANGE
Boulders	Larger than 12 in
Cobbles	3 in to 12 in
Gravel	3 in to No 4 (4.5mm)
Coarse gravel	3 in to 3/4 in
Fine gravel	3/4 in to No 4 (4.5mm)
Sand	No. 4 (4.5 mm) to No. 200 (0.074 mm)
Coarse sand	No. 4 (4.5 mm) to No. 10 (2.0 mm)
Medium sand	No. 10 (2.0 mm) to No. 40 (0.42 mm)
Fine sand	No. 40 (0.42 mm) to No. 200 (0.074 mm)
Silt and Clay	Smaller than No. 200 (0.074mm)

GROUNDWATER WELL COMPLETIONS



NOTES: Soil classifications presented on exploration logs are based on visual and laboratory observation in general accordance with ASTM D 2487 and ASTM D 2488. Soil descriptions are presented in the following general order:

Density/consistency, color, modifier (if any) GROUP NAME, additions to group name (if any), moisture content. Proportion, gradation, and angularity of constituents, additional comments. (GEOLOGIC INTERPRETATION)

Please refer to the discussion in the report text as well as the exploration logs for a more complete description of subsurface conditions.

MOISTURE CONTENT

DRY	Absence of moisture, dusty, dry to the touch.
MOIST	Damp but no visible water.
WET	Visible free water, usually soil is below water table.

HWA GEOSCIENCES INC.

PUYALLUP STATION ACCESS IMPROVEMENTS
PUYALLUP, WASHINGTON

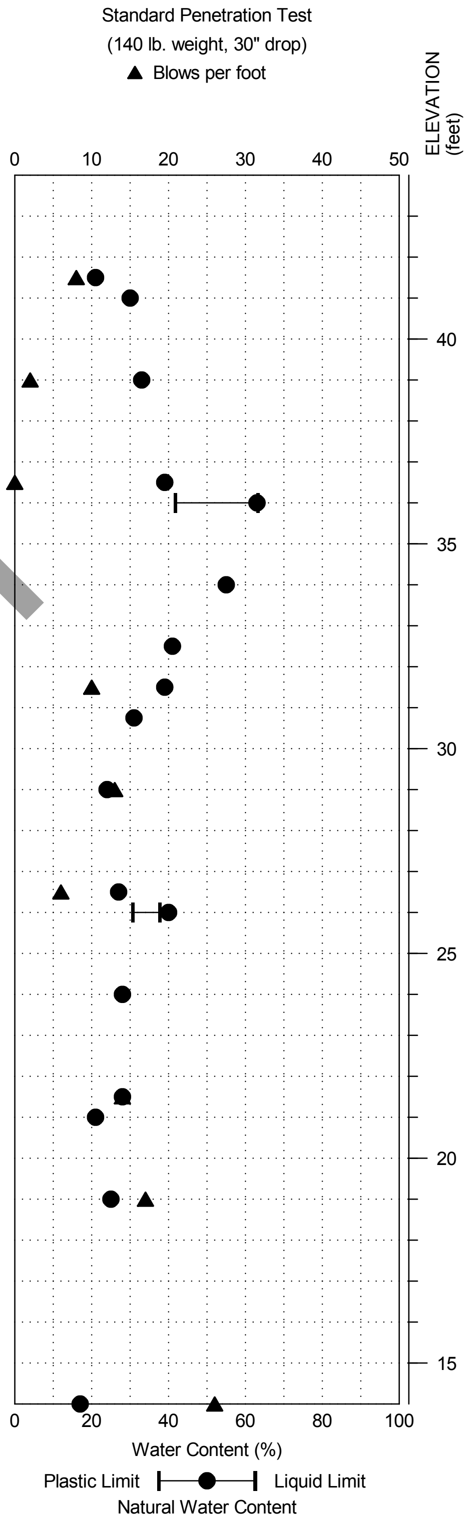
LEGEND OF TERMS AND SYMBOLS USED ON EXPLORATION LOGS

PROJECT NO.: 2013-075-21 FIGURE: A-1

DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Mud Rotary w/ 5" tricone bit
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 8/31/2015
DATE COMPLETED: 9/1/2015
LOGGED BY: B. Thurber/ H. Bray
SURFACE ELEVATION: 44.0 ± feet

USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS
SP SM	3 inches A.C.P.			
	Loose, rust-mottled dark olive brown, slightly silty, fine to medium SAND, moist. **(FILL)**	S-1a S-1b	4-4-4	
ML	Stiff, light brown with rust banding, SILT, moist. **(RECENT ALLUVIUM)**			
SP SM SM	Loose, dark olive brown, slightly silty, fine to medium SAND, moist.	S-2	2-1-1	GS
	Very loose, dark to light brown with heavy rust banding, interbedded very silty, fine SAND and fine sandy SILT, wet.	S-3a	0-0-0	
MH	Very soft, olive brown, elastic SILT, wet, with greenish brown band at 8.3 to 8.4 ft. Scattered organics.	S-3b		AL
	Light brown grades to dark olive gray, slightly fine sandy SILT, wet.	S-4a		DD CN
ML	Medium dense, dark olive gray, very silty fine SAND, wet.	S-4b		GS DD
ML SM	Medium dense, light brown, interbedded slightly silty, fine to coarse SAND and very silty, fine SAND with silt clumps, wet.	S-5a S-5b	2-4-6	DS
	Medium dense, dark olive gray and dark olive brown, silty fine SAND grading to slightly silty, fine to medium SAND, wet. Abundant black and red (volcanic) sand grains.	S-6	6-7-6	GS
	Loose, grayish-black, clean to slightly silty, fine to medium SAND, wet. Thinly bedded.	S-7a	4-3-3	
ML	Medium stiff, olive brown, SILT, wet. Thinly bedded, plastic and non-plastic. Detritial organics at 18.3 to 18.5 feet, with 1/4-inch lens of peat.	S-7b		AL
	Medium stiff, dark olive brown, SILT with reddish black, fine to medium fine sand, moist.	S-8		DD DS CN
SM	Medium dense,reddish black, silty, fine to medium fine SAND with dark brown silt lenses, moist.	S-9a	4-6-8	
ML SM	Medium dense, olive brown, fine sandy SILT grading to very silty fine SAND, moist.	S-9b		GS
SM	Medium dense, grayish-black, clean to slightly silty (interbedded), fine to medium SAND, wet. Scattered coarse sand. Thinly bedded. Abundant black grains, some red and white (volcanic).	S-10	7-8-9	
	Medium dense, dark reddish-black, silty, fine to coarse SAND, wet. Silty 1/8-inch lens at 26 feet.			
GP	Gravelly drill action from 28 to 29 feet.			
SM				



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HWA GEOSCIENCES INC.

PUYALLUP STATION ACCESS IMPROVEMENTS
PUYALLUP, WASHINGTON

BORING:
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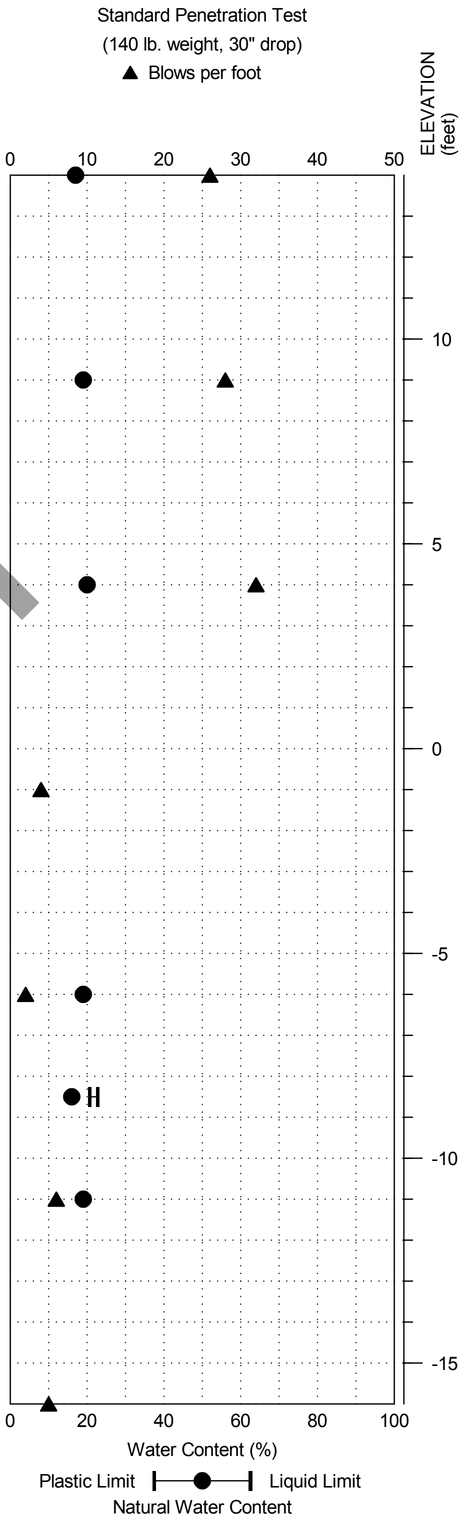
PAGE: 1 of 7

PROJECT NO.: 2013-075-21 FIGURE: A-2

DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Mud Rotary w/ 5" tricone bit
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 8/31/2015
DATE COMPLETED: 9/1/2015
LOGGED BY: B. Thurber/ H. Bray
SURFACE ELEVATION: 44.0 ± feet

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS
30		Medium dense, reddish-black, medium to coarse silty SAND, wet, with lenses of fine gravel; one greenstone clast.	S-11	10-12-14	
35		Medium dense, reddish-black, fine to medium silty SAND, wet. Scattered fine gravel. Gravel is subrounded red and black (andesite and basalt) and greenstone.	S-12	13-14-14	
40	SP SM	Dense, reddish-black, fine to medium slightly silty SAND, wet. Scattered fine gravel. Lens of fine to coarse SAND at 40.7 to 41 feet.	S-13	13-14-18	
	ML SM				
45		Poor recovery. drove rock? Soft, light olive gray, fine sandy SILT, wet. **(OSCEOLA MUDFLOW)**	S-14	0-1-3	
	SM	No recovery. Shelby tube leading edge bent from pushing gravel.	NR		
50		Very loose, light brownish gray, very silty, fine to coarse SAND, wet. Scattered fine gravel and woody organics. Unsorted and non-stratified. Gravel is subrounded to subangular basalt and andesite with some pumice.	S-15	1-1-1	
		Very loose to loose, light olive gray, very silty, fine to coarse SAND wet, with subrounded to subangular fine to coarse gravels, scattered woody organics, rootlets. 2-inch angular basalt gravel clast in tip.	S-16		AL GS DS
55		Loose, light gray, very silty, fine to medium SAND, wet. With scattered gravel, subangular to subrounded.	S-17	1-2-4	
60					



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HWA GEOSCIENCES INC.

PUYALLUP STATION ACCESS IMPROVEMENTS
PUYALLUP, WASHINGTON

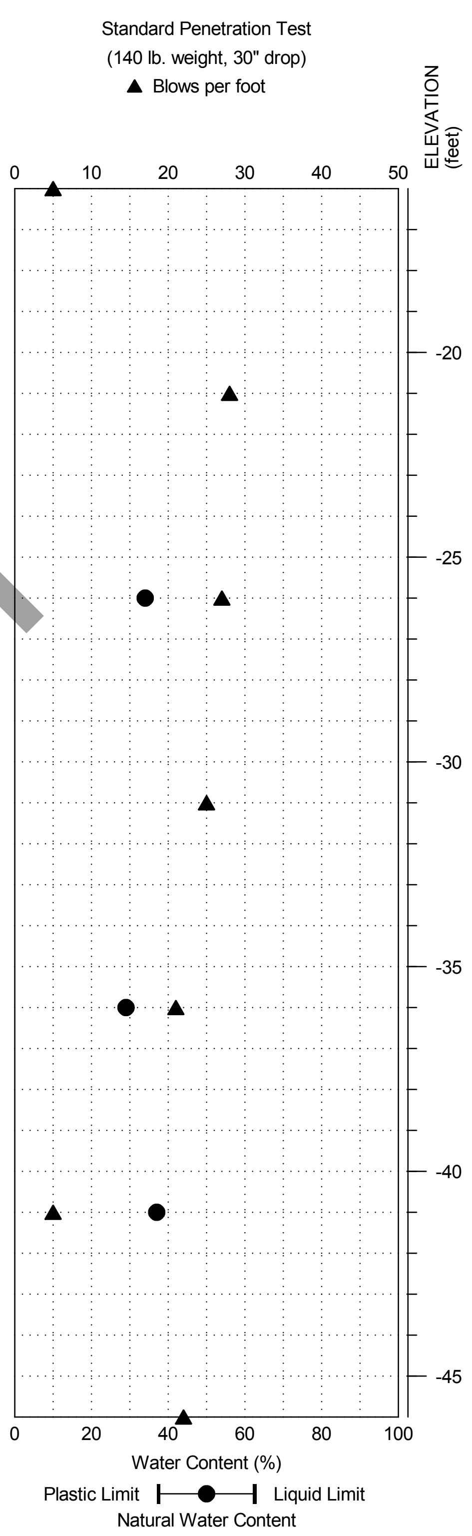
BORING:
BH-1

PROJECT NO.: 2013-075-21 FIGURE: A-2

DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Mud Rotary w/ 5" tricone bit
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 8/31/2015
DATE COMPLETED: 9/1/2015
LOGGED BY: B. Thurber/ H. Bray
SURFACE ELEVATION: 44.0 ± feet

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
60		Poor recovery. Loose, light gray, very silty, fine to medium SAND, wet. Scattered gravel, subangular to subrounded. Fine woody material in cuttings to approx. 63 feet.	☒	S-18	1-2-3		
	SM						
65		Medium dense, light brownish gray, very silty, fine SAND, wet. Thinly bedded, with interbeds of fine sandy SILT. Non-plastic. **(OLDER ALLUVIUM)**	☒	S-19	14-14-14		
70	ML	Medium dense, fine sandy SILT, wet. Non-plastic. Stratified. Driller noted organics in cuttings; woody.	☒	S-20	12-13-14	%F	
	ML SM						
75		Medium dense, light gray and light brown (stratified), very silty, fine to medium SAND, wet. Thinly bedded, with reddish-brown, silty fine SAND in upper 1 inch.	☒	S-21	8-12-13		
80		Medium dense, olive gray, silty fine SAND, wet. With lens of fine sandy SILT and scattered fine woody debris. Thinly bedded, non-plastic.	☒	S-22	7-8-13	GS	
85		Loose, olive gray, fine sandy SILT, wet, with lens of black, silty, fine to medium SAND, wet. Thinly bedded, non-plastic. Scattered partly decomposed organics (rootlets?).	☒	S-23	0-0-5	%F	
	SP SM						
90							



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HWA GEOSCIENCES INC.

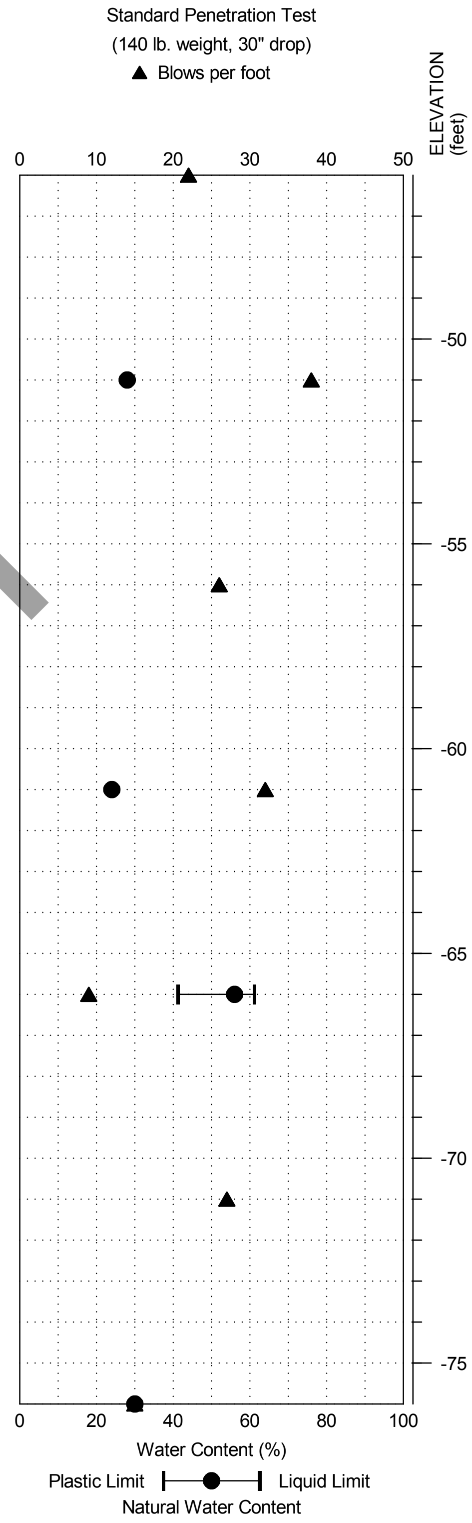
PUYALLUP STATION ACCESS IMPROVEMENTS
PUYALLUP, WASHINGTON

BORING:
BH-1

DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Mud Rotary w/ 5" tricone bit
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 8/31/2015
DATE COMPLETED: 9/1/2015
LOGGED BY: B. Thurber/ H. Bray
SURFACE ELEVATION: 44.0 ± feet

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
90		Medium dense, dark reddish black, slightly silty, fine SAND, wet. Thinly bedded, with fine silt lenses. Scattered gravel (subangular to subrounded basalt).	S-24	15-12-10		
95	ML	Dense, dark brown grading to light brown, fine sandy SILT, wet. Scattered woody debris. Thinly bedded. Cuttings lag of gravel on top of sample (volcanic breccia).	S-25	12-13-25	%F	
100	SP SM	Medium dense, reddish black, fine to medium slightly silty SAND, wet. Thinly bedded; volcanic provenance.	S-26	12-13-13		
105		Dense, reddish black, fine to medium SAND with silt, wet. Thinly bedded; volcanic provenance.	S-27	14-15-17		
110	MH	Stiff, light olive gray with light olive brown rust banding, elastic SILT, wet. 2-inch layer of white volcanic ash at approx. 111 feet with woody material. Rootlets crossing bedding.	S-28	1-5-4	AL	
115	SP	Medium dense, reddish black, fine to medium SAND, wet. Volcanic provenance. Faintly bedded; with 1/2-inch layer of very silty fine SAND, wet. Woody debris at bottom of sample.	S-29	13-16-11		
120	ML					



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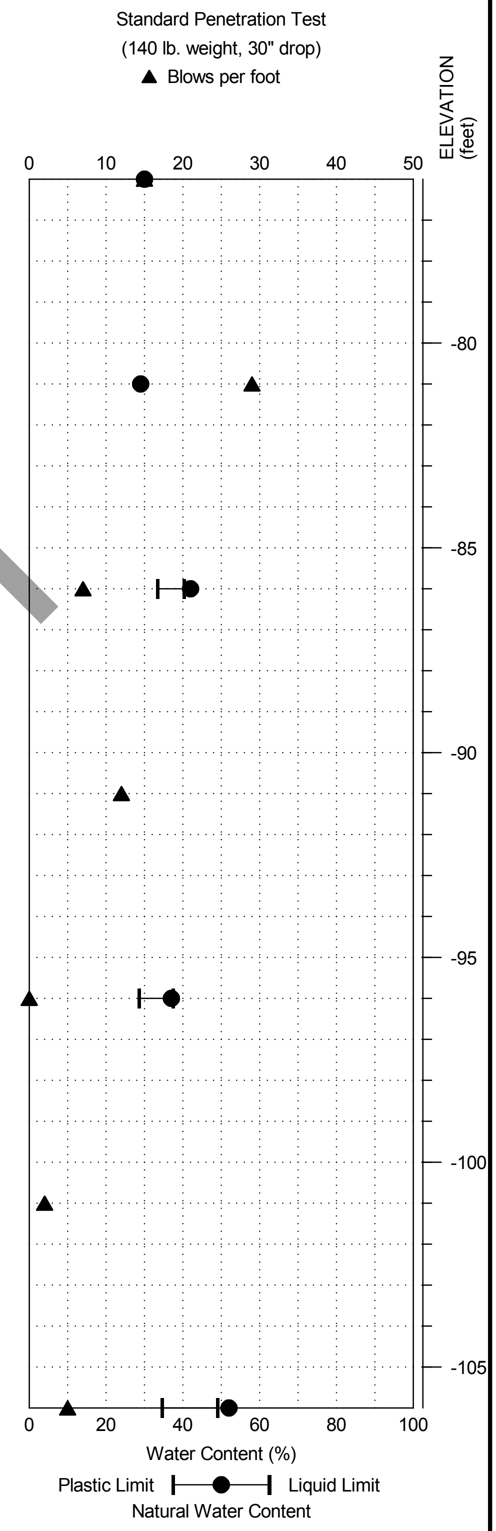
DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Mud Rotary w/ 5" tricone bit
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 8/31/2015
DATE COMPLETED: 9/1/2015
LOGGED BY: B. Thurber/ H. Bray
SURFACE ELEVATION: 44.0 ± feet

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS
120		Medium dense, dark olive gray, very silty fine SAND to fine sandy SILT with a few beds of light gray, fine sandy SILT, wet.	S-30	5-6-9	GS
	ML				
125		Medium dense, olive gray, fine sandy SILT, wet. Thinly bedded, with bands of partly decomposed organics.	S-31	2-12-17	%F
	ML				
130		Medium stiff, interbedded olive brown and olive gray, SILT, wet. With woody organics crossing bedding planes.	S-32a	1-2-5	AL
	SM	Loose, olive gray, very silty, fine SAND, wet. Scattered organics. Thinly bedded.	S-32b		
	ML SM				
135		Medium dense, interbedded olive brown and olive gray, very fine sandy SILT, and very silty SAND, wet. Scattered white specks (shell fragments) and dark brown organics. Thinly bedded.	S-33	3-6-6	
	ML				
140		Very soft, olive gray, SILT, wet. Scattered organics. Thinly bedded.	S-34	0-0-0	AL %F
145		Poor recovery (sampler check-ball valve plugged open). Very soft, olive brown, SILT, wet. Scattered organics.	S-35	1-1-1	
150					



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HWA GEOSCIENCES INC.

PUYALLUP STATION ACCESS IMPROVEMENTS
PUYALLUP, WASHINGTON

BORING:
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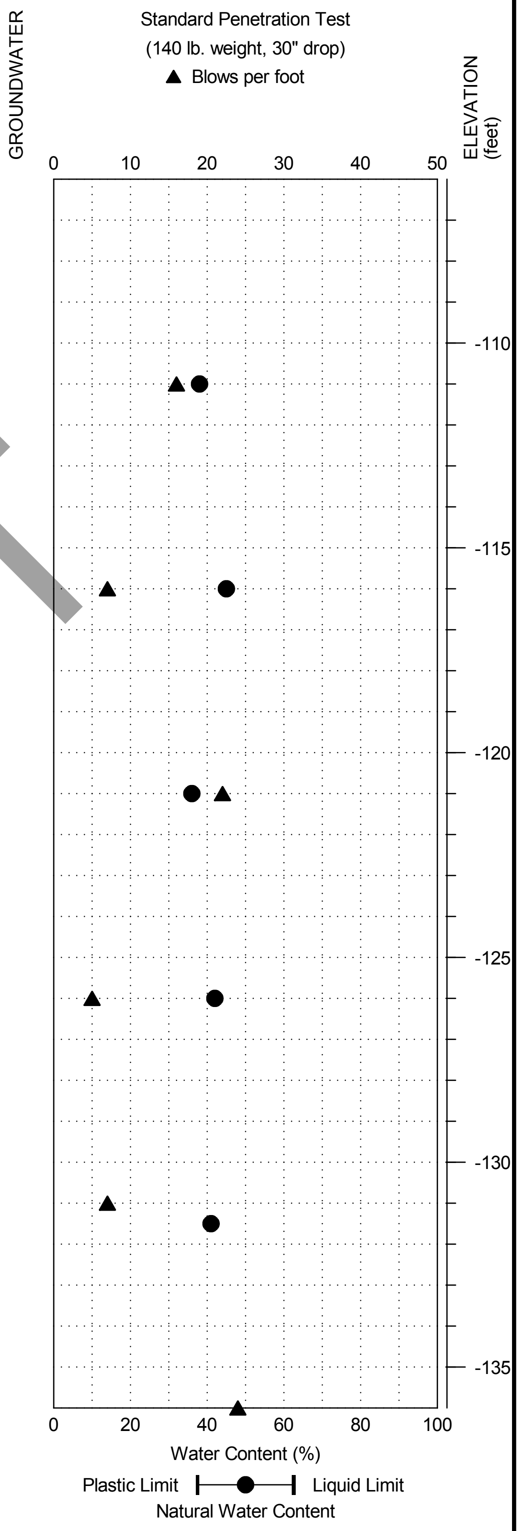
PROJECT NO.: 2013-075-21 FIGURE: A-2

DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Mud Rotary w/ 5" tricone bit
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 8/31/2015
DATE COMPLETED: 9/1/2015
LOGGED BY: B. Thurber/ H. Bray
SURFACE ELEVATION: 44.0 ± feet

DEPTH (feet)	SYMBOL	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
150			Medium stiff, olive gray with olive brown interbeds, SILT with scattered organics, wet. Abundant organics below 151 feet. Thinly bedded grading to laminated. Yellowish gray ASH (?) inclusion at 150.5 feet.	☒	S-36	0-2-3	AL	
		SM						
155			Medium dense, dark olive gray, silty fine SAND, wet, thinly bedded with olive brown SILT, wet. Scattered organics, increasing below 156 feet.	☒	S-37	5-7-9	%F	
		ML						
160			Medium stiff, olive gray with olive brown banding, SILT, wet. Scattered organics. Large chunk of wood at top. Thinly bedded.	☒	S-38	0-3-4		
		ML						
165			Medium dense, olive gray, fine sandy SILT with lenses of SILT and very silty fine SAND, wet. Scattered organics. Thinly bedded.	☒	S-39	5-8-14	%F	
		ML						
170			Medium stiff, olive gray with olive brown banding, non-plastic grading to plastic SILT, wet. Scattered organics, crossing bedded planes. Thinly bedded.	☒	S-40	1-2-3		
175			Loose, reddish black, clean, fine to medium SAND grading to reddish brown, very silty, fine SAND with laminae of light gray, fine sandy SILT, wet. Vertical burrow-like structure 2-inches long by 3/8th inch wide.	☒	S-41a	7-4-3		
		ML	Medium stiff, olive gray, SILT, wet.	☒	S-41b			
		SP SM						
180								



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HWA GEOSCIENCES INC.

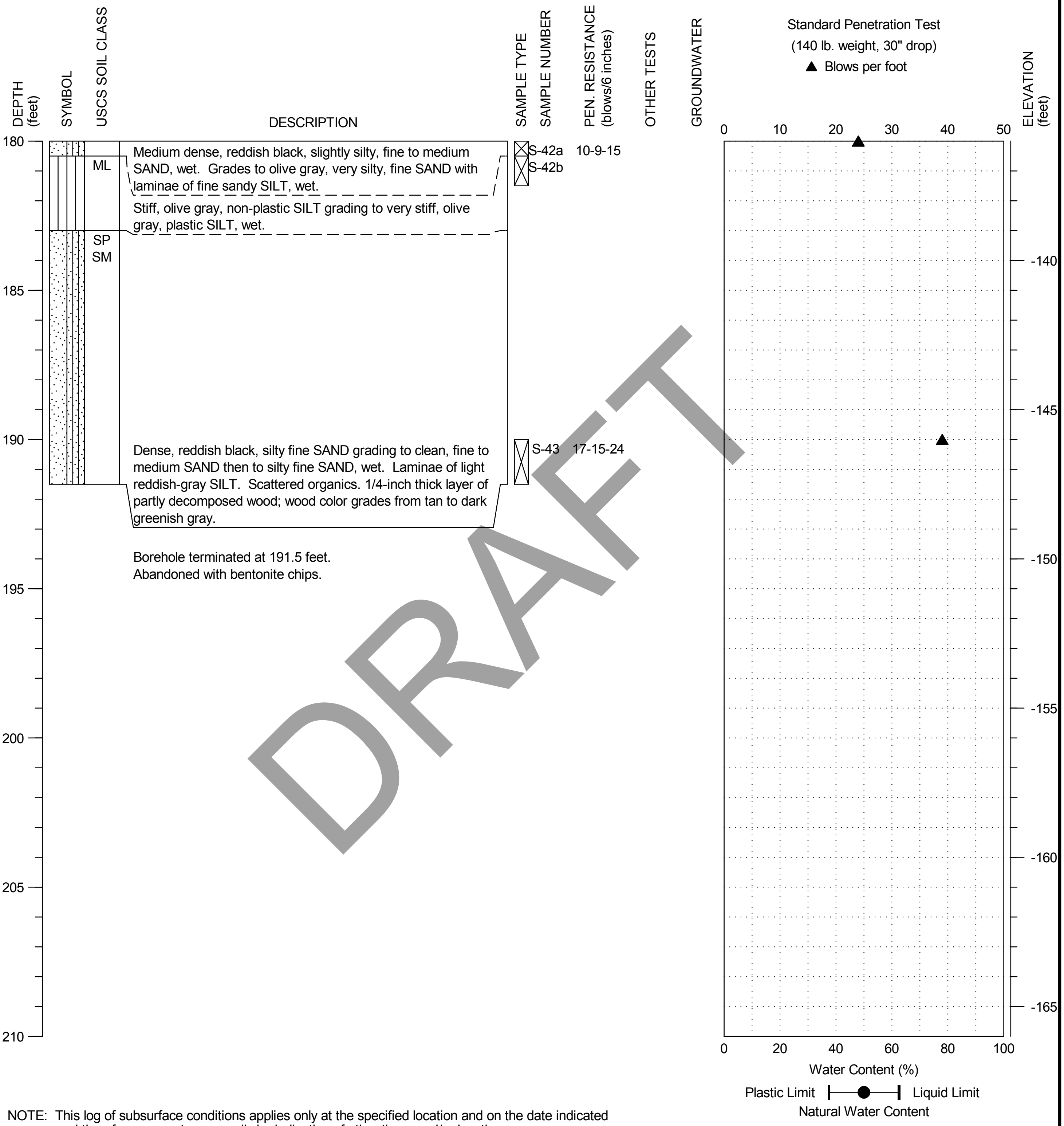
PUYALLUP STATION ACCESS IMPROVEMENTS
PUYALLUP, WASHINGTON

BORING:
BH-1

PROJECT NO.: 2013-075-21 FIGURE: A-2

DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Mud Rotary w/ 5" tricone bit
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 8/31/2015
DATE COMPLETED: 9/1/2015
LOGGED BY: B. Thurber/ H. Bray
SURFACE ELEVATION: 44.0 ± feet



Medium dense, reddish black, slightly silty, fine to medium SAND, wet. Grades to olive gray, very silty, fine SAND with laminae of fine sandy SILT, wet.

Stiff, olive gray, non-plastic SILT grading to very stiff, olive gray, plastic SILT, wet.

Dense, reddish black, silty fine SAND grading to clean, fine to medium SAND then to silty fine SAND, wet. Laminae of light reddish-gray SILT. Scattered organics. 1/4-inch thick layer of partly decomposed wood; wood color grades from tan to dark greenish gray.

Borehole terminated at 191.5 feet.
Abandoned with bentonite chips.

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HWA GEOSCIENCES INC.

PUYALLUP STATION ACCESS IMPROVEMENTS
PUYALLUP, WASHINGTON

BORING:
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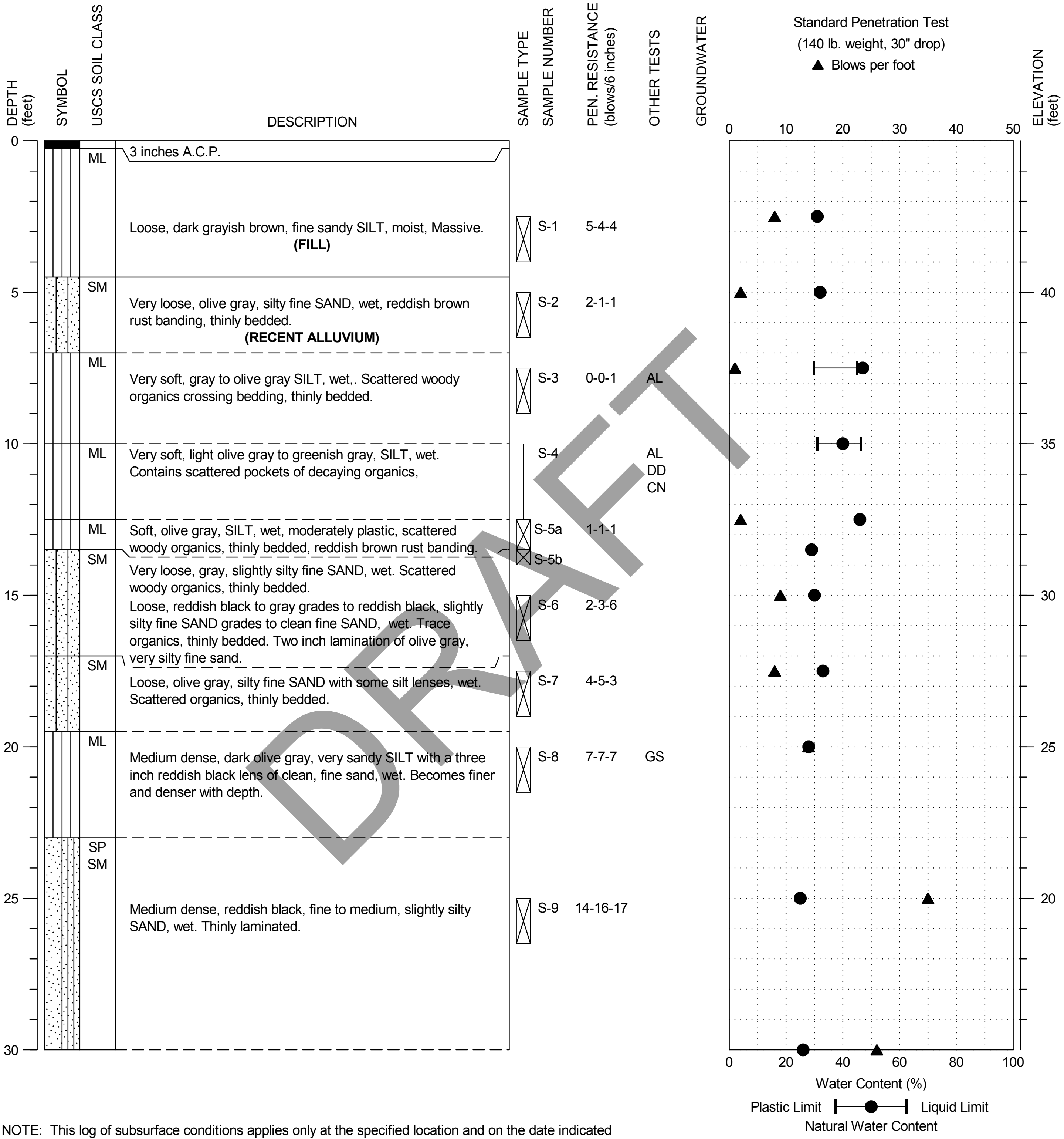
PAGE: 7 of 7

PROJECT NO.: 2013-075-21 FIGURE: A-2

DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Mud Rotary w/ 5" tricone bit
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 9/2/2015
DATE COMPLETED: 9/4/2015
LOGGED BY: H. Bray
SURFACE ELEVATION: 45.0 ± feet

USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS
ML	3 inches A.C.P.			
	Loose, dark grayish brown, fine sandy SILT, moist, Massive. **(FILL)**	S-1	5-4-4	
SM	Very loose, olive gray, silty fine SAND, wet, reddish brown rust banding, thinly bedded. **(RECENT ALLUVIUM)**	S-2	2-1-1	
ML	Very soft, gray to olive gray SILT, wet,. Scattered woody organics crossing bedding, thinly bedded.	S-3	0-0-1	AL
ML	Very soft, light olive gray to greenish gray, SILT, wet. Contains scattered pockets of decaying organics,	S-4		AL DD CN
ML	Soft, olive gray, SILT, wet, moderately plastic, scattered woody organics, thinly bedded, reddish brown rust banding.	S-5a	1-1-1	
SM	Very loose, gray, slightly silty fine SAND, wet. Scattered woody organics, thinly bedded.	S-5b		
	Loose, reddish black to gray grades to reddish black, slightly silty fine SAND grades to clean fine SAND, wet. Trace organics, thinly bedded. Two inch lamination of olive gray, very silty fine sand.	S-6	2-3-6	
SM	Loose, olive gray, silty fine SAND with some silt lenses, wet. Scattered organics, thinly bedded.	S-7	4-5-3	
ML	Medium dense, dark olive gray, very sandy SILT with a three inch reddish black lens of clean, fine sand, wet. Becomes finer and denser with depth.	S-8	7-7-7	GS
SP SM	Medium dense, reddish black, fine to medium, slightly silty SAND, wet. Thinly laminated.	S-9	14-16-17	



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HWA GEOSCIENCES INC.

PUYALLUP STATION ACCESS IMPROVEMENTS
PUYALLUP, WASHINGTON

BORING:
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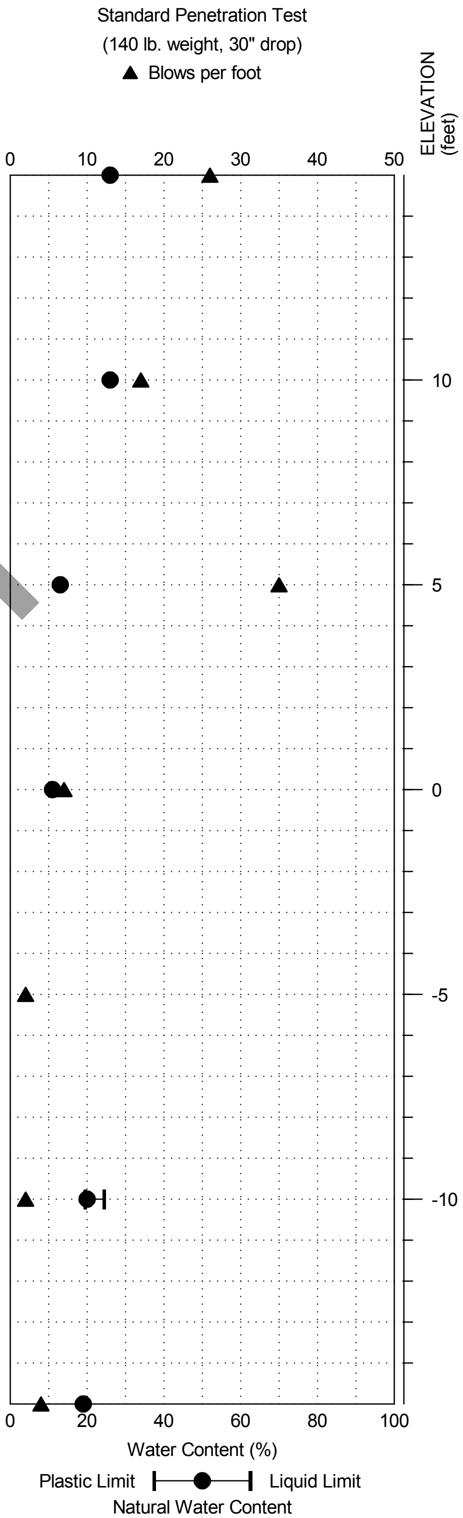
PROJECT NO.: 2013-075-21 FIGURE: A-3

DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Mud Rotary w/ 5" tricone bit
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 9/2/2015
DATE COMPLETED: 9/4/2015
LOGGED BY: H. Bray
SURFACE ELEVATION: 45.0 ± feet

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	ELEVATION (feet)
30	SM	Medium dense, reddish black, fine silty SAND, wet. Thinly bedded.	S-10	9-12-14		
35		Medium dense, reddish black, fine silty SAND, wet. Thinly bedded.	S-11	9-9-8	GS	10
	GP	Becomes harder to drill. Gravelly drill action from 39 to 40 feet below ground surface (bgs).				
40	SP SM	Dense, reddish black, fine to coarse, slightly silty SAND with fine gravels, wet. Stratified, grades from fine to coarse with depth.	S-12	12-19-16		5
	GP GM	Becomes harder to drill. Gravelly drill action from 42 to 43 feet bgs.				
45	GP GM	Very loose, olive gray, silty, fine to coarse grained sandy GRAVEL, wet. Massive. Poor recovery. **(OSCEOLA MUDFLOW)**	S-13	11-4-3	GS	0
50		Poor recovery. Partially decayed scattered woody debris in sampler.	S-14	0-1-1		-5
55	CL ML	Very soft, olive gray, elastic SILT, wet.	S-15	1-1-1	AL	-10
	SM					
60						



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HWA GEOSCIENCES INC.

PUYALLUP STATION ACCESS IMPROVEMENTS
PUYALLUP, WASHINGTON

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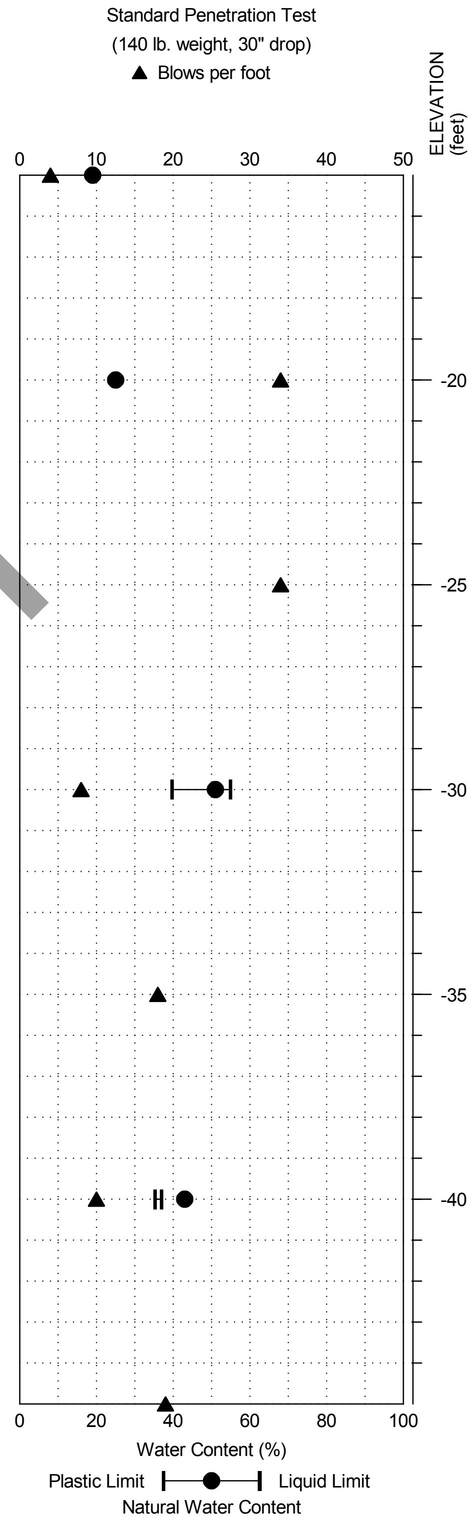
PROJECT NO.: 2013-075-21 FIGURE: A-3

DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Mud Rotary w/ 5" tricone bit
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 9/2/2015
DATE COMPLETED: 9/4/2015
LOGGED BY: H. Bray
SURFACE ELEVATION: 45.0 ± feet

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	ELEVATION (feet)
60		Very loose, olive gray, silty, fine to coarse SAND with fine gravels, wet. Massive.	S-16	2-2-2	GS	
65		Dense, reddish black, silty fine SAND, wet. Thinly bedded. **(OLDER ALLUVIUM)**	S-17	12-15-19		-20
70			S-18	14-15-19		-25
	MH					
75		Stiff, olive gray, elastic SILT, wet, with scattered partially decayed woody organics. Thinly bedded.	S-19	3-5-3	AL	-30
	ML					
80		Very stiff, olive gray, slightly fine sandy SILT, wet, non-plastic. Interbedded with lenses of reddish black very silty fine SAND and scattered woody organics,.	S-20	6-8-10		-35
85		Grades to stiff.	S-21	2-4-6	AL	-40
90						



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HWA GEOSCIENCES INC.

PUYALLUP STATION ACCESS IMPROVEMENTS
PUYALLUP, WASHINGTON

BORING:
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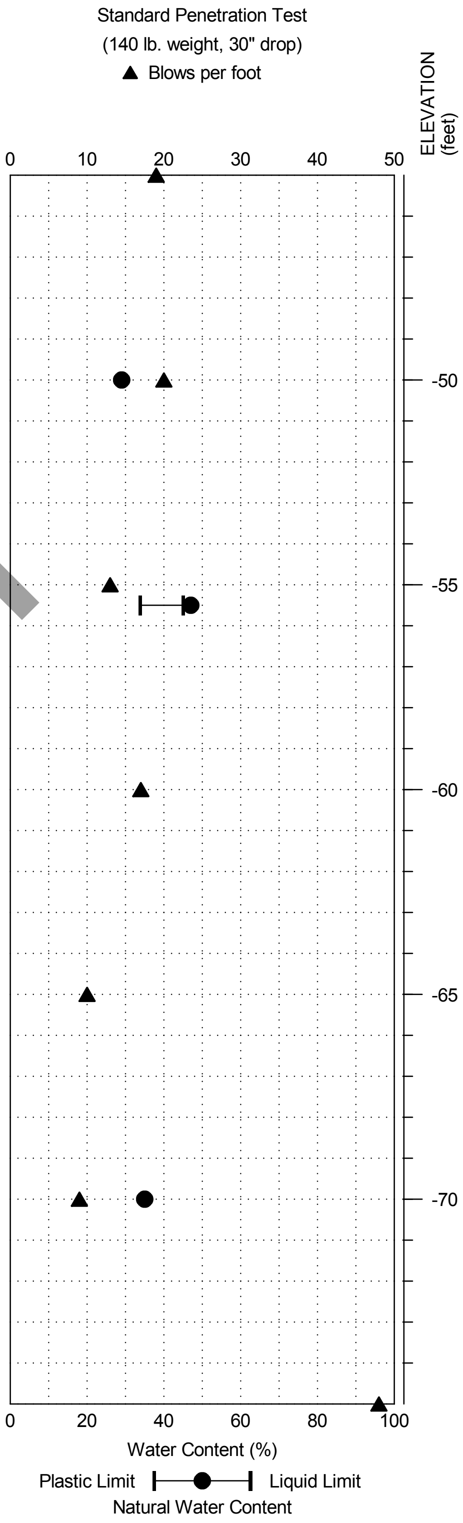
PROJECT NO.: 2013-075-21 FIGURE: A-3

DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Mud Rotary w/ 5" tricone bit
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 9/2/2015
DATE COMPLETED: 9/4/2015
LOGGED BY: H. Bray
SURFACE ELEVATION: 45.0 ± feet

USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS
	Medium dense, reddish black clean fine SAND with interbedded layers of olive gray slightly fine sandy plastic SILT, wet, scattered woody organics.	S-22	10-10-9	
ML	Medium dense, yellowish brown very sandy SILT grades to reddish black silty fine SAND, wet. Scattered woody organics, thinly bedded.	S-23	10-10-10	GS
SP	Medium dense, reddish black clean fine SAND, wet. Scattered woody organics, thinly bedded.	S-24a	14-6-7	
ML	Stiff, olive gray, SILT with brown rust banding, wet. Scattered, partially decayed woody organics, thinly bedded.	S-24b		AL
	No recovery.	S-25	6-7-10	
ML SM	Medium stiff, light olive gray, SILT grades to reddish black slightly silty fine SAND, wet. Scattered, partially decayed rootlets, thinly bedded. Two inch thick white ash layer at 111 feet.	S-26	3-3-7	
SM	Loose, dark olive brown, silty fine SAND with lenses of light brown, very silty fine SAND, wet. Scattered organics, thinly bedded.	S-27	4-5-4	

DEPTH (feet): 90, 95, 100, 105, 110, 115, 120



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PUYALLUP STATION ACCESS IMPROVEMENTS
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BORING:
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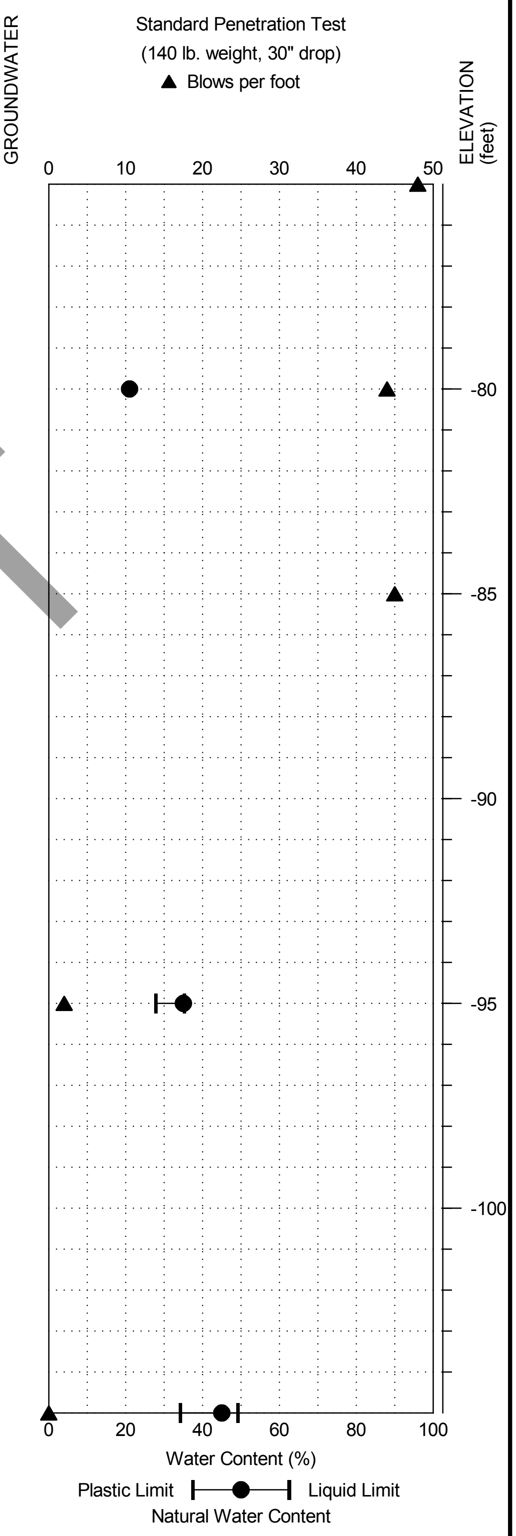
DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Mud Rotary w/ 5" tricone bit
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 9/2/2015
DATE COMPLETED: 9/4/2015
LOGGED BY: H. Bray
SURFACE ELEVATION: 45.0 ± feet

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	ELEVATION (feet)
120	SP SM	Dense, light reddish black, silty fine SAND grades to reddish black, fine to medium fine, slightly silty SAND with brown silt lenses, wet. Thinly bedded.	S-28	19-20-28		
125		Dense, reddish black, fine to medium fine, slightly silty SAND, wet, massive, coarser with depth.	S-29	20-21-23	GS	-80
130			S-30	17-24-21		-85
	ML					
135						-90
140		Soft, light brownish gray, SILT with light brown rust banding, wet. Thinly bedded, scattered organics.	S-31	1-1-1	AL	-95
145						-100
150						



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HWA GEOSCIENCES INC.

PUYALLUP STATION ACCESS IMPROVEMENTS
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BORING:
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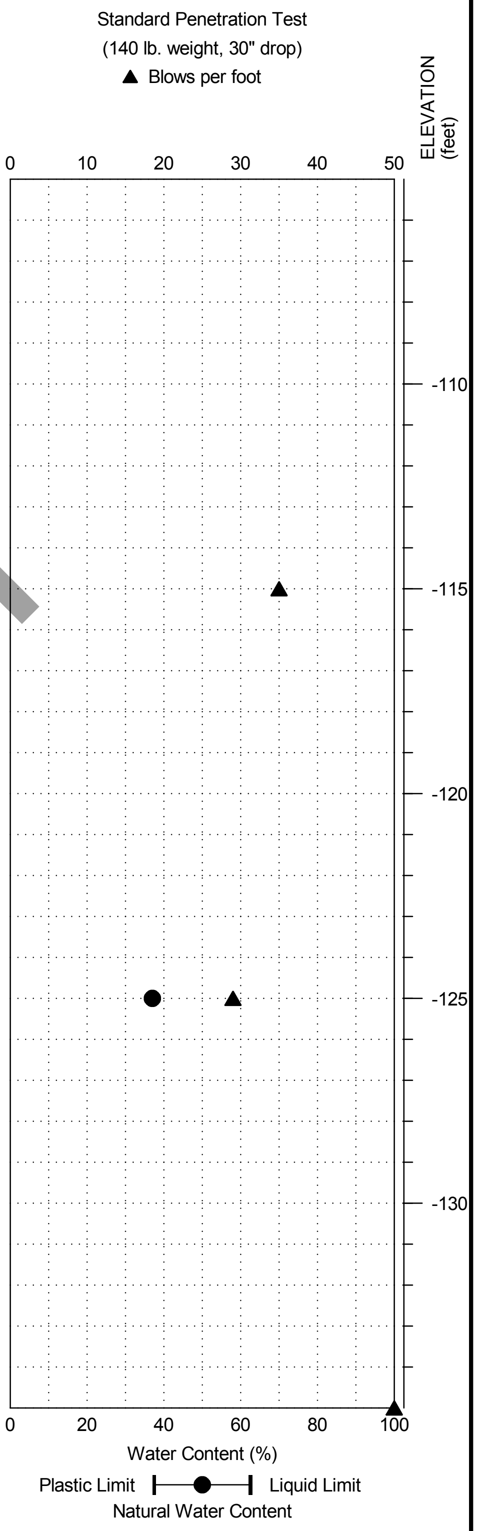
PROJECT NO.: 2013-075-21 FIGURE: A-3

DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Mud Rotary w/ 5" tricone bit
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 9/2/2015
DATE COMPLETED: 9/4/2015
LOGGED BY: H. Bray
SURFACE ELEVATION: 45.0 ± feet

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER	ELEVATION (feet)
150		Weight of the rods. Very soft, olive gray, moderately plastic SILT with brown banding, wet, thinly bedded.	☒	S-32	0/18"	AL		
155								-110
	PT							
160		Stiff to very stiff, very dark brown PEAT. **(PEAT)**	☒	S-33a	8-17-18			-115
	SM	Dense, olive gray, slightly silty fine SAND with lenses of light brown, very silty fine sand, wet. Thinly bedded. **(OLDER RECENT ALLUVIUM)**	☒	S-33b				
165								-120
170		Medium dense, reddish brown slightly silty fine SAND with lenses of very silty fine sand, wet. Thinly bedded.	☒	S-34	8-12-17	GS		-125
175								-130
	SP SM							
180								



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HWA GEOSCIENCES INC.

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PUYALLUP, WASHINGTON

BORING:
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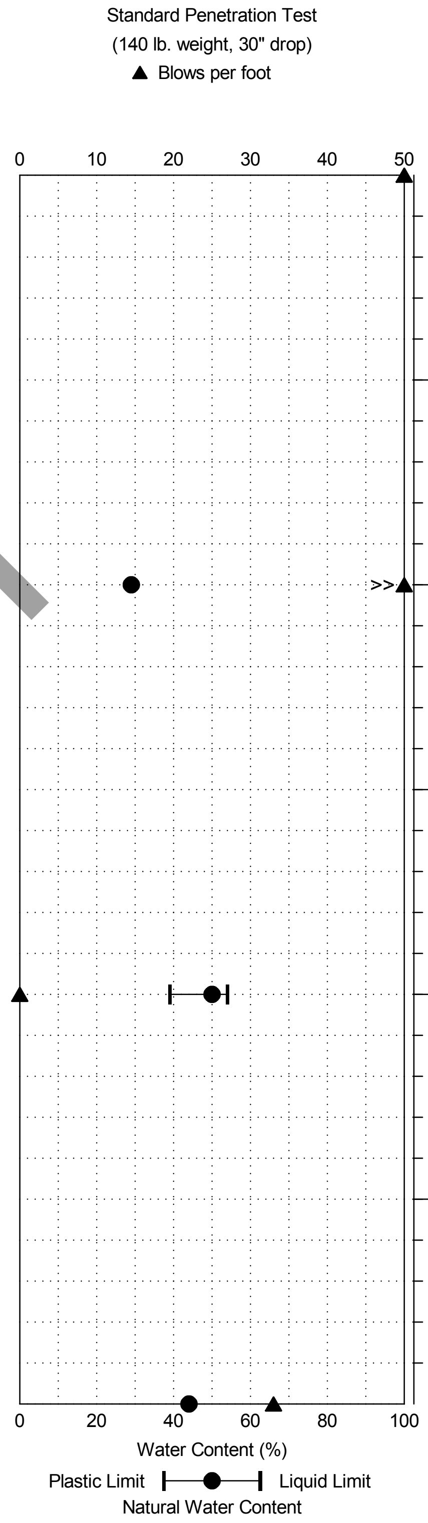
PROJECT NO.: 2013-075-21 FIGURE: A-3

DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Mud Rotary w/ 5" tricone bit
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 9/2/2015
DATE COMPLETED: 9/4/2015
LOGGED BY: H. Bray
SURFACE ELEVATION: 45.0 ± feet

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER	ELEVATION (feet)
180		Very dense, reddish black, fine to medium fine, clean SAND with layers of reddish black, slightly silty, fine sand, wet. Thinly bedded.	☒	S-35	21-23-27			
185								-140
190		Very dense, reddish black, clean, fine SAND with layers of silty fine sand, wet. Thinly bedded.	☒	S-36	19-25-27	GS		-145
	MH							
195								-150
200		Sampler filled without driving by weight of the rods only. Very soft, light olive gray, elastic SILT with light brown rust banding, wet, plastic. Scattered decayed woody organics, thinly bedded.	☒	S-37	0/18"	AL		-155
205								-160
	SM							
210								



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HWA GEOSCIENCES INC.

PUYALLUP STATION ACCESS IMPROVEMENTS
PUYALLUP, WASHINGTON

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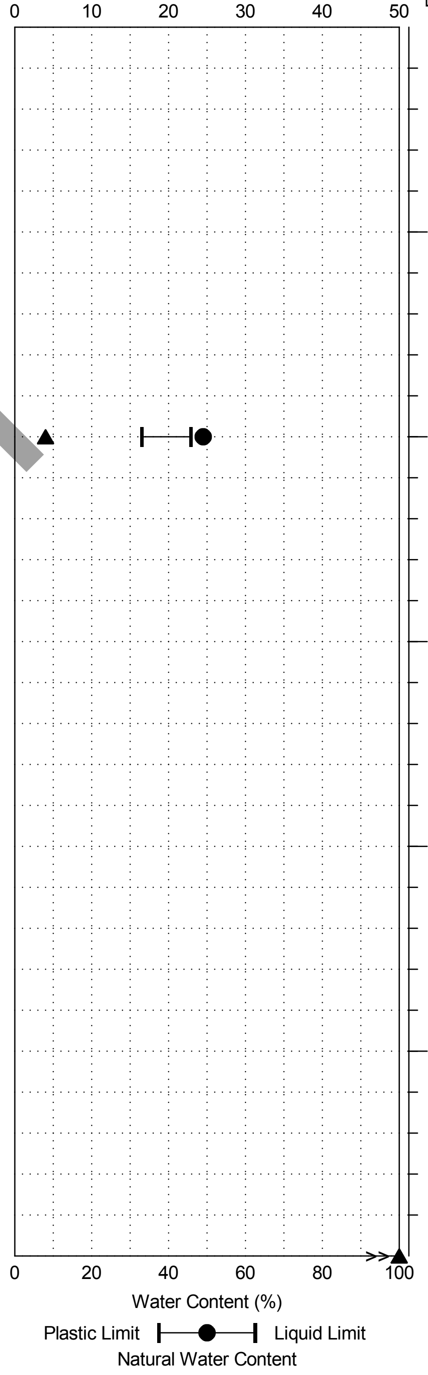
PROJECT NO.: 2013-075-21 FIGURE: A-3

DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Mud Rotary w/ 5" tricone bit
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 9/2/2015
DATE COMPLETED: 9/4/2015
LOGGED BY: H. Bray
SURFACE ELEVATION: 45.0 ± feet

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER	ELEVATION (feet)
210		Dense, olive gray, sandy SILT with layers of very silty fine sand interbedded, wet. Thinly bedded, large chunks of decayed woody organics.	S-38	3-15-18			
215	ML						-170
220		Soft, olive to bluish gray, SILT, wet and plastic. Contains a one inch lens of very silty fine sand and some partially decayed woody organics. Thinly bedded.	S-39	0-0-4	AL		-175
225							-180
	SP SM						
230		Driller notes that dense drilling at 230 feet bgs changed to very hard drilling at 237 feet bgs.					-185
235							-190
240							

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



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HWA GEOSCIENCES INC.

PUYALLUP STATION ACCESS IMPROVEMENTS
PUYALLUP, WASHINGTON

BORING:
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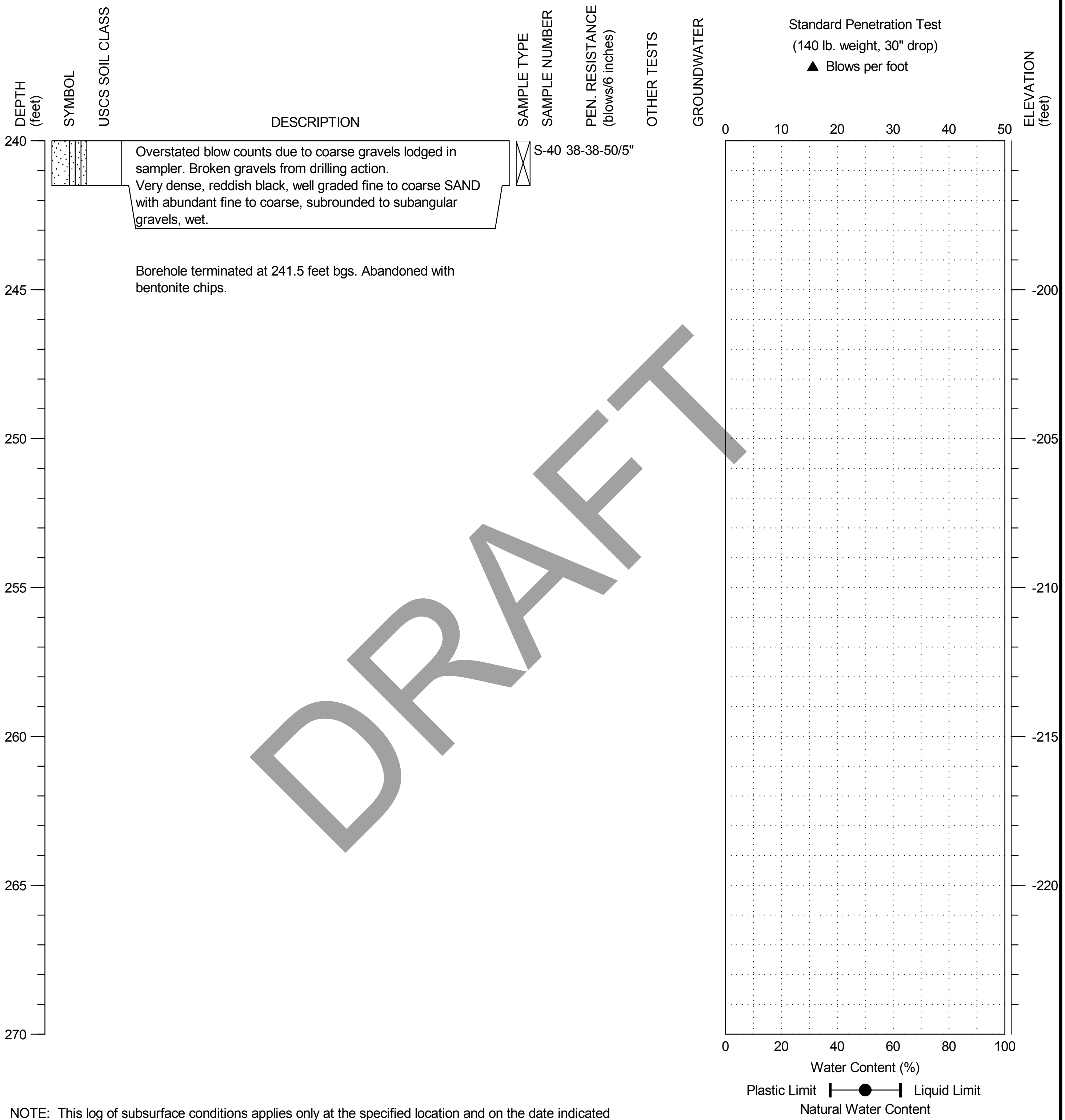
PROJECT NO.: 2013-075-21 FIGURE: A-3

DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Mud Rotary w/ 5" tricone bit
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 9/2/2015
DATE COMPLETED: 9/4/2015
LOGGED BY: H. Bray
SURFACE ELEVATION: 45.0 ± feet



Overstated blow counts due to coarse gravels lodged in sampler. Broken gravels from drilling action.
Very dense, reddish black, well graded fine to coarse SAND with abundant fine to coarse, subrounded to subangular gravels, wet.

Borehole terminated at 241.5 feet bgs. Abandoned with bentonite chips.

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HWA GEOSCIENCES INC.

PUYALLUP STATION ACCESS IMPROVEMENTS
PUYALLUP, WASHINGTON

BORING:
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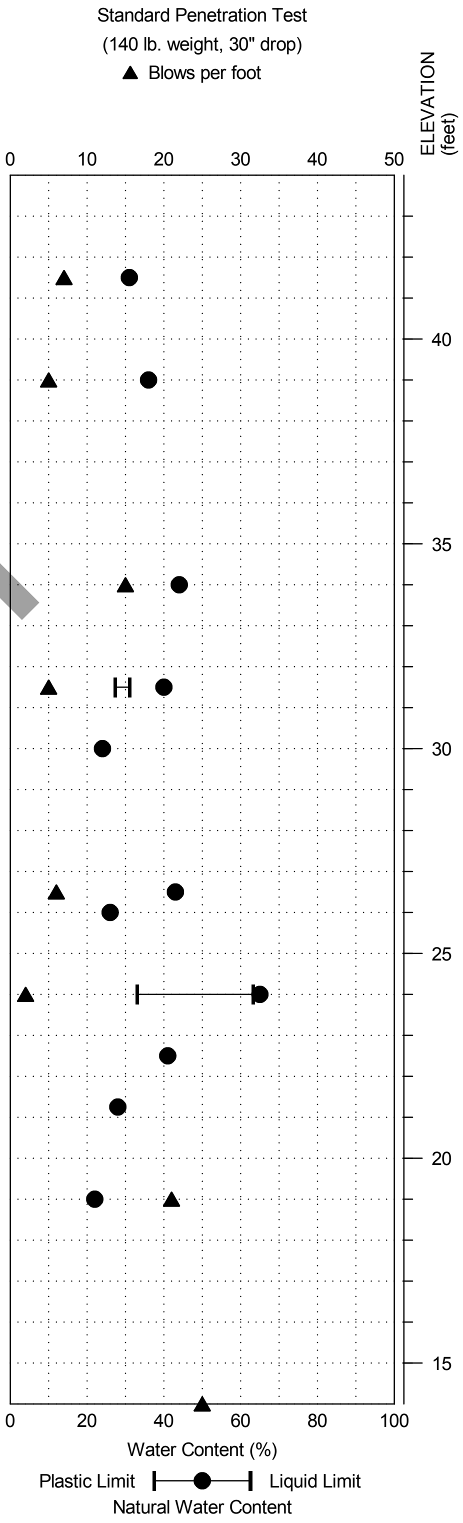
PROJECT NO.: 2013-075-21 FIGURE: A-3

DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Mud Rotary w/ 5" tricone bit
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 10/12/2015
DATE COMPLETED: 10/13/2015
LOGGED BY: H. Bray
SURFACE ELEVATION: 44.0 ± feet

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS
0	ML	3 inches A.C.P.			
		Loose, light yellowish brown, very fine sandy SILT, moist. Thinly bedded with some red rust banding and scattered woody organics. **(RECENT ALLUVIUM)**	S-1	4-3-4	
5		Loose, dark brown grades to light olive gray, very fine sandy SILT, wet. Thinly bedded with red rust banding and some silt lenses.	S-2	3-2-3	
		No recovery.	S-3		
10	ML	Very stiff, dark olive gray, SILT, wet, with layer of green, very silty, sand, moist. Thinly bedded.	S-4	5-7-8	
	ML	Medium stiff, light olive brown, SILT grades to loose, light olive gray, very silty fine SAND, moist. Thinly bedded, scattered woody organics.	S-5	1-2-3	AL
	ML	Medium stiff, dark olive gray, SILT, scattered rootlets, moist.	S-6		GS
15	SM	Loose, reddish black, silty, fine to medium fine SAND, wet. Thinly bedded, contains scattered rootlets, becomes cleaner with depth.			
	ML	Medium stiff, light olive brown, SILT, wet. Thinly bedded.	S-7a	0-1-5	
	SP	Loose, reddish black, fine to medium fine SAND, wet. Thinly bedded.	S-7b		
20	MH	Soft, light gray, elastic SILT, wet, scattered woody debris. Thinly bedded.	S-8	0-1-1	AL
	ML	Soft, dark olive brown, non-plastic SILT, wet.	S-9a		DD DS
	SM	Very loose, reddish dark olive brown, very silty, fine SAND, wet.	S-9b		DD DS
25		Medium dense, reddish black, fine to coarse silty SAND, wet. Thinly bedded.	S-10	9-10-11	GS
	SP SM				
30					



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HWA GEOSCIENCES INC.

PUYALLUP STATION ACCESS IMPROVEMENTS
PUYALLUP, WASHINGTON

BORING:
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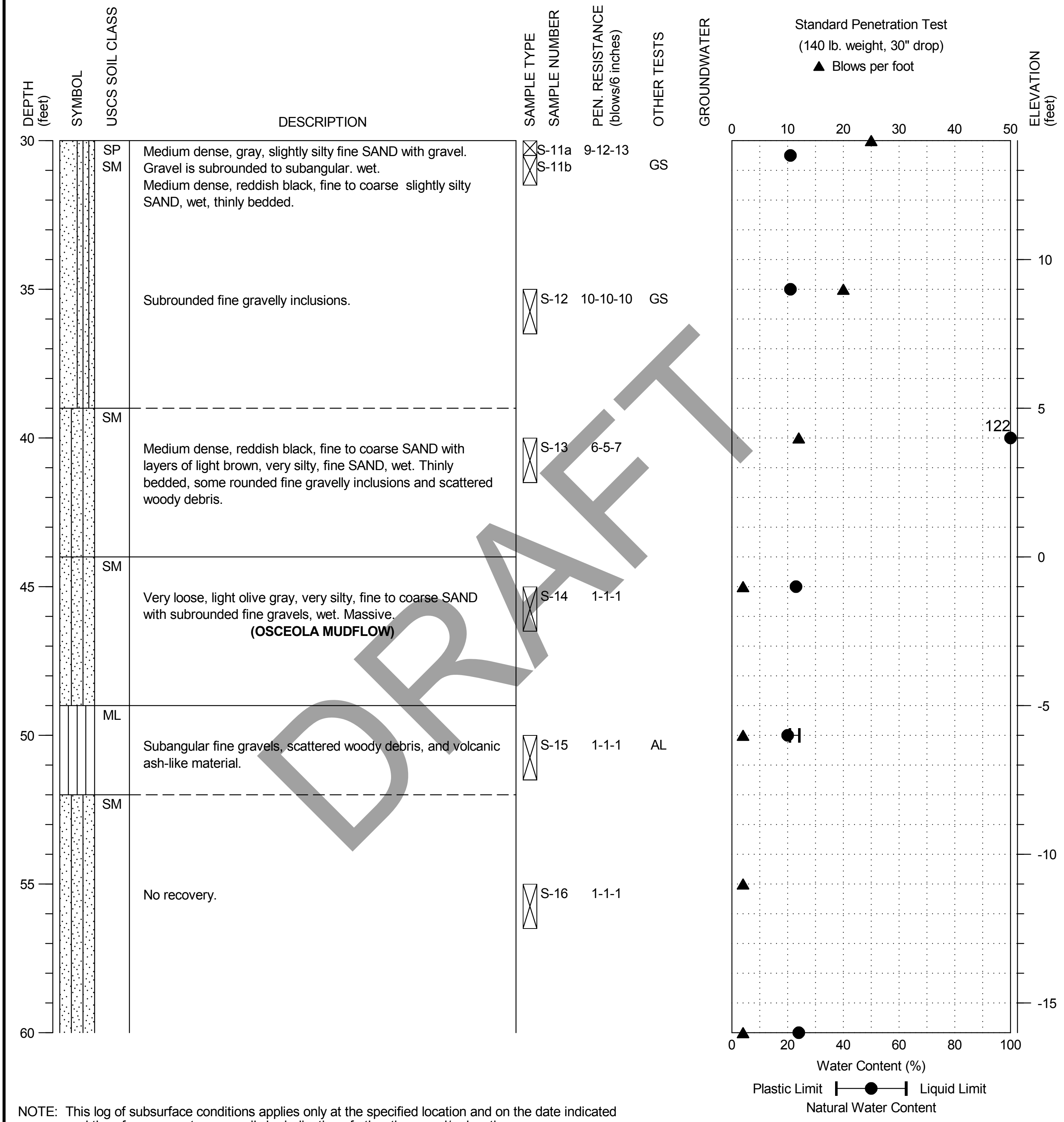
PROJECT NO.: 2013-075-21 FIGURE: A-4

DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Mud Rotary w/ 5" tricone bit
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 10/12/2015
DATE COMPLETED: 10/13/2015
LOGGED BY: H. Bray
SURFACE ELEVATION: 44.0 ± feet

USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS
SP SM	Medium dense, gray, slightly silty fine SAND with gravel. Gravel is subrounded to subangular. wet. Medium dense, reddish black, fine to coarse slightly silty SAND, wet, thinly bedded.	S-11a S-11b	9-12-13	GS
	Subrounded fine gravelly inclusions.	S-12	10-10-10	GS
SM	Medium dense, reddish black, fine to coarse SAND with layers of light brown, very silty, fine SAND, wet. Thinly bedded, some rounded fine gravelly inclusions and scattered woody debris.	S-13	6-5-7	
SM	Very loose, light olive gray, very silty, fine to coarse SAND with subrounded fine gravels, wet. Massive. **(OSCEOLA MUDFLOW)**	S-14	1-1-1	
ML	Subangular fine gravels, scattered woody debris, and volcanic ash-like material.	S-15	1-1-1	AL
SM	No recovery.	S-16	1-1-1	



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HWA GEOSCIENCES INC.

PUYALLUP STATION ACCESS IMPROVEMENTS
PUYALLUP, WASHINGTON

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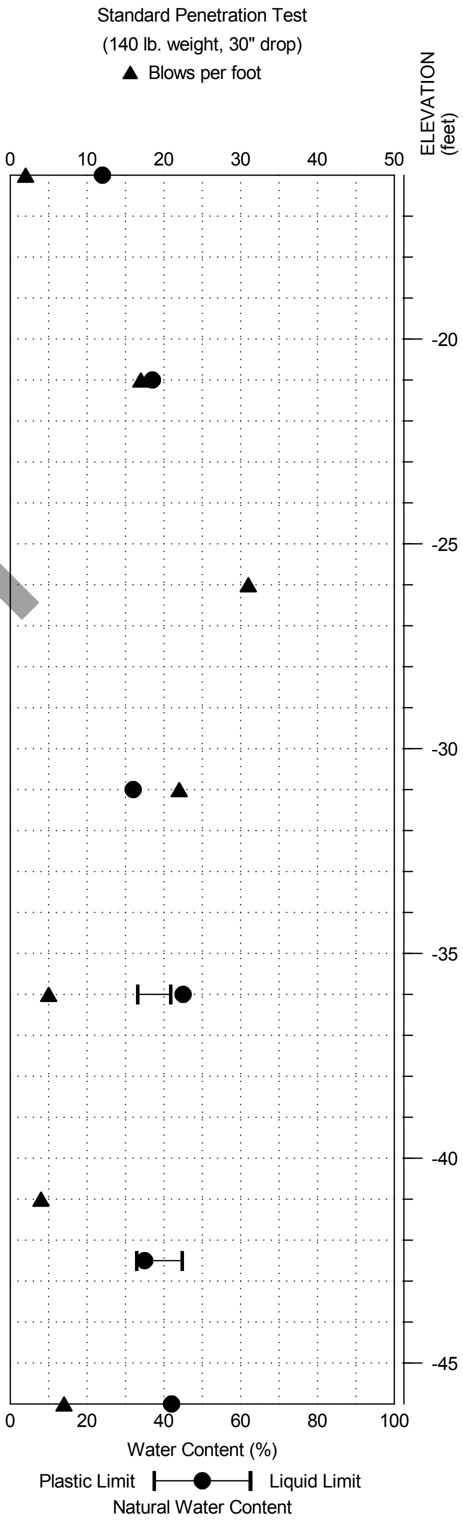
PROJECT NO.: 2013-075-21 FIGURE: A-4

DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Mud Rotary w/ 5" tricone bit
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 10/12/2015
DATE COMPLETED: 10/13/2015
LOGGED BY: H. Bray
SURFACE ELEVATION: 44.0 ± feet

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
60		Coarse gravels, scattered woody debris, and ash tuffs.	S-17	1-1-1	GS	
	ML					
65		Medium dense, reddish black, sandy SILT with slightly silty, fine to medium fine SAND, wet. Thinly bedded with scattered woody debris. **(OLDER ALLUVIUM)**	S-18	9-9-8	GS	
	SP SM					
70		Dense, reddish black, fine to medium fine SAND, wet, thinly bedded.	S-19	12-15-16		
	ML					
75		Medium dense, reddish black, silty fine SAND with light brown silt laminations, wet, thinly bedded.	S-20	8-10-12	GS	
80		Medium stiff, light olive gray, SILT with light brown banding, wet, thinly bedded, scattered organics and woody debris.	S-21	1-2-3	AL	
		Shelby. No recovery.	S-22			
85		Medium stiff, light olive gray, SILT, wet, thinly bedded.	S-23	2-2-2		
			S-24		AL DD DS	
	ML	Loose, dark olive gray, slightly fine sandy SILT grades to dark olive gray, very silty fine SAND, wet.				
90						



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HWA GEOSCIENCES INC.

PUYALLUP STATION ACCESS IMPROVEMENTS
PUYALLUP, WASHINGTON

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PROJECT NO.: 2013-075-21 FIGURE: A-4

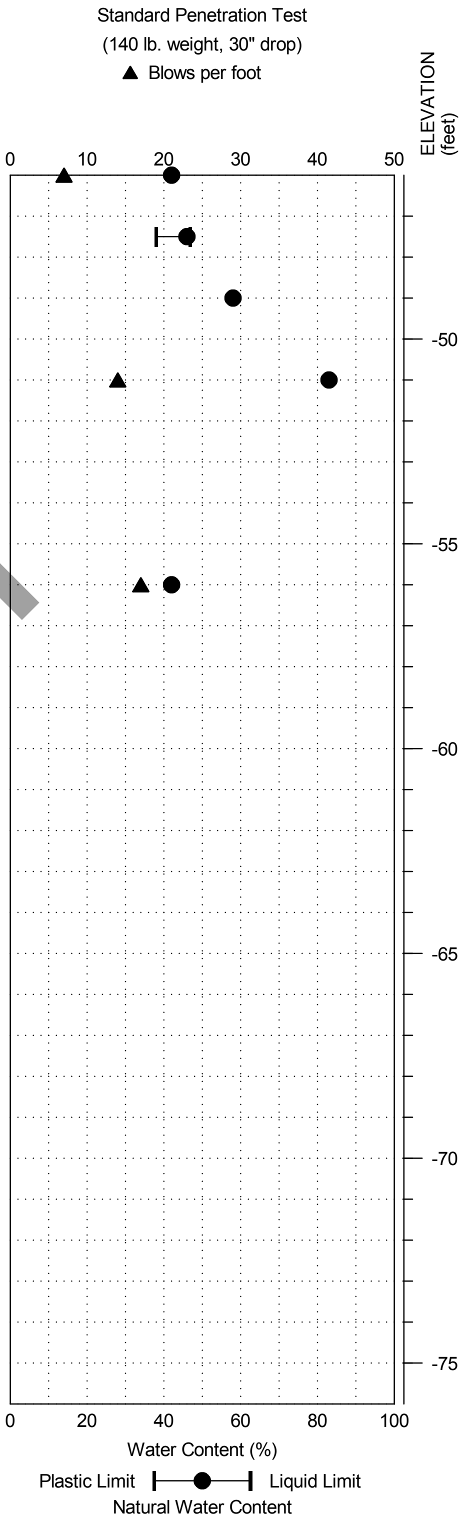
DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Mud Rotary w/ 5" tricone bit
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 10/12/2015
DATE COMPLETED: 10/13/2015
LOGGED BY: H. Bray
SURFACE ELEVATION: 44.0 ± feet

USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS
ML	Medium stiff, light brown, SILT, with 3 inch layer of reddish black, very silty, fine to medium sand, wet. Contains scattered organics, thinly bedded. Loose, dark olive gray, very silty fine SAND grades to dark olive gray, slightly fine sandy SILT, organic laminations, wet.	S-25 S-26a S-26b	6-5-2	AL DD DS %F DD DS
SP SM	Medium dense, light brown grades to reddish black, slightly silty, fine to medium fine SAND, wet. Contains some silt lenses and becomes coarser with depth.	S-27	12-9-5	
ML	Very stiff, light olive gray, non-plastic SILT, wet. Thinly bedded, light brown rust banding and scattered organics.	S-28a	5-7-10	
SP SM	Medium dense, reddish black, slightly silty fine SAND, wet. Thinly bedded.	S-28b		

Borehole terminated at 101.5 feet.
Abandoned with bentonite chips.

DEPTH (feet): 90, 95, 100, 105, 110, 115, 120



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HWA GEOSCIENCES INC.

PUYALLUP STATION ACCESS IMPROVEMENTS
PUYALLUP, WASHINGTON

BORING:
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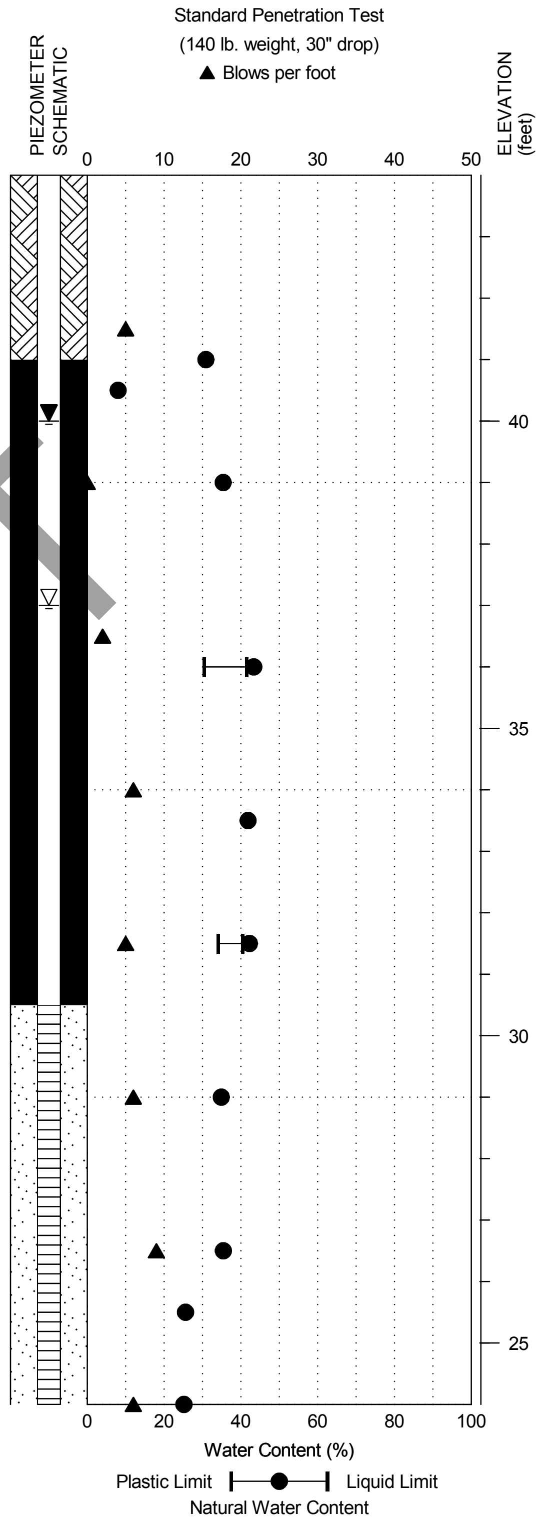
PROJECT NO.: 2013-075-21 FIGURE: A-4

DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Hollow Stem Auger
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 10/13/2015
DATE COMPLETED: 10/13/2015
LOGGED BY: H. Bray
SURFACE ELEVATION: 44.0 ± feet

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS
0		3 inches A.C.P.			
	ML	Loose, dark brown, very silty, fine to coarse, sandy SILT with subrounded fine gravels, moist. **(FILL)**	S-1a	1-2-3	
	ML	Medium stiff, light olive gray, non-plastic SILT, moist. Minor rust banding and scattered organics. **(RECENT ALLUVIUM)**	S-1b		
	SP SM	Loose, light brown, slightly silty fine SAND, moist. Thinly bedded with minor rust banding.	S-1c		
5	SM	Very loose, light olive gray, very silty fine SAND, wet. Thinly bedded with minor rust banding and scattered organics.	S-2	1-0-0	
		Very loose, light brown, very silty fine SAND, wet. Thinly bedded.	S-3a	1-0-2	
	ML	Very loose, light olive gray, very silty fine SAND, wet. Thinly bedded with scattered organic and silty interbeds.	S-3b		AL
10	SM	Loose, light brown, very silty fine SAND, wet. Thinly bedded.	S-4a	1-3-3	
	ML	Medium stiff, light olive gray, non-plastic SILT grades to very silty fine SAND, wet, Thinly bedded with scattered organics.	S-4b		GS
		Medium stiff, dark olive gray, fine sandy SILT grades to medium dense, light olive gray, very silty fine SAND, some coarse sand lenses, wet. Contains scattered organics and is thinly bedded.	S-5	2-2-3	AL
15		Medium stiff, dark olive gray, fine sandy SILT grades to loose, light brown, very silty, fine to medium fine SAND, wet. Thinly bedded and contains scattered organics.	S-6	3-2-4	
		Stiff, light olive gray, slightly fine sandy SILT, grades to reddish black, very silty fine SAND, wet. Thinly bedded and contains scattered organics.	S-7a	3-4-5	
	SP SM	Loose, reddish black, fine to medium slightly silty SAND, wet. Thinly bedded.	S-7b		
20					



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HWA GEOSCIENCES INC.

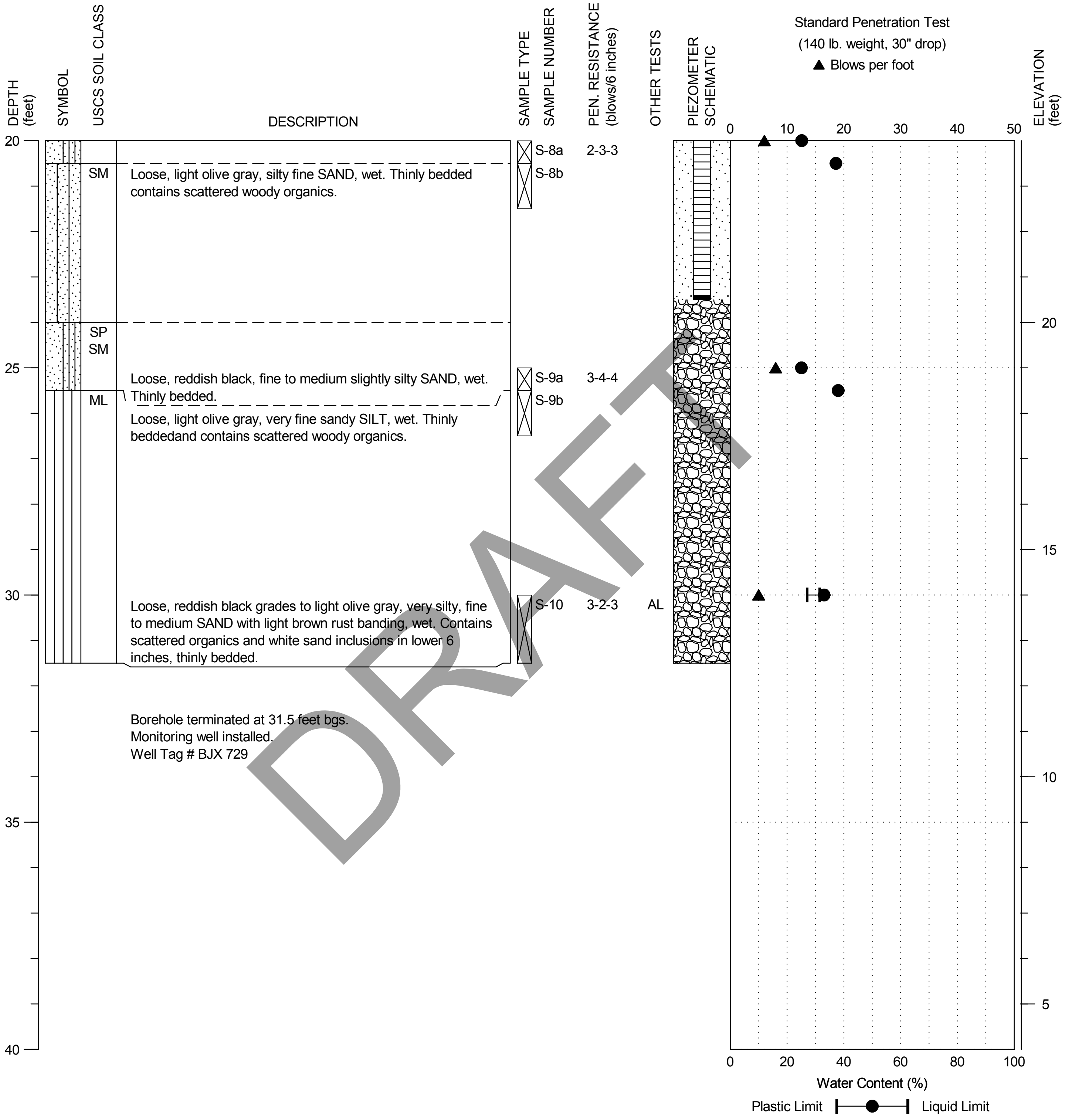
PUYALLUP STATION ACCESS IMPROVEMENTS
PUYALLUP, WASHINGTON

BORING:
BH-4

PROJECT NO.: 2013-075-21 FIGURE: A-5

DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Hollow Stem Auger
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 10/13/2015
DATE COMPLETED: 10/13/2015
LOGGED BY: H. Bray
SURFACE ELEVATION: 44.0 ± feet



DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS
20			S-8a	2-3-3	
	SM	Loose, light olive gray, silty fine SAND, wet. Thinly bedded contains scattered woody organics.	S-8b		
	SP SM				
25		Loose, reddish black, fine to medium slightly silty SAND, wet. Thinly bedded.	S-9a	3-4-4	
	ML	Loose, light olive gray, very fine sandy SILT, wet. Thinly beddedand contains scattered woody organics.	S-9b		
30		Loose, reddish black grades to light olive gray, very silty, fine to medium SAND with light brown rust banding, wet. Contains scattered organics and white sand inclusions in lower 6 inches, thinly bedded.	S-10	3-2-3	AL

Borehole terminated at 31.5 feet bgs.
Monitoring well installed.
Well Tag # BJX 729

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HWA GEOSCIENCES INC.

PUYALLUP STATION ACCESS IMPROVEMENTS
PUYALLUP, WASHINGTON

BORING:
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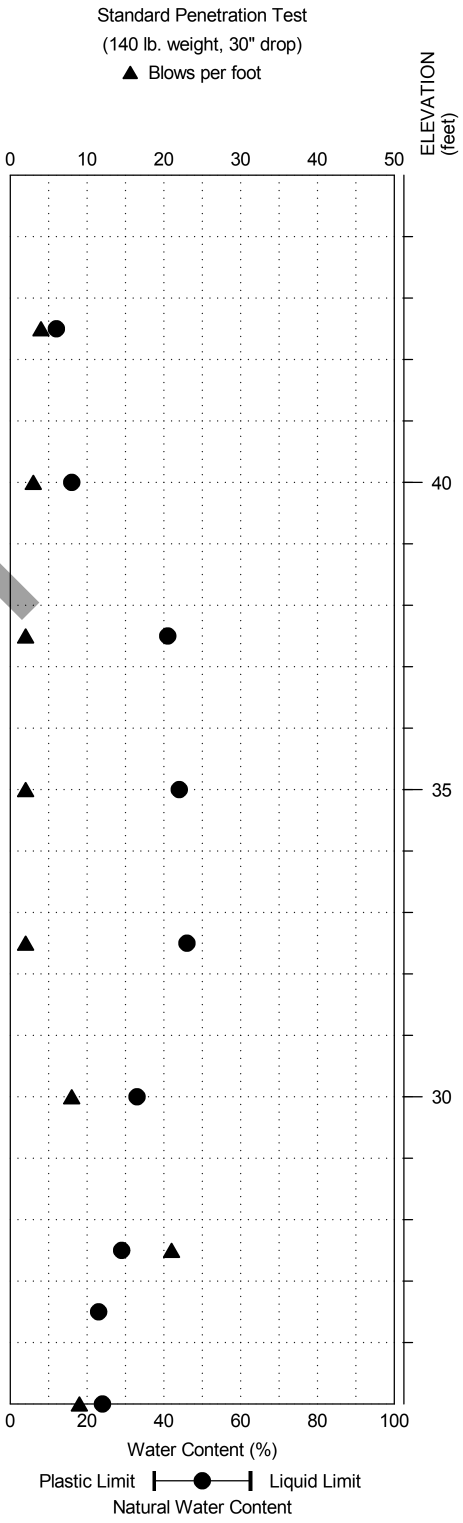
PROJECT NO.: 2013-075-21 FIGURE: A-5

DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Hollow Stem Auger
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 10/16/2015
DATE COMPLETED: 10/16/2015
LOGGED BY: H. Bray
SURFACE ELEVATION: 45.0 ± feet

DEPTH (feet)	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER	ELEVATION (feet)
0	SM	Very loose, dark brown, very silty, fine to coarse SAND with subrounded to subangular fine gravels, moist. Massive, contains scattered rootlets. **(FILL)**						
		Loose, light brown, very silty, fine to coarse SAND with subrounded fine gravels, moist. Scattered rootlets.	☒	S-1	2-2-2			
5	SM	Very loose, dark brown, very silty, fine to coarse SAND with subangular fine gravels, moist. Thinly bedded, with rust banding, scattered organics, coal fragments, and fibrous woody organics.	☒	S-2	2-1-2	GS		40
	ML SM	Very loose, light olive gray, very silty fine SAND grades to very soft, light olive gray, slightly fine sandy SILT, wet, thinly bedded, scattered organics. (RECENT ALLUVIUM)	☒	S-3	0-1-1		∇	
10		Grades to light brown.	☒	S-4	1-1-1			35
		Soft, light olive gray, slightly fine sandy SILT with layers of very silty, fine to coarse SAND, wet. Scattered organics.	☒	S-5	2-1-1			
15	SM	Loose, dark olive gray grades to dark brown, very silty fine SAND with subrounded fine gravel inclusions, wet. Thinly bedded with scattered organics.	☒	S-6	2-1-7			30
	SM	Medium dense, reddish black, very silty, fine the medium fine SAND with silt layers, wet. Thinly bedded with scattered woody organics.	☒	S-7a	5-10-11	GS		
	SP SM	Medium dense, reddish black, slightly silty fine SAND, wet. Thinly bedded.	☒	S-7b				
20	SM	Loose, dark grayish brown, silty SAND, wet.						



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HWA GEOSCIENCES INC.

PUYALLUP STATION ACCESS IMPROVEMENTS
PUYALLUP, WASHINGTON

BORING:
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PAGE: 1 of 2

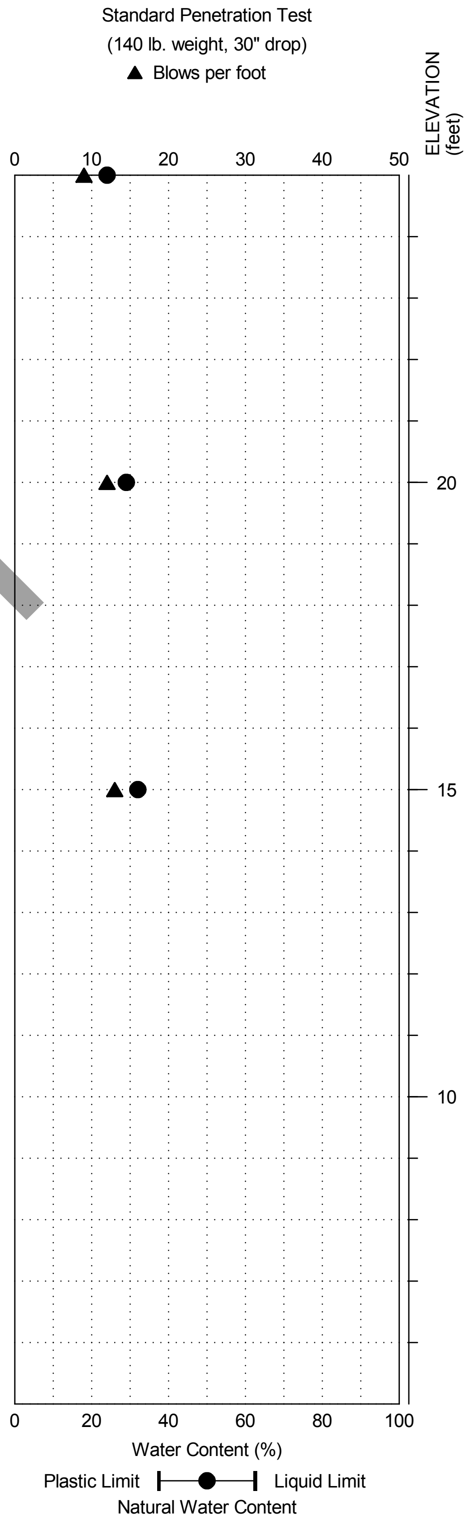
PROJECT NO.: 2013-075-21 FIGURE: A-6

DRILLING COMPANY: Holocene Drilling
DRILLING METHOD: BK-81 Truck Rig, Hollow Stem Auger
SAMPLING METHOD: SPT w/ Autohammer; Shelby Tube
LOCATION: See Figure 2A

DATE STARTED: 10/16/2015
DATE COMPLETED: 10/16/2015
LOGGED BY: H. Bray
SURFACE ELEVATION: 45.0 ± feet

DEPTH (feet)	SYMBOL	USCS SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
20			Loose, reddish black, slightly silty, fine to medium fine SAND with dark brown silt lenses, wet. Thinly bedded.	☒	S-8	4-3-6	GS	
		ML						
25			Medium dense, light reddish gray, fine sandy SILT grades to very silty fine SAND, wet. Contians thin silt lenses in the lower 6 inches.	☒	S-9	8-8-4		
30			Medium dense, light reddish gray, very silty fine SAND with silt lenses to fine sandy SILT, wet. Thinly bedded.	☒	S-10	3-6-7	GS	
35								
40								

Borehole terminated at 31.5 feet bgs.
Abandoned with bentonite chips.



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

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PUYALLUP STATION ACCESS IMPROVEMENTS
PUYALLUP, WASHINGTON

BORING:
BH-5

PAGE: 2 of 2

PROJECT NO.: 2013-075-21 FIGURE: A-6

RELATIVE DENSITY OR CONSISTENCY VERSUS SPT N-VALUE

COHESIONLESS SOILS			COHESIVE SOILS		
Density	N (blows/ft)	Approximate Relative Density(%)	Consistency	N (blows/ft)	Approximate Undrained Shear Strength (psf)
Very Loose	0 to 4	0 - 15	Very Soft	0 to 2	<250
Loose	4 to 10	15 - 35	Soft	2 to 4	250 - 500
Medium Dense	10 to 30	35 - 65	Medium Stiff	4 to 8	500 - 1000
Dense	30 to 50	65 - 85	Stiff	8 to 15	1000 - 2000
Very Dense	over 50	85 - 100	Very Stiff	15 to 30	2000 - 4000
			Hard	over 30	>4000

USCS SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GROUP DESCRIPTIONS	
Coarse Grained Soils More than 50% Retained on No. 200 Sieve Size	Gravel and Gravelly Soils More than 50% of Coarse Fraction Retained on No. 4 Sieve	Clean Gravel (little or no fines)	GW	Well-graded GRAVEL
			GP	Poorly-graded GRAVEL
		Gravel with Fines (appreciable amount of fines)	GM	Silty GRAVEL
			GC	Clayey GRAVEL
	Sand and Sandy Soils 50% or More of Coarse Fraction Passing No. 4 Sieve	Clean Sand (little or no fines)	SW	Well-graded SAND
			SP	Poorly-graded SAND
		Sand with Fines (appreciable amount of fines)	SM	Silty SAND
			SC	Clayey SAND
Fine Grained Soils 50% or More Passing No. 200 Sieve Size	Silt and Clay	Liquid Limit Less than 50%	ML	SILT
			CL	Lean CLAY
			OL	Organic SILT/Organic CLAY
	Silt and Clay	Liquid Limit 50% or More	MH	Elastic SILT
			CH	Fat CLAY
			OH	Organic SILT/Organic CLAY
Highly Organic Soils			PT	PEAT

TEST SYMBOLS

%F	Percent Fines
AL	Atterberg Limits: PL = Plastic Limit LL = Liquid Limit
CBR	California Bearing Ratio
CN	Consolidation
DD	Dry Density (pcf)
DS	Direct Shear
GS	Grain Size Distribution
K	Permeability
MD	Moisture/Density Relationship (Proctor)
MR	Resilient Modulus
PID	Photoionization Device Reading
PP	Pocket Penetrometer Approx. Compressive Strength (tsf)
SG	Specific Gravity
TC	Triaxial Compression
TV	Torvane Approx. Shear Strength (tsf)
UC	Unconfined Compression

SAMPLE TYPE SYMBOLS

⊠	2.0" OD Split Spoon (SPT) (140 lb. hammer with 30 in. drop)
I	Shelby Tube
⊡	3.0" OD Split Spoon with Brass Rings
○	Small Bag Sample
▚	Large Bag (Bulk) Sample
▯	Core Run
⧄	Non-standard Penetration Test (with split spoon sampler)

GROUNDWATER SYMBOLS

▽	Groundwater Level (measured at time of drilling)
▼	Groundwater Level (measured in well or open hole after water level stabilized)

COMPONENT DEFINITIONS

COMPONENT	SIZE RANGE
Boulders	Larger than 12 in
Cobbles	3 in to 12 in
Gravel	3 in to No 4 (4.5mm)
Coarse gravel	3 in to 3/4 in
Fine gravel	3/4 in to No 4 (4.5mm)
Sand	No. 4 (4.5 mm) to No. 200 (0.074 mm)
Coarse sand	No. 4 (4.5 mm) to No. 10 (2.0 mm)
Medium sand	No. 10 (2.0 mm) to No. 40 (0.42 mm)
Fine sand	No. 40 (0.42 mm) to No. 200 (0.074 mm)
Silt and Clay	Smaller than No. 200 (0.074mm)

COMPONENT PROPORTIONS

PROPORTION RANGE	DESCRIPTIVE TERMS
< 5%	Clean
5 - 12%	Slightly (Clayey, Silty, Sandy)
12 - 30%	Clayey, Silty, Sandy, Gravelly
30 - 50%	Very (Clayey, Silty, Sandy, Gravelly)

Components are arranged in order of increasing quantities.

NOTES: Soil classifications presented on exploration logs are based on visual and laboratory observation in general accordance with ASTM D 2487 and ASTM D 2488. Soil descriptions are presented in the following general order:

Density/consistency, color, modifier (if any) GROUP NAME, additions to group name (if any), moisture content. Proportion, gradation, and angularity of constituents, additional comments. (GEOLOGIC INTERPRETATION)

Please refer to the discussion in the report text as well as the exploration logs for a more complete description of subsurface conditions.

MOISTURE CONTENT

DRY	Absence of moisture, dusty, dry to the touch.
MOIST	Damp but no visible water.
WET	Visible free water, usually soil is below water table.

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PUYALLUP COMMUTER RAIL STATION
PUYALLUP, WASHINGTON

LEGEND OF TERMS AND SYMBOLS USED ON EXPLORATION LOGS

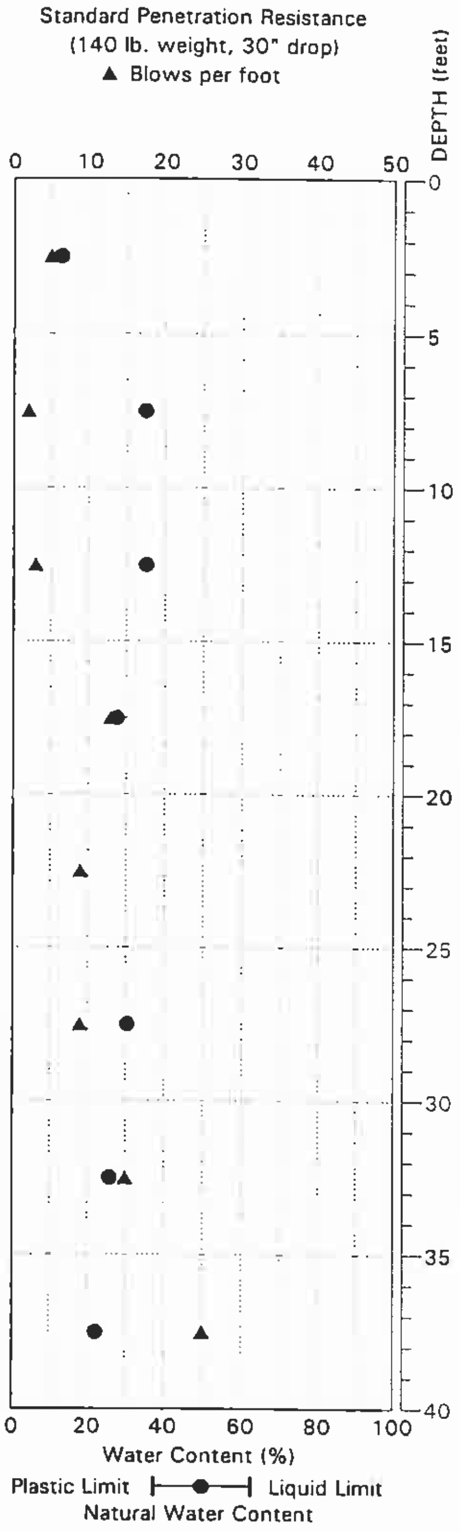
PROJECT NO.: 98156

FIGURE: A-1

DRILLING COMPANY: HOLOCENE DRILLING
DRILLING METHOD: MOBILE B-61, HOLLOW STEM AUGER
SURFACE ELEVATION: 45 ± Feet

LOCATION: See site plan.
DATE COMPLETED: 1/28/99
LOGGED BY: MLR

DEPTH (feet)	SYMBOL	ASTM SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
0		SM	Loose, dark reddish-brown, silty fine to medium SAND, moist. (ALLUVIUM)	☒	S-1	3-2-3	GS	
5		SM ML	Loose to soft, grayish-brown, interbedded very silty, fine to medium SAND and slightly fine sandy SILT, moist to wet.	☒	S-2	0-1-1		
				☒	S-3	2-2-1		∇
15		SM	Medium dense, dark gray to black, silty fine to medium SAND, moist. Sand grains are mostly black with occasional red grains.	☒	S-4	4-5-8		
			No recovery of sample.		S-5	4-5-4		
		SM ML	Stiff to loose, gray, fine sandy SILT grading to silty fine SAND at tip, moist.	☒	S-6	5-4-5		
30		SM ML	Medium dense, dark gray, silty fine to medium SAND, wet.	☒	S-7	6-6-9		
			Grades to reddish dark gray, slightly gravelly, slightly silty, fine to coarse SAND.	☒	S-8	8-11-14		
40								



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

HWA GEOSCIENCES INC.

PUYALLUP COMMUTER RAIL STATION
PUYALLUP, WASHINGTON

BORING: BH-2

PAGE: 1 of 2

PROJECT NO.: 98156

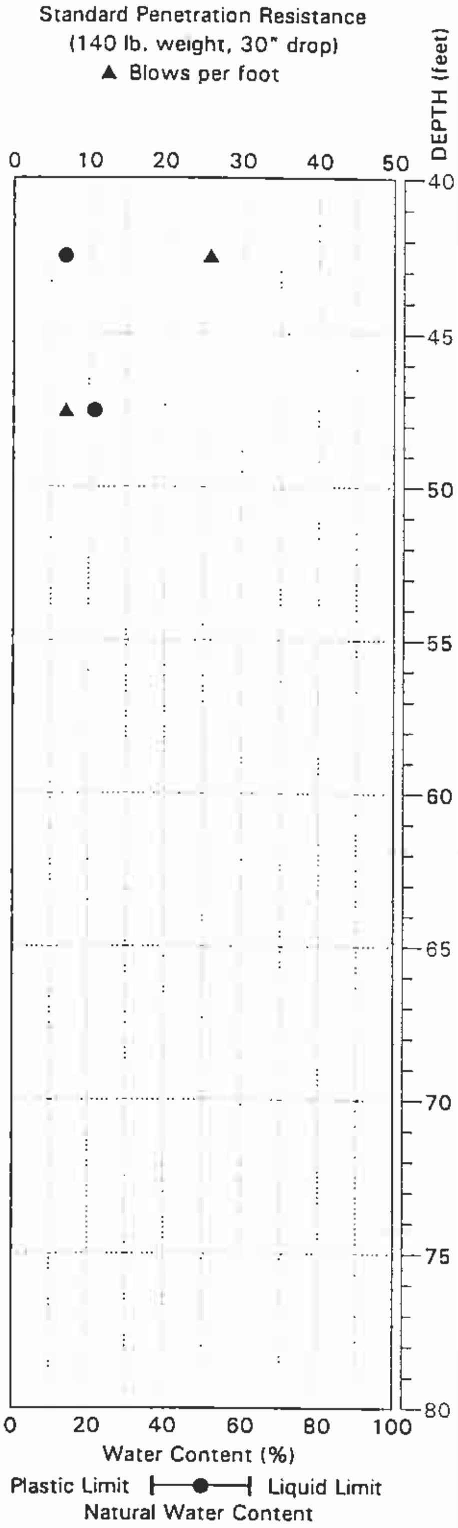
FIGURE: A-3

DRILLING COMPANY: HOLOCENE DRILLING
DRILLING METHOD: MOBILE B-61, HOLLOW STEM AUGER
SURFACE ELEVATION: 45 ± Feet

LOCATION: See site plan.
DATE COMPLETED: 1/28/99
LOGGED BY: MLR

DEPTH (feet)	SYMBOL	ASTM SOIL CLASS	DESCRIPTION	SAMPLE TYPE	SAMPLE NUMBER	PEN. RESISTANCE (blows/6 inches)	OTHER TESTS	GROUNDWATER
40		SM	Medium dense, dark gray, silty fine to medium SAND, wet.	☒	S-9	4-10-16		
45		ML	Medium stiff, gray, slightly fine gravelly, fine to coarse sandy SILT, moist to wet. (MUDFLOW)	☒	S-10	3-3-4		

Bottom of boring at 49 feet.
Free water observed at approximately 13.5 feet and 32 feet.



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

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PUYALLUP COMMUTER RAIL STATION
PUYALLUP, WASHINGTON

BORING: BH-2

PAGE: 2 of 2

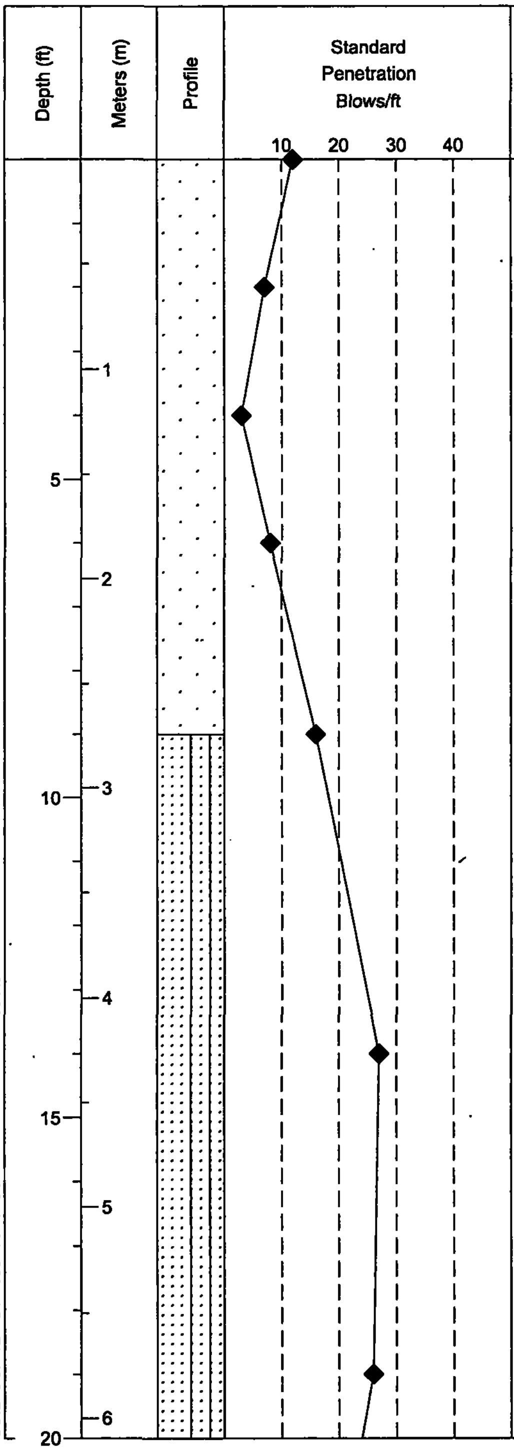
PROJECT NO.: 98156

FIGURE: A-3

Washington State
Department of Transportation

LOG OF TEST BORING

Job No. 0L-3432
SR 167
HOLE No. H-1-00
PROJECT Puyallup to SR 509
Sheet 1 of 5
Inspector Dave Nelson
Station
Offset
Equipment CME 55 w/ autohammer
Latitude
Longitude
Method Wet Rotary
Northing
Easting
Casing HWT x 99.0
Ground Elevation (m)
Start Date June 15, 2000
Completion Date June 21, 2000

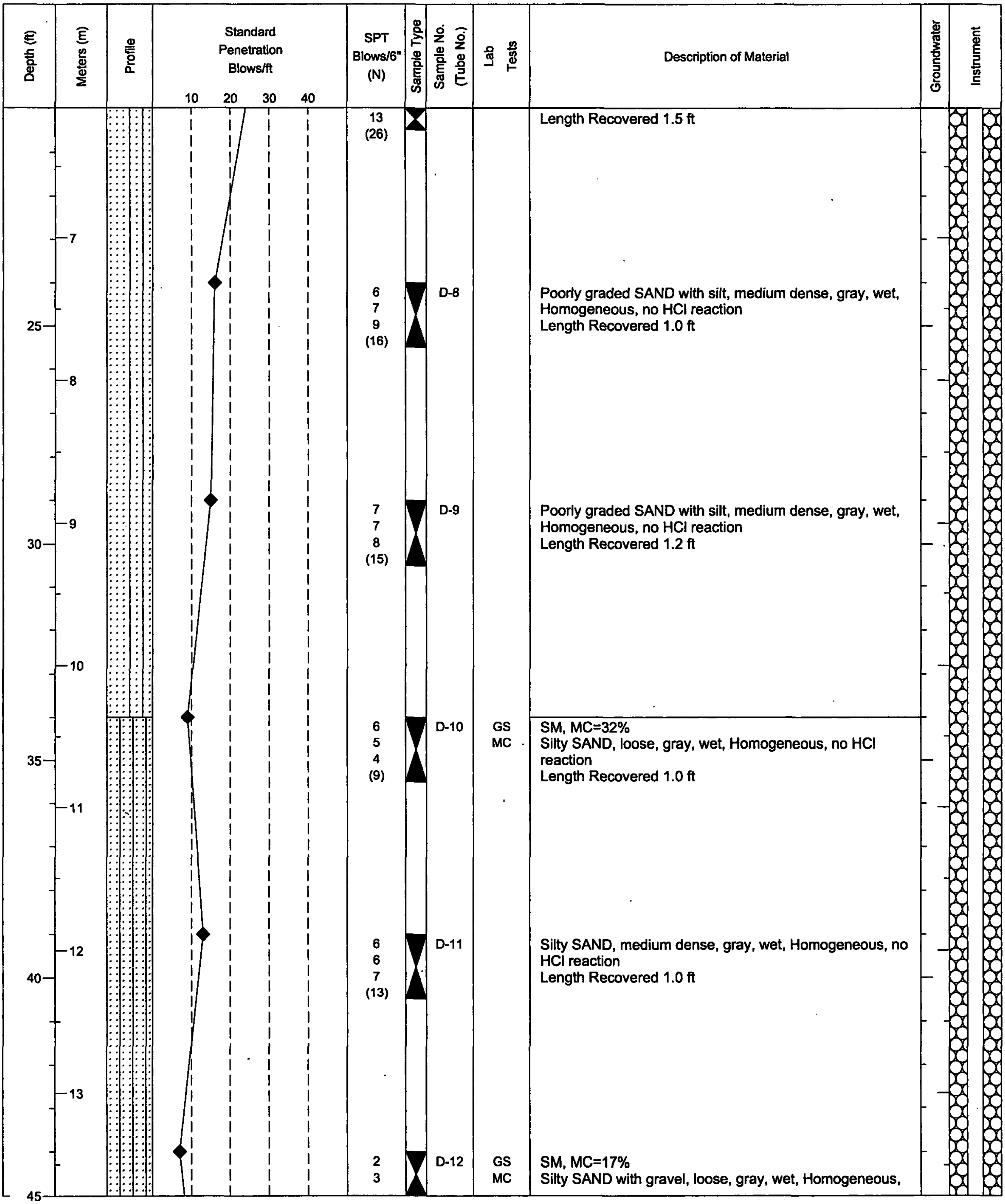


SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
6 6 6 6 (12)	⧗	D-1	GS MC	ML, MC=20% Gravelly SILT with sand, medium dense, brown, moist, Homogeneous, no HCl reaction Length Recovered 2.0 ft		
2 3 4 5 (7)	⧗	D-2	GS MC	ML, MC=39% SILT, loose, brown, moist, Homogeneous, no HCl reaction Length Recovered 2.0 ft		
1 1 2 2 (3)	⧗	D-3		SILT, very loose, brown, moist, Laminated, Fissured, no HCl reaction Length Recovered 2.0 ft		
4 4 4 4 (8)	⧗	D-4		SILT, loose, brown, wet, Laminated, Fissured, no HCl reaction Length Recovered 1.5 ft	▼ 06/20/2000	
4 6 10 (16)	⧗	D-5	GS MC	SP-SM, MC=19% Poorly graded SAND with silt, medium dense, gray, wet, Homogeneous, no HCl reaction Length Recovered 1.0 ft		
8 12 15 (27)	⧗	D-6		Poorly graded SAND with silt, dense, gray, wet, Homogeneous, no HCl reaction Length Recovered 1.5 ft	▽ 06/16/2000	
9 13	⧗	D-7		Poorly graded SAND with silt, dense, gray, wet, Homogeneous, no HCl reaction		

LOG OF TEST BORING

Job No. **0L-3432** SR **167** HOLE No. **H-1-00**

PROJECT **Puyallup to SR 509** Sheet **2** of **5**



SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
13 (26)			Length Recovered 1.5 ft
6 7 9 (16)	D-8		Poorly graded SAND with silt, medium dense, gray, wet, Homogeneous, no HCl reaction Length Recovered 1.0 ft
7 7 8 (15)	D-9		Poorly graded SAND with silt, medium dense, gray, wet, Homogeneous, no HCl reaction Length Recovered 1.2 ft
6 5 4 (9)	D-10	GS MC	SM, MC=32% Silty SAND, loose, gray, wet, Homogeneous, no HCl reaction Length Recovered 1.0 ft
6 6 7 (13)	D-11		Silty SAND, medium dense, gray, wet, Homogeneous, no HCl reaction Length Recovered 1.0 ft
2 3	D-12	GS MC	SM, MC=17% Silty SAND with gravel, loose, gray, wet, Homogeneous,

SOIL OL3432 PUYALLUP.GPJ SOIL.GDT 3/20/02□6:30:30 A3

LOG OF TEST BORING

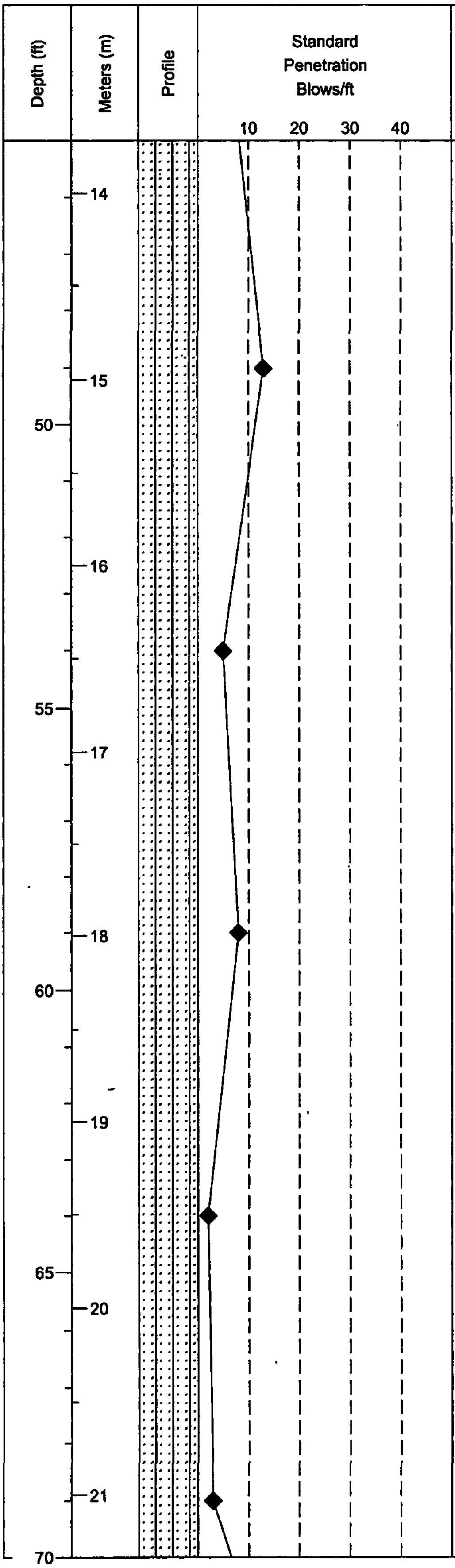
Job No. 0L-3432

SR 167

HOLE No. H-1-00

PROJECT Puyallup to SR 509

Sheet 3 of 5



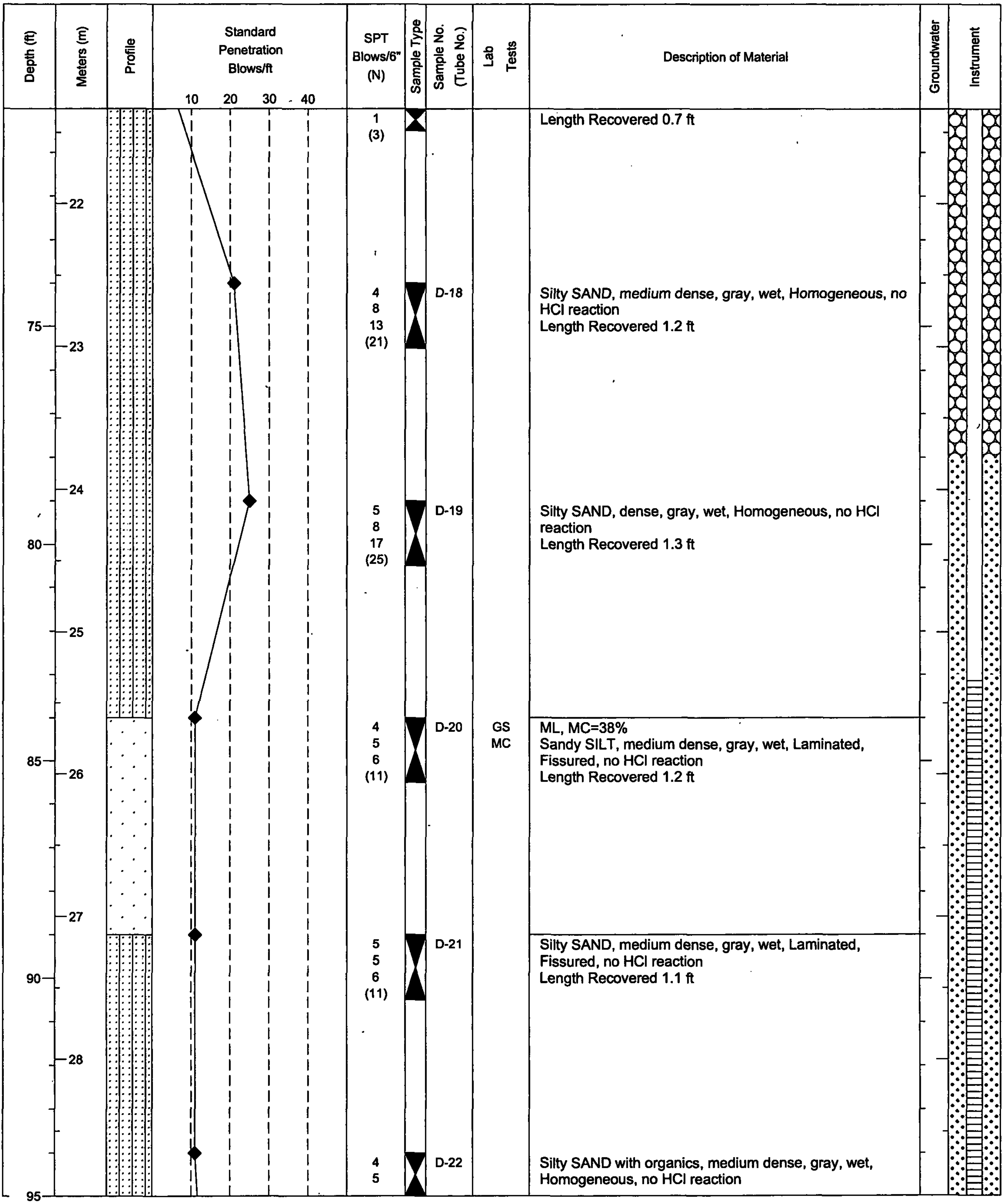
SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
4 (7)			no HCl reaction Length Recovered 1.5 ft
4 6 7 (13)	D-13		Silty SAND, medium dense, gray, wet, Homogeneous, no HCl reaction, in spoon and evident from behavior of drill. Length Recovered 1.5 ft
1 2 3 (5)	D-14		Silty SAND, loose, gray, wet, Homogeneous, no HCl reaction Length Recovered 1.0 ft
2 3 5 (8)	D-15		Silty SAND, loose, gray, wet, Homogeneous, no HCl reaction Length Recovered 0.8 ft
1 1 1 (2)	D-16	GS MC	SM, MC=26% Silty SAND with gravel and wood fragments, very loose, gray, wet, Homogeneous, no HCl reaction Length Recovered 0.8 ft
1 2	D-17		Silty SAND with gravel, very loose, gray, wet, Homogeneous, no HCl reaction

Washington State
Department of Transportation

LOG OF TEST BORING

Job No. **0L-3432** SR **167** HOLE No. **H-1-00**

PROJECT **Puyallup to SR 509** Sheet **4** of **5**



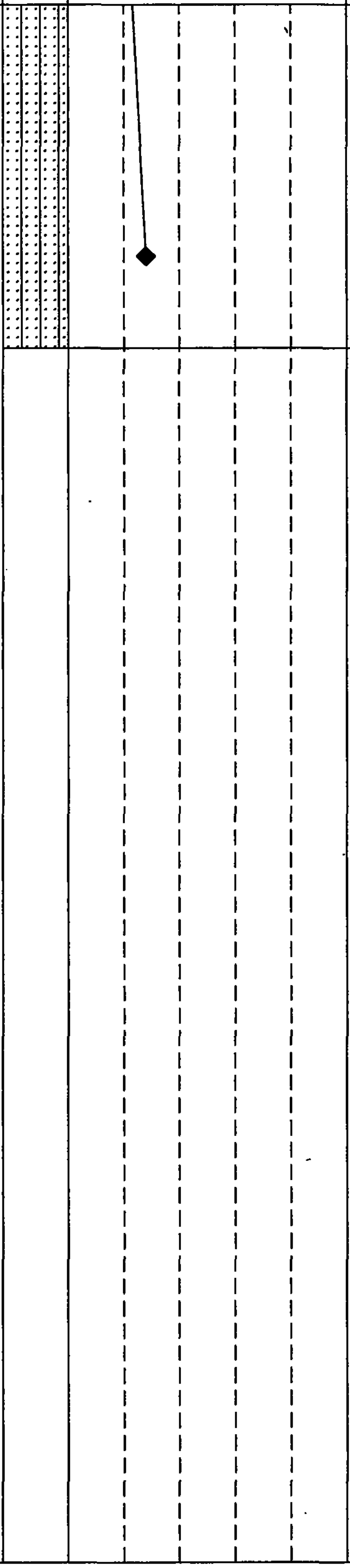
SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
1 (3)			Length Recovered 0.7 ft
4 8 13 (21)	D-18		Silty SAND, medium dense, gray, wet, Homogeneous, no HCl reaction Length Recovered 1.2 ft
5 8 17 (25)	D-19		Silty SAND, dense, gray, wet, Homogeneous, no HCl reaction Length Recovered 1.3 ft
4 5 6 (11)	D-20	GS MC	ML, MC=38% Sandy SILT, medium dense, gray, wet, Laminated, Fissured, no HCl reaction Length Recovered 1.2 ft
5 5 6 (11)	D-21		Silty SAND, medium dense, gray, wet, Laminated, Fissured, no HCl reaction Length Recovered 1.1 ft
4 5	D-22		Silty SAND with organics, medium dense, gray, wet, Homogeneous, no HCl reaction

Washington State
Department of Transportation

LOG OF TEST BORING

Job No. **0L-3432** SR **167** HOLE No. **H-1-00**

PROJECT **Puyallup to SR 509** Sheet **5** of **5**



Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater
	29	6 (11)	⧗			Length Recovered 1.5 ft	
100	30	5 6 8 (14)	⧗	D-23		Silty SAND with organics, medium dense, gray, wet, Homogeneous, no HCl reaction Length Recovered 1.5 ft	
	31					End of test hole boring at 100.5 ft below ground elevation.	
105	32					This is a summary Log of Test Boring. Soil/Rock descriptions are derived from visual field identifications and laboratory test data.	
110	33, 34						
115	35						
120	36						

File Original and First Copy with Department of Ecology
Second Copy — Owner's Copy
Third Copy — Driller's Copy

WATER WELL REPORT

STATE OF WASHINGTON

Start Card No. W16453
UNIQUE WELL I.D. # ABY244
Water Right Permit No.

(1) **OWNER:** Name Mike Stanzel Address 2510 96th Ave CT E Puyallup WA 98371

(2) **LOCATION OF WELL:** County Pierce NE 1/4 NE 1/4 Sec 27 T. 20N N., R. 4E W.M.

(2a) **STREET ADDRESS OF WELL** (or nearest address) 6326 114th Ave CT E Puyallup WA

(3) **PROPOSED USE:** ☒ Domestic ☐ Irrigation ☐ DeWater Industrial ☐ Test Well ☐ Municipal ☐ Other ☒

(4) **TYPE OF WORK:** Owner's number of well (If more than one)
Abandoned ☐ New well ☒ Deepened ☐ Reconditioned ☐
Method: Dug ☐ Cable ☒ Rotary ☐ Bored ☐ Driven ☐ Jetted ☐

(5) **DIMENSIONS:** Diameter of well 6 inches.
Drilled 221 feet. Depth of completed well 221 ft.

(6) **CONSTRUCTION DETAILS:**
Casing installed: 6" Diam. from +3 ft. to 216 ft.
Welded ☒ " Diam. from ft. to ft.
Liner installed ☐ " Diam. from ft. to ft.
Threaded ☐ " Diam. from ft. to ft.

Perforations: Yes ☐ No ☒
Type of perforator used
SIZE of perforations in. by in.
perforations from ft. to ft.
perforations from ft. to ft.
perforations from ft. to ft.

Screens: Yes ☒ No ☐
Manufacturer's Name Cook
Type Model No.
Diam. 5 Slot size 25 from 221 ft. to 216 ft.
Diam. Slot size from ft. to ft.

Gravel packed: Yes ☐ No ☐ Size of gravel
Gravel placed from ft. to ft.

Surface seal: Yes ☒ No ☐ To what depth? 22' ft.
Material used in seal Chip
Did any strata contain unusable water? Yes ☐ No ☒
Type of water? Depth of strata
Method of sealing strata off

(7) **PUMP:** Manufacturer's Name
Type: H.P.

(8) **WATER LEVELS:** Land-surface elevation above mean sea level ft.
Static level +8 ft. below top of well Date
Artesian pressure 3.5 lbs. per square inch Date 11-1-95
Artesian water is controlled by Cap Valve (Cap, valve, etc.)

(9) **WELL TESTS:** Drawdown is amount water level is lowered below static level
Was a pump test made? Yes ☐ No ☐ If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.
" " " "
" " " "

Recovery data (time taken as zero when pump turned off) (water level measured from well top to water level)

Time	Water Level	Time	Water Level	Time	Water Level

Date of test
Bailer test 55 gal./min. with 11 ft. drawdown after 1 hrs.
Airtest gal./min. with stem set at ft. for hrs.
Artesian flow g.p.m. Date
Temperature of water Was a chemical analysis made? Yes ☐ No ☐

(10) **WELL LOG or ABANDONMENT PROCEDURE DESCRIPTION**

Formation: Describe by color, character, size of material and structure, and show thickness of aquifers and the kind and nature of the material in each stratum penetrated, with at least one entry for each change of information.

MATERIAL	FROM	TO
Brown Silty Clay	0	14
Log	14	17
Sandy Silty Clay	17	37
Silty Sand & Gravels	37	65
Silt	65	114
Fine Sand W.B.	114	116
Silty Clay + Peat	116	172
Fine Sand & Clay layer	172	194
Silty Sand & Clay	194	216
Sand & Gravels W.B.	216	221

Work Started 10-19, 1995 Completed 11-1, 1995

WELL CONSTRUCTOR CERTIFICATION:

I constructed and/or accept responsibility for construction of this well, and its compliance with all Washington well construction standards. Materials used and the information reported above are true to my best knowledge and belief.

NAME Holt Drilling Inc (PERSON, FIRM, OR CORPORATION) (TYPE OR PRINT)
Address 10621 Todd Rd E Puyallup WA 98372
(Signed) (WELL DRILLER) License No. 597
Contractor's Registration No. HOLTTI*0810J Date 11-3, 1995

(USE ADDITIONAL SHEETS IF NECESSARY)

APPENDIX B: FIELD EXPLORATIONS

Appendix B

Field Explorations

Appendix B

Subsurface Explorations

CONTENTS

Figures

B.1 INTRODUCTION

The field exploration program consisted of drilling and sampling four borings along the alignment of the proposed storm drain pipeline. The boring locations were selected to be near the beginning and end of the alignment and generally spaced along the alignment. The boring locations included one boring on each side of the proposed trenchless crossing at the BNSF Railroad right-of-way. The borings were completed between November 30 and December 2, 2020 and are designated SWB-1-20 through SWB-4-20. A groundwater observation well was installed in boring SWB-4-20.

Holocene Drilling Inc. of Puyallup, Washington, performed the borings under subcontract to Shannon & Wilson. Figure B-1 presents a key to our classification of the materials encountered. Figures B-2 through B-5 present the boring logs.

B.2 BORING LOCATIONS AND UTILITY CLEARANCE

The locations of the borings are shown in Figure 3. Except for boring SWB-2-20, the borings were advanced within the parking lane adjacent to the northbound lane on 4th Street NW and 5th Street NW. Boring SWB-2-20 was drilled within the landscaped area near the southeast corner of the 5th Street NW and W. Stewart Avenue intersection. Prior to drilling, we requested a utility locate through the Utility Notification Center. Additionally, a vactor truck was used to pothole the initial 5 to 6 feet of each borehole to check for unmarked buried utilities prior to drilling. A field representative from Shannon & Wilson identified the approximate boring locations with a handheld GPS device after drilling was complete.

B.3 DRILLING PROCEDURES

Holocene used a B-58 truck-mounted drill rig and mud rotary drilling techniques to complete the borings. Mud rotary drilling operations use a bentonite slurry to maintain stability of the borehole wall, mitigate heave of saturated soils, and transfer cuttings from the advancing cutting bit to the borehole surface for removal. The boreholes were advanced using a 6-inch-diameter tricone cutting bit.

B.4 SOIL SAMPLES

Disturbed soil samples were obtained by replacing the tricone drill bit with a 2-inch outside diameter (O.D.) split-spoon sampler. Holocene typically used 2-inch O.D. samplers and resampled using 3-inch O.D. samplers when sample recovery was low due to coarse gravel. Split-spoon samples were typically attempted at 2.5-foot intervals.

The split -spoon sampling was performed in conjunction with Standard Penetration Tests (SPTs) following the procedures outlined in ASTM International Designation D1586, Test Method for Penetration Test and Split-Barrel Sampling of Soils (ASTM, 2018). The SPT Standard Penetration Resistance (N-value) is a useful parameter for determining the relative density or consistency of the soils. The relationship between relative density or consistency and N-value is shown in Figure A-1 in Appendix A. The recorded N-values are included in the boring logs in Appendix A.

Relatively undisturbed soil samples were obtained using a 3-inch-diameter, thin-walled sampler following the procedures outlined in ASTM Designation D1587, Standard Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes (ASTM, 2015). The locations of where relatively undisturbed samples were obtained are shown in the boring logs.

B.5 FIELD CLASSIFICATION

Representatives from Shannon & Wilson were present during the field exploration to observe the drilling and sampling operations, retrieve representative soil samples for laboratory testing, and prepare descriptive field logs of the borings. Soil samples were classified using the method described in ASTM Designation D2488, Standard Recommended Practice for Description of Soils (Visual-Manual Procedure) (ASTM, 2020). Representative soil samples were placed in airtight containers and transported to our laboratory in Seattle, Washington, for analysis.

B.6 OBSERVATION WELL INSTALLATION

A 2-inch-diameter groundwater observation well was installed in boring SWB-4-20 after drilling the boring was complete. The well was installed with a slotted polyvinyl chloride screen between approximate depths of 3 and 13 feet below ground surface and completed with a steel, traffic-rated, flush-mount surface monument. Additional observation well installation details are shown graphically on the boring log for SWB-4-20.

B.7 REFERENCES

ASTM International, 2015, Standard Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes, D1587-15, West Conshohocken, Pa., ASTM International, 10 p., available:www.astm.org

ASTM International, 20118, Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils, D1586-18, West Conshohocken, Pa., ASTM International, 26 p., available:www.astm.org

ASTM, 2020, Annual book of standards, construction, v. 4.08, soil and rock (I): D420 - D5876: West Conshohocken, Penn., ASTM International, 1 v.

Shannon & Wilson, Inc. (S&W), uses a soil identification system modified from the Unified Soil Classification System (USCS). Elements of the USCS and other definitions are provided on this and the following pages. Soil descriptions are based on visual-manual procedures (ASTM D2488) and laboratory testing procedures (ASTM D2487), if performed.

S&W INORGANIC SOIL CONSTITUENT DEFINITIONS

CONSTITUENT[2]	FINE-GRAINED SOILS (50% or more fines)[1]	COARSE-GRAINED SOILS (less than 50% fines)[1]
Major	***Silt, Lean Clay, Elastic Silt,*** or ***Fat Clay***[3]	***Sand*** or ***Gravel***[4]
Modifying (Secondary) Precedes major constituent	30% or more coarse-grained: ***Sandy*** or ***Gravelly***[4]	More than 12% fine-grained: ***Silty*** or ***Clayey***[3]
Minor Follows major constituent	15% to 30% coarse-grained: ***with Sand*** or ***with Gravel***[4]	5% to 12% fine-grained: ***with Silt*** or ***with Clay***[3]
	30% or more total coarse-grained *and* lesser coarse-grained constituent is 15% or more: ***with Sand*** or ***with Gravel***[5]	15% or more of a second coarse-grained constituent: ***with Sand*** or ***with Gravel***[5]

[1] All percentages are by weight of total specimen passing a 3-inch sieve.
[2] The order of terms is: *Modifying Major with Minor.*
[3] Determined based on behavior.
[4] Determined based on which constituent comprises a larger percentage.
[5] Whichever is the lesser constituent.

MOISTURE CONTENT TERMS

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

STANDARD PENETRATION TEST (SPT) SPECIFICATIONS

Hammer:	140 pounds with a 30-inch free fall. Rope on 6- to 10-inch-diam. cathead 2-1/4 rope turns, > 100 rpm NOTE: If automatic hammers are used, blow counts shown on boring logs should be adjusted to account for efficiency of hammer.
Sampler:	10 to 30 inches long Shoe I.D. = 1.375 inches Barrel I.D. = 1.5 inches Barrel O.D. = 2 inches
N-Value:	Sum blow counts for second and third 6-inch increments. Refusal: 50 blows for 6 inches or less; 10 blows for 0 inches.

NOTE: Penetration resistances (N-values) shown on boring logs are as recorded in the field and have not been corrected for hammer efficiency, overburden, or other factors.

PARTICLE SIZE DEFINITIONS

DESCRIPTION	SIEVE NUMBER AND/OR APPROXIMATE SIZE
FINES	< #200 (0.075 mm = 0.003 in.)
SAND Fine Medium Coarse	 #200 to #40 (0.075 to 0.4 mm; 0.003 to 0.02 in.) #40 to #10 (0.4 to 2 mm; 0.02 to 0.08 in.) #10 to #4 (2 to 4.75 mm; 0.08 to 0.187 in.)
GRAVEL Fine Coarse	 #4 to 3/4 in. (4.75 to 19 mm; 0.187 to 0.75 in.) 3/4 to 3 in. (19 to 76 mm)
COBBLES	3 to 12 in. (76 to 305 mm)
BOULDERS	> 12 in. (305 mm)

RELATIVE DENSITY / CONSISTENCY

COHESIONLESS SOILS		COHESIVE SOILS	
N, SPT, BLOWS/FT.	RELATIVE DENSITY	N, SPT, BLOWS/FT.	RELATIVE CONSISTENCY
< 4	Very loose	< 2	Very soft
4 - 10	Loose	2 - 4	Soft
10 - 30	Medium dense	4 - 8	Medium stiff
30 - 50	Dense	8 - 15	Stiff
> 50	Very dense	15 - 30	Very stiff
		> 30	Hard

WELL AND BACKFILL SYMBOLS

▧	Bentonite Cement Grout	▩	Surface Cement Seal
▨	Bentonite Grout	■	Asphalt or Cap
▦	Bentonite Chips	▨	Slough
⁙	Silica Sand	▯	Inclinometer or Non-perforated Casing
▤	Perforated or Screened Casing	▮	Vibrating Wire Piezometer

PERCENTAGES TERMS[1, 2]

Trace	< 5%
Few	5 to 10%
Little	15 to 25%
Some	30 to 45%
Mostly	50 to 100%

[1] Gravel, sand, and fines estimated by mass. Other constituents, such as organics, cobbles, and boulders, estimated by volume.

[2] Reprinted, with permission, from ASTM D2488 - 09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428. A copy of the complete standard may be obtained from ASTM International, www.astm.org.

City of Puyallup
4th Avenue Storm Drainage Project
Pierce County, Washington

SOIL DESCRIPTION AND LOG KEY

January 2021 105692-002

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-1
Sheet 1 of 3

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)
(Modified From USACE Tech Memo 3-357, ASTM D2487, and ASTM D2488)

MAJOR DIVISIONS			GROUP/GRAPHIC SYMBOL		TYPICAL IDENTIFICATIONS
COARSE-GRAINED SOILS *(more than 50% retained on No. 200 sieve)*	Gravels *(more than 50% of coarse fraction retained on No. 4 sieve)*	Gravel *(less than 5% fines)*	GW	●	Well-Graded Gravel; Well-Graded Gravel with Sand
			GP	○	Poorly Graded Gravel; Poorly Graded Gravel with Sand
		Silty or Clayey Gravel *(more than 12% fines)*	GM	●	Silty Gravel; Silty Gravel with Sand
			GC	▨	Clayey Gravel; Clayey Gravel with Sand
	Sands *(50% or more of coarse fraction passes the No. 4 sieve)*	Sand *(less than 5% fines)*	SW	⁘	Well-Graded Sand; Well-Graded Sand with Gravel
			SP	⁘	Poorly Graded Sand; Poorly Graded Sand with Gravel
		Silty or Clayey Sand *(more than 12% fines)*	SM	▥	Silty Sand; Silty Sand with Gravel
			SC	▨	Clayey Sand; Clayey Sand with Gravel
FINE-GRAINED SOILS *(50% or more passes the No. 200 sieve)*	Silts and Clays *(liquid limit less than 50)*	Inorganic	ML	▥	Silt; Silt with Sand or Gravel; Sandy or Gravelly Silt
			CL	▨	Lean Clay; Lean Clay with Sand or Gravel; Sandy or Gravelly Lean Clay
		Organic	OL	▤	Organic Silt or Clay; Organic Silt or Clay with Sand or Gravel; Sandy or Gravelly Organic Silt or Clay
	Silts and Clays *(liquid limit 50 or more)*	Inorganic	MH	▥	Elastic Silt; Elastic Silt with Sand or Gravel; Sandy or Gravelly Elastic Silt
			CH	▨	Fat Clay; Fat Clay with Sand or Gravel; Sandy or Gravelly Fat Clay
		Organic	OH	▨	Organic Silt or Clay; Organic Silt or Clay with Sand or Gravel; Sandy or Gravelly Organic Silt or Clay
HIGHLY-ORGANIC SOILS	Primarily organic matter, dark in color, and organic odor		PT	≈	Peat or other highly organic soils (see ASTM D4427)

NOTE: No. 4 size = 4.75 mm = 0.187 in.; No. 200 size = 0.075 mm = 0.003 in.

NOTES

1. Dual symbols *(symbols separated by a hyphen, i.e., SP-SM, Sand with Silt)* are used for soils with between 5% and 12% fines or when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart. Graphics shown on the logs for these soil types are a combination of the two graphic symbols (e.g., SP and SM).
2. Borderline symbols *(symbols separated by a slash, i.e., CL/ML, Lean Clay to Silt; SP-SM/SM, Sand with Silt to Silty Sand)* indicate that the soil properties are close to the defining boundary between two groups.

City of Puyallup
4th Avenue Storm Drainage Project
Pierce County, Washington

SOIL DESCRIPTION AND LOG KEY

January 2021 105692-002

SHANNON & WILSON, INC.
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FIG. B-1
Sheet 2 of 3

GRADATION TERMS

Poorly Graded	Narrow range of grain sizes present or, within the range of grain sizes present, one or more sizes are missing (Gap Graded). Meets criteria in ASTM D2487, if tested.
Well-Graded	Full range and even distribution of grain sizes present. Meets criteria in ASTM D2487, if tested.

CEMENTATION TERMS[1]

Weak	Crumbles or breaks with handling or slight finger pressure.
Moderate	Crumbles or breaks with considerable finger pressure.
Strong	Will not crumble or break with finger pressure.

PLASTICITY[2]

DESCRIPTION	VISUAL-MANUAL CRITERIA	APPROX. PLASTICITY INDEX RANGE
Nonplastic	A 1/8-in. thread cannot be rolled at any water content.	< 4
Low	A thread can barely be rolled and a lump cannot be formed when drier than the plastic limit.	4 to 10
Medium	A thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. A lump crumbles when drier than the plastic limit.	10 to 20
High	It takes considerable time rolling and kneading to reach the plastic limit. A thread can be rerolled several times after reaching the plastic limit. A lump can be formed without crumbling when drier than the plastic limit.	> 20

ADDITIONAL TERMS

Mottled	Irregular patches of different colors.
Bioturbated	Soil disturbance or mixing by plants or animals.
Diamict	Nonsorted sediment; sand and gravel in silt and/or clay matrix.
Cuttings	Material brought to surface by drilling.
Slough	Material that caved from sides of borehole.
Sheared	Disturbed texture, mix of strengths.

PARTICLE ANGULARITY AND SHAPE TERMS[1]

Angular	Sharp edges and unpolished planar surfaces.
Subangular	Similar to angular, but with rounded edges.
Subrounded	Nearly planar sides with well-rounded edges.
Rounded	Smoothly curved sides with no edges.
Flat	Width/thickness ratio > 3.
Elongated	Length/width ratio > 3.

ACRONYMS AND ABBREVIATIONS

ATD	At Time of Drilling
Diam.	Diameter
Elev.	Elevation
ft.	Feet
FeO	Iron Oxide
gal.	Gallons
Horiz.	Horizontal
HSA	Hollow Stem Auger
I.D.	Inside Diameter
in.	Inches
lbs.	Pounds
MgO	Magnesium Oxide
mm	Millimeter
MnO	Manganese Oxide
NA	Not Applicable or Not Available
NP	Nonplastic
O.D.	Outside Diameter
OW	Observation Well
pcf	Pounds per Cubic Foot
PID	Photo-Ionization Detector
PMT	Pressuremeter Test
ppm	Parts per Million
psi	Pounds per Square Inch
PVC	Polyvinyl Chloride
rpm	Rotations per Minute
SPT	Standard Penetration Test
USCS	Unified Soil Classification System
q_u	Unconfined Compressive Strength
VWP	Vibrating Wire Piezometer
Vert.	Vertical
WOH	Weight of Hammer
WOR	Weight of Rods
Wt.	Weight

STRUCTURE TERMS[1]

Interbedded	Alternating layers of varying material or color with layers at least 1/4-inch thick; singular: bed.
Laminated	Alternating layers of varying material or color with layers less than 1/4-inch thick; singular: lamination.
Fissured	Breaks along definite planes or fractures with little resistance.
Slickensided	Fracture planes appear polished or glossy; sometimes striated.
Blocky	Cohesive soil that can be broken down into small angular lumps that resist further breakdown.
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay.
Homogeneous	Same color and appearance throughout.

City of Puyallup
4th Avenue Storm Drainage Project
Pierce County, Washington

SOIL DESCRIPTION AND LOG KEY

January 2021 105692-002

SHANNON & WILSON, INC.
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FIG. B-1
Sheet 3 of 3

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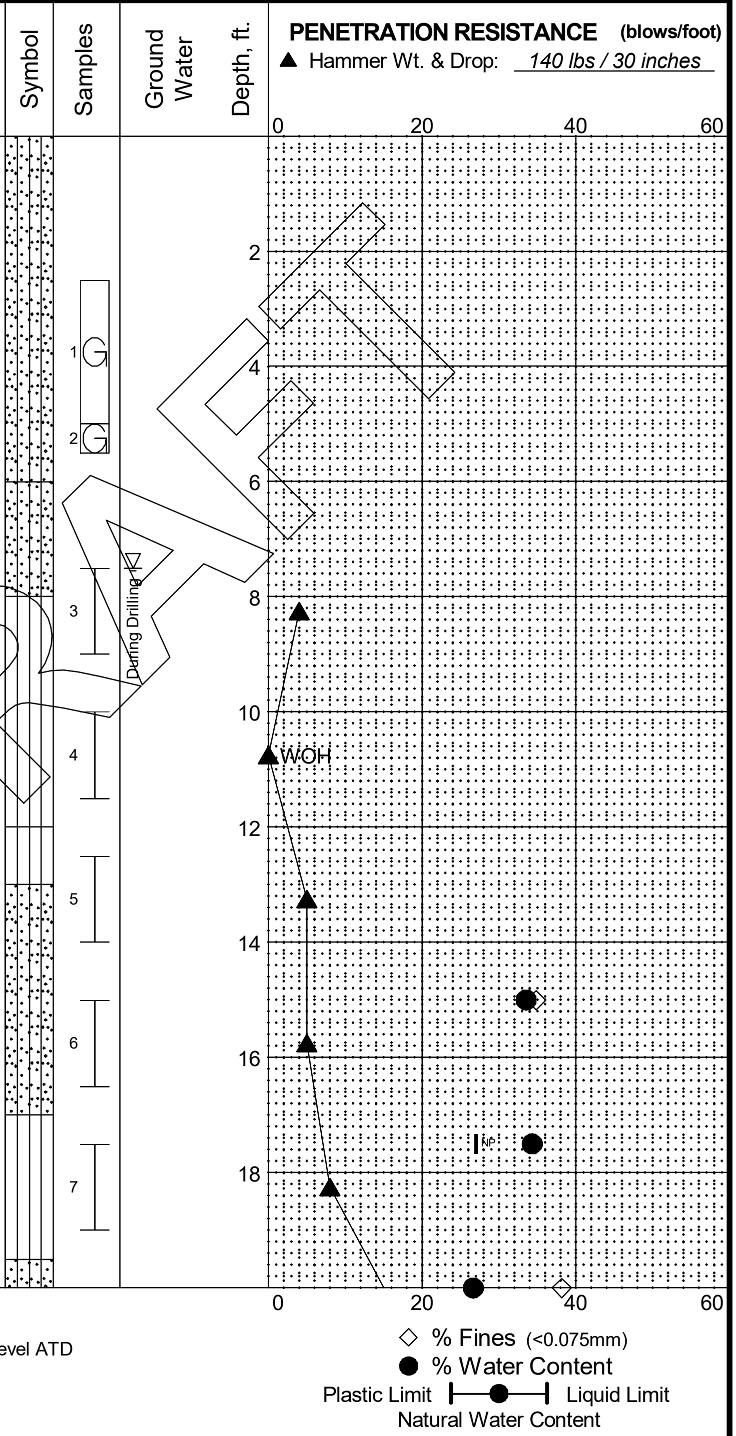
[2] Adapted, with permission, from ASTM D2488 - 09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure), copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428. A copy of the complete standard may be obtained from ASTM International, www.astm.org.

Total Depth:	41.5 ft.	Lat:	~ 47.1928 deg.	Drilling Method:	Mud Rotary	Hole Diam.:	8 in.
Top Elevation:	~ 46 ft.	Long:	~ 122.2990 deg.	Drilling Company:	Holocene Drilling	Rod Diam.:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:		Hammer Type:	Automatic
Horiz. Datum:		Offset:	~	Other Comments:			

SOIL DESCRIPTION *Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.*	Depth, ft.
Brown, *Silty Sand (SM)*; moist; fine sand; nonplastic; few silt seams. (Hf)	6.0
Loose, brown, *Silty Sand (SM)*; wet; fine to medium sand; nonplastic; few silt seams. (Ha)	8.0
Very soft, gray-brown *Silt (ML)* to *Lean Clay (CL)*; moist; low to medium plasticity; few to little organics. (Ha)	12.0
Loose, gray-brown, *Sandy Silt (ML)*; wet; fine to medium sand; nonplastic to low plasticity. (Ha)	13.0
Loose, dark gray to brown, *Silty Sand (SM)*; wet; fine to medium sand; nonplastic to low plasticity; trace organics; few silt seams. (Ha)	17.0
Loose, gray-brown *Silt (ML)*; moist; few fine sand; nonplastic. (Ha)	19.5



CONTINUED NEXT SHEET

LEGEND

* Sample Not Recovered

G Grab Sample

⌶ 2.0" O.D. Split Spoon Sample

⊻ Ground Water Level ATD

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location was measured from existing site features and should be considered approximate.

City of Puyallup
4th Avenue Storm Drainage Project
Pierce County, Washington

LOG OF BORING SWB-1-20

January 2021 105692-002

SHANNON & WILSON, INC.
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FIG. B-2
Sheet 1 of 3

Total Depth: 41.5 ft.
Top Elevation: ~ 46 ft.
Vert. Datum:
Horiz. Datum:
Lat: ~ 47.1928 deg.
Long: ~ 122.2990 deg.
Station: ~
Offset: ~
Drilling Method: Mud Rotary
Drilling Company: Holocene Drilling
Drill Rig Equipment:
Other Comments:
Hole Diam.: 8 in.
Rod Diam.: NWJ
Hammer Type: Automatic

SOIL DESCRIPTION

Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

Medium dense, dark gray, *Silty Sand (SM)*; wet; fine to medium sand; nonplastic.
(Ha)

22.0

Soft to medium stiff, gray-brown *Elastic Silt (MH)*; moist; medium plasticity; trace organics.
(Ha)

26.0

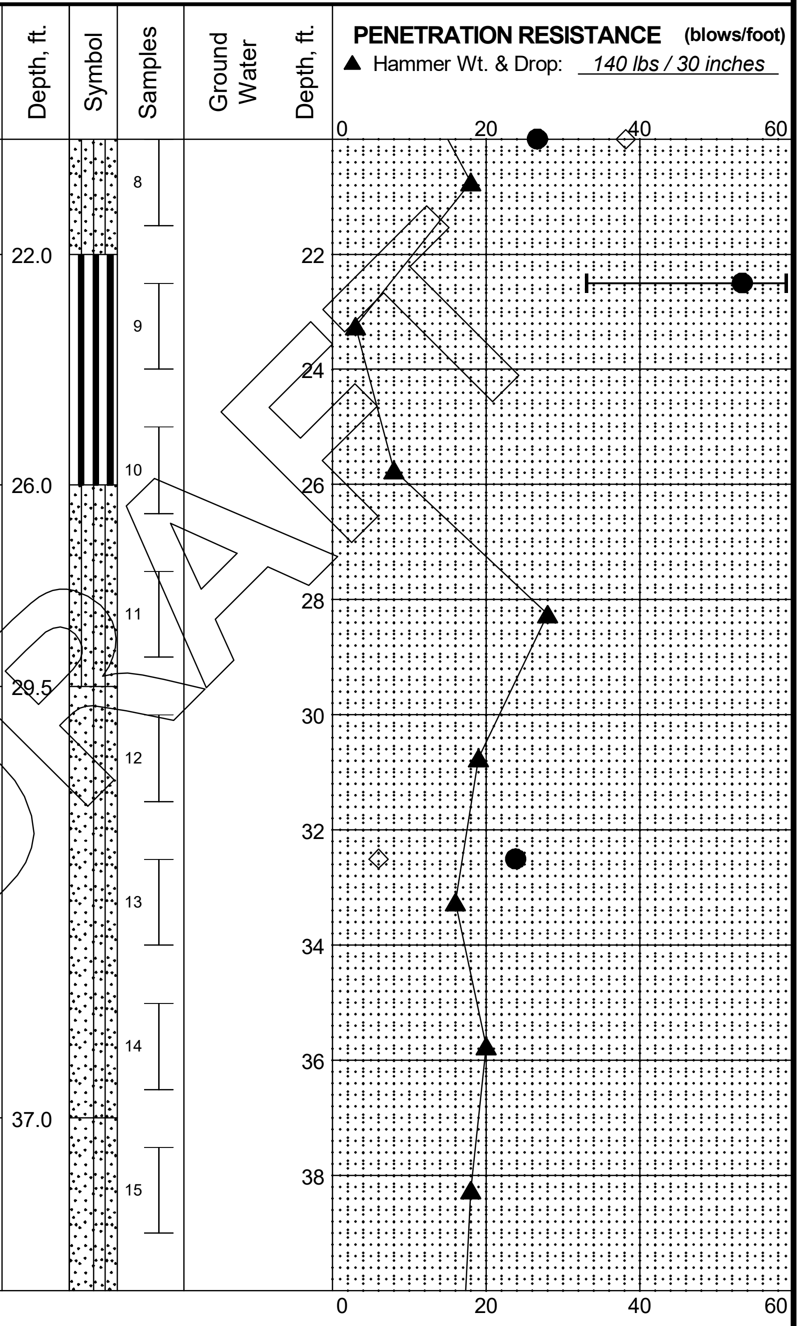
Loose to medium dense, dark gray, *Silty Sand (SM)*; wet; fine to medium sand; nonplastic.
(Ha)

29.5

Medium dense, dark gray, *Poorly Graded Sand with Silt (SP-SM)*; wet; fine to medium sand; nonplastic.
(Ha)
- Few silty, fine sand seams from 30 to 32 feet.

37.0

Medium dense, dark gray and brown, *Poorly Graded Sand with Silt and Gravel (SP-SM)* to *Poorly Graded Sand with Silt (SP-SM)*; wet; fine, subrounded gravel; fine to coarse sand; nonplastic to low plasticity; few silt seams; few



CONTINUED NEXT SHEET

LEGEND

* Sample Not Recovered
⊻ Ground Water Level ATD
G Grab Sample
⌶ 2.0" O.D. Split Spoon Sample

◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location was measured from existing site features and should be considered approximate.

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4th Avenue Storm Drainage Project
Pierce County, Washington

LOG OF BORING SWB-1-20

January 2021
105692-002

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FIG. B-2
Sheet 2 of 3

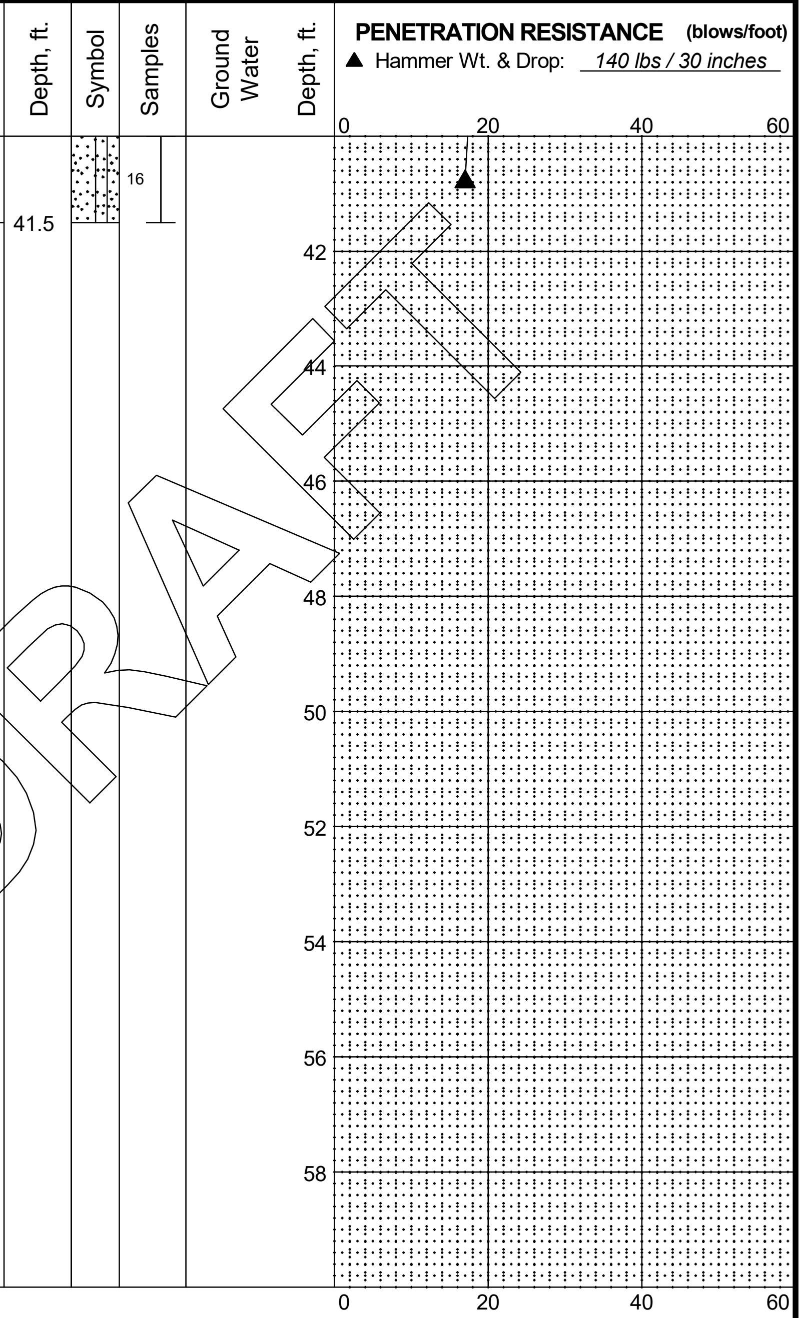
Total Depth: 41.5 ft.
Top Elevation: ~ 46 ft.
Vert. Datum:
Horiz. Datum:
Lat: ~ 47.1928 deg.
Long: ~ 122.2990 deg.
Station: ~
Offset: ~
Drilling Method: Mud Rotary
Drilling Company: Holocene Drilling
Drill Rig Equipment:
Other Comments:
Hole Diam.: 8 in.
Rod Diam.: NWJ
Hammer Type: Automatic

SOIL DESCRIPTION

Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

organics.
(Ha)

BOTTOM OF BORING
COMPLETED 12/2/2020



LEGEND

* Sample Not Recovered
G Grab Sample
⌶ 2.0" O.D. Split Spoon Sample
⊻ Ground Water Level ATD

◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location was measured from existing site features and should be considered approximate.

City of Puyallup
4th Avenue Storm Drainage Project
Pierce County, Washington

LOG OF BORING SWB-1-20

January 2021 105692-002

SHANNON & WILSON, INC.
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FIG. B-2
Sheet 3 of 3

Total Depth: 41.5 ft.
Top Elevation: ~ 47 ft.
Vert. Datum:
Horiz. Datum:
Lat: ~ 47.1935 deg.
Long: ~ 122.2987 deg.
Station: ~
Offset: ~
Drilling Method: Mud Rotary
Drilling Company: Holocene Drilling
Drill Rig Equipment:
Other Comments:
Hole Diam.:
Rod Diam.: NWJ
Hammer Type: Automatic

SOIL DESCRIPTION

Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

Brown *Silt with Sand (ML)*; moist; fine sand; nonplastic to low plasticity; trace organics.
(Hf)

6.0

Medium dense, dark gray, *Silty Sand (SM)*; wet; fine to medium sand; nonplastic.
(Ha)

8.0

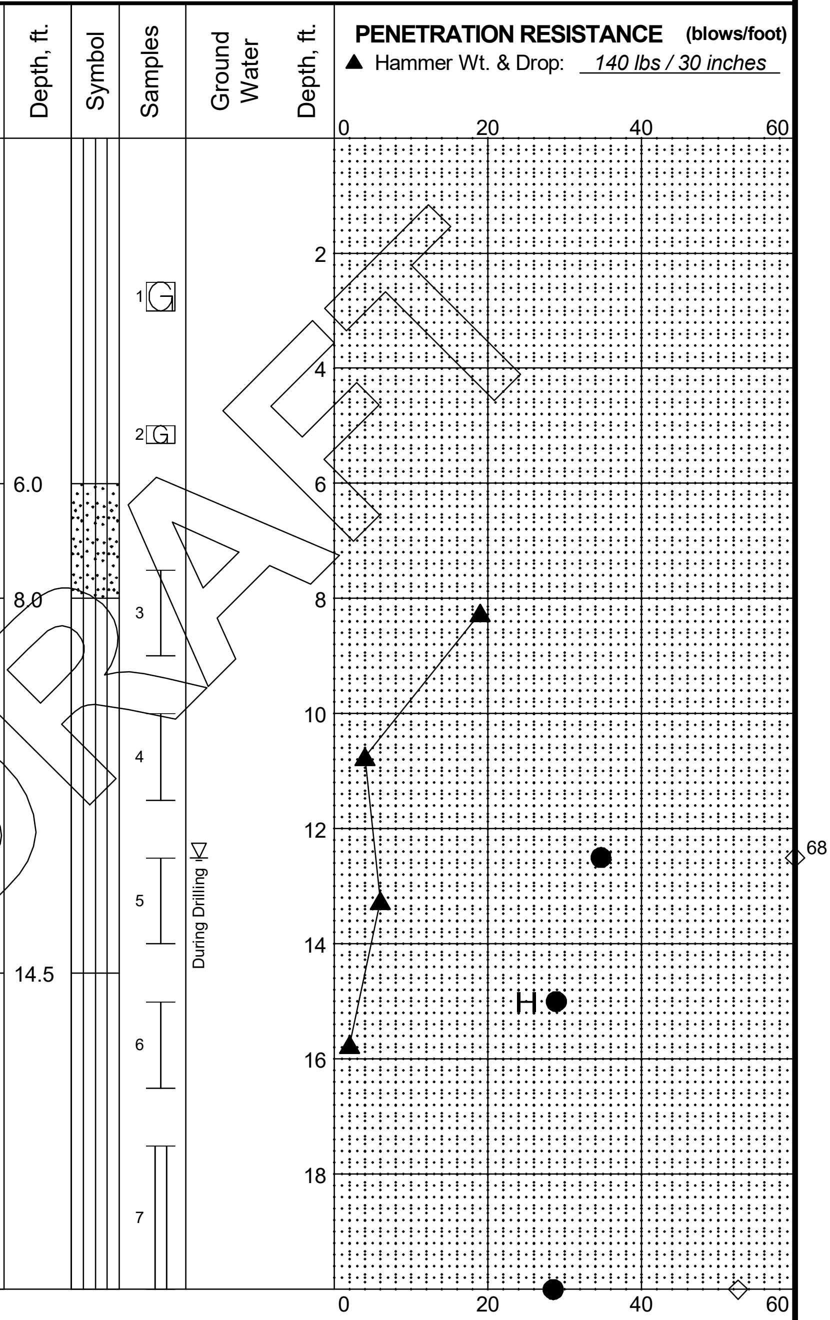
Loose to medium dense, brown to gray-brown, *Sandy Silt (ML)* and *Silty Sand (SM)*; moist to wet; fine sand; nonplastic to low plasticity; interbedded.
(Ha)

14.5

Very soft, gray-brown *Silt with Sand (ML)*; moist; fine sand; low plasticity; trace organics.
(Ha)

-Layer of silty sand from 17.5 to 18.2 feet.

-Layer of silty sand from 19.2 to 19.5 feet.



CONTINUED NEXT SHEET

LEGEND

- * Sample Not Recovered
- G Grab Sample
- I 2.0" O.D. Split Spoon Sample
- II Thin Wall Sample
- ⊻ Ground Water Level ATD

◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location was measured from existing site features and should be considered approximate.

City of Puyallup
4th Avenue Storm Drainage Project
Pierce County, Washington

LOG OF BORING SWB-2-20

January 2021
105692-002

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FIG. B-3
Sheet 1 of 3

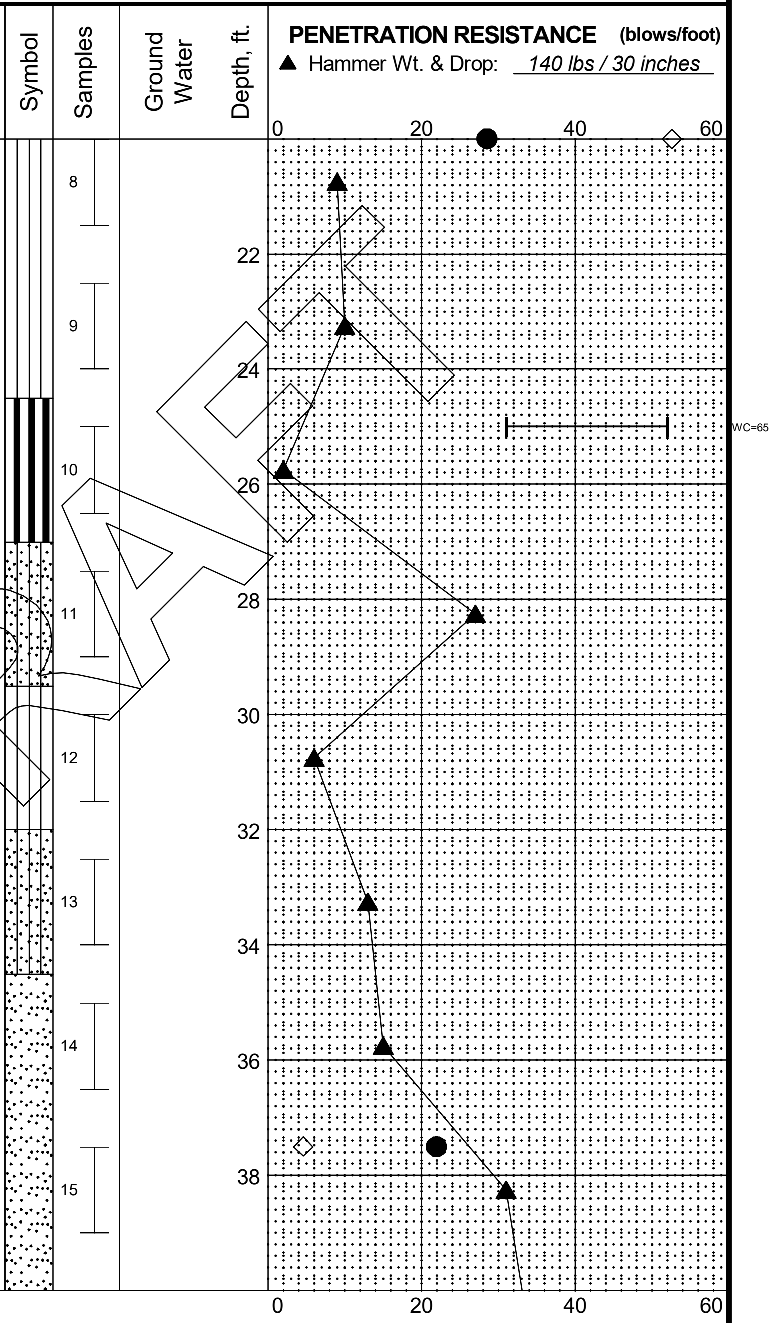
MASTER_LOG_E_LATLONG 105692.GPJ SHAN_WIL.GDT 1/12/21

Total Depth: 41.5 ft.
Top Elevation: ~ 47 ft.
Vert. Datum:
Horiz. Datum:
Lat: ~ 47.1935 deg.
Long: ~ 122.2987 deg.
Station: ~
Offset: ~
Drilling Method: Mud Rotary
Drilling Company: Holocene Drilling
Drill Rig Equipment:
Other Comments:
Hole Diam.:
Rod Diam.: NWJ
Hammer Type: Automatic

SOIL DESCRIPTION

Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

Depth, ft.	SOIL DESCRIPTION
20.0	Loose to medium dense, gray and brown, *Sandy Silt (ML)* to *Silty Sand (SM)* and *Silt (ML);* moist to wet; fine sand; nonplastic to low plasticity; interbedded. (Ha)
24.5	Soft, gray, *Elastic Silt (MH)*; moist; medium plasticity; few organics. (Ha) -Layer of silty sand from 25.5 to 26.4 feet.
27.0	Medium dense, gray-brown, *Silty Sand (SM)*; moist to wet; fine sand; nonplastic. (Ha)
29.5	Medium stiff, gray-brown *Silt (ML)*; moist; few fine sand; low plasticity; few silty, fine sand seams. (Ha)
32.0	Medium dense, dark gray, *Silty Sand (SM)*; wet; fine sand; nonplastic. (Ha)
34.5	Medium dense to dense, dark gray, *Poorly Graded Sand (SP)* to *Poorly Graded Sand with Silt (SP-SM)*; wet; fine to medium sand; nonplastic. (Ha)



CONTINUED NEXT SHEET

LEGEND

* Sample Not Recovered
G Grab Sample
⌶ 2.0" O.D. Split Spoon Sample
Ⅱ Thin Wall Sample
⊻ Ground Water Level ATD

◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├──●──┤ Liquid Limit
Natural Water Content

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location was measured from existing site features and should be considered approximate.

City of Puyallup
4th Avenue Storm Drainage Project
Pierce County, Washington

LOG OF BORING SWB-2-20

January 2021
105692-002

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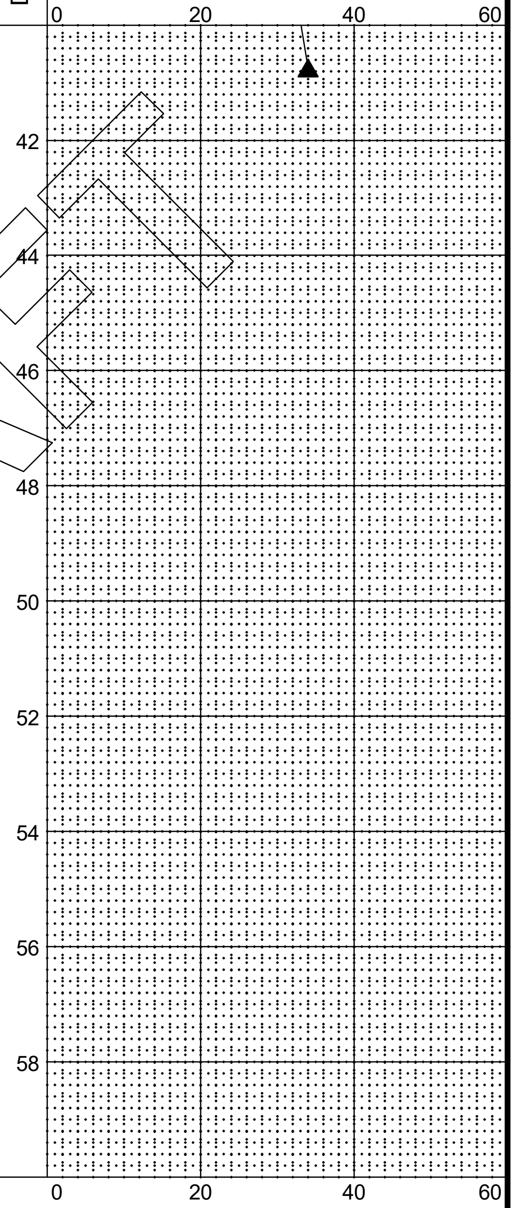
FIG. B-3
Sheet 2 of 3

Total Depth: 41.5 ft.
Lat: ~ 47.1935 deg.
Drilling Method: Mud Rotary
Hole Diam.:
Top Elevation: ~ 47 ft.
Long: ~ 122.2987 deg.
Drilling Company: Holocene Drilling
Rod Diam.: NWJ
Vert. Datum:
Station: ~
Drill Rig Equipment:
Hammer Type: Automatic
Horiz. Datum:
Offset: ~
Other Comments:

SOIL DESCRIPTION *Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.*	Depth, ft.	Symbol	Samples	Ground Water
			16	
BOTTOM OF BORING COMPLETED 12/1/2020	41.5			

PENETRATION RESISTANCE (blows/foot)
▲ Hammer Wt. & Drop: 140 lbs / 30 inches



◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

LEGEND

* Sample Not Recovered
G Grab Sample
Ɪ 2.0" O.D. Split Spoon Sample
Ⅱ Thin Wall Sample
⊻ Ground Water Level ATD

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location was measured from existing site features and should be considered approximate.

City of Puyallup
4th Avenue Storm Drainage Project
Pierce County, Washington

LOG OF BORING SWB-2-20

January 2021
105692-002

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FIG. B-3
Sheet 3 of 3

Total Depth: 41.5 ft.
Top Elevation: ~ 44 ft.
Vert. Datum:
Horiz. Datum:
Lat: ~ 47.1981 deg.
Long: ~ 122.2984 deg.
Station: ~
Offset: ~
Drilling Method: Mud Rotary
Drilling Company: Holocene Drilling
Drill Rig Equipment:
Other Comments:
Hole Diam.:
Rod Diam.: NWJ
Hammer Type: Automatic

SOIL DESCRIPTION

Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

Brown *Silt (ML)* and *Sandy Silt (ML)*; moist; fine sand; nonplastic to low plasticity; few lean clay seams.
(Hf)

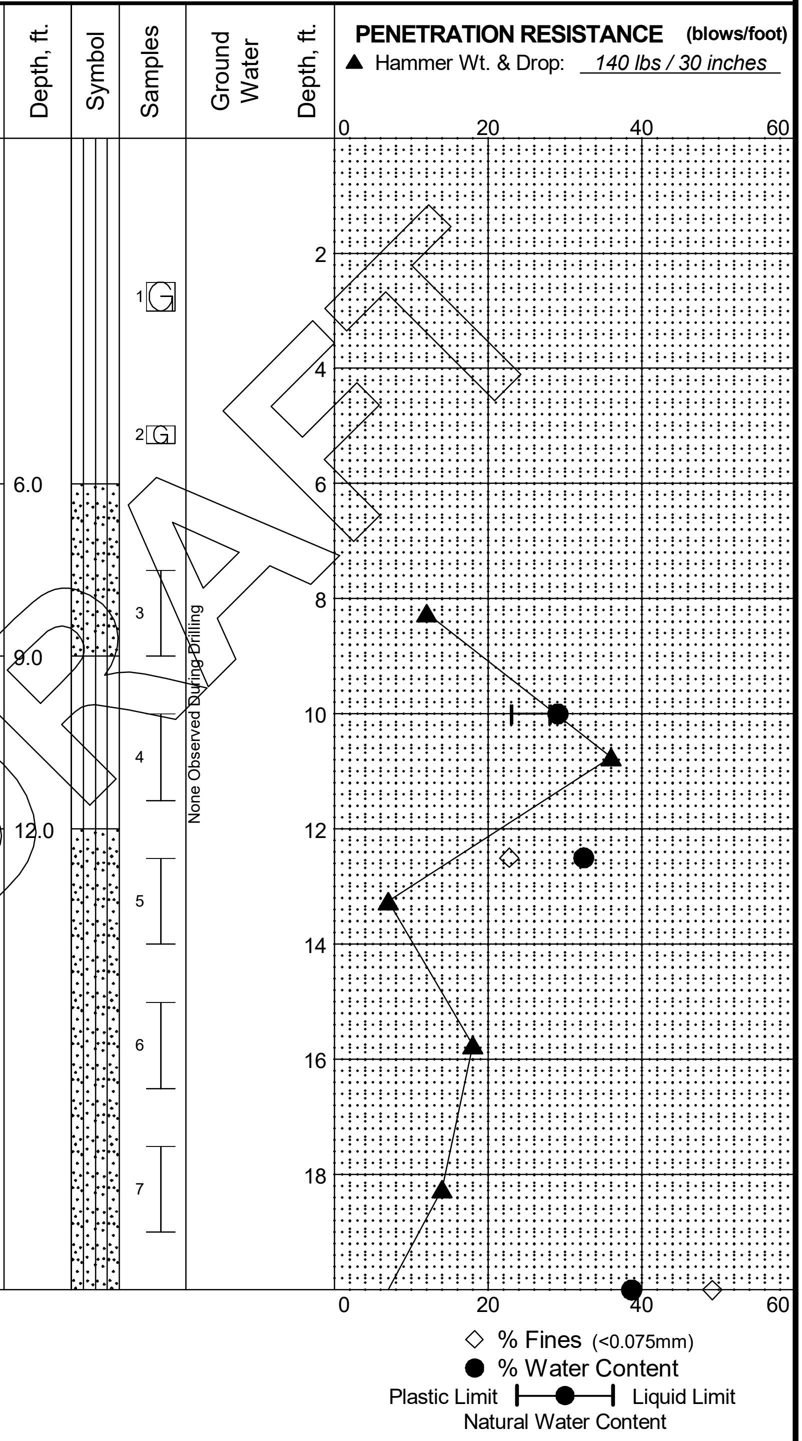
Medium dense, brown, *Silty Sand (SM)*; moist; fine sand; nonplastic.
(Ha)

Dense, brown, *Silt with Sand (ML)*; moist; fine sand; nonplastic; few to little organics.
(Ha)

Loose to medium dense, *Silty Sand (SM)*; wet; fine to medium sand; nonplastic.
(Ha)

- Layer of moist silt from 17.5 to 18.3 feet.

- Few silt seams below 19 feet.



CONTINUED NEXT SHEET

LEGEND

* Sample Not Recovered
G Grab Sample
I 2.0" O.D. Split Spoon Sample
II Thin Wall Sample

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location was measured from existing site features and should be considered approximate.

City of Puyallup
4th Avenue Storm Drainage Project
Pierce County, Washington

LOG OF BORING SWB-3-20

January 2021 105692-002

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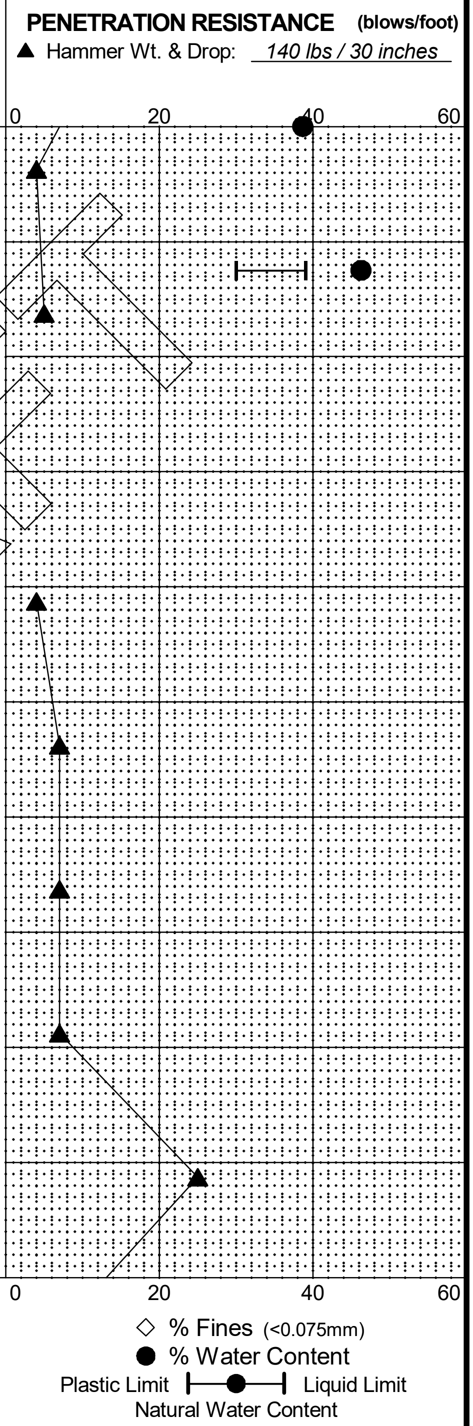
FIG. B-4
Sheet 1 of 3

Total Depth:	41.5 ft.	Lat:	~ 47.1981 deg.	Drilling Method:	Mud Rotary	Hole Diam.:	
Top Elevation:	~ 44 ft.	Long:	~ 122.2984 deg.	Drilling Company:	Holocene Drilling	Rod Diam.:	NWJ
Vert. Datum:		Station:	~	Drill Rig Equipment:		Hammer Type:	Automatic
Horiz. Datum:		Offset:	~	Other Comments:			

SOIL DESCRIPTION

Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

SOIL DESCRIPTION	Depth, ft.	Samples
		8
Medium stiff, gray-brown, *Silt (ML)* and *Lean Clay (CL)*; moist; trace fine sand; low to medium plasticity; few organics. (Ha)	21.0	9 10
Loose, dark gray, *Silty Sand (SM)*; wet; fine to medium sand; nonplastic; few organics. (Ha)	28.0	11
Medium stiff, gray to gray-brown *Silt (ML)*; moist; trace fine sand; low plasticity. (Ha)	29.5	12
Loose, dark gray, *Poorly Graded Sand with Silt (SP-SM)*; wet; fine to medium sand; nonplastic. (Ha)	32.0	
Loose, gray-brown *Silt (ML)*; moist to wet; trace fine sand; nonplastic to low plasticity; trace organics; dilatent. (Ha)	33.0	13 14
Loose, dark gray, *Poorly Graded Sand with Silt (SP-SM)*; wet; fine to medium sand; nonplastic; few silt seams. (Ha)	37.0	15
	39.5	



CONTINUED NEXT SHEET

LEGEND

- * Sample Not Recovered
- G Grab Sample
- I 2.0" O.D. Split Spoon Sample
- II Thin Wall Sample

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location was measured from existing site features and should be considered approximate.

City of Puyallup
4th Avenue Storm Drainage Project
Pierce County, Washington

LOG OF BORING SWB-3-20

January 2021 105692-002

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-4
Sheet 2 of 3

Total Depth: 41.5 ft.
Top Elevation: ~ 44 ft.
Vert. Datum:
Horiz. Datum:
Lat: ~ 47.1981 deg.
Long: ~ 122.2984 deg.
Station: ~
Offset: ~
Drilling Method: Mud Rotary
Drilling Company: Holocene Drilling
Drill Rig Equipment:
Other Comments:
Hole Diam.:
Rod Diam.: NWJ
Hammer Type: Automatic

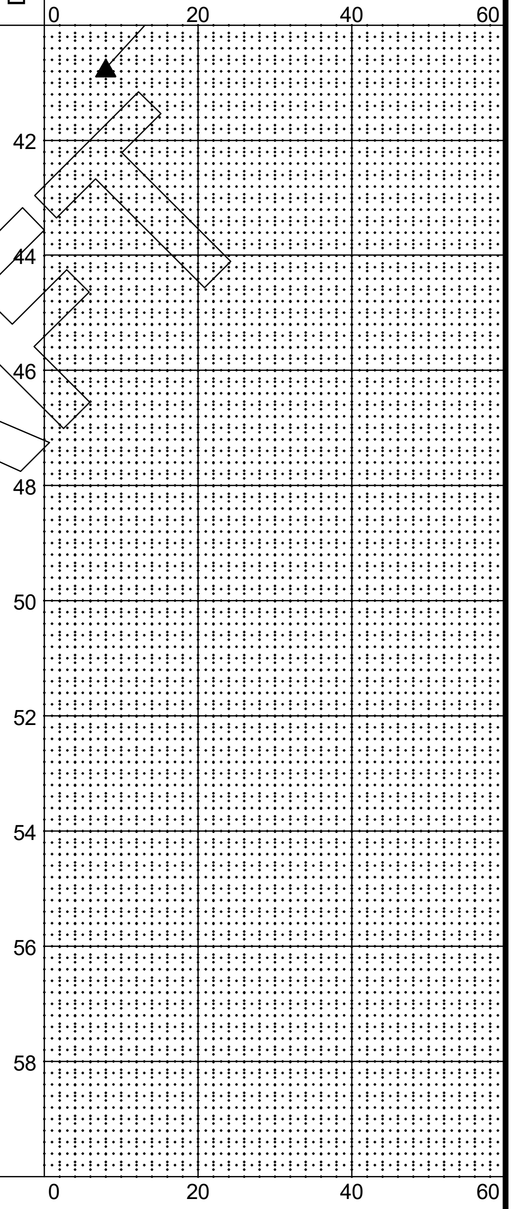
SOIL DESCRIPTION

Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

SOIL DESCRIPTION	Depth, ft.	Symbol	Samples	Ground Water
Loose, gray-brown *Silt with Sand (ML)*; moist; fine sand; nonplastic; few silty sand seams. (Ha)	41.5		16	
BOTTOM OF BORING COMPLETED 11/30/2020				

PENETRATION RESISTANCE (blows/foot)

▲ Hammer Wt. & Drop: 140 lbs / 30 inches



LEGEND

* Sample Not Recovered
G Grab Sample
I 2.0" O.D. Split Spoon Sample
II Thin Wall Sample

◇ % Fines (<0.075mm)
● % Water Content
Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location was measured from existing site features and should be considered approximate.

City of Puyallup
4th Avenue Storm Drainage Project
Pierce County, Washington

LOG OF BORING SWB-3-20

January 2021 105692-002

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

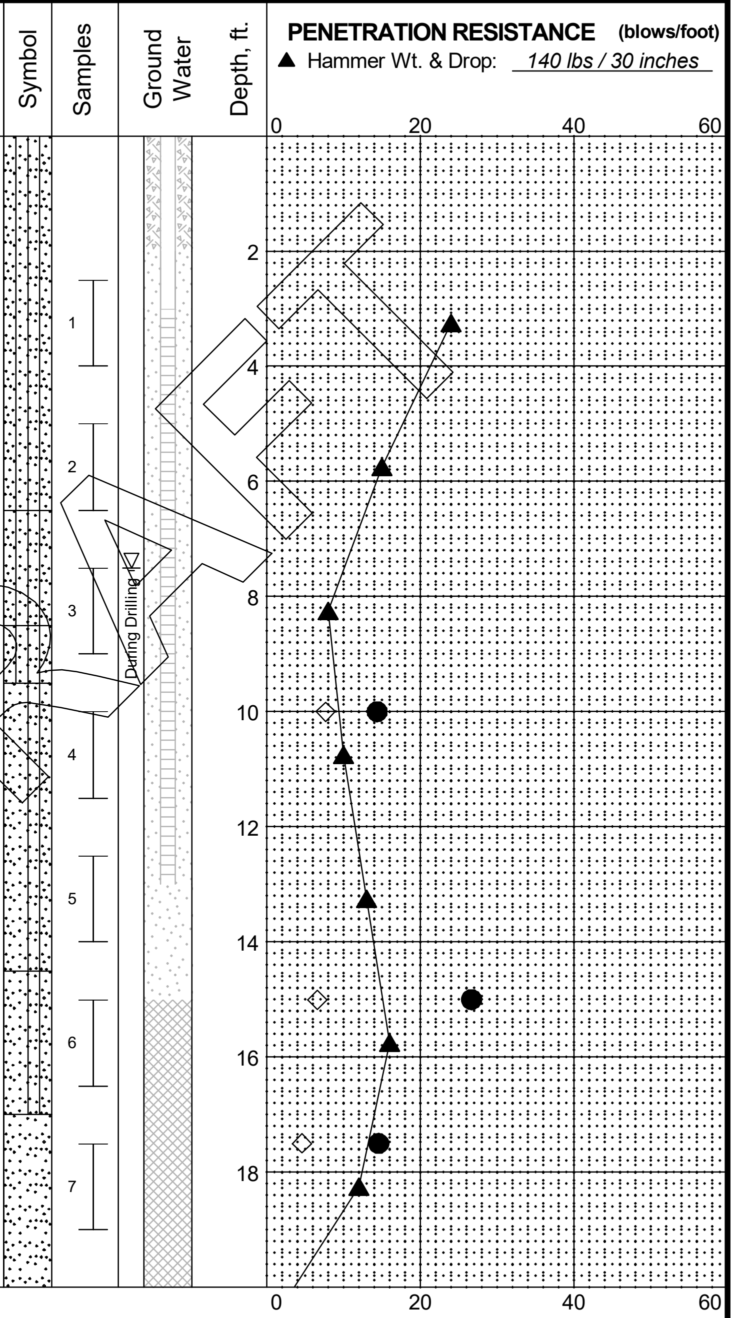
FIG. B-4
Sheet 3 of 3

Total Depth: 41.5 ft.
Top Elevation: ~ 37 ft.
Vert. Datum:
Horiz. Datum:
Lat: ~ 47.2003 deg.
Long: ~ 122.2984 deg.
Station: ~
Offset: ~
Drilling Method: Mud Rotary
Drilling Company: Holocene Drilling
Drill Rig Equipment:
Other Comments:
Hole Diam.:
Rod Diam.: NWJ
Hammer Type: Automatic

SOIL DESCRIPTION Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.	Depth, ft.
Medium dense, brown, *Silty Sand with Gravel (SM)*; moist; fine to coarse, subrounded to subangular gravel; fine to coarse sand; nonplastic to low plasticity. (Hf)	
Loose, dark gray, *Silty Sand (SM)*; moist; fine to medium sand; nonplastic. (Ha)	6.5
Loose, brown, *Silty Sand with Gravel (SM)*; moist; fine, subrounded gravel; fine to medium sand; nonplastic. (Ha)	8.5
Medium dense, dark gray,*Poorly Graded Sand with Silt (SP-SM)* and *Silty Sand (SM)*; moist; fine to medium sand; nonplastic. (Ha)	9.5
Medium dense, dark gray, *Poorly Graded Sand with Silt (SP-SM)*; wet; fine to medium sand; nonplastic. (Ha)	14.5
Very loose to dense, *Poorly Graded Sand with Gravel and Cobbles (SP)* to *Poorly Graded Gravel with Sand and Cobbles (GP)*; wet; few cobbles inferred from drill action; fine to coarse, subrounded gravel; fine to coarse sand;	17.0

PENETRATION RESISTANCE (blows/foot)

▲ Hammer Wt. & Drop: 140 lbs / 30 inches



◇ % Fines (<0.075mm)
● % Water Content

CONTINUED NEXT SHEET

LEGEND

*	Sample Not Recovered
⌶	2.0" O.D. Split Spoon Sample
▦	Well Screen and Sand Filter
▧	Bentonite-Cement Grout
⊠	Bentonite Chips/Pellets
▨	Bentonite Grout
⊻	Ground Water Level ATD

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location was measured from existing site features and should be considered approximate.

City of Puyallup
4th Avenue Storm Drainage Project
Pierce County, Washington

LOG OF BORING SWB-4-20

January 2021
105692-002

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-5
Sheet 1 of 3

Total Depth: 41.5 ft.
Top Elevation: ~ 37 ft.
Vert. Datum:
Horiz. Datum:
Lat: ~ 47.2003 deg.
Long: ~ 122.2984 deg.
Station: ~
Offset: ~
Drilling Method: Mud Rotary
Drilling Company: Holocene Drilling
Drill Rig Equipment:
Other Comments:
Hole Diam.:
Rod Diam.: NWJ
Hammer Type: Automatic

SOIL DESCRIPTION

Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

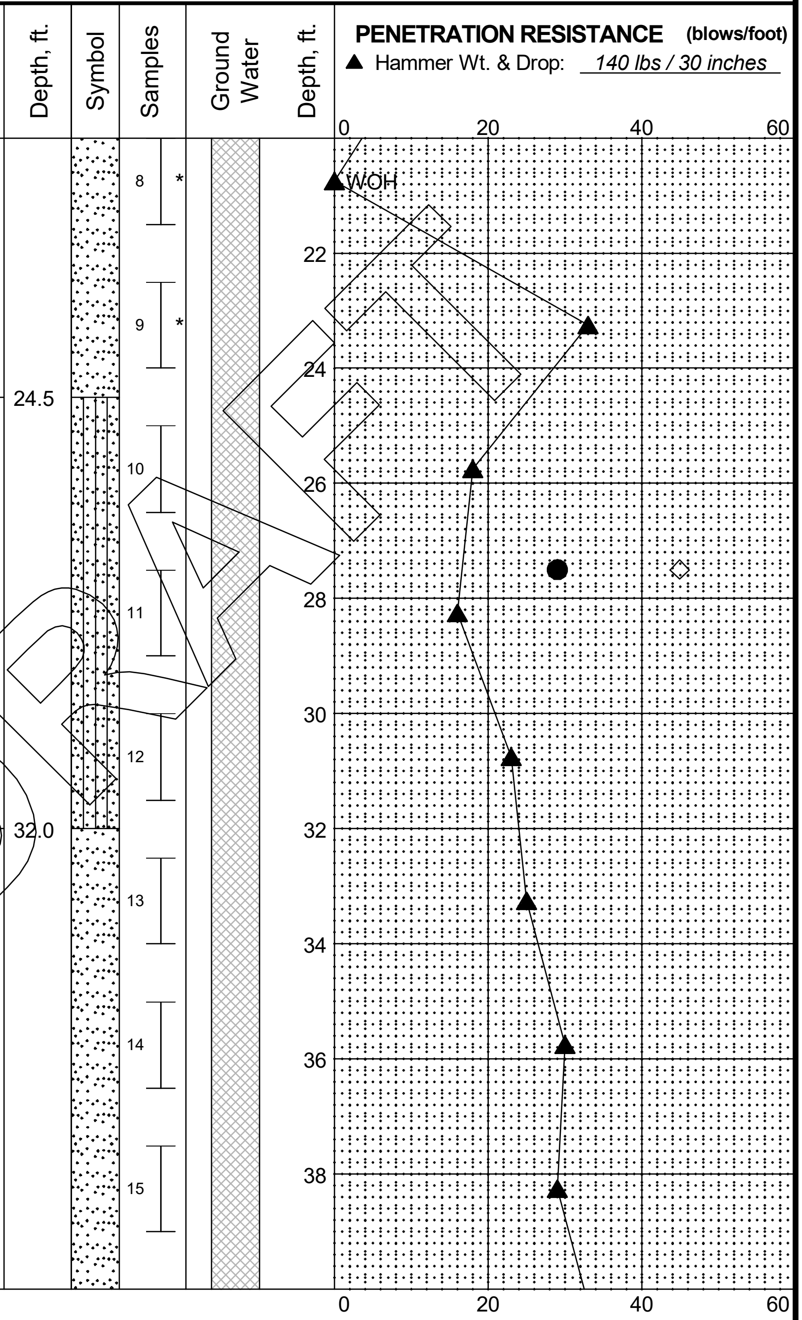
nonplastic.
(Ha)

- Silt to lean clay seam at 20 feet inferred from drill action.

Medium dense, dark gray, *Silty Sand (SM)*; wet; fine to medium sand; nonplastic; few poorly graded sand seams.
(Ha)

Medium dense to dense, dark gray, *Poorly Graded Sand (SP)*; wet; few coarse sand; fine to medium sand; nonplastic.
(Ha)

PENETRATION RESISTANCE (blows/foot)
▲ Hammer Wt. & Drop: 140 lbs / 30 inches



CONTINUED NEXT SHEET

LEGEND

- * Sample Not Recovered
- ⌶ 2.0" O.D. Split Spoon Sample
- ▦ Well Screen and Sand Filter
- ▧ Bentonite-Cement Grout
- ⊠ Bentonite Chips/Pellets
- ▨ Bentonite Grout
- ∇ Ground Water Level ATD

- ◇ % Fines (<0.075mm)
- ● % Water Content

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location was measured from existing site features and should be considered approximate.

City of Puyallup
4th Avenue Storm Drainage Project
Pierce County, Washington

LOG OF BORING SWB-4-20

January 2021 105692-002

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

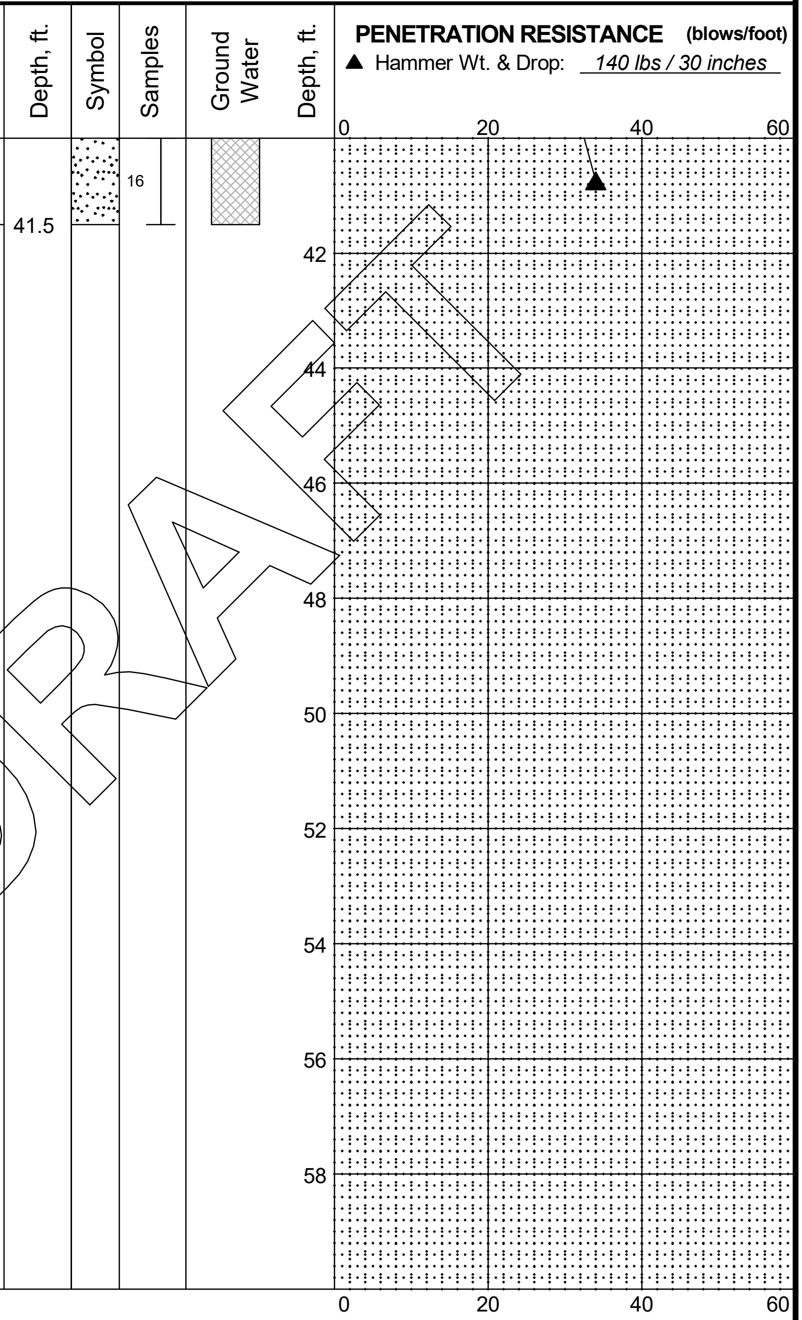
FIG. B-5
Sheet 2 of 3

Total Depth: 41.5 ft.
Top Elevation: ~ 37 ft.
Vert. Datum:
Horiz. Datum:
Lat: ~ 47.2003 deg.
Long: ~ 122.2984 deg.
Station: ~
Offset: ~
Drilling Method: Mud Rotary
Drilling Company: Holocene Drilling
Drill Rig Equipment:
Other Comments:
Hole Diam.:
Rod Diam.: NWJ
Hammer Type: Automatic

SOIL DESCRIPTION

Refer to the report text for a proper understanding of the subsurface materials and drilling methods. The stratification lines indicated below represent the approximate boundaries between material types, and the transition may be gradual.

BOTTOM OF BORING
COMPLETED 11/30/2020



LEGEND

* Sample Not Recovered
⌶ 2.0" O.D. Split Spoon Sample
▦ Well Screen and Sand Filter
▧ Bentonite-Cement Grout
▩ Bentonite Chips/Pellets
▨ Bentonite Grout
⊻ Ground Water Level ATD

NOTES

1. Refer to KEY for explanation of symbols, codes, abbreviations and definitions.
2. Groundwater level, if indicated above, is for the date specified and may vary.
3. USCS designation is based on visual-manual classification and selected lab testing.
4. The hole location was measured from existing site features and should be considered approximate.

City of Puyallup
4th Avenue Storm Drainage Project
Pierce County, Washington

LOG OF BORING SWB-4-20

January 2021
105692-002

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. B-5
Sheet 3 of 3

MASTER LOG E LATLONG 105692.GPJ SHAN WIL.GDT 1/12/21

APPENDIX C: GEOTECHNICAL LABORATORY TESTING

Appendix C

Geotechnical Laboratory Testing

Appendix C

Geotechnical Laboratory Testing

CONTENTS

Tables

Tests

C.1 INTRODUCTION

We performed geotechnical laboratory testing on selected soil samples retrieved from the borings completed for the 4th Avenue Storm Drainage Project. The laboratory testing program included tests to classify the soil and provide data for engineering studies. We performed visual classification on all retrieved samples. Our laboratory testing program included water content determinations, grain-size distribution analyses, and Atterberg Limits determinations.

The following sections describe the laboratory test procedures.

C.2 VISUAL CLASSIFICATION

We visually classified soil samples retrieved from the borings using a system based on ASTM D2487-17, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) (ASTM, 2017), and ASTM D2488-09a, Standard Recommended Practice for Description of Soils (Visual-Manual Procedure). We summarize our classification system in Appendix B. We assigned a Unified Soil Classification System (USCS) group name and symbol based on our visual classification of particles finer than 76.2 millimeters (3 inches). We revised visual classifications using results of the index tests discussed below.

C.3 WATER CONTENT DETERMINATION

We tested the water content of selected samples in accordance with ASTM D2216-10, Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass (ASTM, 2010a). Comparison of the water content of a soil with its index properties can be useful in characterizing soil unit weight, consistency, compressibility, and strength. We present water content test results in the Laboratory Test Summary table in this appendix and graphically in Appendix B exploration logs.

C.4 GRAIN-SIZE DISTRIBUTION ANALYSIS

Grain-size distribution analyses separate soil particles through mechanical or sedimentation processes. Grain-size distributions are used to classify the granular component of soils and can correlate with soil properties, including frost susceptibility, permeability, shear strength, liquefaction potential, capillary action, and sensitivity to moisture. We plot grain-size distribution analysis results in this appendix. Grain-size distribution plots provide tabular information about each specimen, including USCS group symbol and group name, water content, constituent (i.e., cobble, gravel, sand, and fines) percentages, coefficients of uniformity and curvature, if applicable, personnel initials, ASTM standard designation, and testing remarks. Constituent percentages are presented in the Laboratory Test Summary table in this appendix, and fines contents are plotted as data points in Appendix B exploration logs.

We performed mechanical sieve analyses on selected soil specimens to determine the grain-size distribution of coarse-grained soil particles in accordance with ASTM C136/C136M-14, Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates (ASTM, 2014).

C.5 ATTERBERG LIMITS DETERMINATION

We determined soil plasticity by performing Atterberg Limits tests on selected samples in accordance with ASTM D4318-10e1, Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils, Method A (Multi-Point Liquid Limit) (ASTM, 2010b). The Atterberg Limits include liquid limit (LL), plastic limit (PL), and plasticity index (PI=LL-PL). These limits can assist soil classification, indicate soil consistency (when compared to natural water content), provide correlation to soil properties, evaluate clogging potential, and estimate liquefaction potential.

We present soil plasticity test results in the Laboratory Test Summary table and on plasticity charts in this appendix. Plasticity charts provide the LL, PL, PI, USCS group symbol, the sample description, water content, and percent passing the No. 200 sieve (if a grain-size distribution analysis was performed). Soil plasticity test results are also shown graphically on Appendix B exploration logs.

C.6 CONSIDERATIONS

Drilling and sampling methodologies may affect the outcome of prescribed geotechnical laboratory tests. Refer to the field exploration discussion in this report for a discussion of these potential effects. Instances of limited recovery may have resulted in test samples not meeting specified minimum mass requirements per ASTM standards. Test plots show which samples do not meet ASTM-specified minimum mass requirements.

C.7 REFERENCES

ASTM, 2010a, Standard test methods for laboratory determination of water (moisture) content of soil and rock by mass, D2216-10: West Conshohocken, Pa., ASTM International, Annual book of standards, v. 04.08, soil and rock (I): D420 - D5876, 7 p., available: www.astm.org.

ASTM, 2010b, Standard test methods for liquid limit, plastic limit, and plasticity index of soils, D4318-10e1: West Conshohocken, Pa., ASTM International, Annual book of standards, v. 04.08, soil and rock (I): D420 - D5876, 16 p., available: www.astm.org.

ASTM, 2014, Standard test method for sieve analysis of fine and coarse aggregates, C136-14/C136M-14: West Conshohocken, Pa., ASTM International, Annual book of standards, v. 04.02, concrete and aggregates, 5 p., available: www.astm.org.

ASTM, 2017, Standard practice for classification of soils for engineering purposes (unified soil classification system), D2487-17: West Conshohocken, Pa., ASTM International, Annual book of standards, v. 04.08, soil and rock (I): D420 - D5876, 12 p., available: www.astm.org.

Table C-1 - Laboratory Terms

Abbreviations, Symbols, and Terms	Descriptions
%	Percent
*	Sample specimen weight did not meet required minimum mass for the test method
"	Inch
#	Test not performed by Shannon & Wilson, Inc. laboratory
ASTM Std.	ASTM International Standard
Cc	Coefficient of curvature
Clay-size	Soil particles finer than 0.002 mm
cm	Centimeter
cm2	Square centimeter
Coarse-grained	Soil particles coarser than 0.075 mm (cobble-, gravel- and sand-sized particles)
Cobbles	Soil particles finer than 305 mm and coarser than 76.2 mm
Cu	Coefficient of uniformity
CU	Consolidated-Undrained
e	Axial strain
Fine-grained	Soil particles finer than 0.075 mm (silt- and clay-sized particles)
ft	Feet
gm	Wet unit weight
Gravel	Soil particles finer than 76.2 mm and coarser than 4.75 mm
Gs	Specific gravity of soil solids
Ho	Initial height
DH	Change in height
DHload	End of load increment deformation
in	Inch
in3	Cubic inch
LL	Liquid Limit
min	Minute
mm	Millimeter
mm	Micrometer

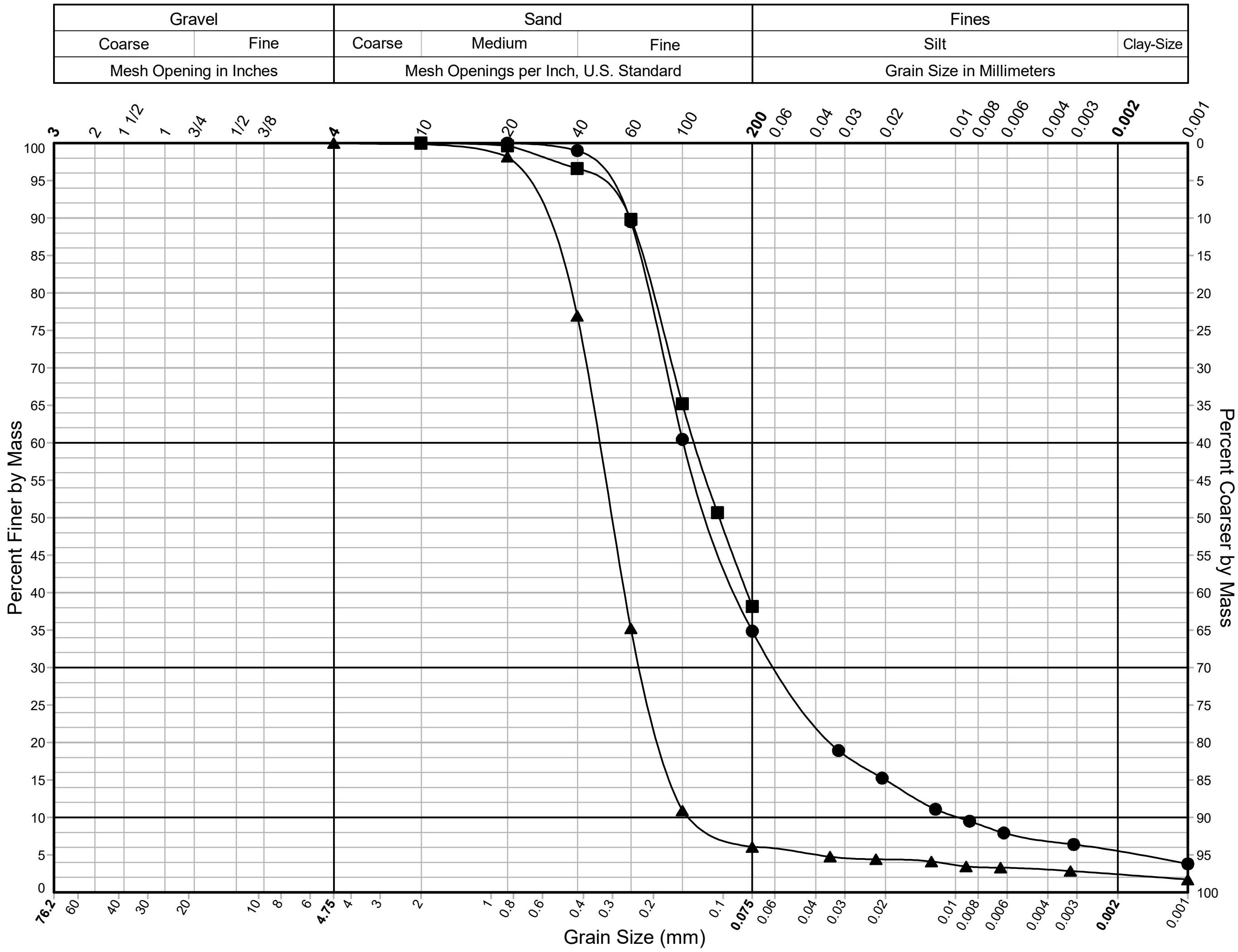
Table C-1 - Laboratory Terms

Abbreviations, Symbols, and Terms	Descriptions
MC	Moisture content
MPa	Mega-Pascal
NP	Non-plastic
OC	Organic content
p	Total stress
p'	Effective stress
Pa	Pascal
pcf	Pounds per cubic foot
PI	Plasticity Index
PL	Plastic Limit
psf	Pounds per square foot
psi	Pounds per square inch
q	Deviatoric stress
Sand	Soil particles finer than 4.75 mm and coarser than 0.075 mm
sec	Second
Silt	Soil particles finer than 0.075 mm and coarser than 0.002 mm
tn	Time to n% primary consolidation
tload	Duration of load increment
tsf	Short tons per square foot
USCS	Unified Soil Classification System
UU	Unconsolidated-Undrained
WC	Water content

GRAIN SIZE DISTRIBUTION PLOT

City of Puyallup
4th Ave Storm Drain Improvements
Pierce County, Washington

BORING SWB-1-20



Sample Identification	Depth (ft)	USCS Group Symbol	USCS Group Name	Gravel %	Sand %	Fines %	< 20µm %	< 2µm %	WC %	Tested By	Review By	ASTM Std.
● SWB-1-20, S-6	15.0	SM	Silty Sand		65	35	15	5	33.5	NS	AKV	D422
■ SWB-1-20, S-8*	20.0	SM	Silty Sand		62	38			26.7	NS	AKV	D6913
▲ SWB-1-20, S-13	32.5	SP-SM	Poorly Graded Sand with Silt		94	6.0	4	2	23.8	NS	AKV	D422

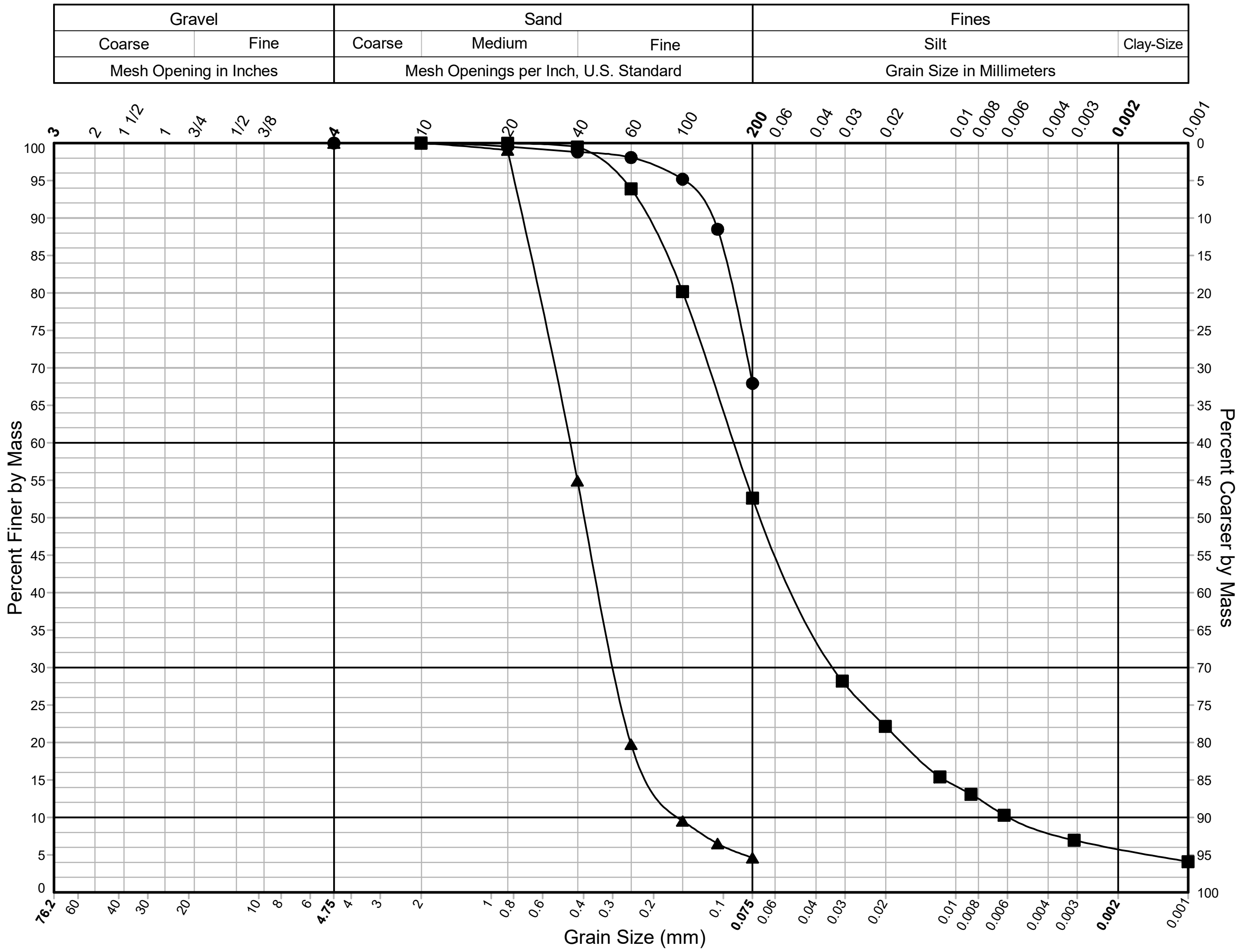
* *Test specimen did not meet minimum mass recommendations.*

SHANNON & WILSON, INC.

GRAIN SIZE DISTRIBUTION PLOT

City of Puyallup
4th Ave Storm Drain Improvements
Pierce County, Washington

BORING SWB-2-20



Sample Identification	Depth (ft)	USCS Group Symbol	USCS Group Name	Gravel %	Sand %	Fines %	< 20µm %	< 2µm %	WC %	Tested By	Review By	ASTM Std.
● SWB-2-20, S-5*	12.5	ML	Sandy Silt		32	68			34.7	NS	AKV	D6913
■ SWB-2-20, S-8	20.0	ML	Sandy Silt		47	53	22	6	28.5	NS	AKV	D422
▲ SWB-2-20, S-15*	37.5	SP	Poorly Graded Sand		95	4.6			21.9	NS	AKV	D6913

* *Test specimen did not meet minimum mass recommendations.*

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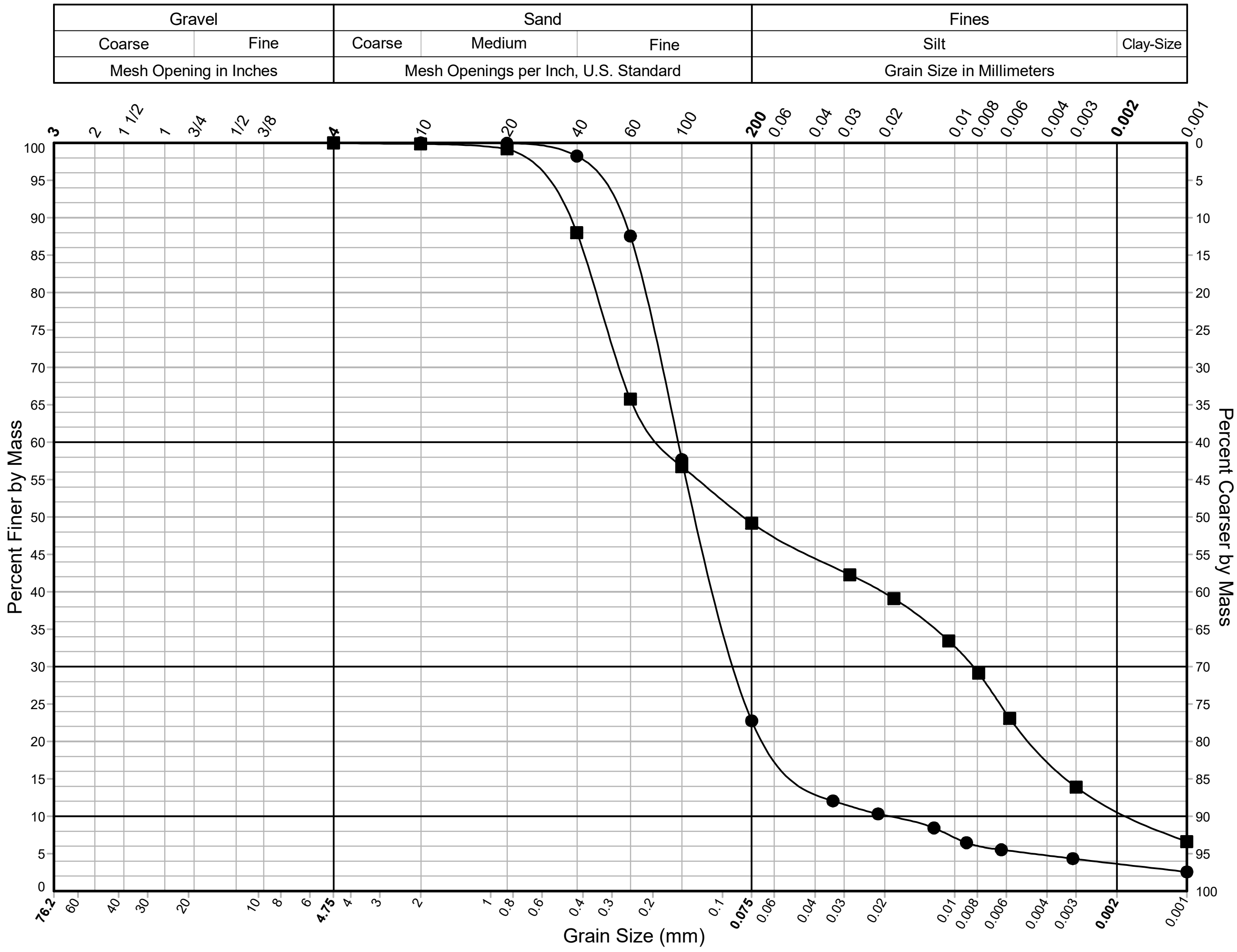
SHANNON & WILSON, INC.

GRAIN SIZE DISTRIBUTION PLOT

City of Puyallup
4th Ave Storm Drain Improvements
Pierce County, Washington

BORING SWB-3-20

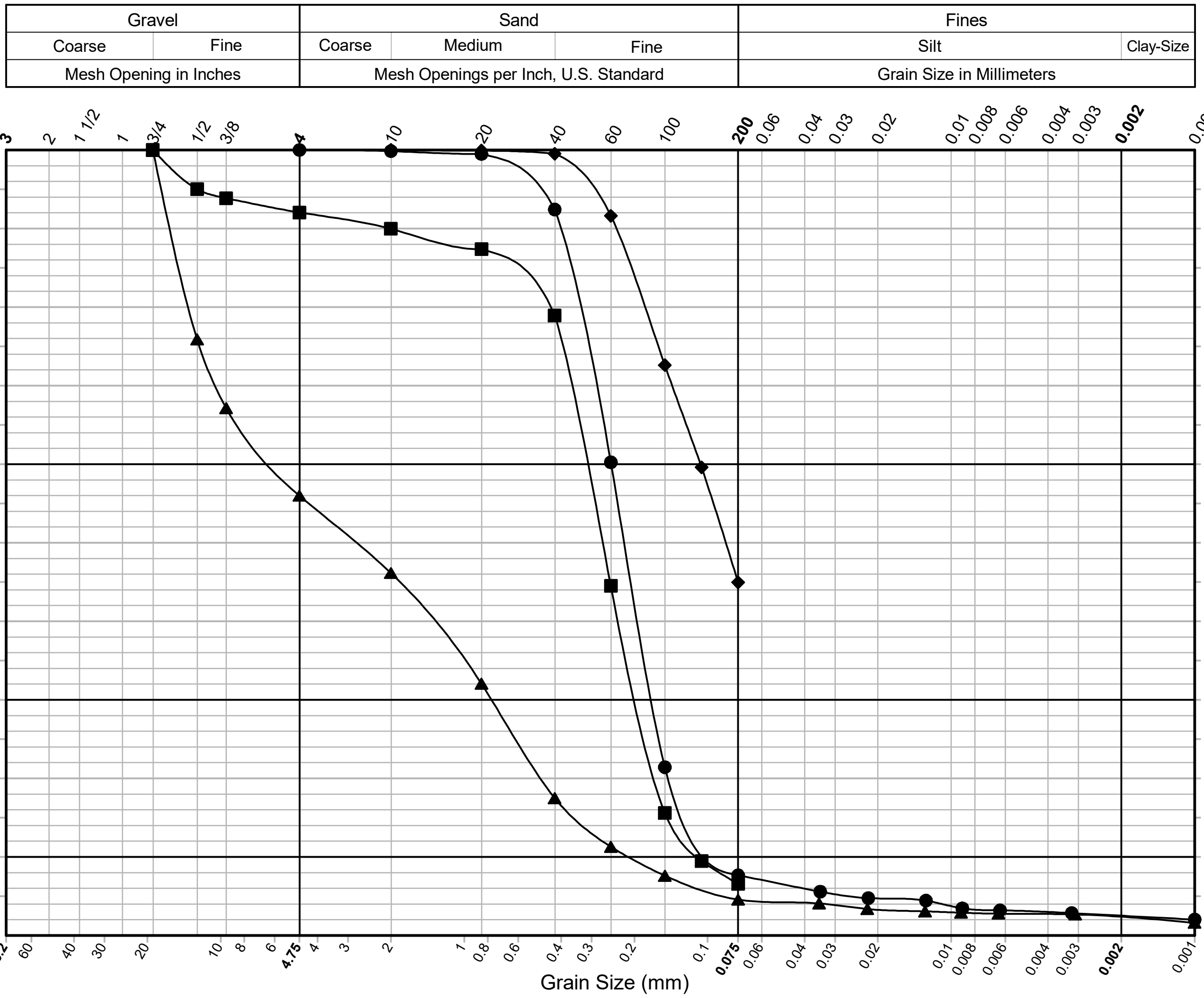


Sample Identification	Depth (ft)	USCS Group Symbol	USCS Group Name	Gravel %	Sand %	Fines %	< 20µm %	< 2µm %	WC %	Tested By	Review By	ASTM Std.
● SWB-3-20, S-5	12.5	SM	Silty Sand		77	23	10	4	32.4	NS	AKV	D422
■ SWB-3-20, S-8	20.0	SM	Silty Sand		51	49	40	11	38.7	NS	AKV	D422

GRAIN SIZE DISTRIBUTION PLOT

City of Puyallup
4th Ave Storm Drain Improvements
Pierce County, Washington

BORING SWB-4-20



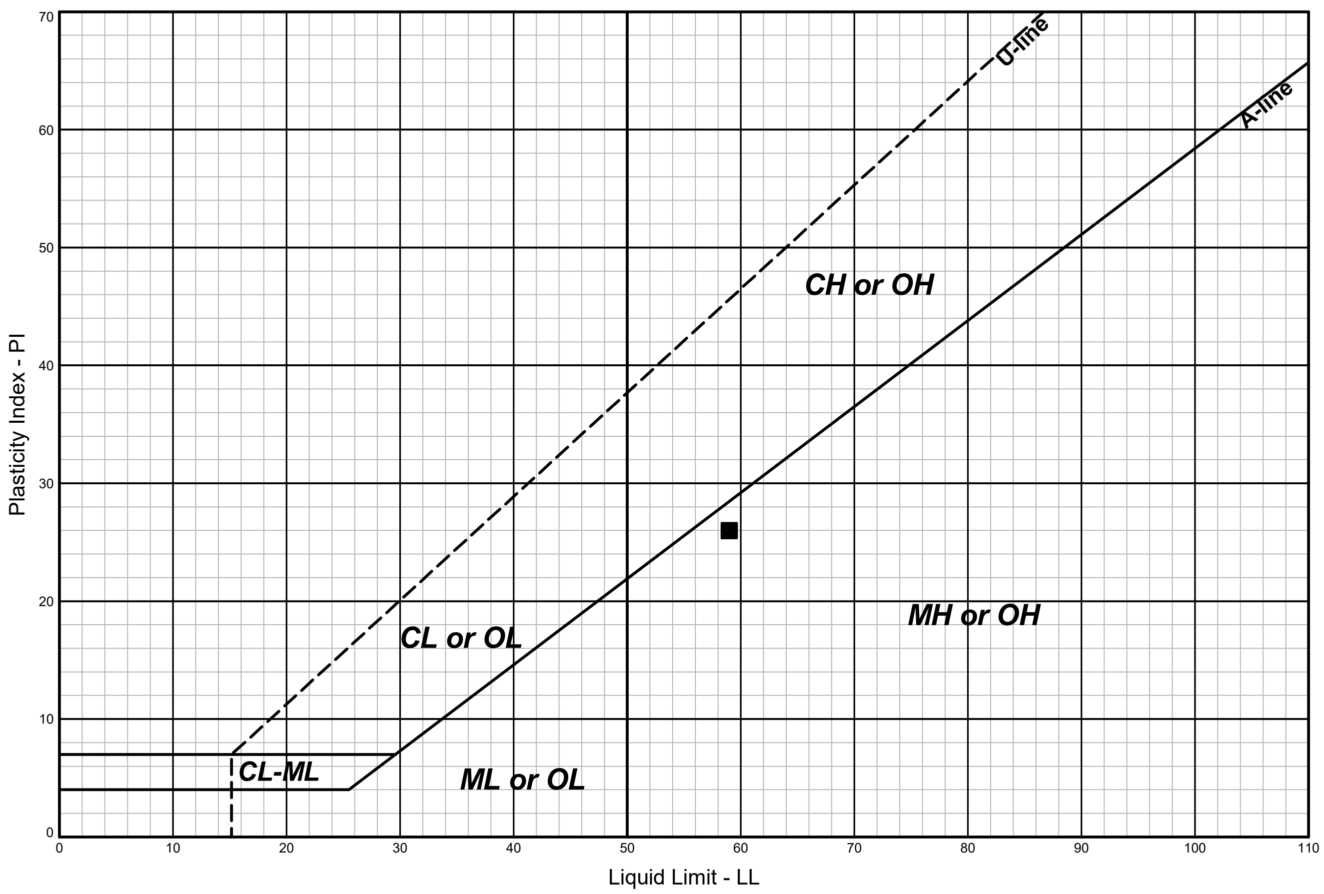
Sample Identification	Depth (ft)	USCS Group Symbol	USCS Group Name	Gravel %	Sand %	Fines %	< 20µm %	< 2µm %	WC %	Tested By	Review By	ASTM Std.
● SWB-4-20, S-4	10.0	SP-SM	Poorly Graded Sand with Silt		92	7.7	5	3	14.4	NS	AKV	D422
■ SWB-4-20, S-6*	15.0	SP-SM	Poorly Graded Sand with Silt	8	85	6.6			26.7	NS	AKV	D6913
▲ SWB-4-20, S-7*	17.5	SP	Poorly Graded Sand with Gravel	44	51	4.6	3	2	14.6	NS	AKV	D422
◆ SWB-4-20, S-11*	27.5	SM	Silty Sand		55	45			29.0	NS	AKV	D6913

* *Test specimen did not meet minimum mass recommendations.*

PLASTICITY CHART

City of Puyallup
4th Ave Storm Drain Improvements
Pierce County, Washington

BORING SWB-1-20

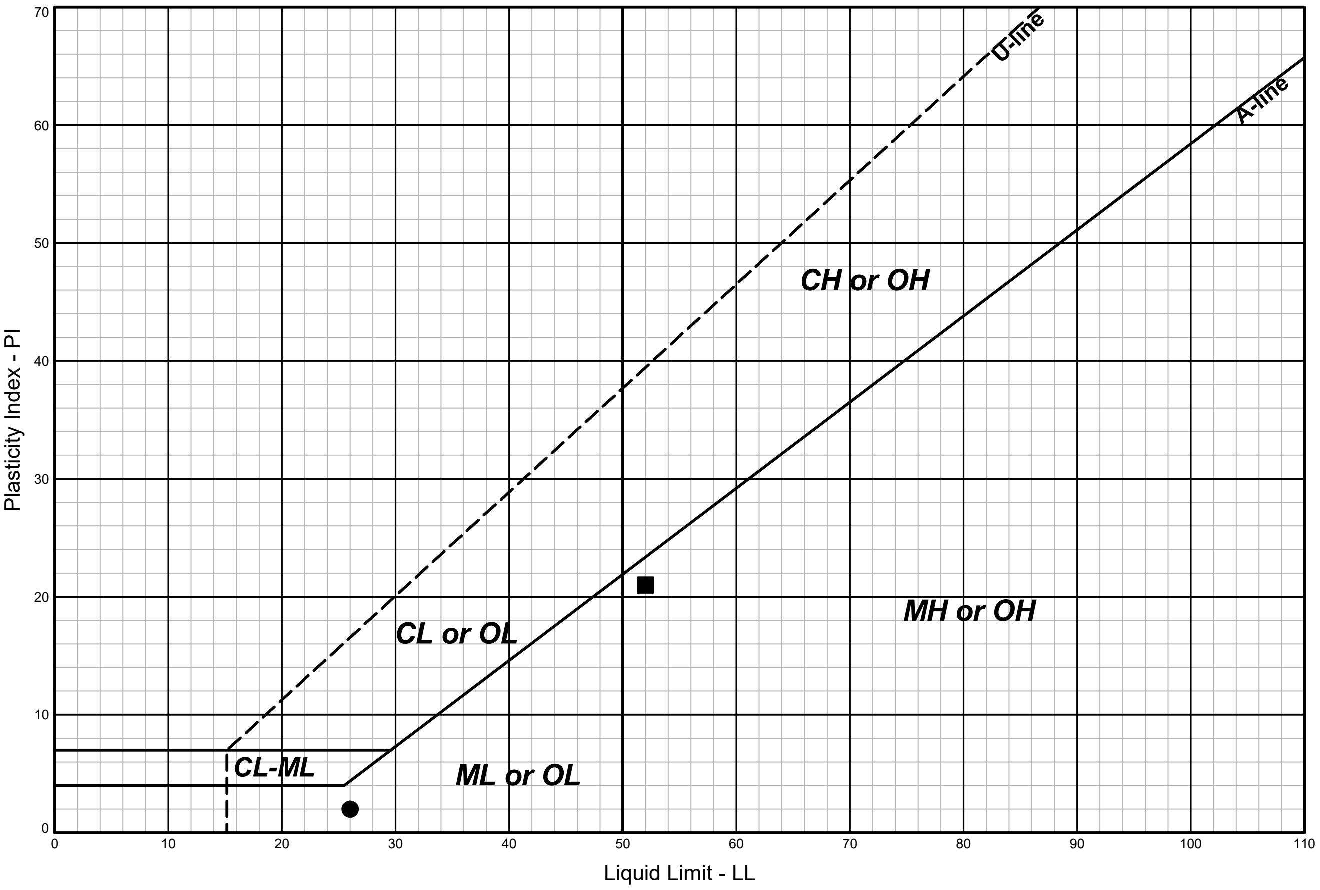


Sample Identification	Depth (ft)	USCS Group Symbol	USCS Group Name	LL	PL	PI	WC %	Gravel %	Sand %	Fines %	< 2µm %	Tested By	Review By	ASTM Std.
SWB-1-20, S-7	17.5	ML	Silt	27	27	**NP**	34.3					AKV	AKV	D4318
■ SWB-1-20, S-9	22.5	MH	Elastic Silt	59	33	26	53.3					BXK	AKV	D4318

PLASTICITY CHART

City of Puyallup
4th Ave Storm Drain Improvements
Pierce County, Washington

BORING SWB-2-20

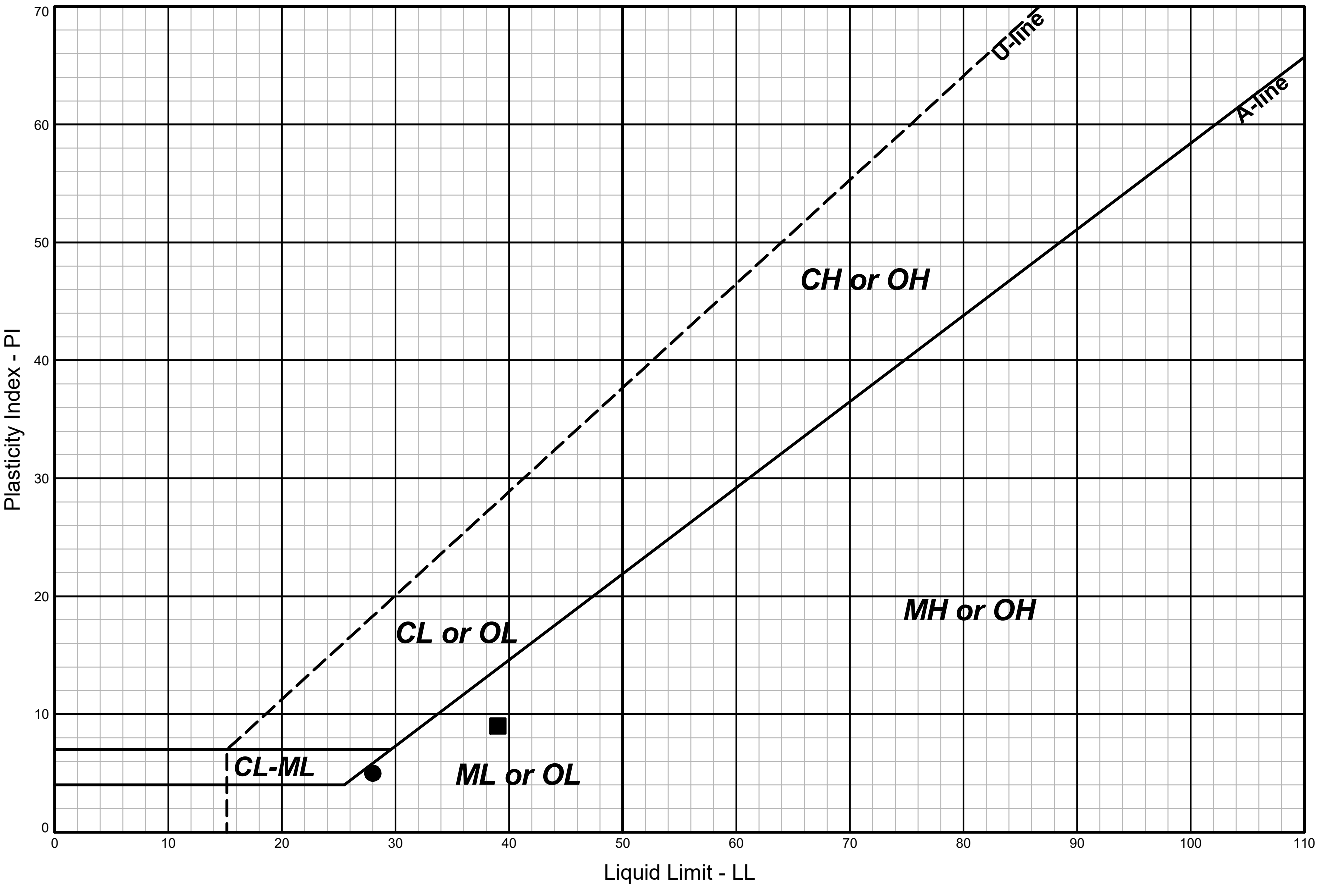


Sample Identification	Depth (ft)	USCS Group Symbol	USCS Group Name	LL	PL	PI	WC %	Gravel %	Sand %	Fines %	< 2µm %	Tested By	Review By	ASTM Std.
● SWB-2-20, S-6	15.0	ML	Sandy Silt	26	24	2	28.9					AKV	AKV	D4318
■ SWB-2-20, S-10	25.0	MH	Elastic Silt	52	31	21	64.6					BXK	AKV	D4318

PLASTICITY CHART

City of Puyallup
4th Ave Storm Drain Improvements
Pierce County, Washington

BORING SWB-3-20



Sample Identification	Depth (ft)	USCS Group Symbol	USCS Group Name	LL	PL	PI	WC %	Gravel %	Sand %	Fines %	< 2μm %	Tested By	Review By	ASTM Std.
● SWB-3-20, S-4	10.0	ML	Silt with Sand	28	23	5	29.1					AKV	AKV	D4318
■ SWB-3-20, S-9	22.5	ML	Silt	39	30	9	46.3					BXK	AKV	D4318

IMPORTANT INFORMATION

Important Information

About Your Geotechnical Report

IMPORTANT INFORMATION

CONSULTING SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND FOR SPECIFIC CLIENTS.

Consultants prepare reports to meet the specific needs of specific individuals. A report prepared for a civil engineer may not be adequate for a construction contractor or even another civil engineer. Unless indicated otherwise, your consultant prepared your report expressly for you and expressly for the purposes you indicated. No one other than you should apply this report for its intended purpose without first conferring with the consultant. No party should apply this report for any purpose other than that originally contemplated without first conferring with the consultant.

THE CONSULTANT'S REPORT IS BASED ON PROJECT-SPECIFIC FACTORS.

A geotechnical/environmental report is based on a subsurface exploration plan designed to consider a unique set of project-specific factors. Depending on the project, these may include the general nature of the structure and property involved; its size and configuration; its historical use and practice; the location of the structure on the site and its orientation; other improvements such as access roads, parking lots, and underground utilities; and the additional risk created by scope-of-service limitations imposed by the client. To help avoid costly problems, ask the consultant to evaluate how any factors that change subsequent to the date of the report may affect the recommendations. Unless your consultant indicates otherwise, your report should not be used (1) when the nature of the proposed project is changed (for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one, or chemicals are discovered on or near the site); (2) when the size, elevation, or configuration of the proposed project is altered; (3) when the location or orientation of the proposed project is modified; (4) when there is a change of ownership; or (5) for application to an adjacent site. Consultants cannot accept responsibility for problems that may occur if they are not consulted after factors that were considered in the development of the report have changed.

SUBSURFACE CONDITIONS CAN CHANGE.

Subsurface conditions may be affected as a result of natural processes or human activity. Because a geotechnical/environmental report is based on conditions that existed at the time of subsurface exploration, construction decisions should not be based on a report whose adequacy may have been affected by time. Ask the consultant to advise if additional tests are desirable before construction starts; for example, groundwater conditions commonly vary seasonally.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes, or groundwater fluctuations may also affect subsurface conditions and, thus, the continuing adequacy of a geotechnical/environmental report. The consultant should be kept apprised of any such events and should be consulted to determine if additional tests are necessary.

MOST RECOMMENDATIONS ARE PROFESSIONAL JUDGMENTS.

Site exploration and testing identifies actual surface and subsurface conditions only at those points where samples are taken. The data were extrapolated by your consultant, who then applied judgment to render an opinion about overall subsurface conditions. The actual interface between materials may be far more gradual or abrupt than your report indicates. Actual conditions in areas not sampled may differ from those predicted in your report. While nothing can be done to prevent such situations, you and your consultant can work together to help reduce their impacts. Retaining your consultant to observe subsurface construction operations can be particularly beneficial in this respect.

A REPORT'S CONCLUSIONS ARE PRELIMINARY.

The conclusions contained in your consultant's report are preliminary, because they must be based on the assumption that conditions revealed through selective exploratory sampling are indicative of actual conditions throughout a site. Actual subsurface conditions can be discerned only during earthwork; therefore, you should retain your consultant to observe actual conditions and to provide conclusions. Only the consultant who prepared the report is fully familiar with the background information needed to determine whether or not the report's recommendations based on those conclusions are valid and whether or not the contractor is abiding by applicable recommendations. The consultant who developed your report cannot assume responsibility or liability for the adequacy of the report's recommendations if another party is retained to observe construction.

THE CONSULTANT'S REPORT IS SUBJECT TO MISINTERPRETATION.

Costly problems can occur when other design professionals develop their plans based on misinterpretation of a geotechnical/environmental report. To help avoid these problems, the consultant should be retained to work with other project design professionals to explain relevant geotechnical, geological, hydrogeological, and environmental findings, and to review the adequacy of their plans and specifications relative to these issues.

BORING LOGS AND/OR MONITORING WELL DATA SHOULD NOT BE SEPARATED FROM THE REPORT.

Final boring logs developed by the consultant are based upon interpretation of field logs (assembled by site personnel), field test results, and laboratory and/or office evaluation of field samples and data. Only final boring logs and data are customarily included in geotechnical/environmental reports. These final logs should not, under any circumstances, be redrawn for inclusion in architectural or other design drawings, because drafters may commit errors or omissions in the transfer process.

To reduce the likelihood of boring log or monitoring well misinterpretation, contractors should be given ready access to the complete geotechnical engineering/environmental report prepared or authorized for their use. If access is provided only to the report prepared for you, you should advise contractors of the report's limitations, assuming that a contractor was not one of the specific persons for whom the report was prepared, and that developing construction cost estimates was not one of the specific purposes for which it was prepared. While a contractor may gain important knowledge from a report prepared for another party, the contractor should discuss the report with your consultant and perform the additional or alternative work believed necessary to obtain the data specifically appropriate for construction cost estimating purposes. Some clients hold the mistaken impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes that aggravate them to a disproportionate scale.

READ RESPONSIBILITY CLAUSES CLOSELY.

Because geotechnical/environmental engineering is based extensively on judgment and opinion, it is far less exact than other design disciplines. This situation has resulted in wholly unwarranted claims being lodged against consultants. To help prevent this problem, consultants have developed a number of clauses for use in their contracts, reports, and other documents. These responsibility clauses are not exculpatory clauses designed to transfer the consultant's liabilities to other parties; rather, they are definitive clauses that identify where the consultant's responsibilities begin and end. Their use helps all parties involved recognize their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your report, and you are encouraged to read them closely. Your consultant will be pleased to give full and frank answers to your questions.

The preceding paragraphs are based on information provided by the ASFE/Association of Engineering Firms Practicing in the Geosciences, Silver Spring, Maryland