

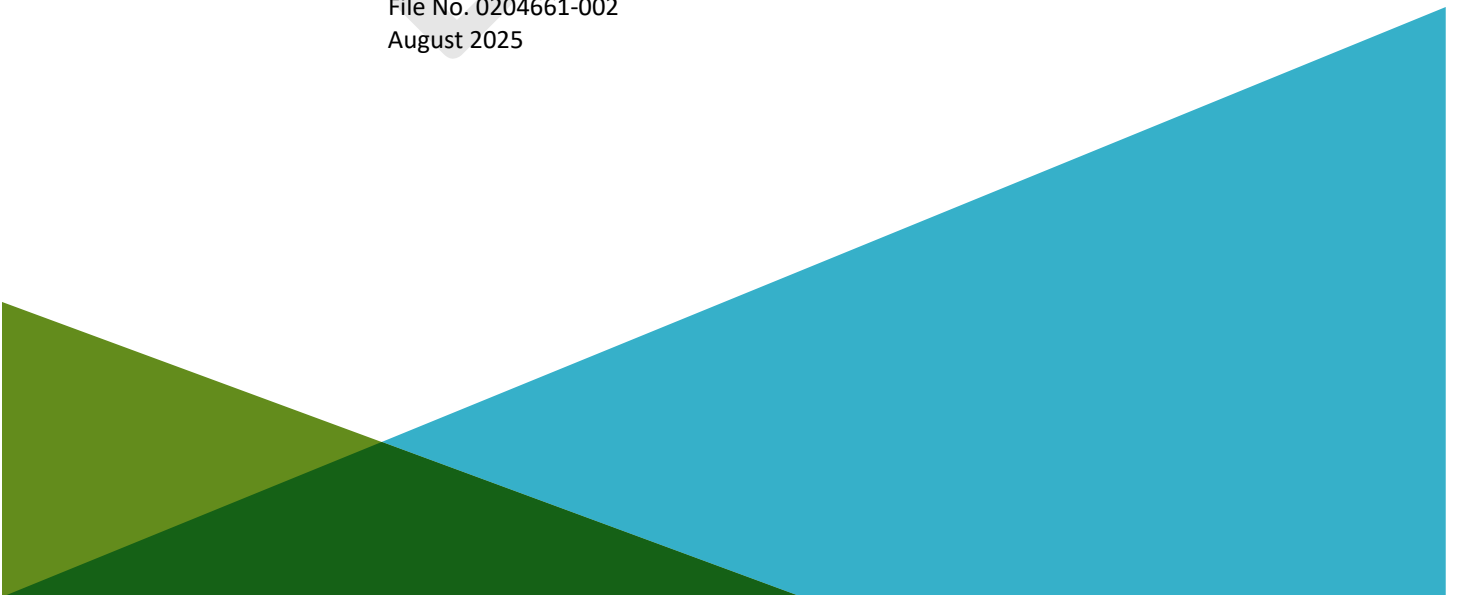
REPORT ON
SEA-TAC IWTP - AGB SITE
SEATTLE-TACOMA INTERNATIONAL AIRPORT
SEATAC, WASHINGTON

by
Haley & Aldrich, Inc.
Seattle, Washington

for
Port of Seattle
Seattle, Washington

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**REPORT ON
SEA-TAC IWTP – AGB SITE
SEATTLE-TACOMA INTERNATIONAL AIRPORT
SEATAC, WASHINGTON**

**PREPARED FOR
PORT OF SEATTLE
SEATTLE, WASHINGTON**

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1. Introduction

This report presents Haley & Aldrich, Inc.'s (Haley & Aldrich's) geotechnical engineering preliminary design recommendations for the proposed Industrial Wastewater Treatment Plant (IWTP) Enhancements project at Seattle-Tacoma International Airport (Sea-Tac) (Figure 1). This report is organized as follows:

1. Introduction;
2. Project Understanding
3. Purpose, Scope, and Use of This Report;
4. Subsurface Conditions;
5. Environmental Considerations;
6. Seismic Considerations;
7. Geotechnical Engineering Design Recommendations;
8. Hydrogeological Recommendations and Considerations; and
9. Recommendations for Continuing Geotechnical Services

2. Project Understanding

Our understanding of this project is based on AMC Engineer's Service Directive 13 with the Port of Seattle (Port), information provided by Gresham Smith and the Port, and the Basis of Design (BOD) prepared by Gresham Smith, dated June 23, 2023.

2.1 SITE DESCRIPTION

The project site is located at the south end of the Seattle-Tacoma International Airport in SeaTac, Washington, as shown in Figure 1. The site was previously developed and currently contains old slabs and elevated concrete foundations above the ground surface. The site exists within the Runway Protection Zone (RPZ) of Runway 34L and contains runway approach lighting. Portions of the site, primarily around the site entrance and abandoned structures, contain asphalt paving, while areas outside the paved zones site contain moderate vegetation. Figure 2 shows the conceptual layout of the Aerated Gravel Bed (AGB) cells, AGB tank, and supporting structures.

The existing site topography is irregular and generally slopes down from north to south. Elevations generally range from about 316 feet at the north end near South 188th Street to approximately 276 feet to the south. Portions of the planned AGB cells will be constructed near existing grade, where others at existing points of higher elevation will require excavation. The site covers approximately 14 acres and is bound to the north by the IWTP Dissolved Air Flotation Treatment (DAF) Building and South 188th Street, to the east by 13th Place South and industrial buildings, to the south by South 190th Street, and to the west by Des Moines Memorial Drive South.

2.2 PROJECT DESCRIPTION

Haley & Aldrich understands the proposed IWTP enhancements will include installation of a pre-treatment system and upgrading the existing systems to ensure compliance with future King County

Department of Natural Resources Industrial Waste Discharge (IWD) permit limits. The two primary areas of focus are the proposed AGB and existing Lagoon 3 sites. Based on our discussions with the Port, we understand that the existing Lagoon 3 site is removed from the Service Directive and data collection at the AGB will take precedence.

The IWTP Expansion is under consideration to address more stringent design discharge limits, projected increases in aircraft deicer application, and existing shortcomings in high-BOD wastewater storage capacity. The planned improvements include construction of AGBs, expansion of high-BOD wastewater storage capacity, and associated site improvements.

The AGBs are a biological treatment system consisting of lined cells filled with gravel beds that are designed to provide a stable environment for biological treatment of the industrial wastewater and deicing compounds. The treatment bed is lined with an impermeable synthetic liner and water levels are expected to be maintained to keep the gravel submerged.

The current concept includes up to six cells; however, the number of cells may be reduced while the overall footprint of the cells may be increased. The side walls of the cells will be constructed using embankments. The BOD depicts the embankment slopes at 1H:1V (horizontal:vertical); however, we understand this may be revised in a future design phase, based on slope stability considerations. Current plans show approximate cuts of up to 13 feet and fills of up to about 10 feet for the embankments.

Construction of the AGB tank and pump station will require deep excavations to approximately an elevation of 277 and 265 feet (or 18 to 31 feet deep), respectively. We understand the general footprint and location of the tank and pumpstation are unlikely to change with revised design concepts.

3. Purpose, Scope, and Use of This Report

The purpose of our services was to assess subsurface conditions at the site and provide geotechnical engineering recommendations related to the design and construction for the project. The fieldwork provides the basis for our geotechnical design recommendations for the IWTP project.

Our scope of services for the study included:

- Completing 19 soil borings;
- Installing monitoring wells in eight borings;
- Installing vibrating wire piezometers (VWP) in one boring;
- Performing laboratory testing on selected samples;
- Performing groundwater development and slug testing;
- Installing data loggers for continuous groundwater monitoring and downloading data quarterly;
- Providing geotechnical engineering and hydrogeological recommendations; and
- Preparing this report to present our analysis and conclusions.

Haley & Aldrich prepared this report for the exclusive use of AMC Engineers, the Port, and their design consultants for specific application to the IWTP project and site location. This report was prepared in accordance with our contract with AMC Engineers with an effective start date of October 21, 2024. Within the constraints of schedule and budget, we completed our services according to generally accepted geotechnical practices in the same or similar localities, related to the nature of the work accomplished, at the time the services were accomplished. We make no warranty, express or implied.

Elevations presented in this report are in reference to the North American Vertical Datum of 1988 (NAVD88) with the possible exception of historical boring logs, which are presented in their original format.

4. Subsurface Conditions

Our understanding of the subsurface conditions at the site is based on borings advanced as part of this study, laboratory tests on select soil samples, logs of existing explorations, and our experience on other projects at Sea-Tac. The locations of the soil explorations are illustrated in our Site and Exploration Plan (Figure 2). Field explorations were conducted from June 2 to 18, 2025. Nineteen borings were advanced. Eleven borings were drilled using a combination of mud rotary and hollow-stem auger methods and eight borings were drilled using sonic drilling. Borings extended to depths ranging from approximately 25 to 60 feet below ground surface (bgs).

Soil and groundwater conditions are summarized in the following sections. Appendix A includes descriptions of field activities performed, exploration logs, and details of the conditions found at the boring locations. The results of geotechnical laboratory testing are in Appendix B. Historical explorations performed by Haley & Aldrich (formerly Hart Crowser) and others at or near the site are in Appendix C. Methodology and results of estimation of hydraulic properties from slug testing and grain size analysis methods are included in Appendix D. Results from dewatering and depressurization analysis are provided in Appendix E.

The subsurface information used for this study represents conditions at discrete locations across the project site and actual conditions in other areas will vary. Furthermore, the nature and extent of any variations may not become evident until additional explorations are performed or until construction begins.

4.1 REGIONAL GEOLOGY

The Puget Sound basin is nestled between the Cascade and Olympic mountains in northwest Washington. Puget Sound is open to the Georgia Depression and the Strait of Juan de Fuca to the north. This area has been subjected to several major glaciations, which have left behind a complex sequence of glacially derived and interglacial sediments. These glaciations are characterized by an intricate sequence of lacustrine deposits, glaciomarine drift, till, and outwash.

The geology of the Puget Sound area is further complicated with the erosion and deposition of sediments during succeeding nonglacial and glacial intervals. During the most recent glaciation, the Vashon Glaciation, the Puget Sound area was covered with 3,000 feet of ice about 15,000 years ago. As the ice receded approximately 14,000 years ago, vast amounts of glacial till and outwash were deposited in the region.

Two primary geologic glacial deposits were encountered at the site:

- Glacial Till is the non-sorted, non-stratified ground moraine material carried along the sole of the glacial ice. In the Puget Sound area, till soils are generally granular in nature and are normally found in a dense to very dense condition and contain scattered or agglomerated cobbles and boulders.
- Advance Outwash are sediments deposited in front of the glacier's leading edge as the glacial ice advanced through the Puget Lowland. This unit is typically found in the same areas as the till soils described above. Advance Outwash soils are generally dense to very dense, clean to silty, fine to coarse sand, and are locally gravelly.

4.2 SOIL CONDITIONS

The soil layers observed during the field exploration program were broadly categorized based on their engineering properties into Engineering Soil Units (ESUs). In general, the soils observed in the explorations consist of the following soil units, described in the order they were encountered from the ground surface.

- **ESU 1 - Fill.** The Fill unit varies in thickness and consistency across the site. Any engineered or non-engineered soils placed by humans is classified as fill (e.g., imported, native till-fill). Fill soils generally have variable properties, and may contain debris and organic matter.

Fill depths at our boring locations varied from about 5 to 18 feet below existing grade and were observed to consist of gravelly sand to silt and sandy silt. Standard Penetration Test (SPT) blow counts indicated the relative compaction of the Fill varied widely. Granular soils ranged from very loose to dense and the fine-grained material ranged from soft to stiff. Concrete, brick, and wood debris were also encountered. The borings indicate that certain zones within the Fill also contain a large amount of organic material. With proper subgrade preparation, the Fill material may be suitable for lightly loaded foundations that can tolerate a moderate amount of settlement.

- **ESU 2 - Glacial Till.** This layer generally consists of very dense silty sand with gravel. The upper portion of this layer may be weathered, resulting in a lower relative density (e.g., medium dense to dense). The Glacial Till was observed below the Fill to approximately 30 to 40 feet bgs. Glacial Till is suitable for support of heavily loaded foundations.

Although not encountered in our explorations, cobbles and boulders may be present within this unit. Such large materials could make drilling and/or excavation difficult. Therefore, the contractor should be prepared to deal with large obstructions. In addition, the Glacial Till unit may also contain relatively clean sand and/or gravel zones, where groundwater may accumulate and be prone to caving when exposed in a vertical face. Provisions should be made in contract documents to account for the possibility of these conditions.

- **ESU 3 - Glacial Outwash.** A unit of Glacial Outwash was encountered below the Glacial Till and generally consist of dense to very dense sand with minor constituents of silt and gravel. The Glacial Outwash extended to the maximum depths explored (up to about 60 feet). Artesian conditions were noted in this unit and are discussed in Section 4.3.

4.3 GROUNDWATER CONDITIONS

Groundwater conditions were observed during drilling and measured in monitoring wells and VWP's installed at the site. Monitoring wells were completed in eight borings in June 2025 (W-1, W-2, W-3, W-4, W-5, W-6, W-7, and W-9). Two VWP's were installed in boring W-8. Monitoring wells W-2, W-3, W-5 and W-6 are screened in the Glacial Till unit and W-1, W-4, W-7, and W-9 are screened in the Glacial Outwash. The VWP's in W-8 are installed in the Glacial Outwash. Groundwater measurements obtained during drilling are presented on the boring logs in Appendix A. A summary of monitoring well and VWP construction is presented in Table 1 (attached). VWP calibration sheets are attached in Appendix A.

Manual groundwater level measurements were collected from the selected monitoring wells between June and August 2025. Continuous groundwater level monitoring is being performed using pressure transducers with integrated data loggers installed in monitoring wells (W-2, W-3, W-4, and W-5) and VWP's installed in W-8. Water levels could not be measured in W-1, W-6, W-7, and W-9 because of flowing water artesian conditions. Results of groundwater monitoring, including manual measurements and hydrographs, are provided in Appendix D.

During drilling, groundwater was encountered within the Fill/Glacial Till unit at depths of 5 to 12 feet (elevation 268 to 299 feet). Saturated conditions were also encountered in granular lenses within the Glacial Till unit during drilling and in monitoring wells completed in the Glacial Till. Groundwater within the Glacial Till ranges from approximately 274 to 296 feet elevation. Shallow groundwater in the Fill is indicative of an unconfined, perched groundwater table within the Fill unit. Groundwater in the Fill and Glacial Till generally flows from north to south.

Pressurized groundwater conditions were encountered within the Glacial Outwash unit at the time of drilling. Groundwater levels within wells screened in the Glacial Outwash unit (W-4, W-6, W-7, and W-9) indicate artesian conditions in which the piezometric level are near or higher than ground surface. Piezometric levels in the Glacial Outwash unit ranged from an elevation of 302 feet (W-4) to flowing artesian conditions with piezometric level above the ground surface (W-1, W-6, W-7, and W-9). Groundwater pressure measured in the Glacial Outwash unit ranges from an elevation of 302 to 309 feet (or approximately 12 to 15 feet above the ground surface in the vicinity of W-7). The Glacial Outwash unit is a confined, artesian aquifer.

Hydrographs from the monitoring wells (W-2, W-3, W-4, and W-5) and VWP (W-8) showing groundwater levels collected in June through August 2025 show relatively stable groundwater levels with water levels fluctuating by less than 1 foot (Appendix D, Figures D-1 to D-3). Groundwater levels are expected to rise during the wet season. Groundwater level fluctuations can be expected to occur from variations in rainfall, season, flooding, atmospheric conditions, and other factors.

An upward vertical gradient of approximately 0.3 to 0.9 foot per foot (ft/ft) exists between the Glacial Outwash and Glacial Till units due to the pressurization of the Glacial Outwash. An upward gradient of approximately 0.1 ft/ft was measured within the Glacial Outwash unit between the two VWP's. Tables with calculations for vertical gradient and a summary of the results are attached in Appendix D in Tables D-5 and D-6.

Riser pipes were added to wells with flowing conditions, but water levels rose above the higher riser-pipe elevation. Due to the flowing conditions in these monitoring wells (W-6, W-7, and W-9), they will

not be able to measure artesian water levels through the wet season. Only W-8 will be able to measure, since it contains VWP's that measure pressure rather than the physical water level. We recommend the installation of one additional well with VWP's for long-term monitoring of artesian pressures.

4.4 REVIEW OF EXISTING SUBSURFACE INFORMATION

As part of our study, we reviewed available boring logs and cross sections within the vicinity of the project site. Historical borings near the site were generally shallow, typically not exceeding depths more than 20 feet. In addition to the shallow extents, the majority of the soil borings were advanced using direct-push methods without SPTs, limiting the available information on soil density and consistency. In addition to unknown density of the drilled material, and because some zones of Fill consist of repurposed Glacial Till, the thickness of the Fill is not always identifiable across the site.

4.4.1 Lagoon 3 Site

Additional borings were drilled in the surrounding areas as part of prior site development. The Lagoon 3 site, located to the east, includes subsurface information. These borings penetrated into the Glacial Outwash where artesian conditions were noted. The log of historical boring MWE-07, drilled as part of the STIA IWS Hydrogeological study, identified the presence of Advance Glacial Outwash at about an elevation of 271 feet Mean Sea Level (MSL). At the time of drilling, water was observed to rise to approximately 275 feet MSL. A subsequent reading was also collected after the completion of drilling and water was measured at about an elevation of 300 feet MSL.

Haley & Aldrich has requested geotechnical reports associated with the Lagoon 3 site from the Port. These historical reports were not available at the time of this report. We understand the contractor encountered groundwater in the Advanced Outwash layer and organic soil/peat during mass excavation. We recommend that we review data and reports from Lagoon 3 prior to finalizing our report.

4.5 HYDRAULIC PROPERTIES OF SITE SOILS

Hydraulic conductivity of site soils was estimated from correlations with grain size data and from slug testing performed in monitoring wells. Hydraulic conductivity is a measure of the ability of aquifer materials to transmit groundwater and is controlled by the size, amount, and interconnection of void spaces in the water-bearing zones. Hydraulic conductivity is an important parameter in predicting the amount of water produced from construction dewatering. Detailed description of methodology and results of hydraulic parameter analyses are included in Appendix D.

Mean hydraulic conductivity values from slug testing were 1.4 feet per day (ft/day) (4.9×10^{-4} centimeters per second (cm/sec)) in the Fill unit, from 0.9 to 7.3 ft/day (3×10^{-4} to 2.6×10^{-3} cm/sec) in the Glacial Till unit, and 5.2 feet per day ft/day (1.8×10^{-3} cm/sec) in the Glacial Outwash unit. These values are generally consistent with published ranges (Freeze and Cherry, 1979). In our experience, hydraulic conductivity of Glacial Till is typically one to two orders of magnitude less than measured. This discrepancy can often be explained by the location of well screens in cleaner sand lenses within the Glacial Till unit.

Estimates of hydraulic conductivity of the Glacial Outwash from grain size data range from 10 to 331 ft/day (3.6×10^{-3} to 1.2×10^{-1} cm/sec). Use of grain size methods to estimate hydraulic conductivity is often accurate only to the general order of magnitude (Eggleston and Rojstaczer, 2001). However, this

provides insight into the potential variability of hydraulic conductivity within the Glacial Outwash to supplement the slug testing, which was possible only in W-4 screened in the Glacial Outwash.

5. Environmental Considerations

Based on review of Washington State Department of Ecology (Ecology)-listed sites at or near Sea-Tac and use of the site, potential constituents of concern include petroleum hydrocarbons, metals, and per- and polyfluoroalkyl substances in soil and/or groundwater. During our explorations, we field screened using visual and olfactory observations for potentially impacted soil. We also performed headspace vapor screening using a photoionization detector (PID). In general, PID levels were relatively low (less than approximately 5 parts per million [ppm]) except those recorded from borings B-9 between about 0 and 10 feet bgs, W-2 between about 5 and 25 feet bgs, and W-9 between about 10 and 40 feet bgs. The samples obtained at these locations had PID readings up to a maximum of 17.1 ppm. No other indicators of potentially impacted soil, such as staining, sheen, or petroleum-like odor, were observed during the borings completed for this project. We submitted several soil and groundwater samples to an Ecology-accredited laboratory for analytical testing. The results of our environmental testing program will be provided later in a memorandum.

6. Seismic Considerations

The site is in a seismically active area. In this section, we describe the seismic setting at the project site, identify the seismic BOD, provide recommendations for design response spectra, and discuss the seismic hazards at the site.

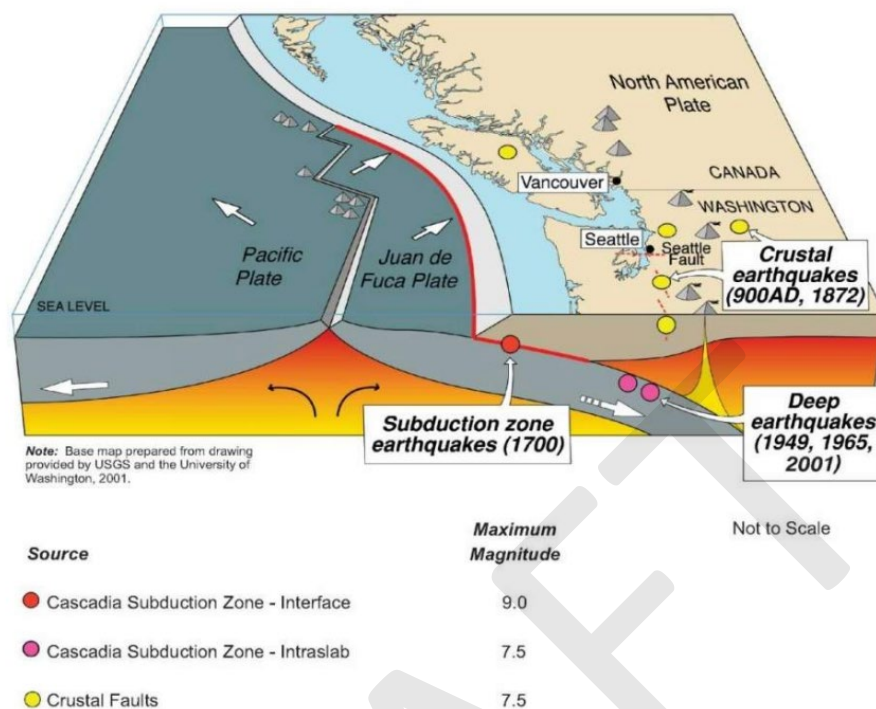
6.1 SEISMIC SETTING

The seismicity of western Washington is dominated by the Cascadia Subduction Zone, in which the offshore Juan de Fuca Plate subducts beneath the continental North American Plate. Three types of earthquakes are associated with subduction zones: interface subduction, intraslab subduction, and crustal earthquakes.

Interface and Intraslab Subduction Earthquakes. The offshore Juan de Fuca Plate is subducting (pushing below) below the North American Plate, causing two distinct types of seismic events. Large-magnitude interface subduction earthquakes occur at shallow depths near the Washington coast at the interface between the two plates (e.g., the 1700 earthquake, with magnitude of approximately 9.0). A deeper zone of seismicity is associated with bending of the Juan de Fuca Plate below the Puget Sound region. The bending produces intraslab subduction earthquakes at depths of 40 to 70 kilometers (e.g., the 1949, 1965, and 2001 earthquakes).

Crustal Earthquakes. Recent fault trenching and seismic records in the Puget Sound area indicate a distinct shallow zone of crustal seismicity (e.g., Seattle and Tacoma Faults), which may have surficial expressions and can extend 25 to 30 kilometers deep. The Seattle Fault Zone is an east-west trending thrust (reverse) fault that separates thick sediment to the north (Seattle Basin) from near-surface

bedrock and thin sediment to the south. The project site is located approximately 8 miles (13 kilometers) south of the middle of the Seattle Fault Zone. (Exhibit 1).



[Source: Cascadia Earthquake Sources (<https://pnsn.org/outreach/earthquakesources>)]

Exhibit 1. Characteristic Tectonics of the Pacific Northwest

6.2 SEISMIC PARAMETERS

Table 2 presents applicable seismic design parameters in accordance with design codes: 2021 International Building Code (IBC) (which references American Society of Civil Engineers [ASCE] 7-16, 2017) These parameters were obtained from the U.S. Seismic Design Maps web application (<https://www.usgs.gov/natural-hazards/earthquakehazards/design-ground-motions>), accessed on August 11, 2025.

Haley & Aldrich understands that, since the timeline for site development is still undecided, the 2024 IBC, referencing ASCE 7-22 for seismic design, may be adopted. If the preferred approach is to develop site class parameters based on the 2024 IBC, we can provide an updated site class and design response spectrum parameters in a future design report.

Table 2. Seismic Design Parameters for IBC 2021 and ASCE 7-16	
Parameter	Value
Latitude	47.43501
Longitude	-122.318003
Site Class	C
Special response acceleration at short periods, S_s	1.48
Special response acceleration at 1-second periods, S_1	0.50
Mapped peak ground acceleration (PGA)	0.63
Site coefficient at short periods, F_a	1.2
Site coefficient at 1-second periods, F_v	1.5
Seismic coefficient, F_{PGA}	1.2

6.3 SEISMICALLY INDUCED GEOTECHNICAL HAZARDS

To assess seismically induced geotechnical hazards, we considered the soil explorations discussed in this report, our experience in this region, and our knowledge of local seismicity. The potential for surface rupture is very low because no known faults intersect the project areas and the known earthquake source nearest the site, the Seattle Fault Zone, is approximately 8 miles (13 kilometers) north of the site and has a return period of thousands of years. The risk of liquefaction is also very low, because the glacially overridden soils are dense, and no saturated loose granular soil has been identified at the site. Overall, we conclude the potential for seismically induced geotechnical hazards, such as surface rupture and liquefaction, is very low at the project site during the design life of the structure.

7. Geotechnical Engineering Design Recommendations

Our recommendations are based on our current understanding of the project and the subsurface conditions revealed by recent and historical borings. If the nature or location of the proposed project elements is different than our understanding presented herein, Haley & Aldrich should be notified so we can change or confirm our recommendations.

7.1 GENERAL CONSIDERATIONS

The primary geotechnical aspects of this project are as follows:

- Embankments.** Construction of the AGB cells will require embankments with varying heights. Preliminary concepts indicate side slopes of approximately 1H:1V, although these may be adjusted during future design phases and based on slope stability analyses. The embankments will be constructed using engineered fill and zones of cut and fill will vary across the site depending on existing elevation. The embankments should be constructed with suitable fill and properly compacted for stability. Settlement will also need to be evaluated and could be significant in areas with thick zones of fill over organic material.
- Temporary Shoring.** The site will require an excavation of approximately 25 to 30 feet for construction of the AGB Tank. A soldier pile and tieback shoring system may be necessary to support the excavation. However, the selection of the most appropriate shoring system should be made through discussions with the owner, structural engineer, the shoring designer, and the contractor. The decision should include consideration of the cost and schedule differences, as

well as the soil and groundwater conditions, availability of materials, and availability of installation subcontractors.

- **Shallow Foundations.** Based on our review of the boring data and the planned foundation depths, the native soils at the project site are suitable to support the tank foundation. In areas with lightly loaded shallow foundations near the existing ground surface in fill, removal of existing soils, all organic material, and replacement of 2 feet of structural fill may be required.
- **Temporary Groundwater Control.** Drainage of perched water and groundwater will need to be accommodated by the shoring system during excavation. This water may require shallow well points around the site. If a limited volume of water is present, sumps and pumps within the excavation may be suitable. The lower aquifer will need to be dewatered (i.e., depressurized) during excavation to prevent basal heave.
- **Permanent Drainage.** A suitable permanent foundation wall and underslab drainage system will be needed for the tank. If instead, the tank is designed without drainage, it will need to resist potential hydrostatic uplift forces.

7.2 SITE PREPARATION AND GRADING

Based on our understanding of the proposed site layout and structure configuration, site preparation will involve clearing existing vegetation and existing pavement, demolishing old slabs and foundations, and removing obstructions in the Fill that may interfere with construction. In some areas, excavation will be required to achieve the proposed foundation and subgrade elevations. We recommend site grading, paving, and any utility trenching be conducted during relatively dry weather, if possible.

The proposed AGB cells are generally located in areas with varying degrees of development, ranging from completely undeveloped to asphalt paved. Excavated soils that meet the structural fill requirements in Section 7.10 may be reused to construct embankments.

It may also be necessary to relocate or abandon some utilities. Excavation of these utility lines will occur through fill materials. Abandoned underground utilities should be removed or completely grouted. Remaining abandoned utility lines should be sealed to prevent piping of soil or water into the utility pipe. Soft or loose backfill materials should be removed, and excavations should be backfilled with structural fill. Coordination with the utility owners is generally required in addressing existing utilities.

We recommend that a representative from Haley & Aldrich (not from a materials testing firm) be present to observe initial stripping, overexcavation, and subgrade preparation activities and identify areas that may require additional removal of unsuitable material. This will be critical for the overexcavation of unsuitable materials because an on-site judgment will be needed regarding the limits of overexcavation. This is also especially important in areas where existing soils will be left in place for the pond side slopes and as subgrade to support new compacted embankments.

7.3 TEMPORARY AND PERMANENT SLOPES

7.3.1 Temporary Cut Slopes

The stability and safety of cut slopes depend on a number of factors, including:

- Type and density of the soil;

- Presence and amount of any seepage;
- Depth of the cut;
- Proximity of the cut to any surcharge loads near the top of the cut, such as stockpiled material, traffic, or structures, and the magnitude of these surcharges;
- Duration of the open excavation; and
- Care and methods used by the contractor.

Temporary soil cuts for site excavations that are more than 4 feet deep should be adequately sloped back to prevent sloughing and collapse in accordance with Washington Department of Occupational Safety and Health (DOSH) guidelines (Washington Administrative Code [WAC] Chapter 296-155 Part N). Using these guidelines, Fill is classified as Type C. The native cohesive soils (e.g., Glacial Till) are Type B when they are above the water table. We recommend the following for open cuts:

- For excavations less than 20 feet deep, use a maximum allowable slope of:
 - 1.5H:1V for cuts in Soil Type C; and
 - 1H:1V for cuts in Soil Type B.
- Use a maximum allowable slope of 1.5H:1V, or less steep if groundwater seepage is encountered within the excavation slopes.
- Consult with the geotechnical engineer during construction to limit the size of these excavations and the amount of time they remain open.
- Protect the slope from erosion by using plastic sheeting, especially during wet weather excavation.
- Limit the maximum duration of the open excavation to the shortest time possible.
- Place no surcharge loads (equipment, materials) within 10 feet of the top of the slope, in general. However, more or less stringent requirements may apply depending on field conditions and actual surcharge loads.

Because of the variables involved, before construction, actual slope angles required for stability in temporary cut areas can only be estimated. We recommend that stability of the temporary slopes used for construction be solely the responsibility of the contractor, since the contractor is in control of the construction operation and is continuously at the site to observe the nature and condition of the subsurface. All excavations should be made in accordance with all local, state, and federal safety requirements.

7.3.2 Permanent Slopes

Permanent slopes in medium dense to dense granular soils should be no steeper than 2H:1V. Final grading should be such that surface water runoff is directed away from permanent slopes. A Haley & Aldrich representative should be on site during the slope cutting to recommend whether a shallower slope should be used in the upper fill soils, or if the existing fill should be overexcavated and replaced.

Embankment fill slopes typically become loosened near the slope face as successively higher lifts are placed and compacted. We recommend the face of compacted slopes be overbuilt at least 2 feet

laterally and the final slope face trimmed with a long boom excavator such as a trackhoe. We recommend that the Contractor use a dozer to track-walk the final cut and fill slope surfaces, and establish vegetation to limit slope erosion.

7.4 EMBANKMENT DESIGN

7.4.1 Embankment Construction

The construction of the proposed embankment or berm can be accomplished using suitable excavated soils, as described in Section 7.10. If the excavated soils do not meet these requirements, imported structural fill will be necessary to construct stable embankments that meet the intent of design.

7.4.2 Slope Stability

Site development will include construction of AGB cells that will be constructed with imported structural fill. The number and footprint of the AGB cells has not been determined. At this time, slope stability analyses have not been performed. Slope stability will be evaluated once the cell configurations are determined to confirm that the berms meet the applicable factors of safety under static and seismic loads. It will also be critical to confirm that stability is met when the cells are flooded.

Based on our experience, soil embankments like those proposed (i.e., a 1H:1V embankment retaining soil and water to full height of the embankment) often need to be flatted to 2H:1V to achieve an adequate factor of safety against slope instability and sliding for the seismic analysis case. We recommend showing slopes at 2H:1V for planning purposes.

7.4.3 Embankment Settlement

In some areas near the embankment, fill will be placed to raise the existing ground to a higher elevation, and settlement of the proposed earthen embankment may occur due to compression and consolidation of *in situ* foundation soils. We estimated settlement to assist in determining approximately how much additional fill would need to be added during construction to achieve the final design elevations. However, the magnitude of settlement, time rate of settlement, and duration of settlement depend on a variety of factors (e.g., fill height, soil type, thickness, compressibility parameters, loading, drainage, and permeability). These factors vary across the site and are difficult to accurately estimate with a limited number of explorations at discrete locations with samples collected at discrete depths. We recommend survey monitoring be used to more accurately determine settlement that occurs during construction to determine if the final embankment crest meets design elevation requirements.

7.4.4 Embankment Settlement from Foundation Soils

The existing foundation soils primarily consist of slightly silty to silty, gravelly to very gravelly sand with scattered interbedded layers of silt, and peat in various locations. The silts were essentially non-plastic, based on our lab results (Appendix B). In view of these soil conditions, we anticipate settlement of the granular foundation soils to occur over about the same time frame as overlying fill is placed, except for the peat, which will undergo long-term consolidation settlement.

To estimate settlement, we estimated the stresses imposed on the foundation materials below the embankment construction. Immediate settlement was calculated using elastic theory, neglecting any

changes in horizontal stresses. Values of Young's modulus were selected from correlations to standard penetration values (Bowles, 1996).

We evaluated settlement for one section where significant Fill is planned to raise existing grade. The analysis assumed approximately 10 feet of Fill with groundwater at about 5 feet, based on Cell 6. Subsurface conditions were represented using the profile at Boring B-7, which we consider representative of the critical area. Based on the estimated thickness and loading from the fill, we estimate up to about 1 inch of settlement, which is not expected to adversely affect the proposed structures. Greater settlement could occur if the embankment extends over a broader area of fill or where organic soils are present. Because of the potential for organic material at the site, we recommend performing an additional exploration phase. Recommendations for the supplemental exploration phase are provided in Section 9.1.1.

7.5 SUPPORT OF EXCAVATION

Temporary shoring walls may be required to support the vertical sides of the AGB Tank excavation. The shoring system should be designed to provide temporary lateral support for the excavation while ensuring safety and stability of the buildings, utilities, and other infrastructure adjacent to the excavation.

Based on the subsurface soil conditions and the surrounding structures, it is our opinion that the project excavation could be supported using conventional soldier piles with tieback anchors. Alternatively, if there is sufficient space, the tank may be installed with an open cut. The selection of a suitable temporary shoring system for earth retention will depend on numerous factors, as presented above.

7.5.1 General Considerations

The shoring must be designed by a professional engineer registered in Washington State. Haley & Aldrich should be given the opportunity to review the proposed shoring design before construction.

This report is not intended to provide specific requirements for the contractor's construction means and methods. It should be the responsibility of the shoring contractor to verify actual ground conditions at the site and determine the construction means, methods, and procedures needed to install an appropriate shoring system.

7.6 SOLDIER PILE/TIEBACK TEMPORARY SUPPORT OF EXCAVATION

The basic geotechnical criteria for the design of a conventional soldier pile/tieback shoring wall system are: (1) lateral earth pressure; (2) tieback geometry and anchor capacity, and (3) vertical bearing capacity of soldier piles. Figures 6 through 8 provide recommended parameters for temporary support of excavation using soldier piles and tiebacks, as discussed in this section.

7.6.1 Lateral Earth Pressures

Lateral earth pressures for the shoring design depend on the type of shoring and its ability to deform. If the top of the shoring is allowed to deform about 0.001 to 0.002 times the shoring height, and if no settlement-sensitive structures or utilities are within the potential zone of deformation behind the shoring wall, the shoring may be designed using active earth pressures. If settlement-sensitive structures or utilities exist within the potential zone of deformation, or where the shoring system is too stiff to

allow sufficient lateral movement for development of an active condition, at-rest earth pressures should be used for the shoring design.

Depending on the excavation and construction phases, and the specific shoring wall configuration considered for design, equivalent fluid unit weights resulting in a triangular distribution of lateral earth pressure may be used when the shoring wall is under cantilevered conditions, as shown on Figure 6. Single-braced and multiple-braced walls should be designed using a trapezoidal apparent earth pressure distribution, as shown on Figures 7 and 8, respectively. These lateral earth pressure recommendations assume a level ground surface behind the walls, and a fully drained condition behind the walls so that hydrostatic pressures do not act on the walls above the excavation base. Lateral earth pressures for cantilevered walls (Figure 6) and single-braced walls (Figure 7) will need to be considered in the design of multiple-braced walls to model conditions of the early construction stages.

We generally expect the shoring system to deflect up to 0.5 to 1 inch into the excavation when designed considering active earth pressures. Individual soldier piles may deflect more than 1 inch or deflect away from the excavation under tieback stressing loads. As recommended herein, Haley & Aldrich should review the results of shoring monitoring.

Lateral pressures due to surcharge loads, such as building foundations, footings, heavy equipment, sloped ground, and large material stockpiles, should be calculated using the methods shown on Figure 9 and added as additional design loads. Any additional lateral pressure due to existing and surcharge loads should be added to the soil load calculated for the shoring walls design. We recommend that Haley & Aldrich review or calculate the lateral earth pressures when surcharge loads, footprints, and configurations become available.

7.6.2 Soldier Pile Design and Installation

Soldier piles must be designed to carry bending stresses from lateral earth pressure resulting from various sources in combination with applicable vertical loads. Also, the embedded portion of the piles must be deep enough to resist lateral kickout and vertical loads.

- Design soldier piles according to recommendations on Figures 6 through 9.
- For design against kickout, compute the lateral resistance on the basis of passive pressure acting over three times the diameter of the soldier pile section or the pile spacing, whichever is less. Use a factor of safety no less than 1.5 to calculate allowable passive resistance.
- Embed soldier piles at least 10 feet below the deepest point of the excavation within 15 feet of the pile location or the required structural depth to resist applied vertical tieback loads, whichever is greater.

Conditions such as caving soil or groundwater can loosen soil at the bottom of the soldier pile borehole, thereby reducing the bearing capacity. Tieback destressing and shoring failure could occur if soldier pile bearing capacity is inadequate and soldier piles settle under the vertical component of the inclined tieback load. We recommend that a Haley & Aldrich representative closely monitor soldier pile installation for these conditions so that construction methods can be adjusted accordingly. The contractor should be prepared to:

- Use casing or drilling mud if substantial perched water is encountered during soldier pile installation. The actual need for casing and/or drilling mud can be determined in the field at the time of installation.
- Tremie concrete from the bottom of the hole to displace groundwater or drilling mud used to maintain an open hole. Drilling mud should not be used unless the mix is reviewed and approved by Haley & Aldrich and the structural engineer.
- Excavate the soldier piles in a manner that prevents “heave” or “boiling” at the bottom of the soldier pile excavation. It may be necessary to over-drill the borehole and backfill the bottom of the borehole with structural concrete bearing on undisturbed soil.

The lateral earth pressures presented herein are based on dewatered and/or drained backfill conditions so that hydrostatic pressure does not act on the walls.

7.6.3 Solder Pile Lagging

Timber lagging is usually used to prevent ground loss between the soldier piles. The lagging is inserted between the webs of the soldier piles and is designed for some fraction of the applied pressure on the wall. Limiting the exposed lift height and prompt and careful installation of lagging to support the exposed height is particularly important for seepage areas and loose soil areas so that the integrity of the excavation is ensured and maintained. The shoring contractor should be responsible for installing lagging to prevent soil failure, sloughing, and ground loss, and to provide safe working conditions. Refer to Section 7.9 below for temporary dewatering considerations.

Soldier pile shoring system construction may be difficult if boulders, cobbles, or loose sand and gravel are encountered in the excavation. If these conditions are encountered, substantial soil raveling could occur. The contractor should be prepared to place lagging in small vertical increments and to backfill voids caused by ground loss behind the shoring system during construction.

Backfill voids greater than 1 inch using sand or a porous slurry. Backfill the void spaces progressively as the excavation deepens. The backfill must not allow potential hydrostatic pressure buildup behind the wall. Drainage behind the wall must be maintained or hydrostatic pressure should be added to the recommended lateral earth pressures.

We recommend the rough-cut timber lagging thickness based on recommendations in Federal Highway Administration (FHWA) *Geotechnical Engineering Circular No. 4* (FHWA, 1999), as shown in Table 3.

Table 3. Recommended Lagging Thickness						
Excavation Depth in feet	Recommended Lagging Thickness (rough-cut) for Clear Spans of:					
	5 feet	6 feet	7 feet	8 feet	9 feet	10 feet
0 to 25	2 inches	3 inches	3 inches	3 inches	4 inches	4 inches
25 to 60	3 inches	3 inches	3 inches	4 inches	4 inches	5 inches

7.6.4 Tieback Anchor Design and Construction

Our tieback anchor design recommendations are based on the assumption that cased boreholes at least 6 inches in diameter and pressure grouting techniques will be used. We anticipate the anchors will be installed by single-stage, high-pressure grouting as the casings are withdrawn. Allowable load transfer (adhesion) values provided on Figures 7 and 8 may be used for the planning and design of

pressure-grouted anchors described herein, although the final adhesion values will be set by the shoring designer and confirmed through field testing. The shoring contractor is responsible to achieve the design anchor capacities, which could require secondary grouting, if the initial pressure grouting is insufficient. Alternatively, the anchor zone could be lengthened. We can provide alternate bond adhesion recommendations if anchors are to be grouted under gravity using tremie methods.

Pressure-grouted tieback anchors used for external lateral support of the soldier pile walls should be designed using the following recommendations.

- For planning purposes, design anchors in accordance with Figures 7 and 8.
- Locate tieback anchors no closer to each other than 4 feet.
- Install a bond breaker such as plastic sheathing or a polyvinyl chloride pipe around the tie rods/cables within the no-load zone.
- Grout and backfill drilled installations immediately after drilling; do not leave holes open overnight.
- Advance drill holes using rotary methods with air flush, dry auger, and cased methods (for less stable ground). Drill the soil nail holes using equipment and techniques that will minimize caving and loss of ground. Drilling with a casing will reduce the potential for ground loss. Ensure that the hole is clean of disturbed material prior to grouting.
- Maintain continuous cutting return if using pneumatic drilling techniques so that air pressure, which may damage subgrade structures, is not channeled to nearby utility vaults, corridors, or subgrade slabs.
- Plot and compare anchor lengths with any underground support elements of adjacent structures to avoid interference.
- The shoring designer and contractor should particularly note the presence of existing facilities adjacent to the project site, including buried utilities and foundations of adjacent buildings, as these may affect the location, orientation, and the length of the anchor holes.
- Install the anchor holes in a manner that will minimize ground loss and not disturb previously installed anchors. During tieback drilling, wet or saturated zones may be encountered, and soil could cave in, especially within the Outwash unit. Drilling with casing reduces the potential for soil caving and ground loss.

We recommend that selection of the materials and the installation technique be left to the shoring contractor. The shoring contractor shall be made contractually responsible for the design of the tieback anchors, as tieback capacity is largely a function of the means and methods of installation. The selected tieback anchor installation method must be subject to field verification with verification testing and proof testing.

Haley & Aldrich should review the design for anchor locations, capacities, and related criteria before construction begins. We recommend a factor of safety of at least 2.0 against anchor pullout. This factor of safety provides for a reasonable additional load capacity should an unforeseen increase in load develop during excavation and construction. The variable soil conditions and unit friction values mean that some field changes in anchor length may be necessary.

7.6.5 Tieback Anchor Testing

The tieback anchor testing program should include verification testing of select tiebacks and proof testing of all production tiebacks. We recommend that tieback testing be done in general accordance with the recommendations in the publication *Recommendations for Prestressed Rock and Soil Anchors* by the Post Tensioning Institute (PTI, 2014) and the recommendations below.

7.6.5.1 Verification Tests

We recommend a minimum of two verification tests for each installation method and soil type before installation of production anchors to validate the design pullout value. Haley & Aldrich will select the testing locations with input from the shoring subcontractor. Haley & Aldrich or the shoring designer may require additional verification tests when creep susceptibility is suspected, or when varying ground conditions are encountered.

Tiebacks for verification tests should be installed using the same methods, personnel, material, and equipment as are used for the production tiebacks. Deviations may require additional verification testing, as determined by the engineer.

Verification tests load the tieback to 200 percent of the design load (DL) and include a 60-minute creep test at 150 percent of the DL. The tieback DLs should be clearly shown on the shoring plans/drawings. The tieback load should not exceed 80 percent of the steel's ultimate tensile strength. Verification test tiebacks should be incrementally loaded and unloaded using the schedule in Table 4, and as recommended below.

- The alignment load (AL) should be the minimum required to align the testing assembly and should be less than 5 percent of the DL. The dial gauge should be zeroed after the AL has stabilized.
- The verification test will measure anchor stress and displacement incrementally to values of unit skin friction (adhesion) to 200 percent of the design adhesion.
- The soldier piles and/or anchor tendons may require extra reinforcement and/or stands to permit stressing to 2.0 DL, as required for the performance test.
- Load levels during hold intervals should be held constant to within 50 pounds per square inch (psi), and deflection measurements shall be made to minimum accuracy of 0.01 inches. This may require pressure adjustments during hold times.
- Obtain and record deflection measurements for loading at intervals of 1, 2, 3, 5, 7, and 10 minutes for a 10-minute hold interval.
- The creep test at 1.5 DL should be performed by recording deflections at 1, 2, 3, 5, 7, 10, 20, 30, 50, and 60 minutes.

Table 4. Tieback Verification Test Incremental Load and Hold Time	
Load Level	Hold Time
AL	Until stable
0.25DL	10 minutes
0.5DL	10 minutes
0.75DL	10 minutes
1.0DL	10 minutes
1.25DL	10 minutes
1.5DL	60 minutes
1.75DL	10 minutes
2.0DL	10 minutes
AL	Until stable

The acceptance criteria for a verification test are as follows.

- Exhibits a linear or near-linear relationship between unit stress and movement over the percent stress range during loading from AL to 2.0 DL.
- Holds the maximum test unit stress at 1.5 DL without noticeable creep. Noticeable creep is defined as a rate of movement of more than 0.04 inches between the 1- and 10-minute readings, or more than 0.08 inches between the 6- and 60-minute readings. If the reading does not stabilize to 0.08 inches or less per log cycle of time, the test shall be considered as failing the creep criteria.
- Satisfies the apparent free tendon length criteria. Apparent free length criteria are as follows:
 - Minimum apparent free length, based on the measured elastic and residual movement, should be greater than 80 percent of the designed free length plus the jack length; and
 - Maximum apparent free length, based on the measured elastic and residual movement, should be less than 100 percent of the designed free length plus 50 percent of the bond length plus the jack length.
- The anchor does not pull out under repeated loading or at 2.0 DL.

7.6.5.2 Proof Tests

Proof tests load all the production tiebacks to 1.33 DL and include a 10-minute hold time at 1.33 DL. The purpose of proof tests is to quickly and economically determine the acceptability of each anchor for adequate performance after lock-off at DL. The tieback DLs should be indicated on the shoring drawings. The tieback load should not exceed 80 percent of the steel's ultimate tensile strength. Proof tests should be incrementally loaded and unloaded using the schedule in Table 5.

Table 5. Tieback Proof Test Schedule	
Load Level	Hold Time
AL	Until stable
0.25DL	1 minute
0.5DL	1 minute
0.75DL	1 minute
1.0DL	1 minute
1.33DL	10 minutes

The AL should be the minimum load required to align the testing assembly and should be less than 5 percent of the DL. The dial gauge should be zeroed after the alignment load has stabilized.

The load should be held constant to within 50 psi and deflections recorded at 1, 2, 3, 5, 6, and 10 minutes. If the tieback deflection between 1 and 10 minutes at 1.33 DL exceeds 0.04 inches, the load should be held for an additional 50 minutes and deflections recorded at 20, 30, 50, and 60 minutes.

The acceptance criteria for a proof test are:

- The creep rate at 1.33DL is less than 0.04 inches between 1 and 10 minutes or less than 0.08 inches between 6 and 60 minutes and the creep rate is linear or decreasing during the creep test;
- Satisfies the apparent free tendon length criteria, as described above, for verification test; and
- The anchor does not show pull out failure or tendency to failure during loading.

7.7 SHALLOW FOUNDATIONS

New structures may bear on shallow spread and/or continuous footings. Because some amount of fill is expected and due to the elevation of native soils varies across the site, we recommend using an allowable bearing pressure of 2.5 kips per square foot for footings bearing on properly compacted subgrade.

For the design and construction of shallow foundations, we recommend the following:

- Locate the base of all footings at least 18 inches below the lower adjacent grade to protect against frost effects for exterior footings.
- Footings should be founded outside of an imaginary 1H:1V plane projected upward from the bottom edge of adjacent footings and utility trenches. If new footings are located within this plane, additional protective measures may be required. We should be consulted for such instances to evaluate specific cases.
- Verify that subgrade soil is in a very dense, non-yielding condition before placing concrete for footings. Remove loosened soil and standing water.
- Have a Haley & Aldrich representative observe exposed subgrades before footing construction to verify design assumptions about subsurface conditions and subgrade preparation.

Once the foundation design and loads are established, we recommend that we be allowed to analyze and estimate post-construction settlement.

7.8 TOWER CRANES AND OTHER TEMPORARY STRUCTURES

Design recommendations in this report should not be used for the design of foundations for tower cranes or any other temporary structure to be used during construction. Tower cranes and temporary structures should be the responsibility of the contractor.

7.9 CONSTRUCTION DEWATERING

We understand that the proposed excavation for the AGB Tank is planned to extend to approximately an elevation of 278 feet and the pumping station to approximately an elevation of 266 feet. Groundwater was observed in the Fill/Glacial Till units at a maximum elevation of 299 feet. Shoring could extend to depths of 10 feet below the excavations (an elevation of 268 and 256 feet). The bottom of the excavations will be completed in the Glacial Till unit.

Dewatering will be required when the excavation extends below the groundwater table. We recommend that the groundwater level be lowered to at least 2 feet below the bottom of the excavation level. Perched water will be encountered in the Fill and Glacial Till units. The amount of groundwater encountered in the excavations will be variable and dependent on the season. Dewatering methods for the perched water could include trenches, sumps, and wellpoints. The amount of groundwater recovered in the excavation will likely be less than 10 gallons per minute (gpm), depending on season and dewatering method selected by the contractor.

The hydraulic head in Glacial Outwash unit extends above ground surface (an elevation of 303 to 309 feet) in the vicinity of the excavations. Depressurization of the Glacial Outwash unit by lowering the hydraulic head will be required to maintain stability in the bottom of the excavation from heave, prevent piping, and minimize groundwater flow into the excavation. The amount of depressurization will depend on the excavation size and depth, and the depth of shoring. Depressurization methods for the Glacial Outwash unit would most likely be completed using relatively deep, large-diameter pumping wells screened in the Glacial Outwash unit around the perimeter of the excavations. Because of the large uncertainty in our estimate of hydraulic conductivity of the Glacial Outwash unit, we estimate the depressurization will require pumping rates in the range of approximately 200 to 12,000 gpm (Appendix E).

The dewatering and depressurization systems should be planned and designed by a qualified dewatering designer and constructed with an experienced specialty contractor.

7.9.1 Pump Test Recommendations

Pressurized groundwater conditions were encountered within the Glacial Outwash. Explorations completed as part of this study did not encounter the bottom of the unit. The preliminary estimates of hydraulic parameters made during this study utilized slug testing and grain size analysis methods, which are typically suitable for identifying the order of magnitude. These preliminary estimates suggest there is variability in the Glacial Outwash hydraulic conductivity and potentially high hydraulic conductivity.

Haley & Aldrich recommends completion of pumping tests in the Glacial Outwash unit to reduce uncertainty and achieve better estimates of hydraulic properties. A pumping well and new monitoring wells are recommended to be completed for the tests.

7.10 STRUCTURAL FILL SELECTION, PLACEMENT, AND COMPACTION

Backfill placed within the building and tanks areas, against walls, or below paved areas, should be considered structural fill. The following sections include our recommendations for structural fill selection, placement, and compaction.

7.10.1 Reuse of Site Soil as Structural Fill

The suitability of site soils for use as structural fill should be evaluated during construction. The suitability of excavated site soils for compacted structural fill depends on the gradation and moisture content of the soil when it is placed. As the amount of fines (that portion passing the U.S. Standard No. 200 mesh sieve) increases, the soil becomes increasingly sensitive to small changes in moisture content and adequate compaction becomes more difficult to achieve. Soil containing more than about 5 percent fines cannot be consistently compacted to a dense non-yielding condition when the water content is greater than about 2 percent above or below optimum. During dry weather, imported soil can contain fines up to 20 to 30 percent, provided it is compacted at a moisture content within 2 percent of the optimum moisture content. Reusable soil must also be free of organic and other deleterious material.

The site soils generally contain more than 5 percent fines. The Glacial Till and Outwash may have upwards of 30 or more percent fines. As such the suitability of site soils to be reused as structural fill will depend highly on their moisture condition at the time of placement. If the contractor intends to reuse excavated material, stockpiles should be covered and protected from rain, and the material should be assessed by a qualified geotechnical engineer at the time of placement.

7.10.2 Selection of Import Fill

For import soil to be used as structural fill, we recommend using a non-silty, well-graded sand or sand and gravel with less than 5 percent passing the U.S. No. 200 mesh sieve by dry weight (based on the minus 3/4-inch fraction) for import structural fill placed during wet weather periods. During dry weather, import soil can contain fines up to 20 to 30 percent, provided it is compacted at a moisture content within 2 percent of the optimum moisture content.

7.10.3 Placement and Compaction of Structural Fill

We make the following recommendations for the proposed structure:

- Before fill control can begin, the compaction characteristics or proposed fill material must be determined from representative samples of the structural and drainage fill. Samples should be obtained as soon as possible, but at least three days prior to use on site. A study of compaction characteristics should include determination of optimum and natural moisture contents and maximum dry density of these soils at the time of placement. Additionally, the grain size distribution of the fill should be determined.
- Structural fill can consist of either imported soil or recompacted selected on-site soil if its moisture content is suitable and weather conditions allow.
- Compact structural fill to a minimum of 95 percent of the maximum dry density as determined by the modified Proctor (ASTM D1557) test method, except within 2 feet horizontally of structural walls where the compaction requirement should be 92 percent.
- Maintain moisture content within 2 percent of the optimum moisture content (ASTM D1557).
- Place structural fill only on dense, non-yielding subgrade soils.
- Place and compact all structural fill in even lifts, with a loose thickness no greater than 10 inches. If small, hand-operated compaction equipment is used to compact structural fill, fill lifts should not exceed 6 to 8 inches in loose thickness.

- In wet subgrade areas, clean material with a gravel content (material coarser than a U.S. No. 4 mesh sieve) of at least 30 to 35 percent may be necessary.
- The compacted densities of all lifts should be verified by testing. Any material to be used as structural fill should be sampled and tested prior to use on site, to determine its maximum dry density and gradation.

7.11 ASPHALT PAVEMENT DESIGN

We anticipate that new rigid (concrete) and flexible (asphalt) exterior pavements may be constructed as part of the IWTP Enhancements. Pavement thickness design depends on traffic loading information, which was not available at the time of our report. We should update our preliminary recommendations below when pavement loading is provided:

- For passenger vehicle parking lot areas, we recommend a minimum flexible pavement section of 4 inches of asphalt and 6 inches of crushed surfacing base course (CSBC) overlying properly prepared subgrade. Alternatively, if rigid pavement is to be used, we recommend a minimum of 4 inches of Portland Cement Concrete and 6 inches of CSBC overlying properly prepared subgrade for these areas.
- For driveway, loading, unloading, delivery, or other areas subjected to truck, bus, recreational vehicle, or emergency vehicles, we recommend a minimum pavement section of 6 inches of asphalt and 6 inches of CSBC overlying properly prepared subgrade. Alternatively, if rigid pavement is to be used, we recommend a minimum of 8 inches of Portland Cement Concrete and 4 inches of CSBC overlying properly prepared subgrade, for these areas.

7.12 PAVEMENT SUBGRADE

All pavement sections should be supported on a minimum thickness of 18 inches of well-compacted subgrade, following requirements outlined in Section 2-06.3 (1) and 2-06.3(2) of the WSDOT Specification (WSDOT, 2020). Subgrade may consist of compacted structural fill, natural soils that have been compacted in-place, or dense, natural soil. In general, the pavement sections can be supported on the existing near-surface soil, provided that: (1) it is compacted to a dense, non-yielding condition by a heavy vibratory roller; (2) all unsuitable materials, including organic matter, construction debris, boulders, etc., are removed; and (3) the final surface is successfully proof rolled with a fully loaded dump truck, showing negligible rutting and pumping. When structural fill is required, the upper 2 feet of material beneath the pavement section should be compacted to at least 95 percent of the modified Proctor maximum dry density (ASTM D1557).

We recommend that Haley & Aldrich observe pavement subgrade proof rolling prior to placement of the pavement section to confirm that the surface is firm and non-yielding.

8. Hydrogeological Recommendations and Considerations

8.1 PERMANENT DRAINAGE CONSIDERATIONS

As noted above, the perched groundwater will be present and regional groundwater is somewhat close to the bottom of excavation for the AGB Tank and pump station. Accordingly, after the construction

dewatering is complete, groundwater seepage will produce flow into the excavation. It will be necessary to install a permanent drainage system and pressure relief for the subgrade walls and the slab at the bottom of the excavation.

Drainage material should consist of well-graded coarse sand and gravel with a fines content of less than 3 percent by dry weight (percentage of material passing the U.S. No. 200 mesh sieve based on the minus 3/4-inch fraction). We anticipate that a permanent drainage system for this project site would consist of the elements described in the following sections.

The foundation and wall drainage system recommendations presented herein are intended to prevent buildup of hydrostatic pressure that could damage the structure. The recommended systems may not result in a totally dry wall or slab.

8.1.1 Drainage Beneath AGB Tank

The AGB foundation may be constructed as slab-on-grade above a drainage layer. We recommend the following for permanent drainage and a passive sump system:

- Provide sub-slab drainage by using a combination of perimeter and cross drains beneath slabs-on-grade.
- Install cross drains on 20- to 30-foot centers. The cross drains (with cleanouts) should consist of at least 4-inch-diameter perforated pipe placed on a bed of, and surrounded by 6 inches of drainage material. The cross drains and the perimeter drains should be tied together to a suitable sump. The drainage pipes should be sloped to drain. Drainage material and piping should be compatible such that soil intrusion into the pipe does not take place.
- Connect all wall, perimeter, and underslab drainage pipes to one or more underslab sumps, complete with appropriate sump pumps. We estimate that inflow to the underslab drainage system will vary seasonally and is expected to be on the order of 20 to 50 gpm.
- Use backup power supplies and pumps as required to ensure that the underslab sumps are drained during a power outage or pump malfunction.

8.1.2 Basement Wall and Foundation Drainage System

We recommend the following for permanent drainage behind the basement walls, perimeter of walls, and foundations.

- Miradrain-type composite panels should be laid flush on the shoring wall (on the outside of the permanent wall) and be connected to a collector pipe that runs along the foundation, at an elevation lower than the bottom of the floor slab. This will allow water collected outside the wall to be tight-lined beneath the slab and into a central drainage sump. We recommend installing a minimum of one strip of paneling between each soldier pile (or on a spacing of 8 to 10 feet on a soil nail wall, as previously described) from the top of the wall down the full face of the wall to drain any perched water.
- Perimeter drains should be installed near the base of the perimeter wall foundation. The perimeter drains should be a minimum 4-inch-diameter perforated pipe and should be surrounded by 6 inches of drainage material. All pipes should be sloped to drain.

- All wall, perimeter, and underslab drainage pipes should be connected to a central underslab sump, complete with an appropriate sump pump.

8.1.3 Waterproofing

The lower-level basement walls and any other structural elements extending below the water table should be waterproofed. We recommend waterproofing be installed to at least 2 feet above the design groundwater elevation, to allow for the possibility of some groundwater level fluctuations.

A specialty waterproofing subconsultant should be retained to design the waterproofing. We have seen waterproofing systems such as heavy plastic membrane liners, bentonite clay panels (i.e., Volclay or equivalent), and other exterior sealants used effectively on similar projects.

It is important to recognize that special attention will need to be paid to the installation of waterproofing membranes below the water table. Although construction dewatering will be implemented, there is still a potential for vertical upward water pressure to be experienced within the interior of the Site. Because most of the Site is underlain by “tight” glacial soils the potential for significant upward flow is relatively low. However, in a situation where the waterproofing membrane is placed on a properly prepared subgrade, it is possible that any minor upward flow may accumulate below the membrane over time (prior to construction of the mat foundation). This potential upward flow could cause heave of the membrane.

We recommend working closely with the contractor, dewatering designer, and subcontractor to supplement drainage and dewatering of the membrane areas during the initial stages of construction. Measures such as sumps or the use of synthetic drainage media below the membrane to allow for “pressure relief” below the membrane may be appropriate.

8.1.4 Site Drainage

Final grades should be sloped to carry surface water runoff away from structures to prevent water from infiltrating near foundation walls. Roof drainage and new pavement drainage should not be tied into the subdrain system or discharged onto the site.

8.2 STORMWATER INFILTRATION

The upper 10 feet of the on-site soils generally consists of Fill and glacially consolidated soils with high fines content (i.e., hydraulically restrictive soils) and are, therefore, unlikely to allow water to infiltrate quickly. We do not recommend using a stormwater infiltration system for the proposed development, since this could cause a buildup of water above the fine-grained glacial soils.

9. Recommendations for Continuing Geotechnical Services

9.1 DESIGN AND CONSULTING SERVICES

Throughout this report, we recommend that Haley & Aldrich provide additional geotechnical input during the design and construction process. These recommendations are generally summarized in this section.

We recommend that, before construction begins, we:

- Complete supplemental explorations;
- Continue to monitor groundwater levels through the 2025/2026 wet season;
- Update our analysis and report recommendations;
- Complete pumping tests in the Glacial Outwash unit to better characterize hydraulic properties. A pumping well and new monitoring wells are recommended to be completed for the tests;
- Continue to meet with the design team periodically as design concepts and design documents progress; and
- Review the final design plans to verify that the geotechnical engineering recommendations have been properly interpreted and implemented into the design.

9.1.1 Supplementary Exploration Program

We recommend installing an additional VWP well before the 2025/2026 wet season to better characterize artesian pressures.

As discussed in the Subsurface Conditions section of this report, we encountered localized zones of organic soils within the Fill. These soils are susceptible to settlement if not removed prior to construction. Furthermore, the full extent of the organic material is currently unknown. Therefore, we recommend conducting a supplementary exploration program to better characterize and evaluate these soils. Test pits are the preferred method, as they allow for observation and documentation of a broader soil profile.

Additionally, a pressurized water-bearing unit was encountered within the Glacial Outwash. To better understand the groundwater pressures within this unit, we recommend that additional VWPs be installed as part of the supplementary exploration program. The installation of these piezometers should utilize mud rotary techniques to mitigate the potential for soil heave and minimize disturbance during installation.

9.2 CONSTRUCTION SERVICES

During the construction phase of the project, we recommend we be retained to review contractor submittals and observe the following activities:

- Soldier pile and tieback installations;
- Groundwater pumping and control;

- Subgrade preparation;
- Placement and density testing of structural fill at the site (if any); and
- Other observations as required by the Port or City of SeaTac.

Other additional tasks would include the following:

- Attend meetings, as needed; and
- Assist with other geotechnical engineering considerations that may arise during the course of construction.

The purpose of our observations is to verify compliance with design concepts and recommendations, and to allow design changes or evaluation of appropriate construction methods in the event that subsurface conditions differ from those anticipated prior to the start of construction.

DRAFT

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https://haleyaldrich.sharepoint.com/sites/PortofSeattle/Shared Documents/0204661.POS SeaTac Mech and Elec IDIQ/002 IWTP Treatment Facility/Deliverables/Geotech Report/2025_0822_HAI_SeaTac_IWTP_GeotechReport_D.docx

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TABLE

TABLE 1

SUMMARY OF EXPLORATIONS

SEA-TAC IWTP - AGB SITE

SEATAC, WASHINGTON

Boring ID	Location (Latitude, Longitude) ^a	Drilling Method	Ground Surface Elevation (feet) ^b	Boring Depth (feet bgs)	Well Screen Depth (feet bgs ^c)	Approximate Well Screen Elevations (feet)	VWP ^d Depths (feet bgs)	VWP Elevations (feet)
B-1	47.435390, -122.318386	Mud Rotary/Hollow Stem Auger	297	25	--	--	--	--
B-2	47.434722, -122.318486	Mud Rotary/Hollow Stem Auger	288	25	--	--	--	--
B-3	47.434125, -122.318494	Mud Rotary/Hollow Stem Auger	282	25	--	--	--	--
B-4	47.433522, -122.318505	Mud Rotary/Hollow Stem Auger	277	25	--	--	--	--
B-5	47.435547, -122.317585	Mud Rotary/Hollow Stem Auger	304	25	--	--	--	--
B-6	47.435038, -122.317830	Mud Rotary/Hollow Stem Auger	292	25	--	--	--	--
B-7	47.434251, -122.317778	Mud Rotary/Hollow Stem Auger	285	25	--	--	--	--
B-8	47.433896, -122.317832	Mud Rotary/Hollow Stem Auger	281	25	--	--	--	--
B-9	47.433696, -122.317839	Mud Rotary/Hollow Stem Auger	279	25	--	--	--	--
B-10	47.434432, -122.318978	Mud Rotary/Hollow Stem Auger	283	25	--	--	--	--
W-1	47.433256, -122.318964	Sonic	278	45	34-44	234-244	--	--
W-2	47.433278, -122.317846	Sonic	279	25	13-23	256-266	--	--
W-3	47.436169, -122.317997	Sonic	304	25	10-20	284-294	--	--
W-4	47.435636, -122.317207	Sonic	307	45	40-45	262-267	--	--
W-5	47.434276, -122.317301	Sonic	292	30	7-12	280-285	--	--
W-6	47.434711, -122.316191	Sonic	294	35	18-28	266-276	--	--
W-7	47.435182, -122.316248	Sonic		50	40-50	246-256	--	--
W-8	47.435184, -122.316956	Mud Rotary/Hollow Stem Auger	294	60	--	--	40, 59	254, 235
W-9	47.435185, -122.316724	Sonic	294	80	30-40	254-264	--	--

Notes:

a. WGS 1984 Geographic coordinate system

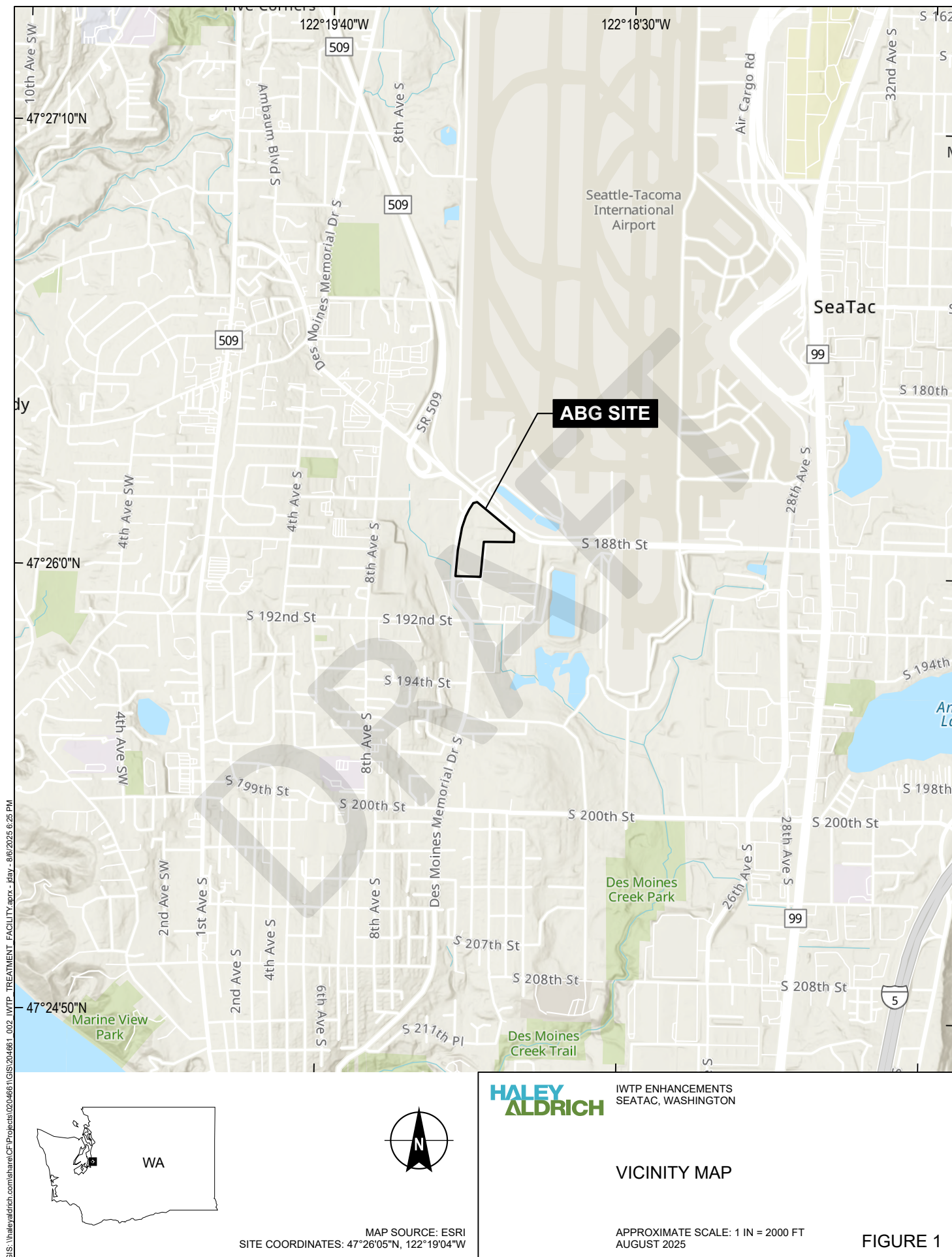
b. NAVD88 vertical datum

c. bgs: below ground surface

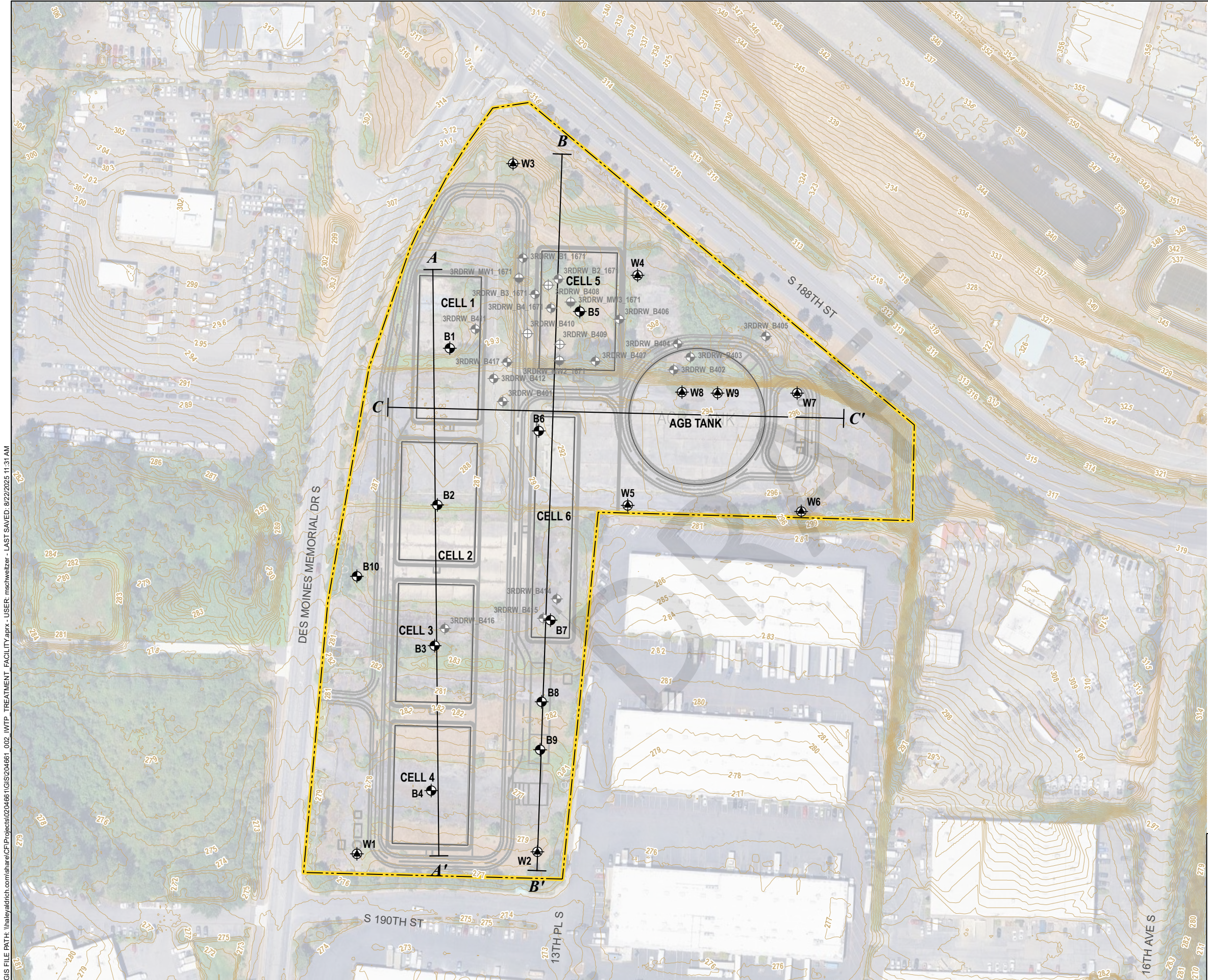
d. VWP: vibrating wire piezometer

DRAFT

FIGURES



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LEGEND

CURRENT STUDY

-  BORING
-  MONITORING WELL

HISTORICAL EXPLORATION

-  BORING
-  PUSH PROBE - INCLUDES STRATAPROBE, GAS PROBE
-  MONITORING WELL
-  CROSS SECTION

 TOPOGRAPHIC ELEVATION CONTOUR; 1-FT INTERVAL (NAVD 88)

 PROPOSED FEATURE

 PROJECT BOUNDARY

NOTES

- ALL LOCATIONS AND DIMENSIONS ARE APPROXIMATE.
- FINAL AS-DRILLED LOCATIONS WILL BE UPDATED ONCE SURVEY IS COMPLETE
- AERIAL IMAGERY SOURCE: GOOGLE EARTH



0 150 300
SCALE IN FEET

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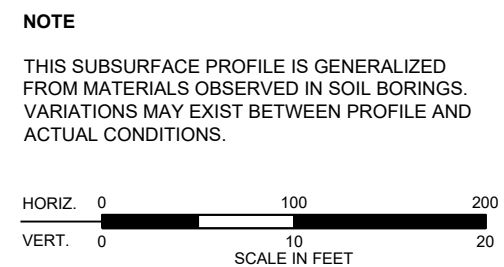
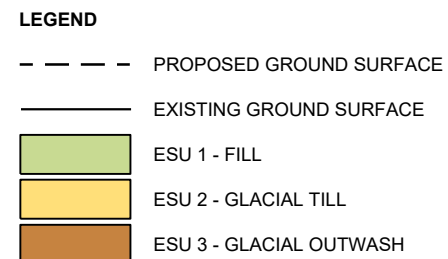
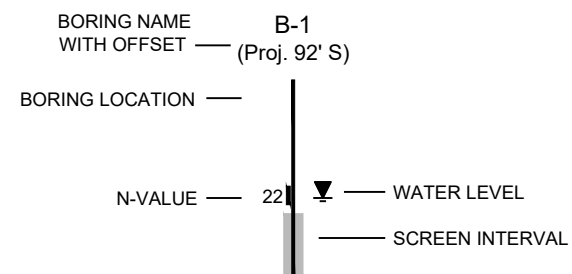
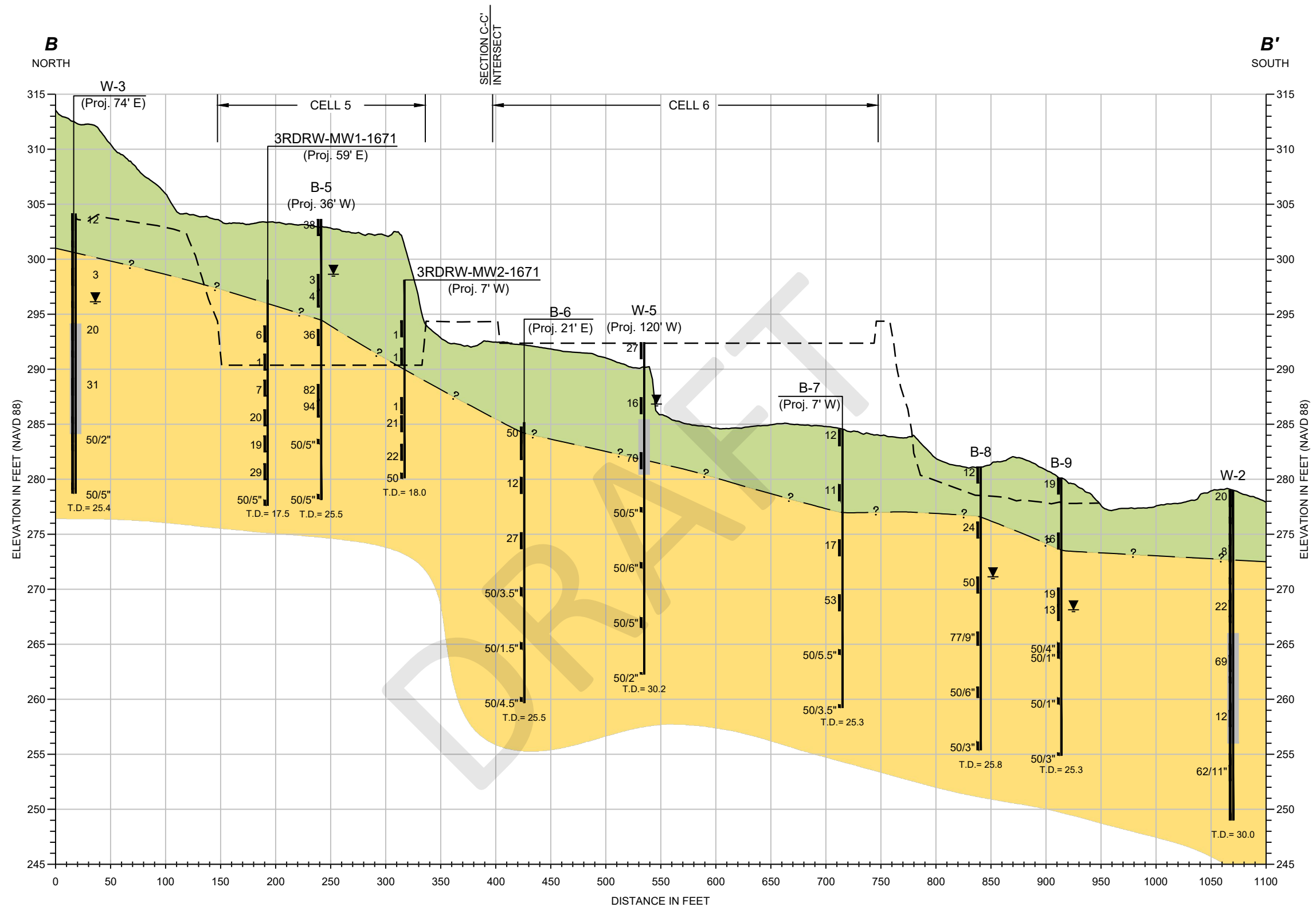
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SITE AND EXPLORATION PLAN

AUGUST 2025

FIGURE 2

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HALEY ALDRICH IWTP ENHANCEMENTS SEATAC, WASHINGTON

CROSS SECTION B-B'

AUGUST 2025

FIGURE 4

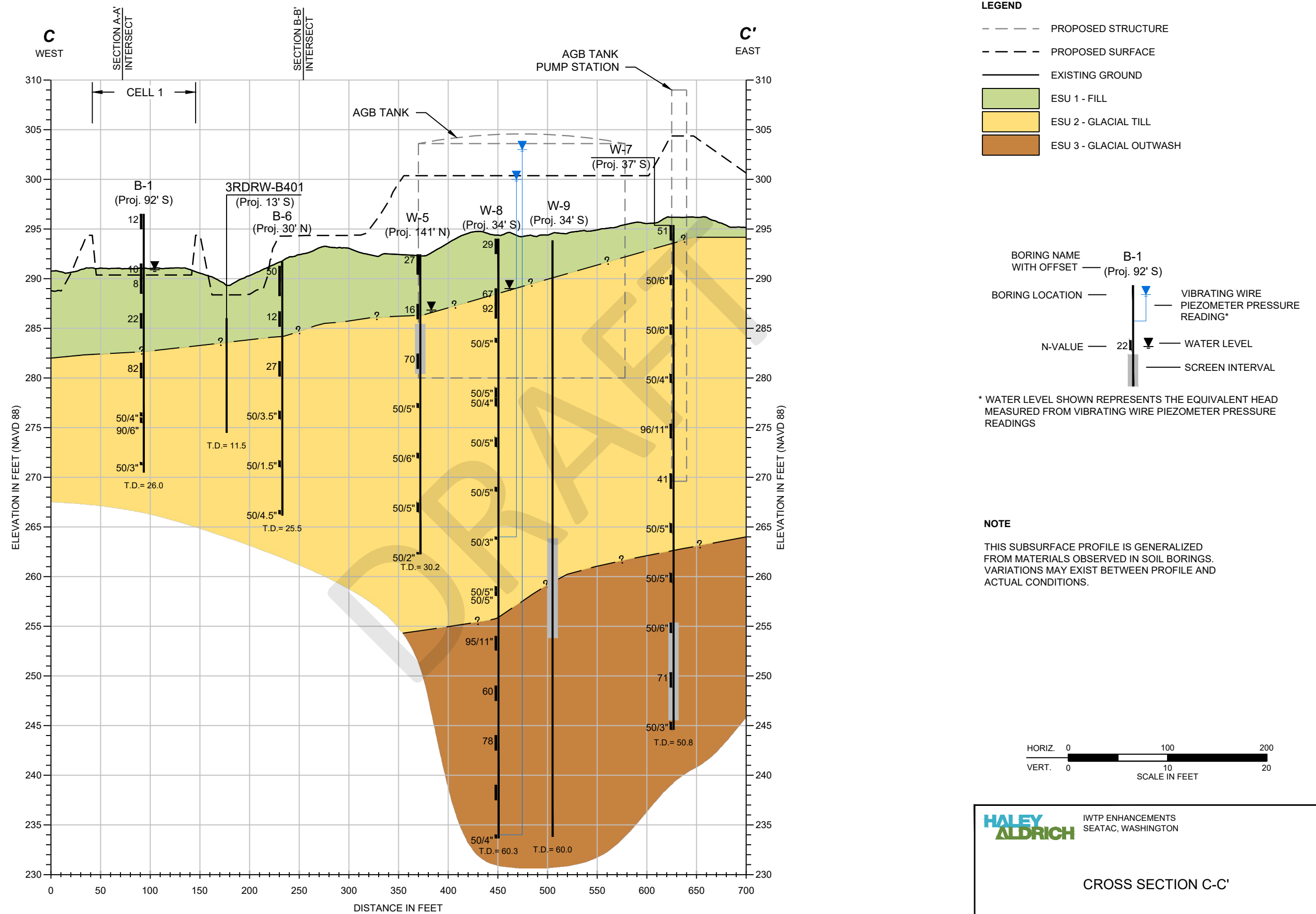
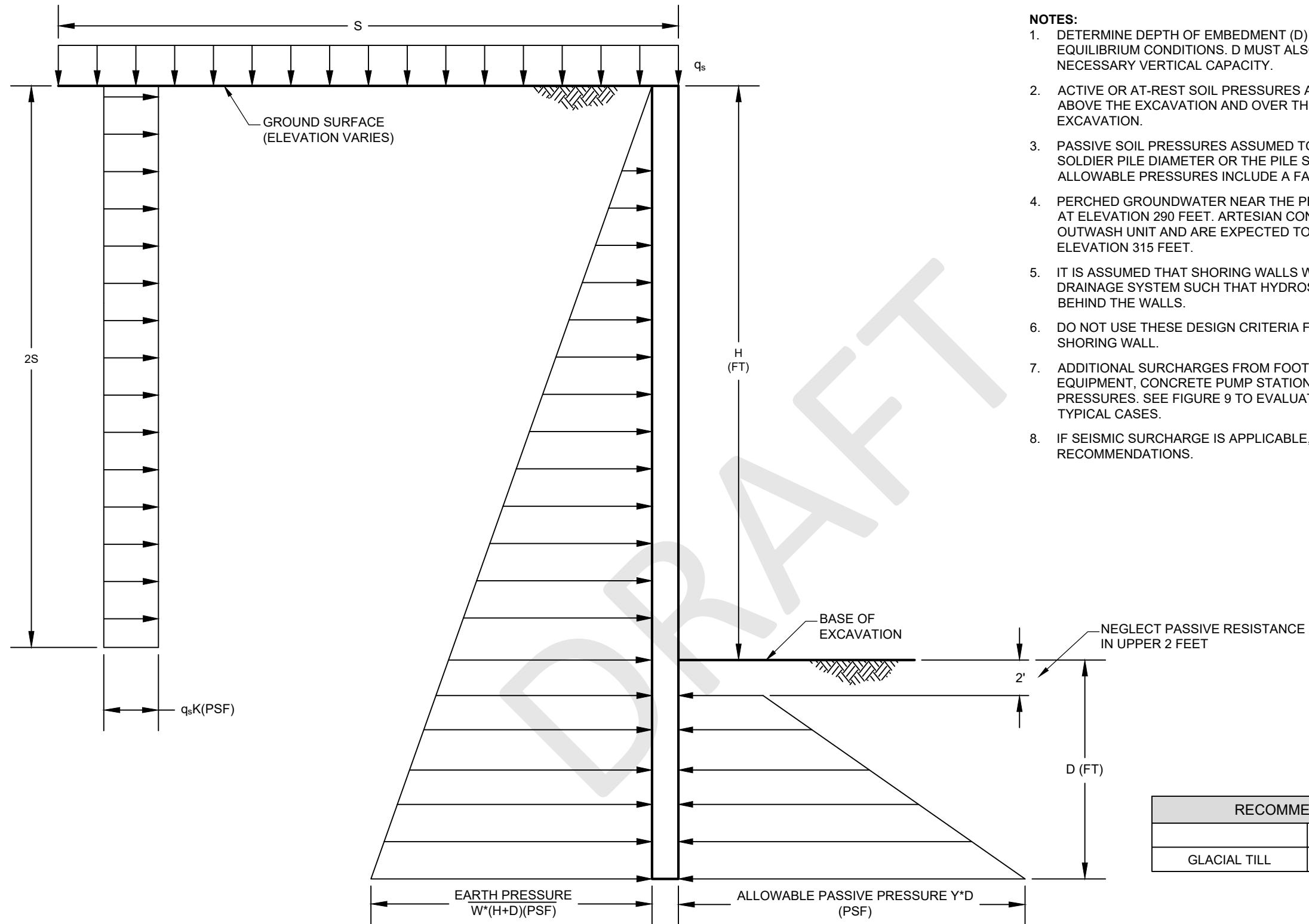


FIGURE 5

MSCHWEITZER Printed: 8/22/2025 11:37 AM Sheet: CANTILEVER SOLDIER PILE
\\HALEY\ALDRICH\COM\SHARE\CF\PROJECTS\0204661\CAD\FIGURES\204661_000_EPD.DWG



- NOTES:**
1. DETERMINE DEPTH OF EMBEDMENT (D) BY LATERAL SOIL PRESSURE EQUILIBRIUM CONDITIONS. D MUST ALSO BE SUFFICIENT TO PROVIDE NECESSARY VERTICAL CAPACITY.
 2. ACTIVE OR AT-REST SOIL PRESSURES ASSUMED TO ACT OVER PILE SPACING ABOVE THE EXCAVATION AND OVER THE PILE DIAMETER BELOW THE EXCAVATION.
 3. PASSIVE SOIL PRESSURES ASSUMED TO ACT OVER 3 TIMES THE GROUTED SOLDIER PILE DIAMETER OR THE PILE SPACING, WHICHEVER IS LESS. ALLOWABLE PRESSURES INCLUDE A FACTOR OF SAFETY OF 1.5.
 4. PERCHED GROUNDWATER NEAR THE PROPOSED EXCAVATION WAS OBSERVED AT ELEVATION 290 FEET. ARTESIAN CONDITIONS ARE EXPECTED IN THE OUTWASH UNIT AND ARE EXPECTED TO HAVE PRESSURE HEAD OF ABOUT ELEVATION 315 FEET.
 5. IT IS ASSUMED THAT SHORING WALLS WILL BE INSTALLED WITH PROPER DRAINAGE SYSTEM SUCH THAT HYDROSTATIC PRESSURES DO NOT BUILD UP BEHIND THE WALLS.
 6. DO NOT USE THESE DESIGN CRITERIA FOR DESIGN OF ANY OTHER TYPE OF SHORING WALL.
 7. ADDITIONAL SURCHARGES FROM FOOTINGS, LARGE STOCKPILES, HEAVY EQUIPMENT, CONCRETE PUMP STATIONS, ETC., MUST BE ADDED TO THESE PRESSURES. SEE FIGURE 9 TO EVALUATE LATERAL EARTH PRESSURES FOR TYPICAL CASES.
 8. IF SEISMIC SURCHARGE IS APPLICABLE, REFER TO REPORT TEXT FOR RECOMMENDATIONS.

LEGEND
 H = WALL HEIGHT (FEET)
 D = EMBEDMENT DEPTH (FEET)
 S = WIDTH OF SURCHARGE LOAD AREA (FEET)
 q_s = 250 PSF (MINIMUM TRAFFIC & TEMPORARY LOADS)

RECOMMENDED VALUES OF W IN PCF		
SOIL UNIT(S)	ACTIVE CONDITIONS	AT REST CONDITIONS
FILL	35	55
GLACIAL TILL	29	48

RECOMMENDED VALUES OF K		
SOIL UNIT(S)	ACTIVE CONDITIONS	AT REST CONDITIONS
FILL	0.28	0.44
GLACIAL TILL	0.22	0.36

RECOMMENDED VALUES OF Y IN PCF		
	ABOVE GWT	BELOW GWT
GLACIAL TILL	410	220

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ALDRICH**

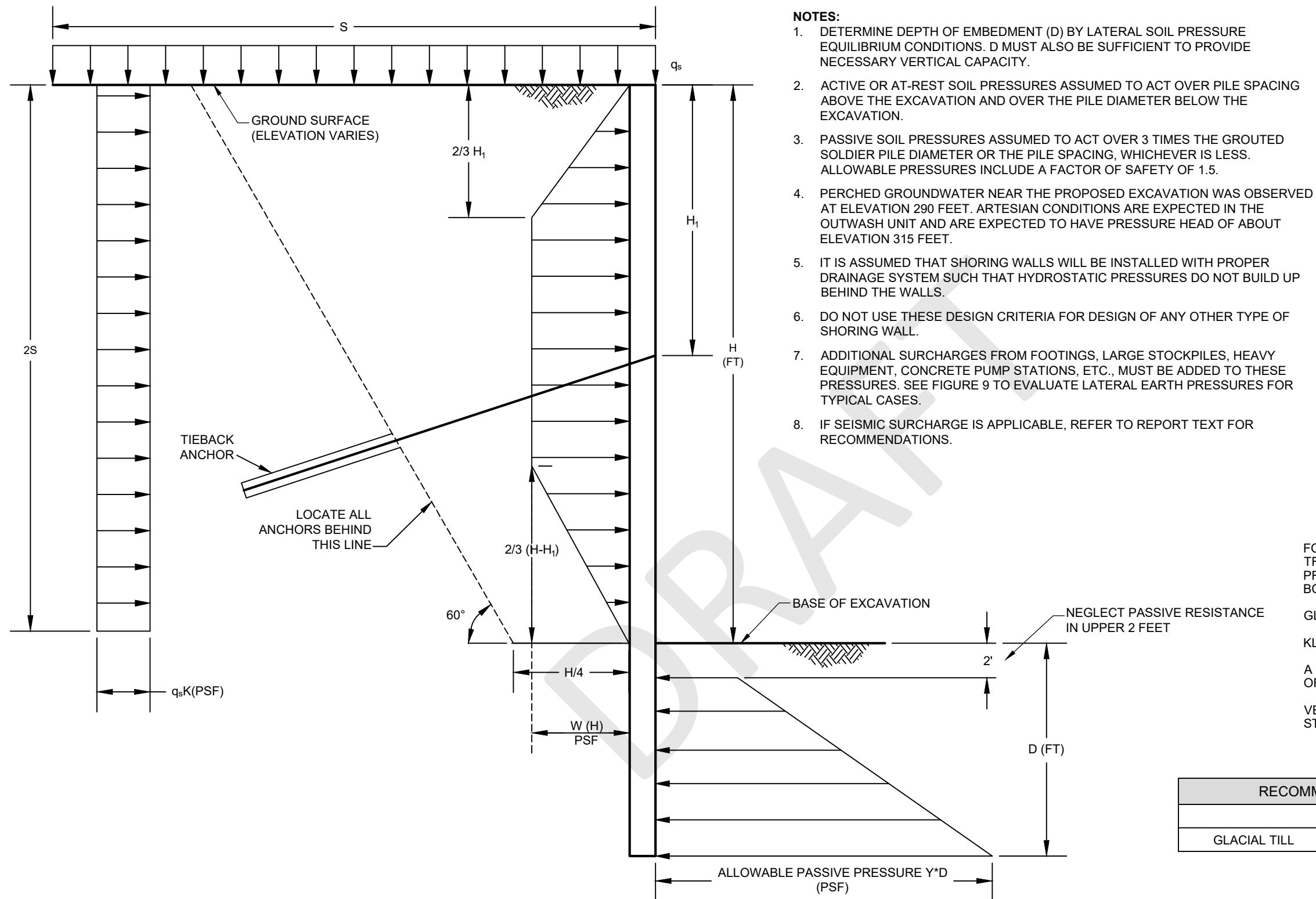
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SEATAC, WASHINGTON

**DESIGN OF TEMPORARY
CANTILEVER SOLDIER PILE
SHORING**

NOT TO SCALE
AUGUST 2025

FIGURE 6

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\\HALEYALDRICH.COM\SHARE\CF\PROJECTS\0204661\CAD\FIGURES\204661_000_EPD.DWG



- NOTES:**
1. DETERMINE DEPTH OF EMBEDMENT (D) BY LATERAL SOIL PRESSURE EQUILIBRIUM CONDITIONS. D MUST ALSO BE SUFFICIENT TO PROVIDE NECESSARY VERTICAL CAPACITY.
 2. ACTIVE OR AT-REST SOIL PRESSURES ASSUMED TO ACT OVER PILE SPACING ABOVE THE EXCAVATION AND OVER THE PILE DIAMETER BELOW THE EXCAVATION.
 3. PASSIVE SOIL PRESSURES ASSUMED TO ACT OVER 3 TIMES THE GROUTED SOLDIER PILE DIAMETER OR THE PILE SPACING, WHICHEVER IS LESS. ALLOWABLE PRESSURES INCLUDE A FACTOR OF SAFETY OF 1.5.
 4. PERCHED GROUNDWATER NEAR THE PROPOSED EXCAVATION WAS OBSERVED AT ELEVATION 290 FEET. ARTESIAN CONDITIONS ARE EXPECTED IN THE OUTWASH UNIT AND ARE EXPECTED TO HAVE PRESSURE HEAD OF ABOUT ELEVATION 315 FEET.
 5. IT IS ASSUMED THAT SHORING WALLS WILL BE INSTALLED WITH PROPER DRAINAGE SYSTEM SUCH THAT HYDROSTATIC PRESSURES DO NOT BUILD UP BEHIND THE WALLS.
 6. DO NOT USE THESE DESIGN CRITERIA FOR DESIGN OF ANY OTHER TYPE OF SHORING WALL.
 7. ADDITIONAL SURCHARGES FROM FOOTINGS, LARGE STOCKPILES, HEAVY EQUIPMENT, CONCRETE PUMP STATIONS, ETC., MUST BE ADDED TO THESE PRESSURES. SEE FIGURE 9 TO EVALUATE LATERAL EARTH PRESSURES FOR TYPICAL CASES.
 8. IF SEISMIC SURCHARGE IS APPLICABLE, REFER TO REPORT TEXT FOR RECOMMENDATIONS.

TENTATIVE ANCHOR PULLOUT RESISTANCE

FOR DESIGN PURPOSES, USE ALLOWABLE LOAD TRANSFER (ADHESION) AS FOLLOWS FOR CASED, PRESSURE GROUTED, AT LEAST 6-INCH-DIAMETER BOREHOLES (AIR ROTARY DRILLING) IN:

GLACIAL TILL 4.5 KLF

KLF: KIPS ER LINEAL FOOT

A MINIMUM ANCHOR LOAD LENGTH (BONDED ZONE) OF 15 FEET IS RECOMMENDED

VERIFY WITH LOAD TEST TO 200% OF DESIGN STRESS LEVEL. SEE TEXT.

RECOMMENDED VALUES OF Y IN PCF		
	ABOVE GWT	BELOW GWT
GLACIAL TILL	410	220

LEGEND

H = WALL HEIGHT (FEET)
D = EMBEDMENT DEPTH (FEET)
S = WIDTH OF SURCHARGE LOAD AREA (FEET)
q_s = 250 PSF (MINIMUM TRAFFIC & TEMPORARY LOADS)

RECOMMENDED VALUES OF W IN PCF		
SOIL UNIT(S)	ACTIVE CONDITIONS	AT REST CONDITIONS
FILL	35	55
GLACIAL TILL	29	48

RECOMMENDED VALUES OF K		
SOIL UNIT(S)	ACTIVE CONDITIONS	AT REST CONDITIONS
FILL	0.28	0.44
GLACIAL TILL	0.22	0.36



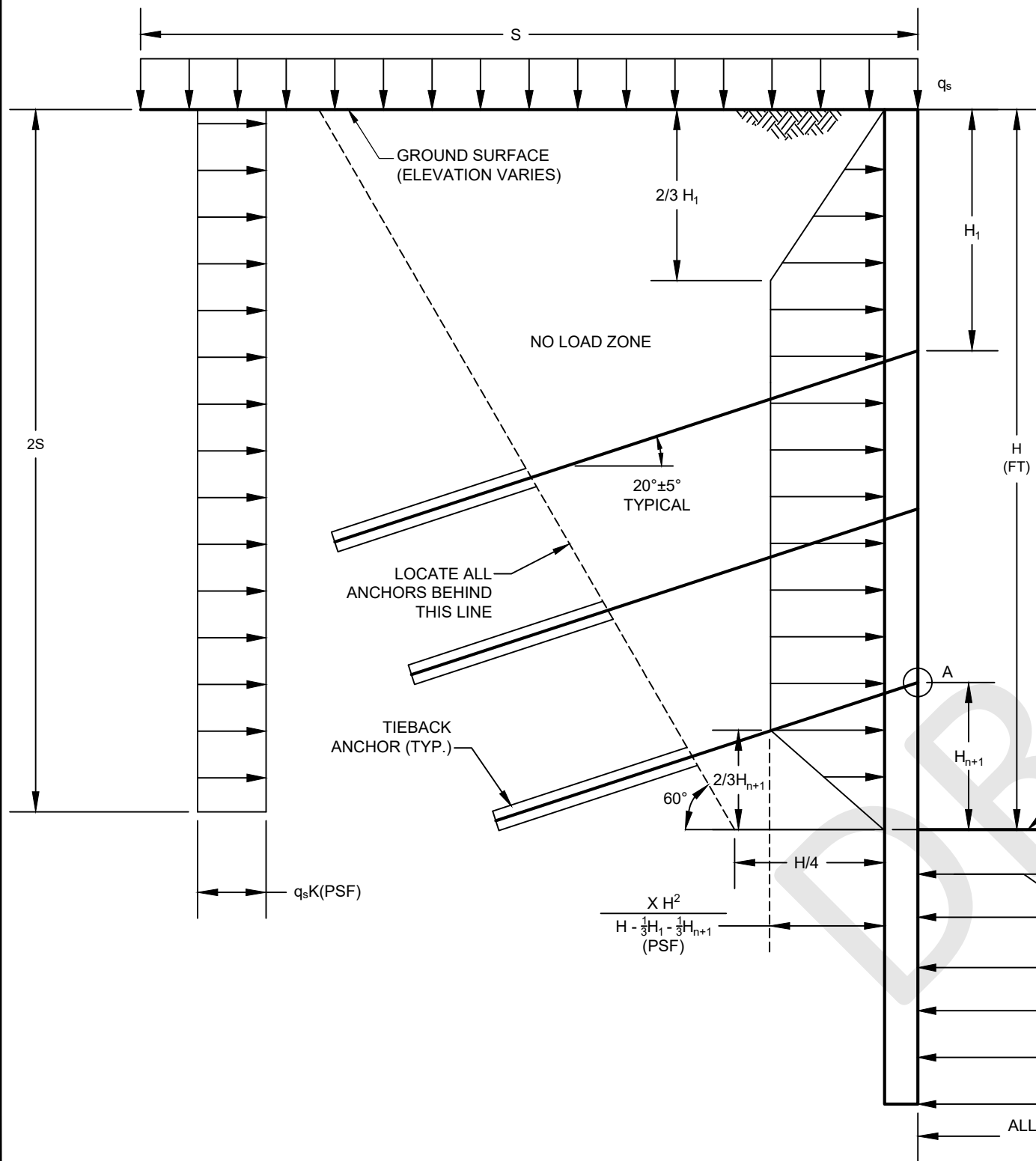
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SEATAC, WASHINGTON

DESIGN OF SINGLE BRACE SOLDIER PILE SHORING

NOT TO SCALE
AUGUST 2025

FIGURE 7

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\\HALEYALDRICH.COM\SHARE\CF\PROJECTS\0204661\CAD\FIGURES\204661_000_EPD.DWG



NOTES:

1. DETERMINE DEPTH OF EMBEDMENT (D) BY LATERAL SOIL PRESSURE EQUILIBRIUM CONDITIONS. D MUST ALSO BE SUFFICIENT TO PROVIDE NECESSARY VERTICAL CAPACITY.
2. ACTIVE OR AT-REST SOIL PRESSURES ASSUMED TO ACT OVER PILE SPACING ABOVE THE EXCAVATION AND OVER THE PILE DIAMETER BELOW THE EXCAVATION.
3. PASSIVE SOIL PRESSURES ASSUMED TO ACT OVER 3 TIMES THE GROUTED SOLDIER PILE DIAMETER OR THE PILE SPACING, WHICHEVER IS LESS. ALLOWABLE PRESSURES INCLUDE A FACTOR OF SAFETY OF 1.5.
4. PERCHED GROUNDWATER NEAR THE PROPOSED EXCAVATION WAS OBSERVED APPROXIMATELY 5 FEET BELOW THE GROUND SURFACE. ARTESIAN CONDITIONS ARE EXPECTED IN THE OUTWASH UNIT AND ARE EXPECTED TO HAVE AN EQUIVALENT HEAD OF ABOUT ELEVATION 306 TO 309 FEET.
5. IT IS ASSUMED THAT SHORING WALLS WILL BE INSTALLED WITH PROPER DRAINAGE SYSTEM SUCH THAT HYDROSTATIC PRESSURES DO NOT BUILD UP BEHIND THE WALLS.
6. DO NOT USE THESE DESIGN CRITERIA FOR DESIGN OF ANY OTHER TYPE OF SHORING WALL.
7. ADDITIONAL SURCHARGES FROM FOOTINGS, LARGE STOCKPILES, HEAVY EQUIPMENT, CONCRETE PUMP STATIONS, ETC., MUST BE ADDED TO THESE PRESSURES. SEE FIGURE 9 TO EVALUATE LATERAL EARTH PRESSURES FOR TYPICAL CASES.
8. DEPTH OF FILL AND WEATHERED TILL (H_f) IS ESTIMATED TO BE UP TO 12 FEET ALONG THE PERIMETER OF THE SITE.
9. IF SEISMIC SURCHARGE IS APPLICABLE, REFER TO REPORT TEXT FOR RECOMMENDATIONS.

TENTATIVE ANCHOR PULLOUT RESISTANCE

FOR DESIGN PURPOSES, USE ALLOWABLE LOAD TRANSFER (ADHESION) AS FOLLOWS FOR CASED, PRESSURE GROUTED, AT LEAST 6-INCH-DIAMETER BOREHOLES (AIR ROTARY DRILLING) IN:

GLACIAL TILL 4.5 KLF

KLF: KIPS ER LINEAL FOOT

A MINIMUM ANCHOR LOAD LENGTH (BONDED ZONE) OF 15 FEET IS RECOMMENDED

VERIFY WITH LOAD TEST TO 200% OF DESIGN STRESS LEVEL. SEE TEXT.

RECOMMENDED VALUES OF Y IN PCF

	ABOVE GWT	BELOW GWT
GLACIAL TILL	410	220

LEGEND

H = WALL HEIGHT (FEET)
D = EMBEDMENT DEPTH (FEET)
S = WIDTH OF SURCHARGE LOAD AREA (FEET)
q_s = 250 PSF (MINIMUM TRAFFIC & TEMPORARY LOADS)

RECOMMENDED VALUES OF X IN PCF

SOIL UNIT(S)	ACTIVE CONDITIONS	AT REST CONDITIONS
FILL	22	35
GLACIAL TILL	18	31

RECOMMENDED VALUES OF K

SOIL UNIT(S)	ACTIVE CONDITIONS	AT REST CONDITIONS
FILL	0.28	0.44
GLACIAL TILL	0.22	0.36

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ALDRICH

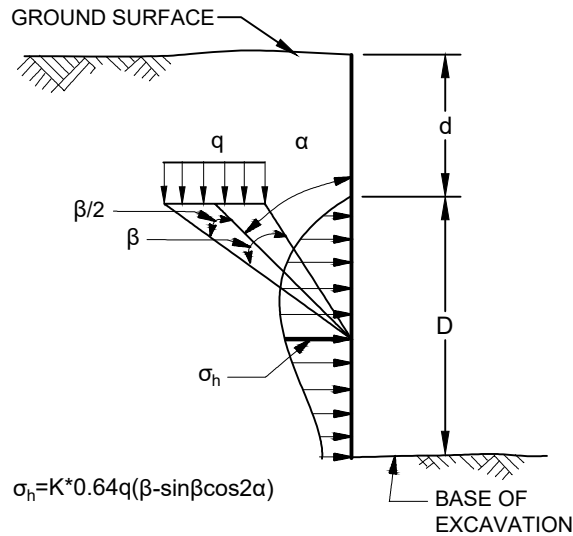
IWTP ENHANCEMENTS
SEATAC, WASHINGTON

DESIGN OF MULTIPLE BRACE SOLDIER PILE SHORING

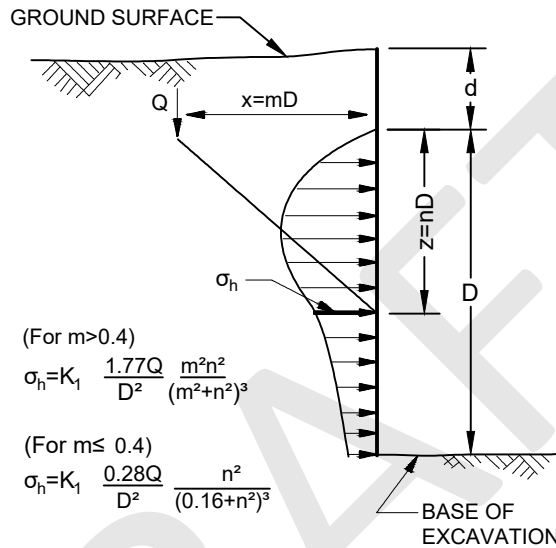
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AUGUST 2025

FIGURE 8

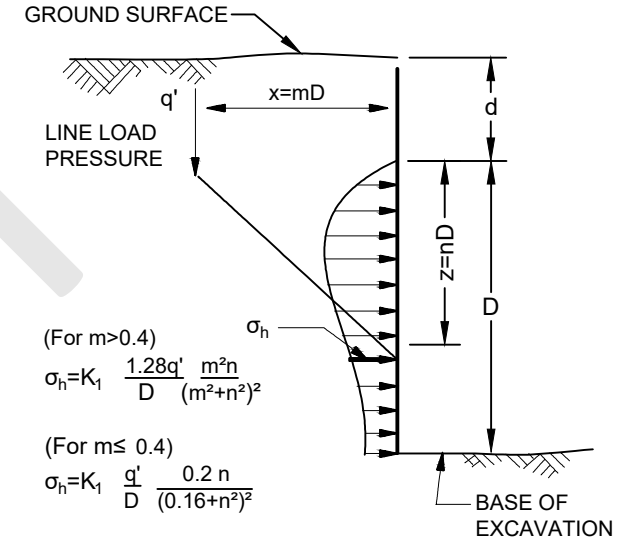
A. STRIP FOOTING CROSS SECTION VIEW



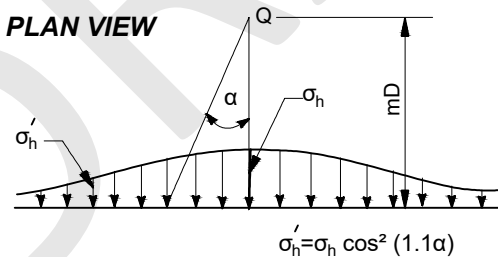
B(1). SMALL ISOLATED FOOTING CROSS SECTION VIEW



C. CONTINUOUS WALL FOOTING PARALLEL TO EXCAVATION CROSS SECTION VIEW



B(2). PLAN VIEW



DEFINITION AND UNITS

- Q FOOTING LOAD IN POUNDS
- D EXCAVATION DEPTH BELOW FOOTING IN FEET
- d DEPTH TO BASE OF FOOTING IN FEET
- σ_h LATERAL SOIL PRESSURE IN PSF
- q UNIT LOADING PRESSURE IN PSF
- q' FOOTING LOAD IN POUNDS PER FOOT
- α, β RADIANS

NOTES:

1. LATERAL PRESSURES FROM ADJACENT STRUCTURES SHOULD BE ADDED TO LATERAL PRESSURES ON FIGURES 6 THROUGH 8.
2. WALL FOOTINGS ACTING OTHER THAN PARALLEL TO THE EXCAVATION CAN BE TREATED AS SERIES OF DISCRETE POINT LOADS, USING DIAGRAM B.
3. CONTACT HALEY & ALDRICH FOR SURCHARGE RECOMMENDATIONS, IF NECESSARY.

K_1	CONDITIONS
0.3	ACTIVE EARTH PRESSURE ON A FLEXIBLE WALL (E.G., SHORING)
0.46	AT-REST CONDITIONS, WHERE SURCHARGE LOADS EXIST PRIOR TO EXCAVATION
1.0	AT-REST CONDITIONS, WHERE SURCHARGE LOADS ARE APPLIED AFTER CONSTRUCTION ON PERMANENT WALL

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ALDRICH**

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SEATAC, WASHINGTON

LATERAL EARTH PRESSURES ON
ADJACENT SHORING
DUE TO SURCHARGE PRESSURES

NOT TO SCALE
AUGUST 2025

FIGURE 9

APPENDIX A
Field Exploration Methods and Analysis

Appendix A

Field Exploration Methods and Analysis

This appendix documents the processes Haley & Aldrich used to determine the nature of the site soil and groundwater. This appendix includes information on the following subjects:

- Explorations and Their Location;
- Hollow Stem Auger and Mud Rotary Borings;
- Standard Penetration Test Procedures;
- Sonic Drilling Test Procedures;
- Water Level Measurements
- Soil Screening and Analysis
- Groundwater Monitoring Wells;
- Vibrating Wire Piezometers;

Explorations and Their Location

Subsurface explorations for this project included 11 mud rotary (MR) and 8 sonic borings. The exploration log in this appendix shows our interpretation of the drilling, excavation, sampling, and testing data. The log indicates the depth where soils change. Note that the actual change may be gradual. In the field, we classified the samples taken from the explorations according to the methods presented on Figure A-1 - Key to Exploration Logs. This figure also provides a legend explaining the symbols and abbreviations used in the logs.

Figure 2 illustrates the horizontal locations of explorations, which are based on field measurements from existing physical features. The elevations on the logs are approximated based on available survey at the site. The vertical datum is NAVD88. Drilling locations were not surveyed at the time of this report but are planned for a later date.

Hollow Stem Auger and Mud Rotary Borings

Eleven borings, designated B-1 to B-10 and W-8, were drilled from June 10 to June 18, 2025, from 25 to 60 feet bgs using a combination of hollow stem auger and mud rotary techniques. Each of these borings was initially drilled using hollow stem auger techniques and then switched over to mud rotary upon reaching the groundwater table. The borings were completed using either a Mobile B-57 track-mounted drill rig or a CME-75 truck-mounted drill rig. All mud rotary borings were drilled with a 6-inch diameter mud rotary bit. The boring was advanced by Holt Services, Inc., and continuously observed by a geologist from Haley & Aldrich. A detailed field log was prepared. Samples were obtained at 2.5- to 5-foot-depth intervals using standard penetration test procedures. Drilling fluid was continually added to the augers or drill rod and maintained at a level to control heaving conditions at the bottom of the rods.

The boring logs are presented on Figure A-2 through A-11.

Standard Penetration Test (SPT) Procedures

This test is an approximate measure of soil density and consistency. To be useful, the results must be used with engineering judgment in conjunction with other tests. The SPT (as described in ASTM D 1586) was used to obtain disturbed samples. This test employs a standard 2-inch outside diameter split-spoon sampler. Using a 140-pound autohammer, free-falling 30 inches, the sampler is driven into the soil for 18 inches. The number of blows required to drive the sampler the last 12 inches only is the Standard Penetration Resistance. This resistance, or blow count, measures the relative density of granular soils and the consistency of cohesive soils. The blow counts are plotted on the boring logs at their respective sample depths.

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

IN THE EVENT OF HARD DRIVING

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

Penetration less than 6 inches. The log indicates the total number of blows over the number of inches of penetration.

Penetration greater than 6 inches. The blow count noted on the log is the sum of the total number of blows completed after the first 6 inches of penetration. This sum is expressed over the number of inches driven that exceed the first 6 inches. The number of blows needed to drive the first 6 inches are not reported. For example, a blow count series of 12 blows for 6 inches, 30 blows for 6 inches, and 50 (the maximum number of blows counted within a 6-inch increment for SPT) for 3 inches would be recorded as 80/9.

Sonic Drilling

With depths ranging from 25 to 60 feet below the ground surface, eight sonic drilling explorations, designated W-1 through W-7 and W-9, were advanced from June 2 to June 7, 2025. The sonic explorations used a 6-inch-diameter steel casing with a carbide drill bit and were advanced with a track-mounted drill rig subcontracted by Haley & Aldrich. A field geologist from Haley & Aldrich continuously observed the drilling and conducted the soil sampling activities. The large diameter casing is rotated and/or vibrated into the subsurface and collects a continuous core sample. Samples are collected by vibrating the core out of the casing and into a flexible plastic sleeve by the sonic rig. Sample sleeves are made of clear plastic for convenient inspection of the soil sample. Soil samples were generally collected in continuous 5-foot-depth intervals. Samples were classified in general accordance with ASTM D 2488 and were screened for potential soil contamination. The density/consistency of the soils (where presented parenthetically on the probe logs to indicate their having been estimated) is based on visual observation and probe reaction. Detailed logs were prepared of each boring.

The sonic boring logs are presented on Figures A-12 through A-20.

Water Level Measurements

Water levels in the borings were either estimated while drilling (i.e. using drill rods as a reference), or measured during the short time the boreholes could remain open, using a water level probe graduated in 0.01-foot increments.

Soil Screening and Analysis

During our explorations, we field screened samples at approximately 5-foot intervals for evidence of petroleum- and/or volatile organic compound (VOC)-related impacts using visual and olfactory observations. We also performed headspace vapor screening using a MultiRAE photoionization detector (PID) for samples at 5-foot intervals, typically in the upper 25 to 30 feet in each boring.

The effectiveness of field screening varies with temperature, moisture content, organic content, soil type, and age of the constituents. Visual examination consists of inspecting the soil for stains that may indicate petroleum or VOC impacts. Visual screening is generally more effective when impacts are related to heavy petroleum hydrocarbons, such as motor or hydraulic oil, or when hydrocarbon concentrations are high.

Field screening results were used as a general guideline to identify potential chemical constituents in soil samples. In addition, field screening results were used as a basis for selecting soil samples for chemical analysis.

Groundwater Monitoring Wells

WELL CONSTRUCTION

Dedicated monitoring wells were completed in eight borings in June 2025 (W-1, W-2, W-3, W-4, W-5, W-6, W-7, and W-9) and screened from approximately 7 to 50 feet below ground surface (bgs).

Groundwater monitoring wells were constructed of 2-inch-diameter, flush-threaded Schedule 40 polyvinyl chloride (PVC) casing with 0.010-inch machine-slotted PVC screen. Wells were completed with 5-foot or 10-foot screened intervals.

A filter pack was typically installed around the well screen which extends from the bottom of the well screen to 1 ft above the top of the well screen. Filter pack material consisted of commercially prepared 10-20 silica sand. For well W-5, a bentonite seal was placed from the bottom of the hole to the bottom of the well screen following placement of the well screen and casing in the borehole. Well W-9 was completed with two 5-ft sections of pre-packed screen. The pre-packed screen consisted of a 2-inch inner diameter PVC screen with 0.010-inch slots, an outer stainless-steel mesh screen with outer diameter of 2.8-inch, and size 20/40 silica sand filter between the inner and outer screens. A bentonite seal at least 1-ft thick was placed above the filter pack up to about 2 feet bgs. The surface of each well was completed with a concrete seal extending from the top of the bentonite seal up to the ground surface. Steel flush-mount monuments were concreted in place from the surface to a depth of about 1.5 feet bgs. Where flowing artesian conditions were encountered, wells were completed with either a 2-inch PVC ball valve (W-1, W-7, W-9) or threaded PVC cap (W-6).

WELL DEVELOPMENT

Monitoring wells were developed to remove water introduced into the well during drilling, stabilize the filter pack and formation materials surrounding the well screen, and restore the hydraulic connection between the well screen and the surrounding soil.

The well screens were developed after installation by two methods. Flowing artesian wells screened in the Glacial Outwash were allowed to flow freely (wells W-1, W-7, and W-9). Other wells (W-2, W-3, W-4, W-5) were developed by surging and over-pumping with a submersible pump. Well W-6 was not developed as it was not completed with a ball valve which would enable controlled flow. Depths to water in the non-flowing monitoring wells were measured prior to development.

Development continued until a minimum of 10 casing volumes of water had been removed and turbidity of the discharged water was relatively low. Water that was removed from the well during well development activities was stored on the property in labeled 55-gallon drums.

Vibrating Wire Piezometers

Two vibrating wire piezometers (VWPs) were installed in boring W-8 at depths of approximately 40 and 59 ft bgs to monitor groundwater pressure within the Glacial Outwash unit. The borehole was completed using a fully-grouted construction, in which a grout mixture of Portland cement, bentonite, water, and powdered barite (Baroid 41). Grout was tremied into the borehole from the bottom up to approximately 1 ft bgs. Calibration sheets for the VWPs are included in this Appendix.

Sample Description

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

Relative Density/Consistency

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

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

Moisture

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

Minor Constituents

Estimated Percentage

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

Soil Test Symbols

%F	Percent Passing No. 200 Sieve
AL	Atterberg Limits (%)
	Liquid Limit (LL)
	Water Content (WC)
	Plastic Limit (PL)

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

USCS Soil Classification Chart (ASTM D 2487)

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

Groundwater Indicators

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

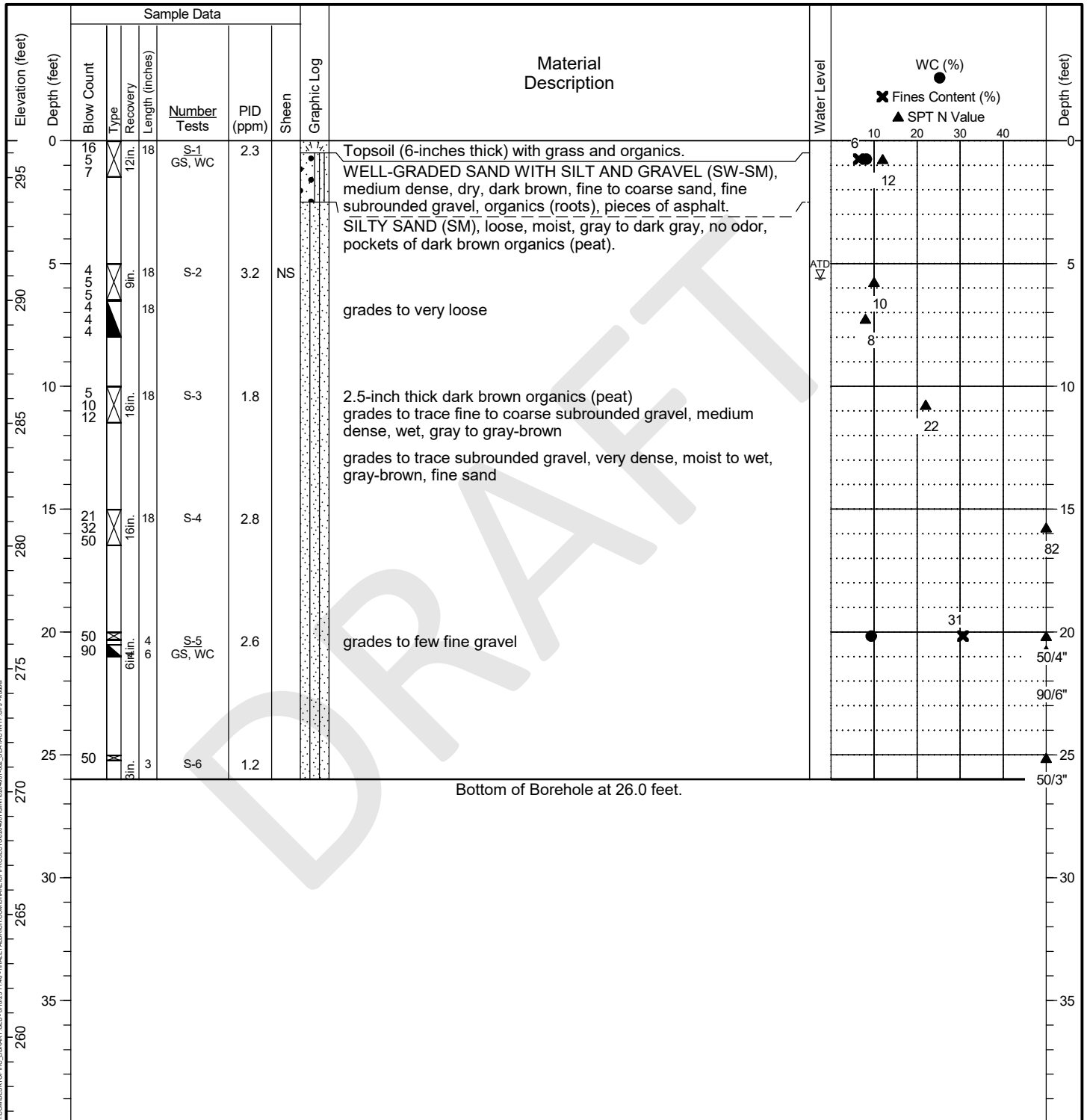
Sample Symbols

☒	1.5" I.D. Split Spoon	■	Rock Core Run	☒	Grab
☒	3.0" I.D. Split Spoon	■	Sonic Core	☒	Cuttings
☒	Modified California Sampler	☒	Thin-walled Sampler	☒	Push Probe

Well Symbols

Monument	Signal Cable
Surface Seal	Extensometer Sensor (EXT)
Bentonite Seal	Extensometer
Bentonite-Cement	Anchor
Well Casing	Vibrating Wire
Sand Pack	Piezometer (VP)
Well Tip or Slotted Screen	
Slough	

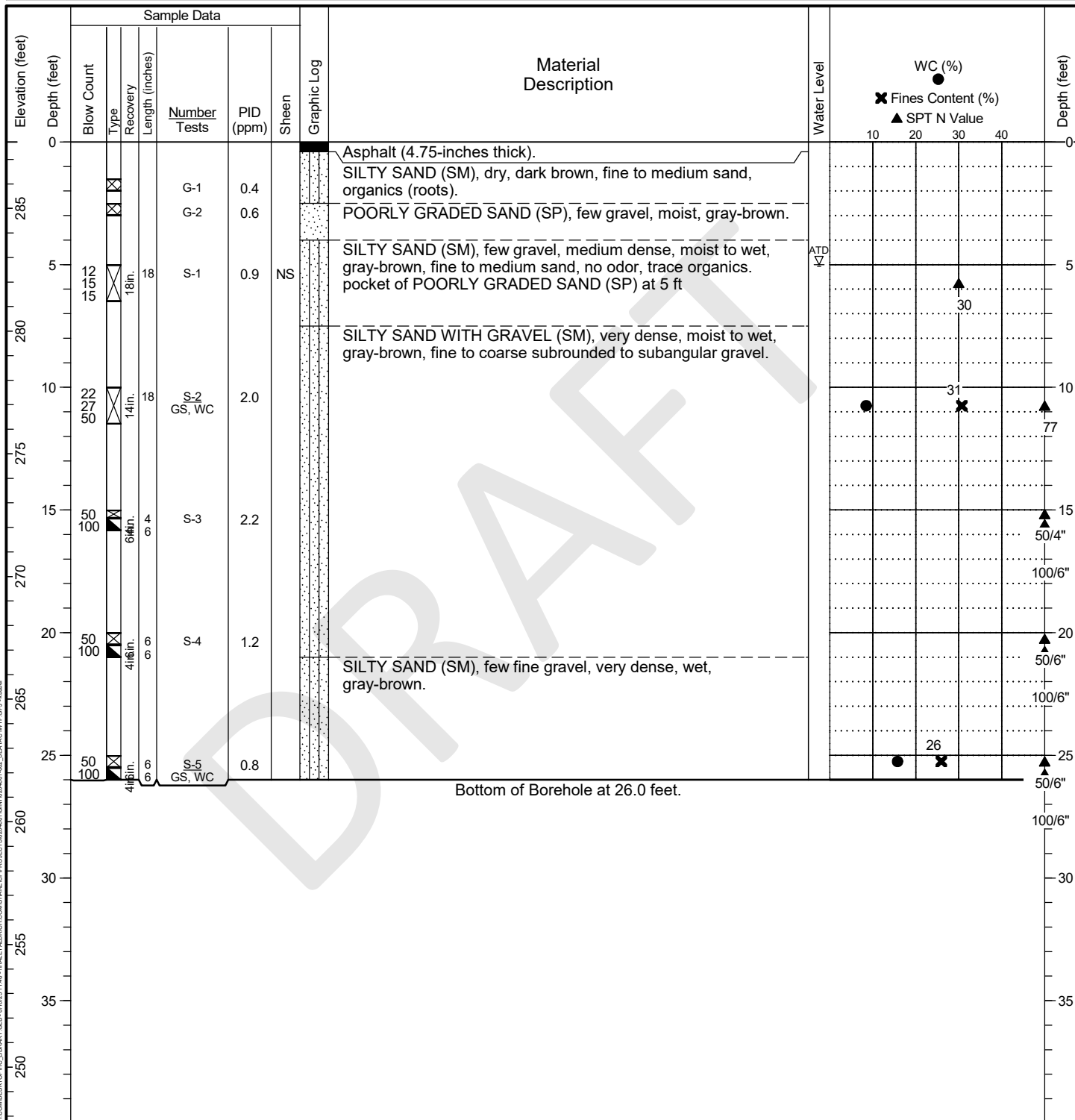
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Logged by: G. Sebbane	Checked by: A. Ung	Drilling Method: Hollow Stem Auger/Mud Rotary
Location: Lat: 47.435344 Long: -122.318438 (WGS 84)		Rig Model/Type: Mobile B-57 / Track-mounted drill rig
Ground Surface Elevation: 296.50 feet (NAVD 88)		Hammer Type: Auto-hammer
Comments: Cal sampler blow counts are uncorrected. Relative density for Cal		Hammer Weight (pounds): 140 Hammer Drop Height (inches): 30
Samples correspond to corrected N-value. Cal sampler is 3"-OD, 2.4"-ID.		Measured Hammer Efficiency (%): 84.1
		Hole Diameter: 4 inches Well Casing Diameter: NA
		Total Depth: 26.0 feet Depth to Groundwater: 5.6 feet



General Notes:

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Material stratum lines are interpretive and actual changes may be gradual. Solid lines indicate distinct contacts and dashed lines indicate gradual or approximate contacts.
3. USCS designations are based on visual-manual identification (ASTM D 2488), unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling/excavation (ATD) or for date specified. Level may vary with time.
5. Location and ground surface elevations are approximate.

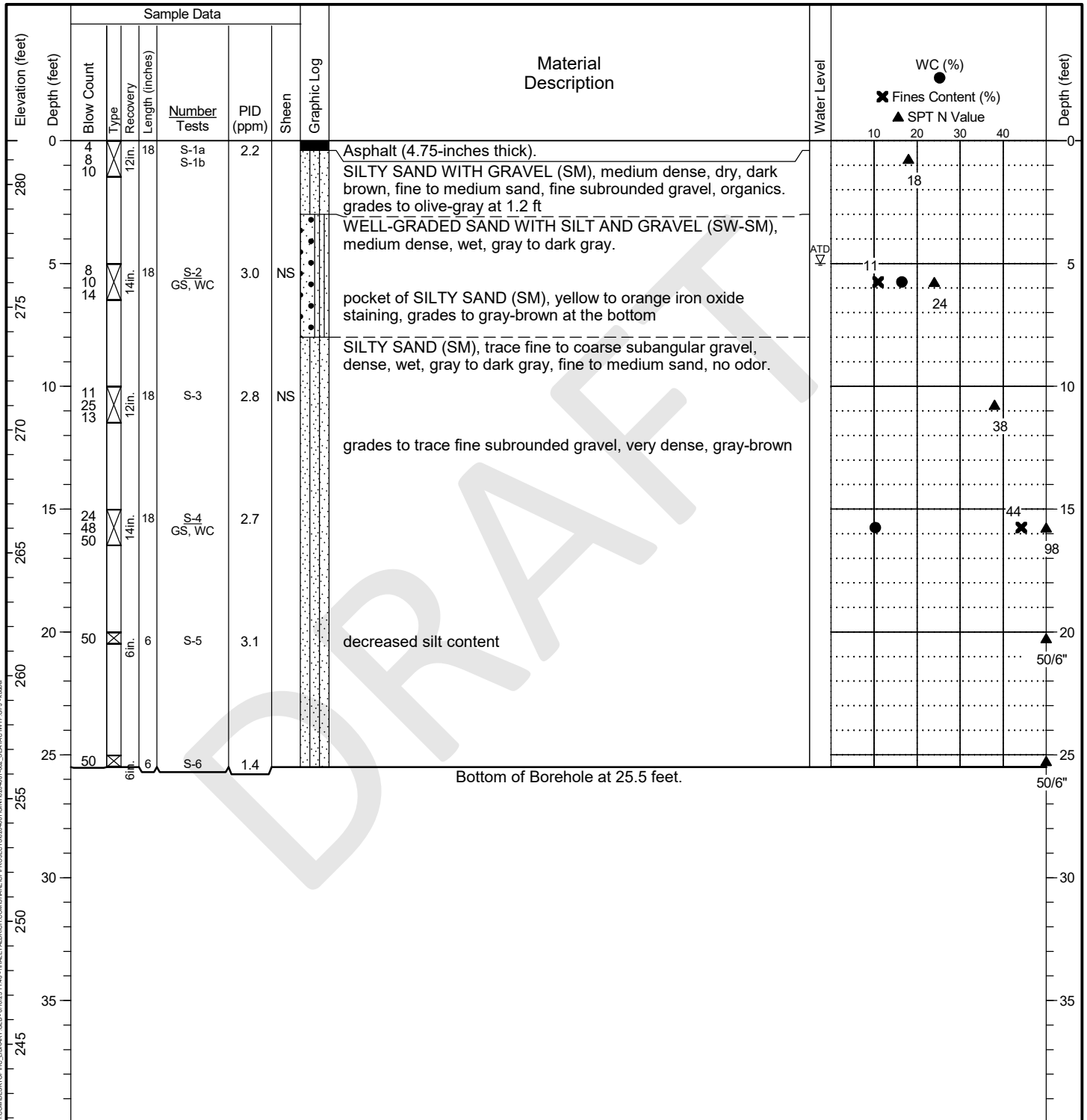
Date Started: 06/17/2025	Date Completed: 06/17/2025	Drilling Contractor/Crew: Holt Services, Inc. / A. Causland
Logged by: G. Sebbane	Checked by: A. Ung	Drilling Method: Hollow Stem Auger/Mud Rotary
Location: Lat: 47.434686 Long: -122.318497 (WGS 84)		Rig Model/Type: Mobile B-57 / Track-mounted drill rig
Ground Surface Elevation: 287.71 feet (NAVD 88)		Hammer Type: Auto-hammer
Comments: Cal sampler blow counts are uncorrected. Relative density for Cal		Hammer Weight (pounds): 140 Hammer Drop Height (inches): 30
Samples correspond to corrected N-value. Cal sampler is 3"-OD, 2.4"-ID.		Measured Hammer Efficiency (%): 84.1
		Hole Diameter: 4 inches Well Casing Diameter: NA
		Total Depth: 26.0 feet Depth to Groundwater: 5 feet



General Notes:

1. Refer to Figure A-1 for explanation of descriptions and symbols.
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4. Groundwater level, if indicated, is at time of drilling/excavation (ATD) or for date specified. Level may vary with time.
5. Location and ground surface elevations are approximate.

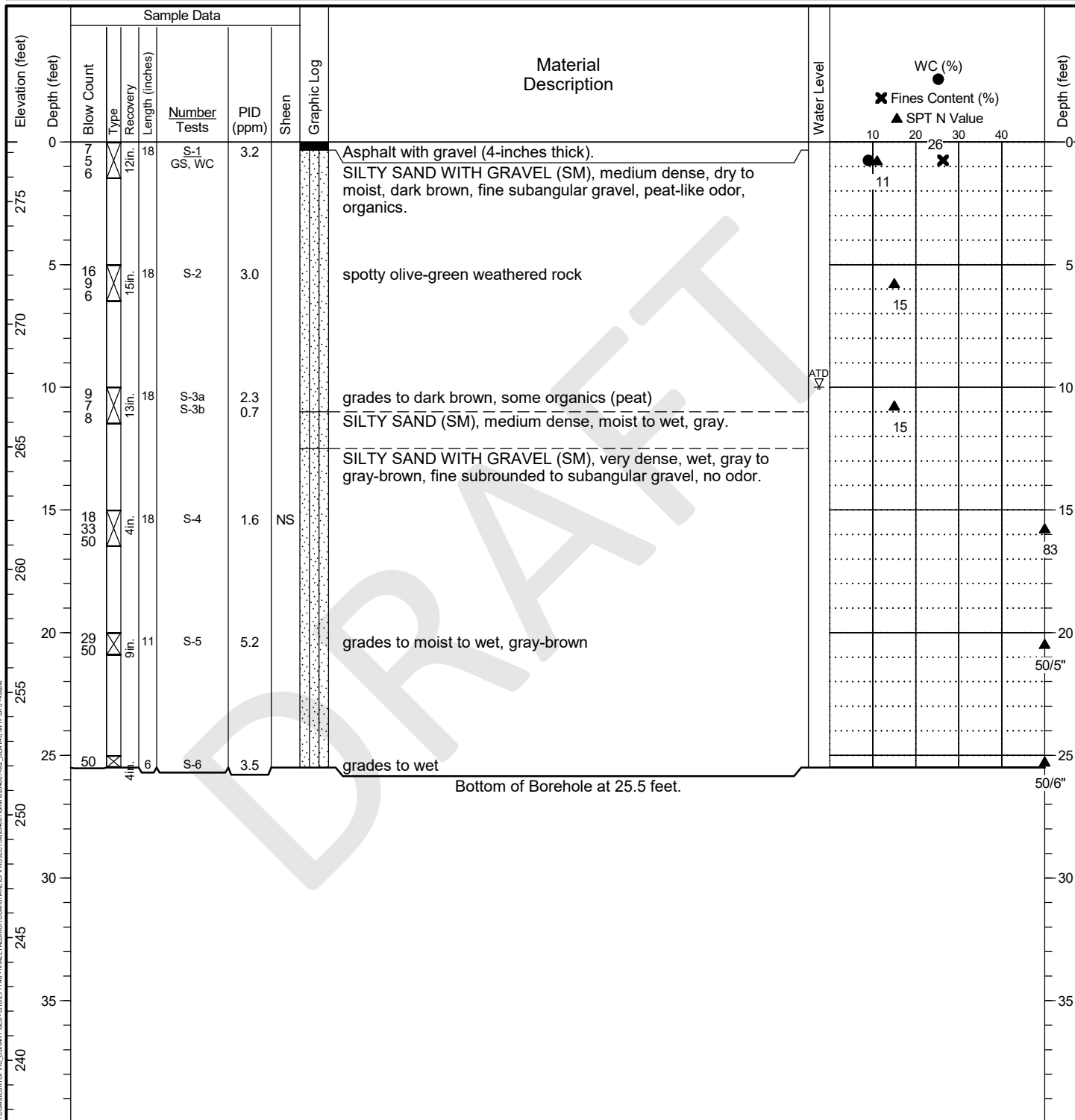
Date Started: 06/11/2025	Date Completed: 06/11/2025	Drilling Contractor/Crew: Holt Services, Inc. / Isaiah
Logged by: G. Sebbane	Checked by: A. Ung	Drilling Method: Hollow Stem Auger/Mud Rotary
Location: Lat: 47.434095 Long: -122.318497 (WGS 84)		Rig Model/Type: CME-75 / Track-mounted drill rig
Ground Surface Elevation: 281.78 feet (NAVD 88)		Hammer Type: Auto-hammer
Comments: Cal sampler blow counts are uncorrected. Relative density for Cal		Hammer Weight (pounds): 140
Samples correspond to corrected N-value. Cal sampler is 3"-OD, 2.4"-ID.		Hammer Drop Height (inches): 30
		Measured Hammer Efficiency (%): 89.5
		Hole Diameter: 4 inches
		Well Casing Diameter: NA
		Total Depth: 25.5 feet
		Depth to Groundwater: 5 feet



General Notes:

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Material stratum lines are interpretive and actual changes may be gradual. Solid lines indicate distinct contacts and dashed lines indicate gradual or approximate contacts.
3. USCS designations are based on visual-manual identification (ASTM D 2488), unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling/excavation (ATD) or for date specified. Level may vary with time.
5. Location and ground surface elevations are approximate.

Date Started: 06/10/2025	Date Completed: 06/10/2025	Drilling Contractor/Crew: Holt Services, Inc. / Isaiah
Logged by: G. Sebbane	Checked by: A. Ung	Drilling Method: Hollow Stem Auger/Mud Rotary
Location: Lat: 47.433487 Long: -122.318500 (WGS 84)		Rig Model/Type: CME-75 / Track-mounted drill rig
Ground Surface Elevation: 277.43 feet (NAVD 88)		Hammer Type: Auto-hammer
Comments: Cal sampler blow counts are uncorrected. Relative density for Cal		Hammer Weight (pounds): 140 Hammer Drop Height (inches): 30
Samples correspond to corrected N-value. Cal sampler is 3"-OD, 2.4"-ID.		Measured Hammer Efficiency (%): 89.5
		Hole Diameter: 4 inches Well Casing Diameter: NA
		Total Depth: 25.5 feet Depth to Groundwater: 10 feet



General Notes:

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Material stratum lines are interpretive and actual changes may be gradual. Solid lines indicate distinct contacts and dashed lines indicate gradual or approximate contacts.
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4. Groundwater level, if indicated, is at time of drilling/excavation (ATD) or for date specified. Level may vary with time.
5. Location and ground surface elevations are approximate.

Drilling Contractor/Crew: Holt Services, Inc. / A. Causland

Drilling Method: Hollow Stem Auger/Mud Rotary

Rig Model/Type: Mobile B-57 / Track-mounted drill rig

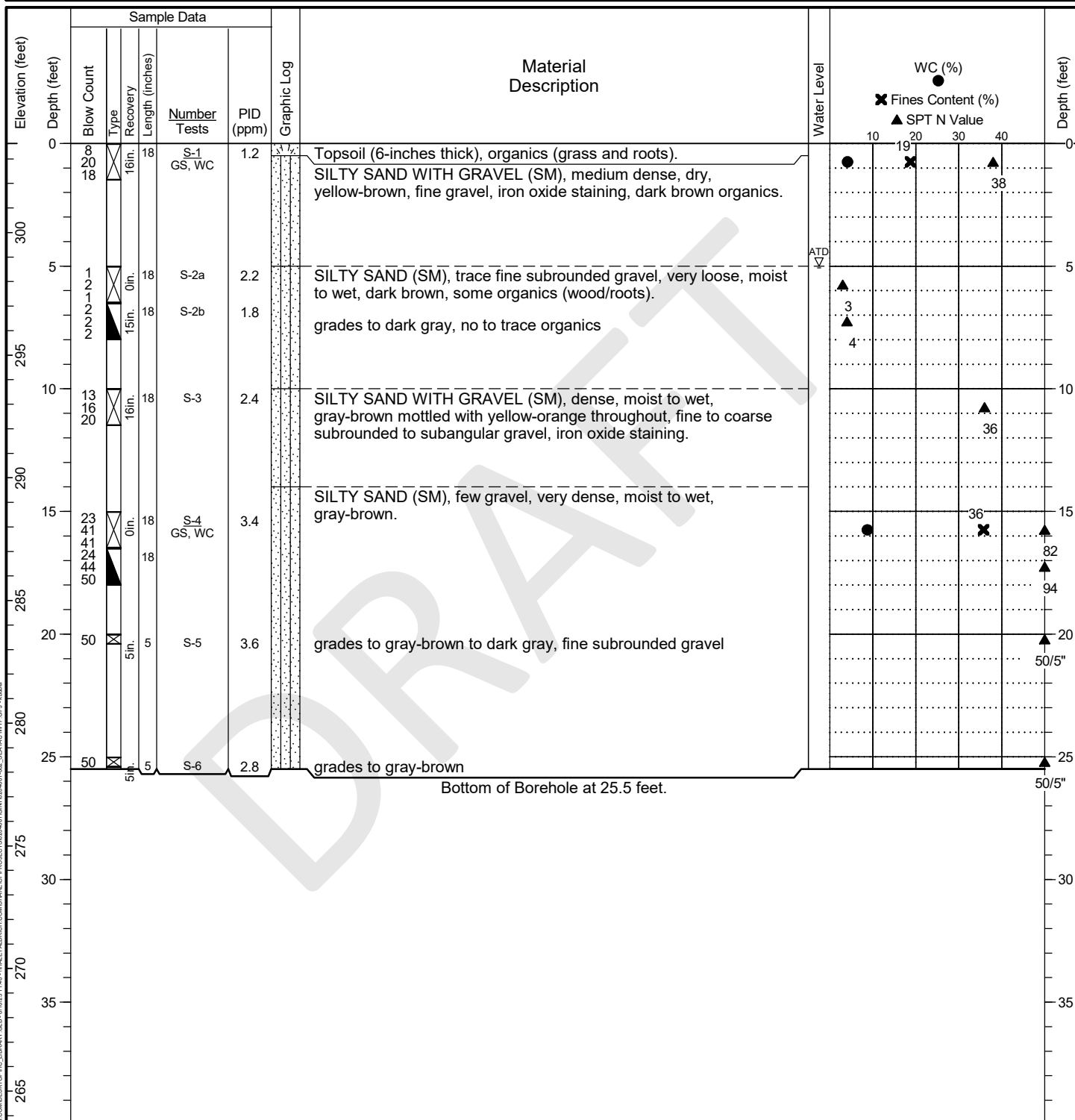
Hammer Type: Auto-hammer

Hammer Weight (pounds): 140 Hammer Drop Height (inches): 30

Measured Hammer Efficiency (%): 84.1

Well Casing Diameter: NA

Depth to Groundwater: 5 feet

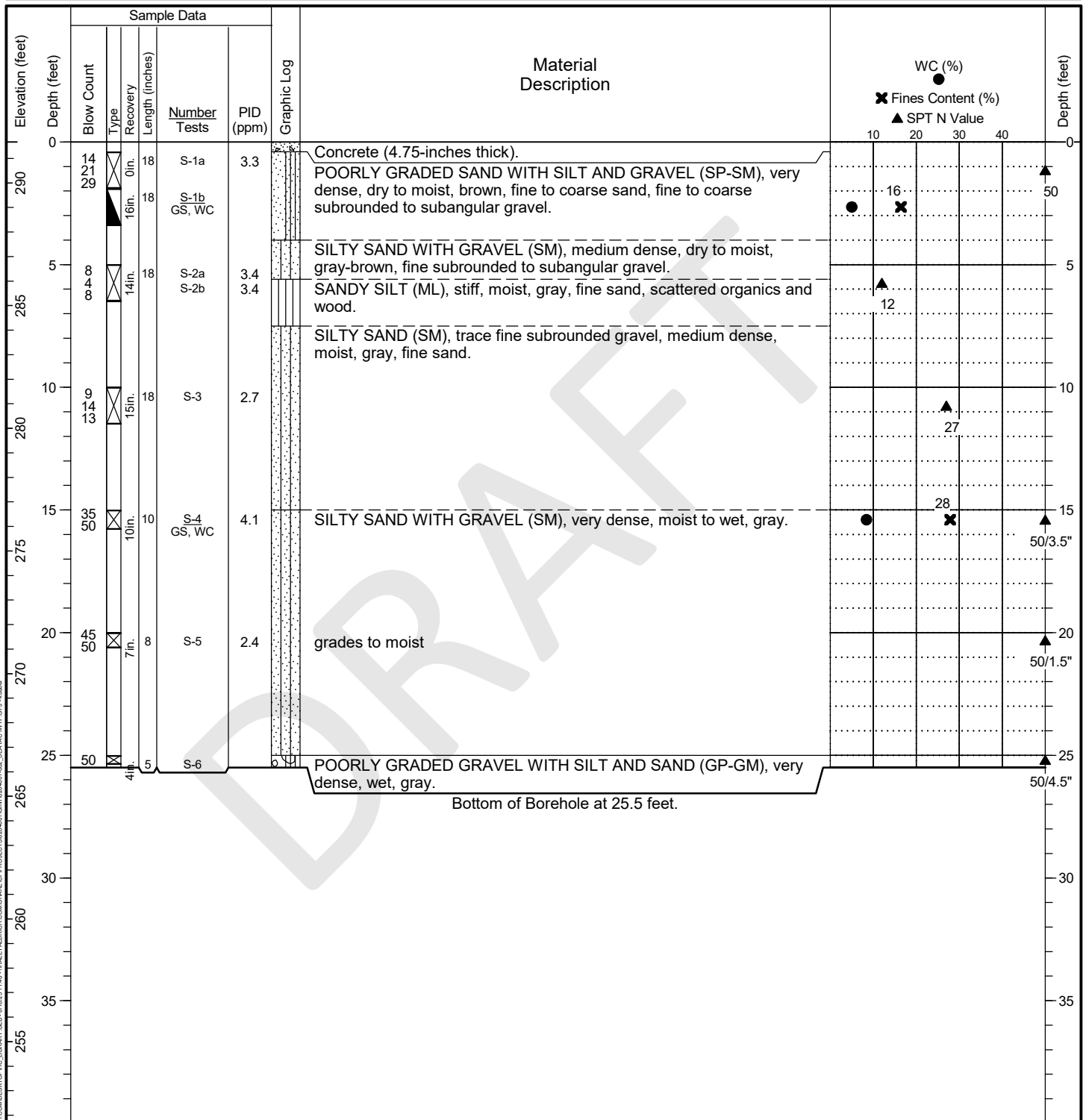


General Notes:

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Material stratum lines are interpretive and actual changes may be gradual. Solid lines indicate distinct contacts and dashed lines indicate gradual or approximate contacts.
3. USCS designations are based on visual-manual identification (ASTM D 2488), unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling/excavation (ATD) or for date specified. Level may vary with time.
5. Location and ground surface elevations are approximate.

Date Started: 06/13/2025 Date Completed: 06/13/2025
Logged by: G. Jones Checked by: A. Ung
Location: Lat: 47.435005 Long: -122.317878 (WGS 84)
Ground Surface Elevation: 291.67 feet (NAVD 88)
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Samples correspond to corrected N-value. Cal sampler is 3"-OD, 2.4"-ID.

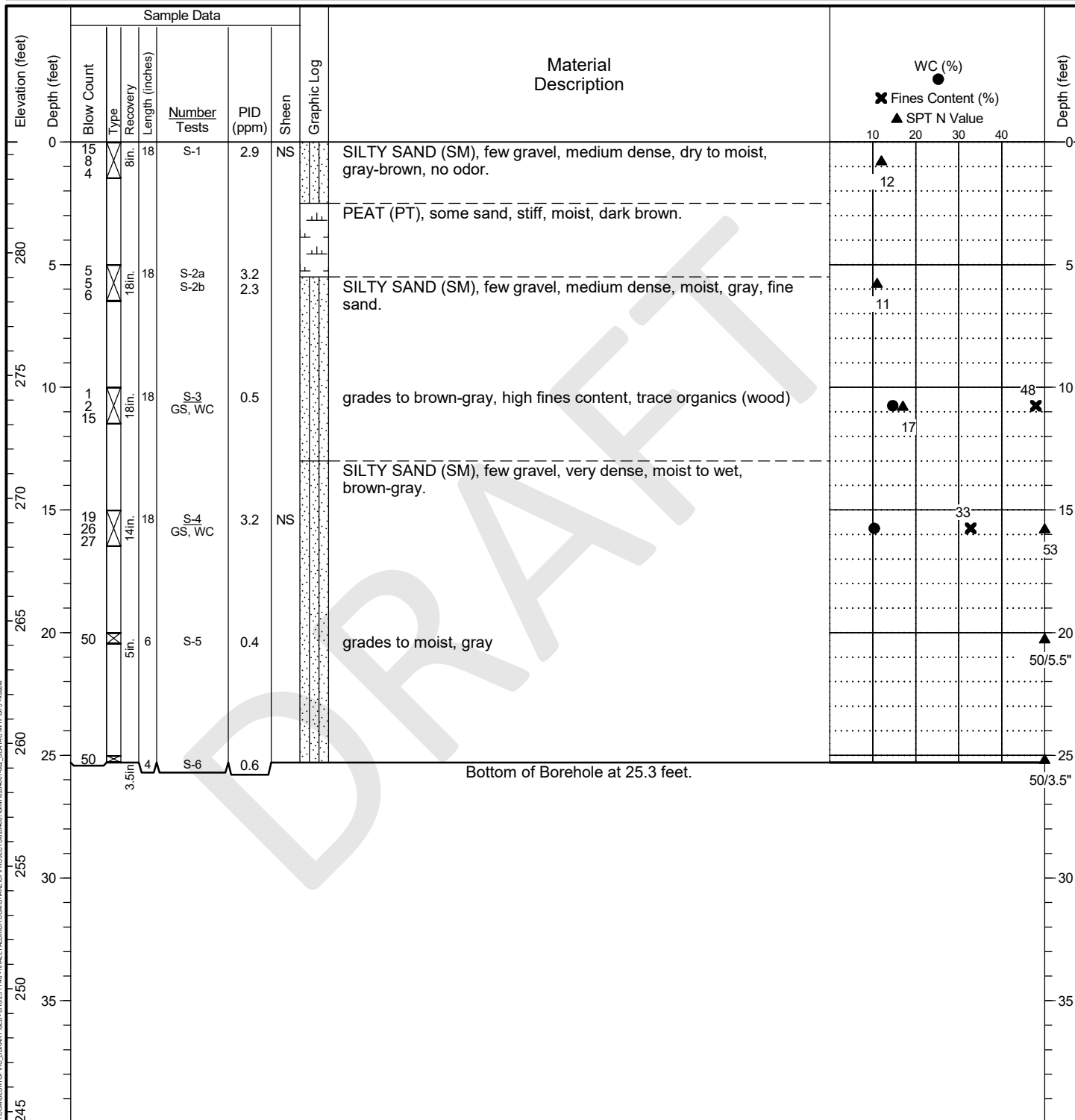
Drilling Contractor/Crew: Holt Services, Inc. / Travers
Drilling Method: Hollow Stem Auger/Mud Rotary
Rig Model/Type: CME-75 / Track-mounted drill rig
Hammer Type: Auto-hammer
Hammer Weight (pounds): 140 Hammer Drop Height (inches): 30
Measured Hammer Efficiency (%): 89.5
Hole Diameter: 4 inches Well Casing Diameter: NA
Total Depth: 25.5 feet Depth to Groundwater: Not Identified



General Notes:

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Material stratum lines are interpretive and actual changes may be gradual. Solid lines indicate distinct contacts and dashed lines indicate gradual or approximate contacts.
3. USCS designations are based on visual-manual identification (ASTM D 2488), unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling/excavation (ATD) or for date specified. Level may vary with time.
5. Location and ground surface elevations are approximate.

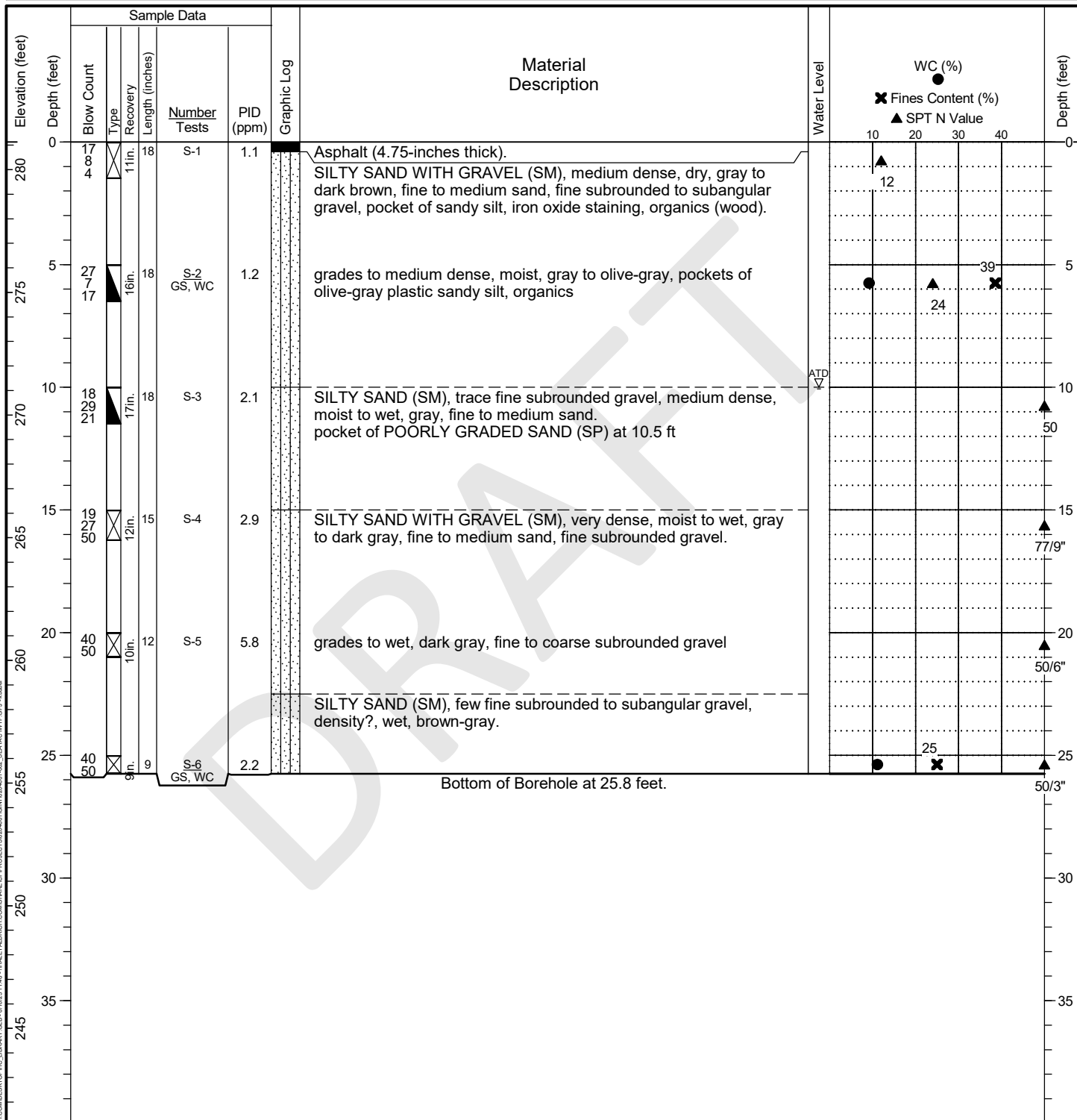
Date Started: 06/12/2025	Date Completed: 06/12/2025	Drilling Contractor/Crew: Holt Services, Inc. / Isaiah
Logged by: G. Jones	Checked by: A. Ung	Drilling Method: Hollow Stem Auger/Mud Rotary
Location: Lat: 47.434212 Long: -122.317783 (WGS 84)		Rig Model/Type: CME-75 / Track-mounted drill rig
Ground Surface Elevation: 284.52 feet (NAVD 88)		Hammer Type: Auto-hammer
Comments: Cal sampler blow counts are uncorrected. Relative density for Cal		Hammer Weight (pounds): 140 Hammer Drop Height (inches): 30
Samples correspond to corrected N-value. Cal sampler is 3"-OD, 2.4"-ID.		Measured Hammer Efficiency (%): 89.5
		Hole Diameter: 4 inches Well Casing Diameter: NA
		Total Depth: 25.3 feet Depth to Groundwater: Not Identified



General Notes:

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Material stratum lines are interpretive and actual changes may be gradual. Solid lines indicate distinct contacts and dashed lines indicate gradual or approximate contacts.
3. USCS designations are based on visual-manual identification (ASTM D 2488), unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling/excavation (ATD) or for date specified. Level may vary with time.
5. Location and ground surface elevations are approximate.

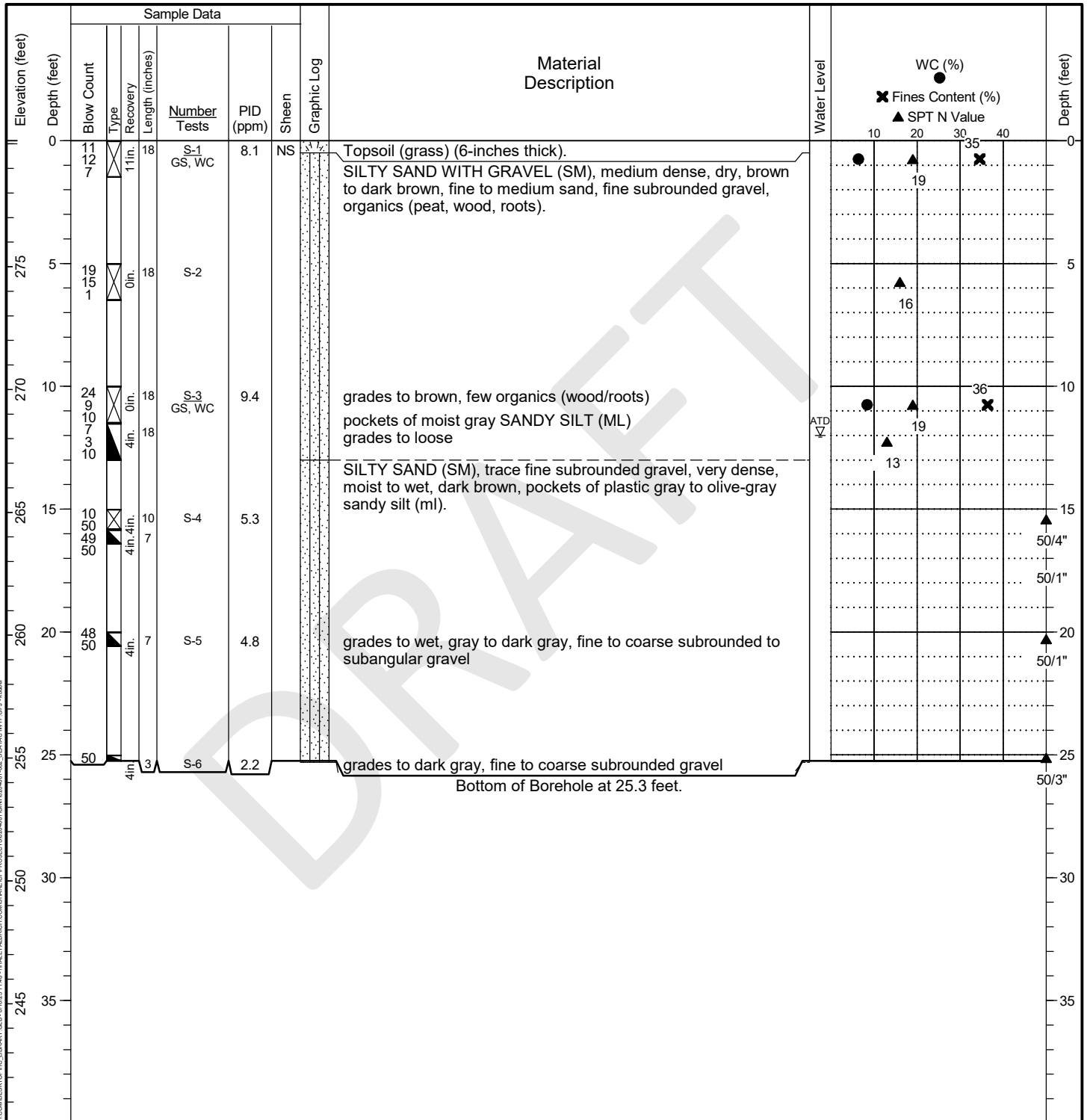
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Logged by: G. Sebbane	Checked by: A. Ung	Drilling Method: Hollow Stem Auger/Mud Rotary
Location: Lat: 47.433867 Long: -122.317827 (WGS 84)		Rig Model/Type: CME-75 / Track-mounted drill rig
Ground Surface Elevation: 281.13 feet (NAVD 88)		Hammer Type: Auto-hammer
Comments: Cal sampler blow counts are uncorrected. Relative density for Cal		Hammer Weight (pounds): 140 Hammer Drop Height (inches): 30
Samples correspond to corrected N-value. Cal sampler is 3"-OD, 2.4"-ID.		Measured Hammer Efficiency (%): 89.5
		Hole Diameter: 4 inches Well Casing Diameter: NA
		Total Depth: 25.8 feet Depth to Groundwater: 10 feet



General Notes:

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

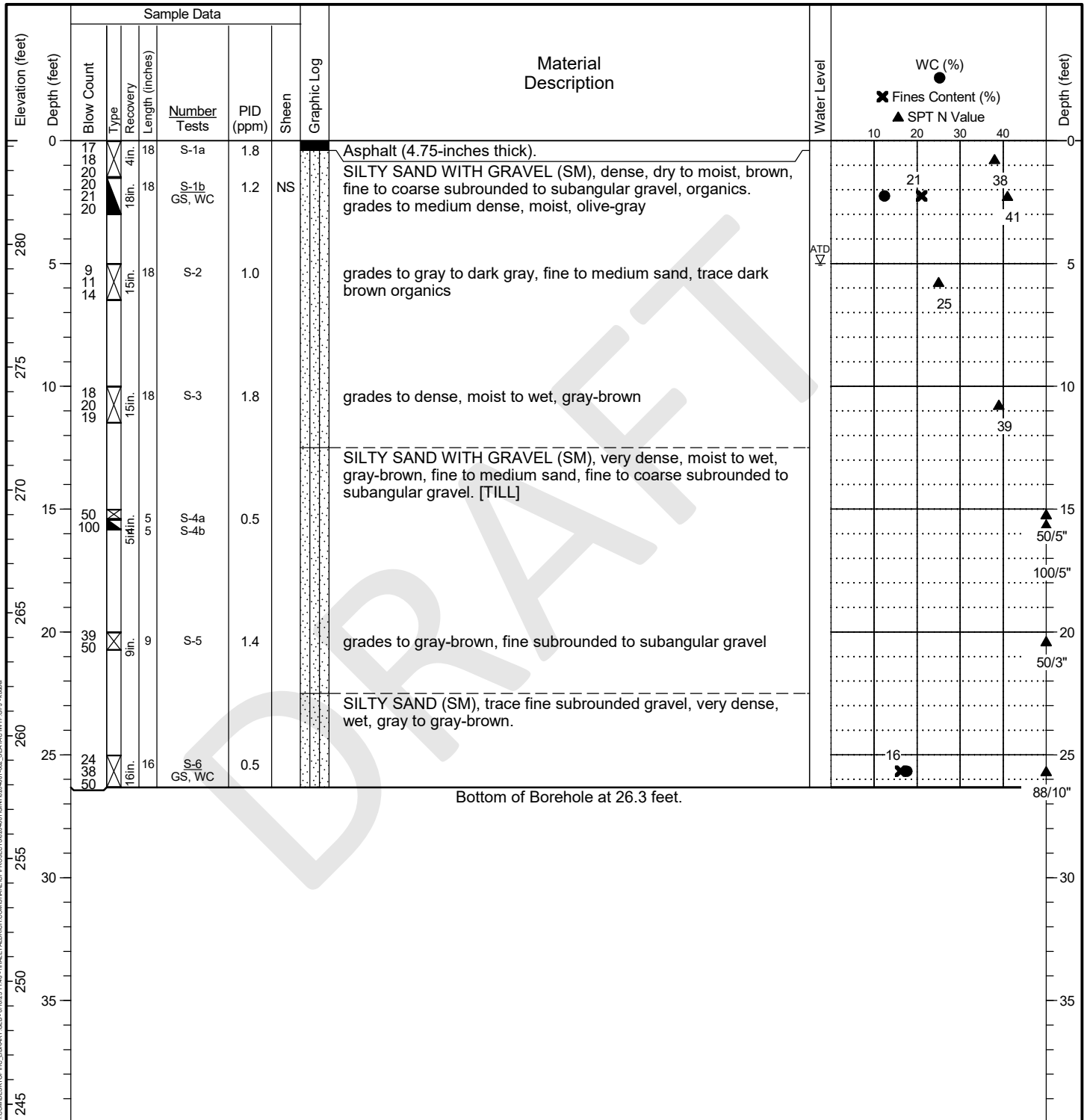
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Logged by: G. Sebbane	Checked by: A. Ung	Drilling Method: Hollow Stem Auger/Mud Rotary
Location: Lat: 47.433667 Long: -122.317831 (WGS 84)		Rig Model/Type: CME-75 / Track-mounted drill rig
Ground Surface Elevation: 280.13 feet (NAVD 88)		Hammer Type: Auto-hammer
Comments: Cal sampler blow counts are uncorrected. Relative density for Cal		Hammer Weight (pounds): 140 Hammer Drop Height (inches): 30
Samples correspond to corrected N-value. Cal sampler is 3"-OD, 2.4"-ID.		Measured Hammer Efficiency (%): 89.5
		Hole Diameter: 4 inches Well Casing Diameter: NA
		Total Depth: 25.3 feet Depth to Groundwater: 12 feet



General Notes:

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

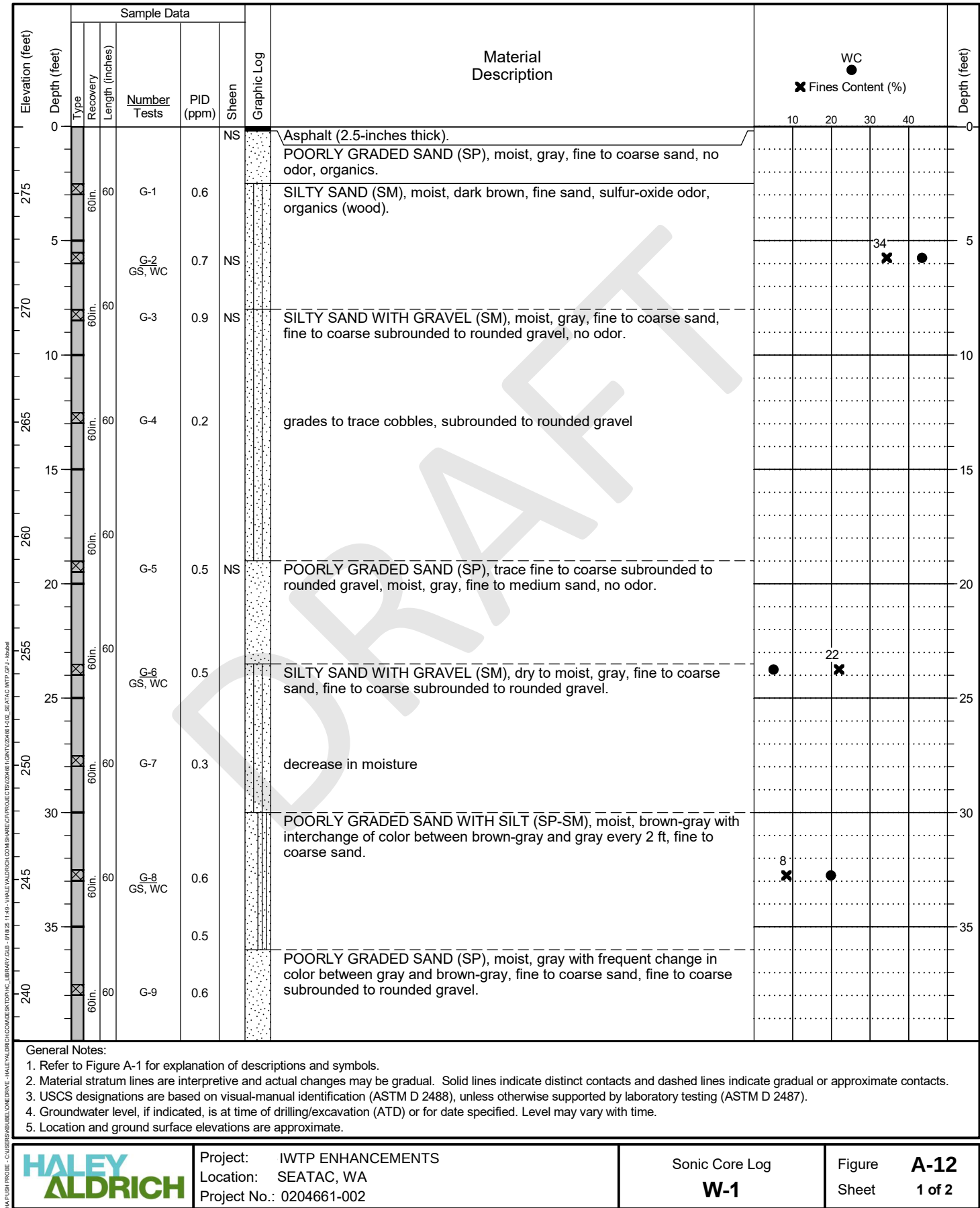
Date Started: 06/16/2025	Date Completed: 06/16/2025	Drilling Contractor/Crew: Holt Services, Inc. / A. Causland
Logged by: G. Sebbane	Checked by: A. Ung	Drilling Method: Hollow Stem Auger/Mud Rotary
Location: Lat: 47.434381 Long: -122.318985 (WGS 84)		Rig Model/Type: Mobile B-57 / Track-mounted drill rig
Ground Surface Elevation: 284.22 feet (NAVD 88)		Hammer Type: Auto-hammer
Comments: Cal sampler blow counts are uncorrected. Relative density for Cal		Hammer Weight (pounds): 140 Hammer Drop Height (inches): 30
Samples correspond to corrected N-value. Cal sampler is 3"-OD, 2.4"-ID.		Measured Hammer Efficiency (%): 84.1
		Hole Diameter: 4 inches Well Casing Diameter: NA
		Total Depth: 26.3 feet Depth to Groundwater: 5 feet



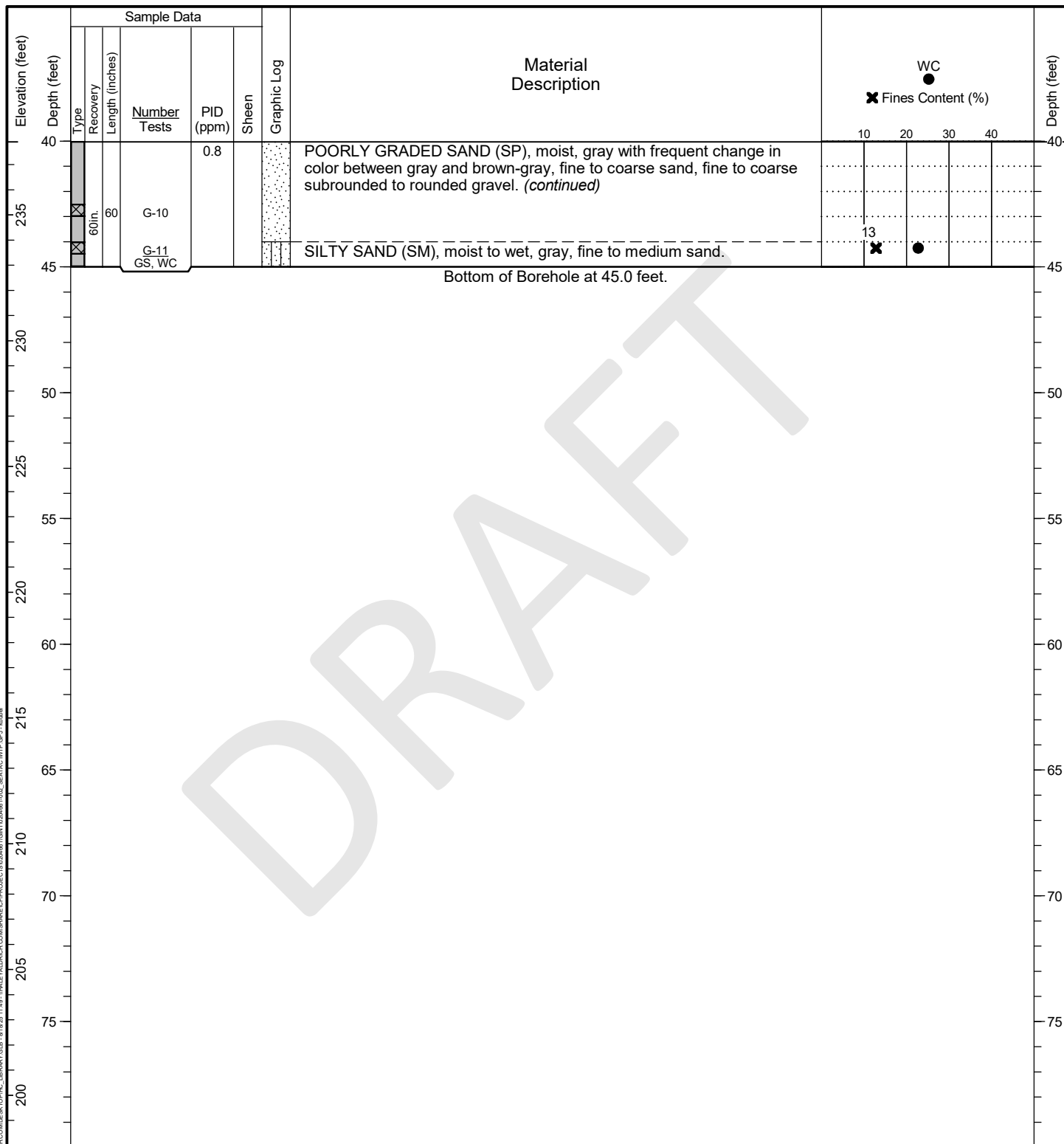
General Notes:

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Material stratum lines are interpretive and actual changes may be gradual. Solid lines indicate distinct contacts and dashed lines indicate gradual or approximate contacts.
3. USCS designations are based on visual-manual identification (ASTM D 2488), unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling/excavation (ATD) or for date specified. Level may vary with time.
5. Location and ground surface elevations are approximate.

Date Started: 06/06/2025	Date Completed: 06/06/2025	Contractor/Crew: Holt Services, Inc. / Javier
Logged by: T. Scott	Checked by: A. Ung	Rig Model/Type: TSi 150CC / Track-mounted drill rig
Location: Lat: 47.433215 Long: -122.318952 (WGS 84)	Hole Diameter: 6 inches	Well Casing Diameter: NA
Ground Surface Elevation: 277.93 feet (NAVD 88)	Total Depth: 45.0 feet	Depth to Groundwater: Not Identified
Comments:		



Date Started: 06/06/2025	Date Completed: 06/06/2025	Contractor/Crew: Holt Services, Inc. / Javier
Logged by: T. Scott	Checked by: A. Ung	Rig Model/Type: TSi 150CC / Track-mounted drill rig
Location: Lat: 47.433215 Long: -122.318952 (WGS 84)	Hole Diameter: 6 inches	Well Casing Diameter: NA
Ground Surface Elevation: 277.93 feet (NAVD 88)	Total Depth: 45.0 feet	Depth to Groundwater: Not Identified
Comments:		



General Notes:

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Material stratum lines are interpretive and actual changes may be gradual. Solid lines indicate distinct contacts and dashed lines indicate gradual or approximate contacts.
3. USCS designations are based on visual-manual identification (ASTM D 2488), unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling/excavation (ATD) or for date specified. Level may vary with time.
5. Location and ground surface elevations are approximate.

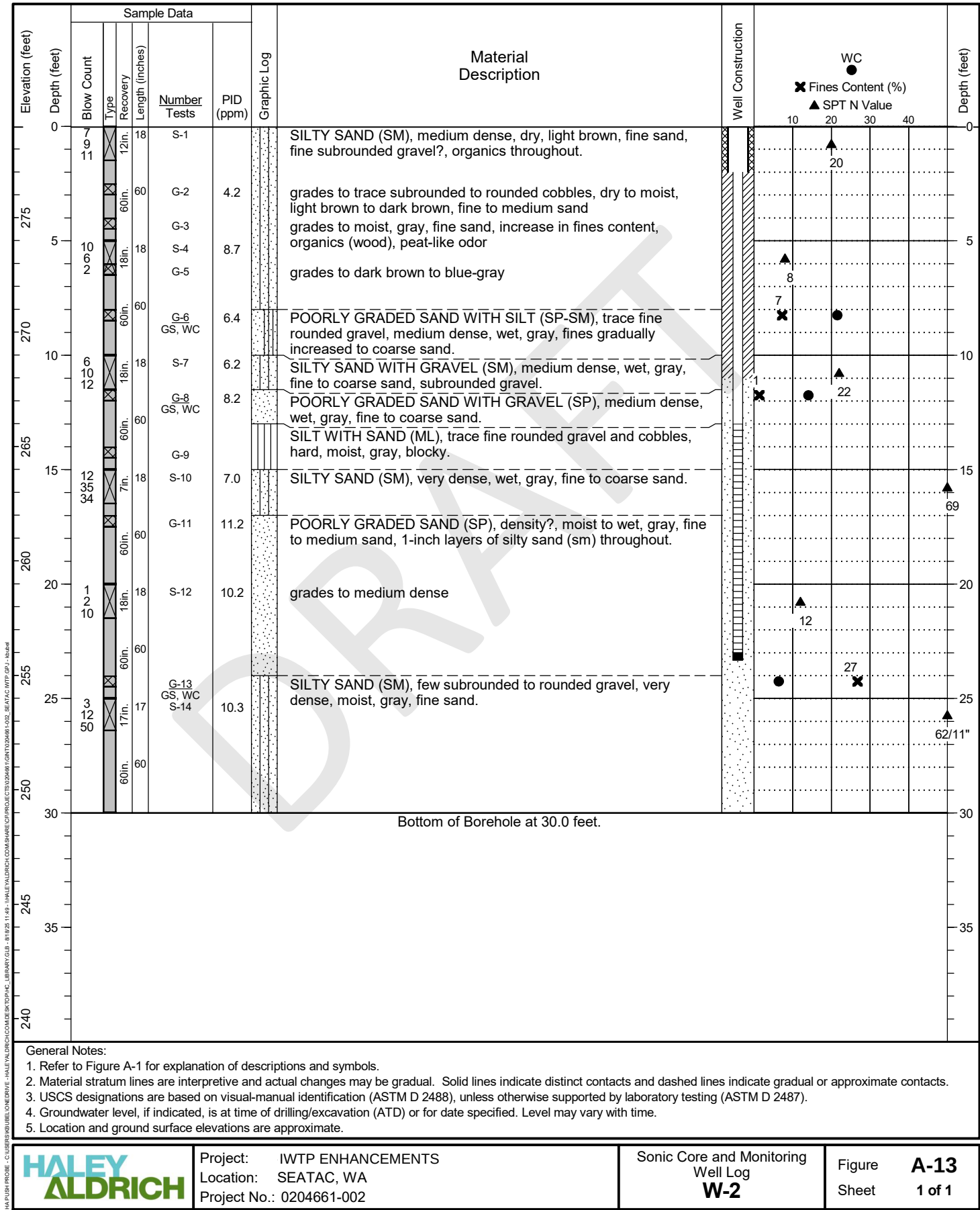


Project: IWTP ENHANCEMENTS
Location: SEATAC, WA
Project No.: 0204661-002

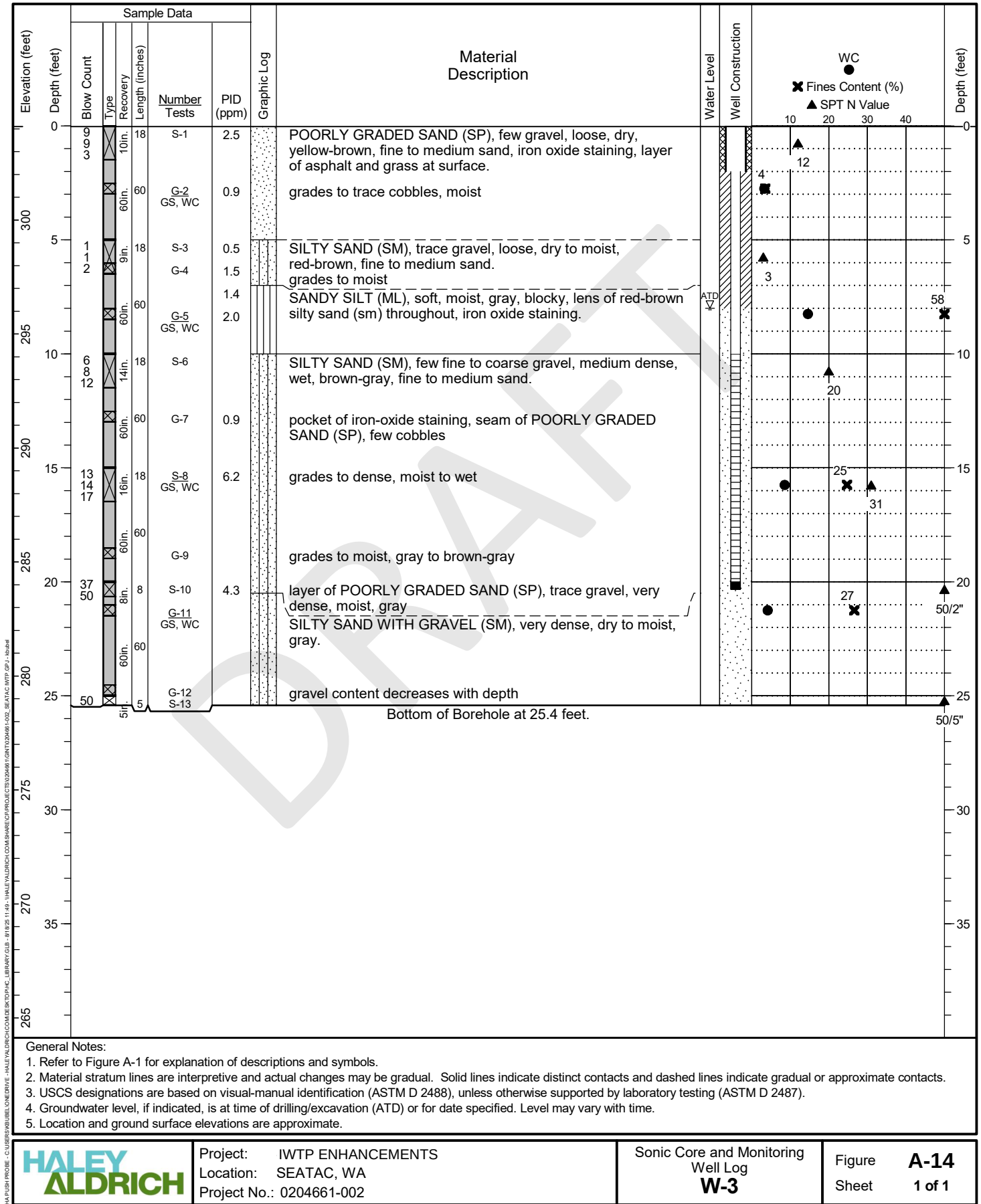
Sonic Core Log
W-1

Figure **A-12**
Sheet **2 of 2**

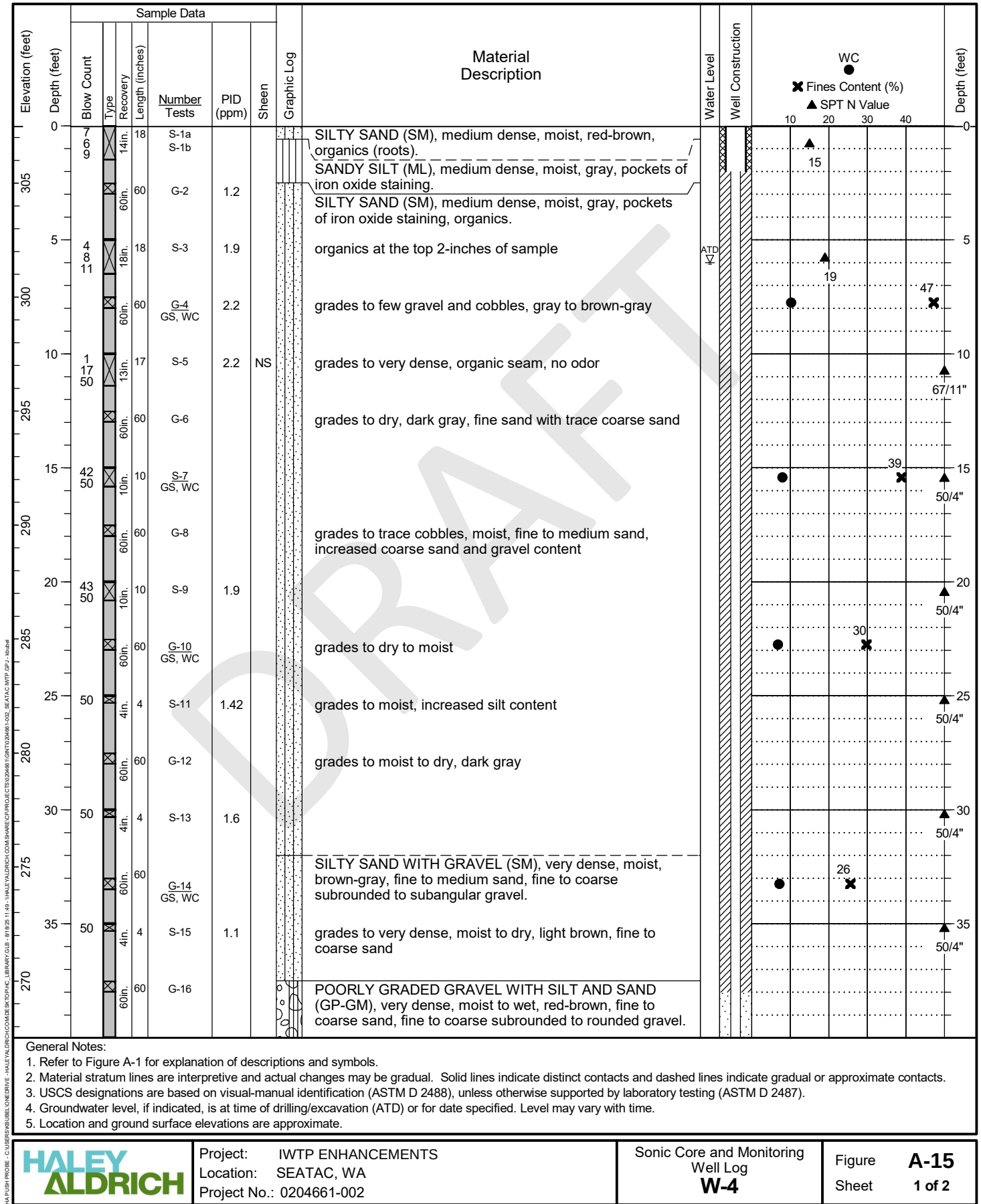
Date Started: 06/05/2025	Date Completed: 06/05/2025	Contractor/Crew: Holt Services, Inc. / Javier
Logged by: T. Scott	Checked by: A. Ung	Rig Model/Type: TSi 150CC / Track-mounted drill rig
Location: Lat: 47.433239 Long: -122.317836 (WGS 84)	Hole Diameter: 6 inches	Well Casing Diameter: ID: 2 inches
Ground Surface Elevation: 278.99 feet (NAVD 88)	Total Depth: 30.0 feet	Depth to Groundwater: Not Identified
Comments:		



Date Started: 06/02/2025	Date Completed: 06/02/2025	Contractor/Crew: Holt Services, Inc. / Travers
Logged by: T. Scott	Checked by: A. Ung	Rig Model/Type: TSi 150CC / Track-mounted drill rig
Location: Lat: 47.436125 Long: -122.318069 (WGS 84)	Hole Diameter: 6 inches	Well Casing Diameter: ID: 2 inches
Ground Surface Elevation: 304.13 feet (NAVD 88)	Total Depth: 25.4 feet	Depth to Groundwater: 8 feet
Comments:		



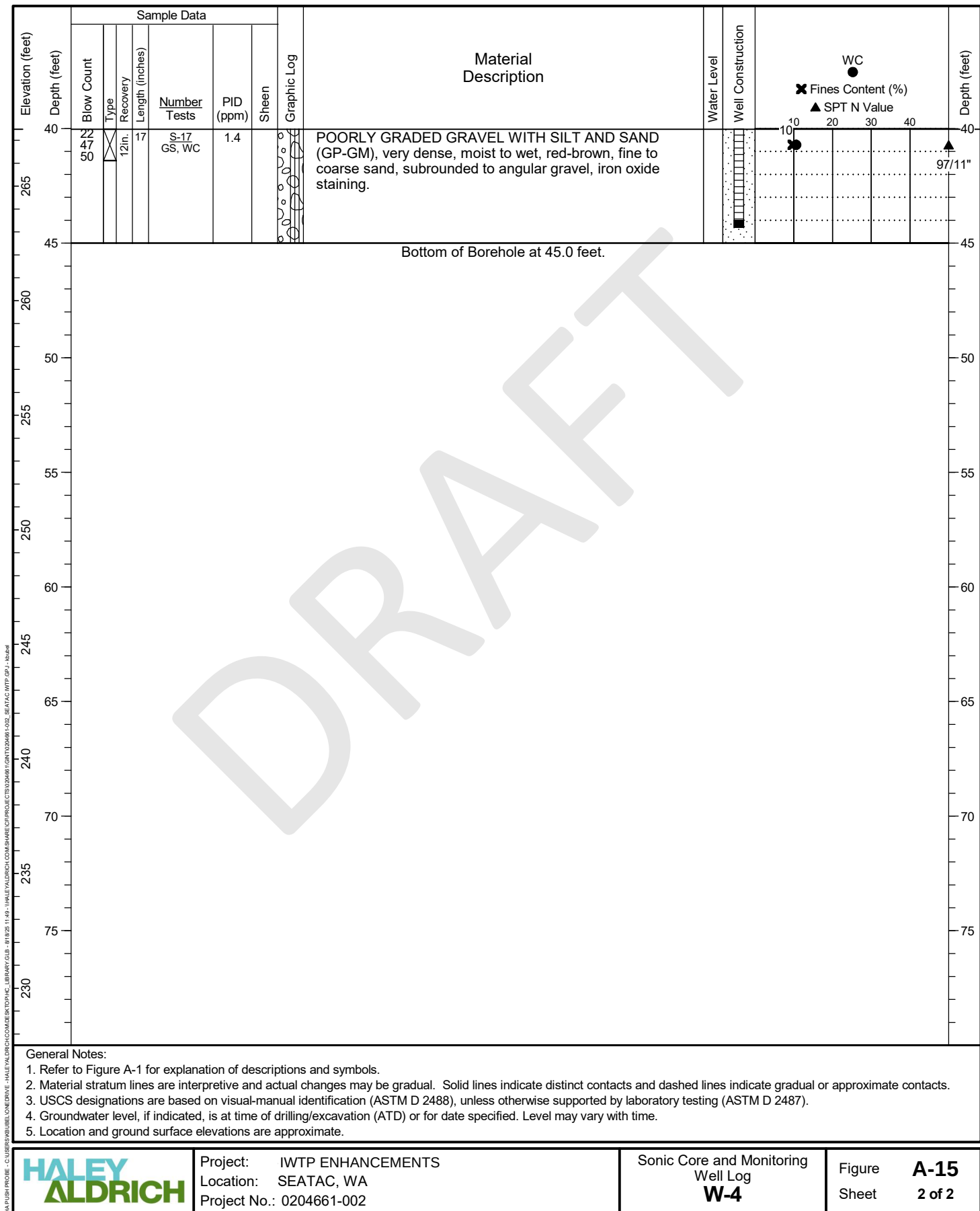
Date Started: 06/02/2025	Date Completed: 06/02/2025	Contractor/Crew: Holt Services, Inc. / Travers
Logged by: T. Scott	Checked by: A. Ung	Rig Model/Type: TSi 150CC / Track-mounted drill rig
Location: Lat: 47.435667 Long: -122.317286 (WGS 84)	Hole Diameter: 6 inches	Well Casing Diameter: ID: 2 inches
Ground Surface Elevation: 307.51 feet (NAVD 88)	Total Depth: 45.0 feet	Depth to Groundwater: 6 feet
Comments:		



General Notes:

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Material stratum lines are interpretive and actual changes may be gradual. Solid lines indicate distinct contacts and dashed lines indicate gradual or approximate contacts.
3. USCS designations are based on visual-manual identification (ASTM D 2488), unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling/excavation (ATD) or for date specified. Level may vary with time.
5. Location and ground surface elevations are approximate.

Date Started: 06/02/2025	Date Completed: 06/02/2025	Contractor/Crew: Holt Services, Inc. / Travers
Logged by: T. Scott	Checked by: A. Ung	Rig Model/Type: TSi 150CC / Track-mounted drill rig
Location: Lat: 47.435667 Long: -122.317286 (WGS 84)	Hole Diameter: 6 inches	Well Casing Diameter: ID: 2 inches
Ground Surface Elevation: 307.51 feet (NAVD 88)	Total Depth: 45.0 feet	Depth to Groundwater: 6 feet
Comments:		



Contractor/Crew: Holt Services, Inc. / Travers

Rig Model/Type: TSi 150CC / Track-mounted drill rig

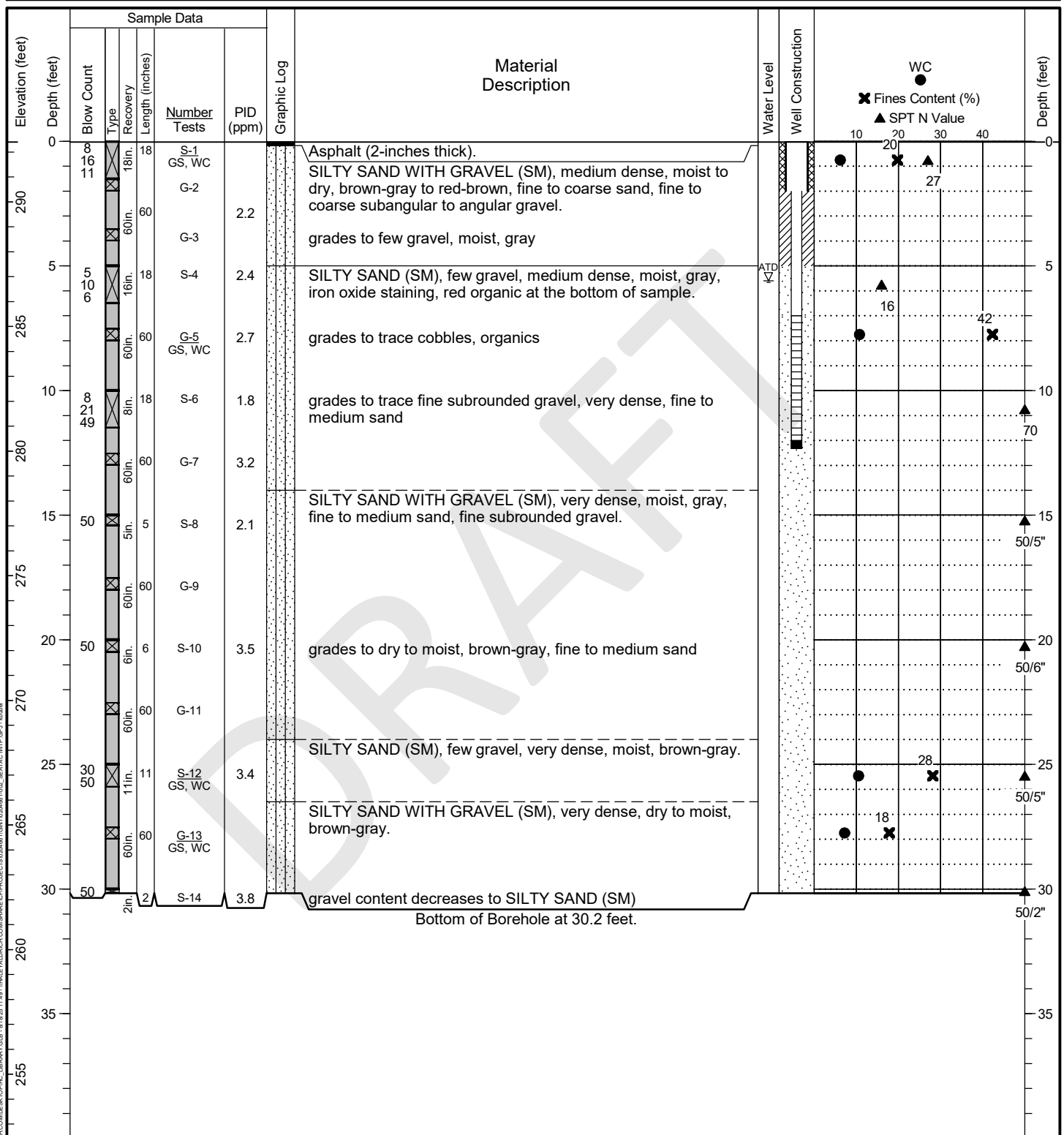
Hole Diameter: 6 inches

Well Casing Diameter: ID: 2 inches

Total Depth: 30.2 feet

Depth to Groundwater: 5.6 feet

Comments:



General Notes:

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Material stratum lines are interpretive and actual changes may be gradual. Solid lines indicate distinct contacts and dashed lines indicate gradual or approximate contacts.
3. USCS designations are based on visual-manual identification (ASTM D 2488), unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling/excavation (ATD) or for date specified. Level may vary with time.
5. Location and ground surface elevations are approximate.

Date Started: 06/04/2025

Date Completed: 06/04/2025

Contractor/Crew: Holt Services, Inc. / Travers

Logged by: T. Scott

Checked by: A. Ung

Rig Model/Type: TSi 150CC / Track-mounted drill rig

Location: Lat: 47.434689 Long: -122.316245 (WGS 84)

Hole Diameter: 6 inches

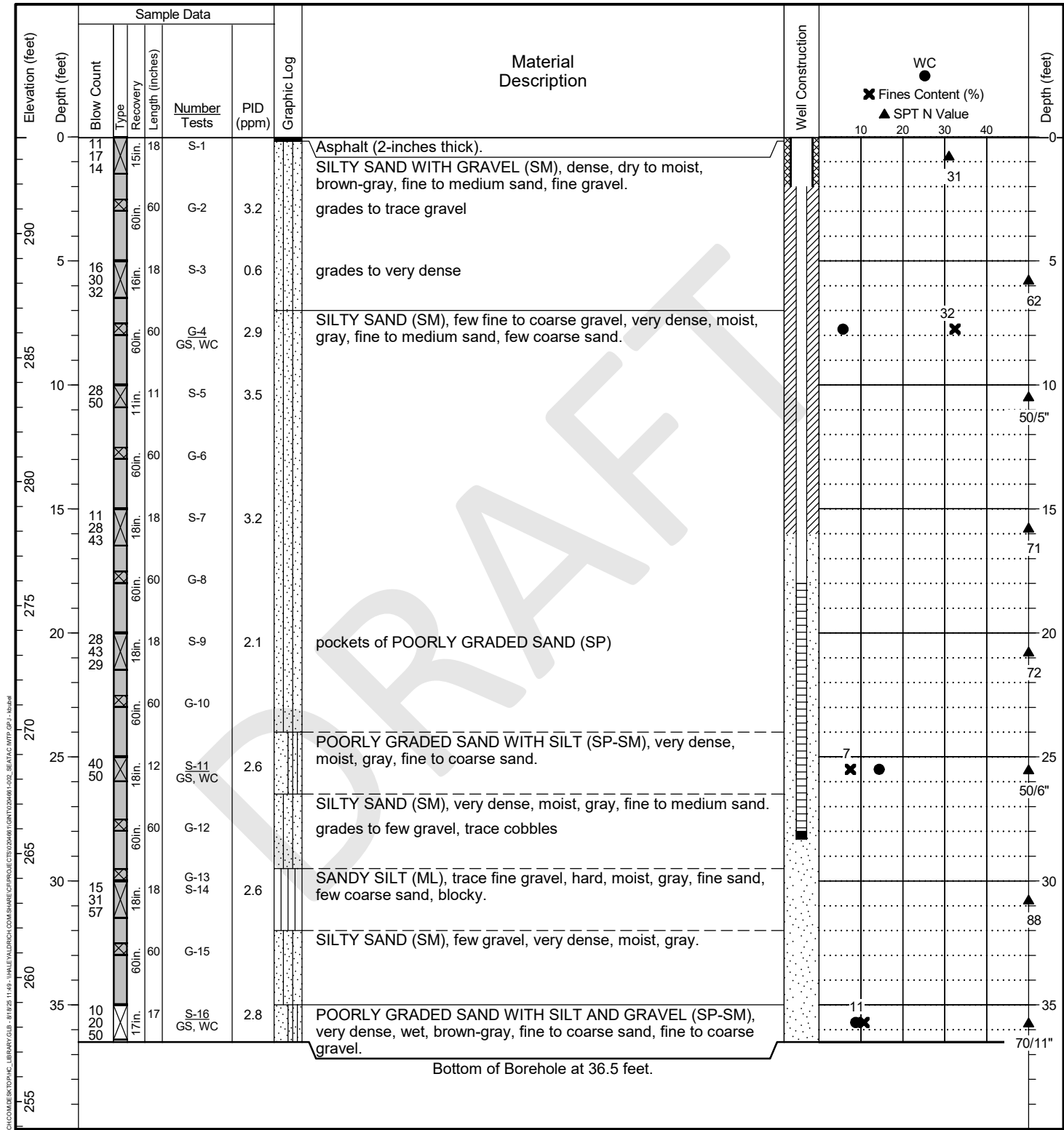
Well Casing Diameter: ID: 2 inches

Ground Surface Elevation: 293.90 feet (NAVD 88)

Total Depth: 36.5 feet

Depth to Groundwater: Not Identified

Comments:



General Notes:

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Material stratum lines are interpretive and actual changes may be gradual. Solid lines indicate distinct contacts and dashed lines indicate gradual or approximate contacts.
3. USCS designations are based on visual-manual identification (ASTM D 2488), unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling/excavation (ATD) or for date specified. Level may vary with time.
5. Location and ground surface elevations are approximate.

Contractor/Crew: Holt Services, Inc. / Travers

Rig Model/Type: TSi 150CC / Track-mounted drill rig

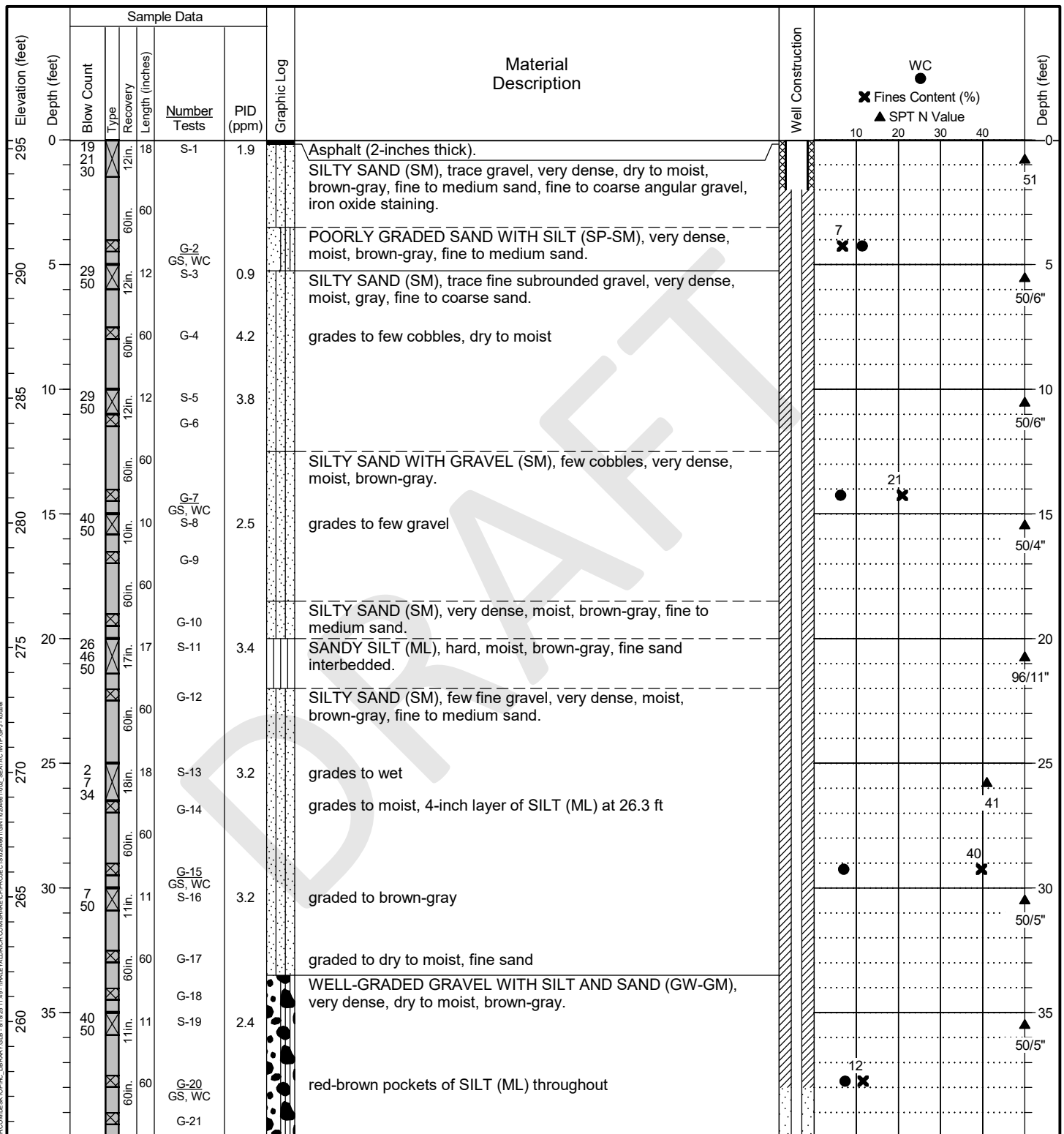
Hole Diameter: 6 inches

Well Casing Diameter: ID: 2 inches

Total Depth: 50.8 feet

Depth to Groundwater: Not Identified

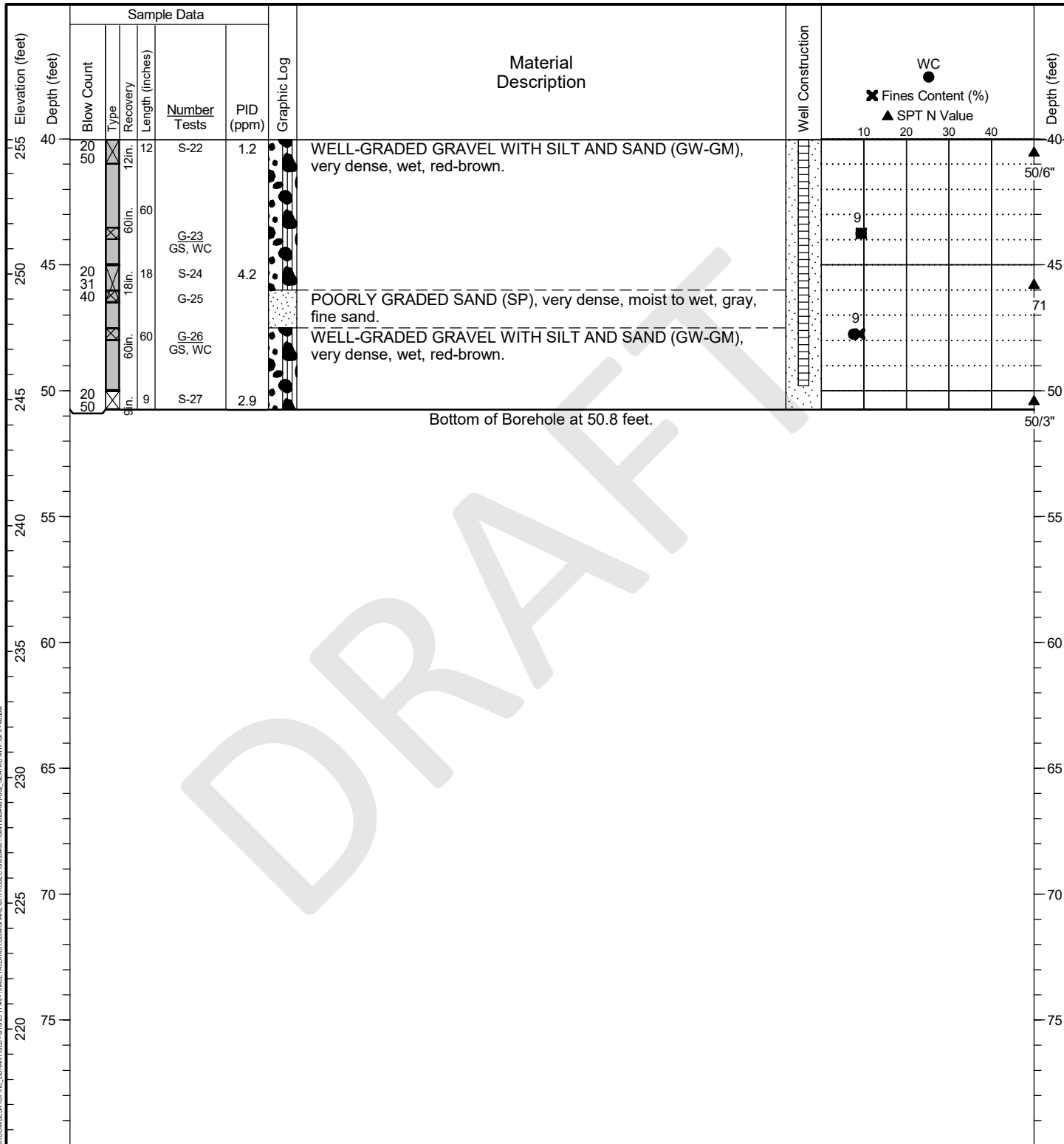
Comments:



General Notes:

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Material stratum lines are interpretive and actual changes may be gradual. Solid lines indicate distinct contacts and dashed lines indicate gradual or approximate contacts.
3. USCS designations are based on visual-manual identification (ASTM D 2488), unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling/excavation (ATD) or for date specified. Level may vary with time.
5. Location and ground surface elevations are approximate.

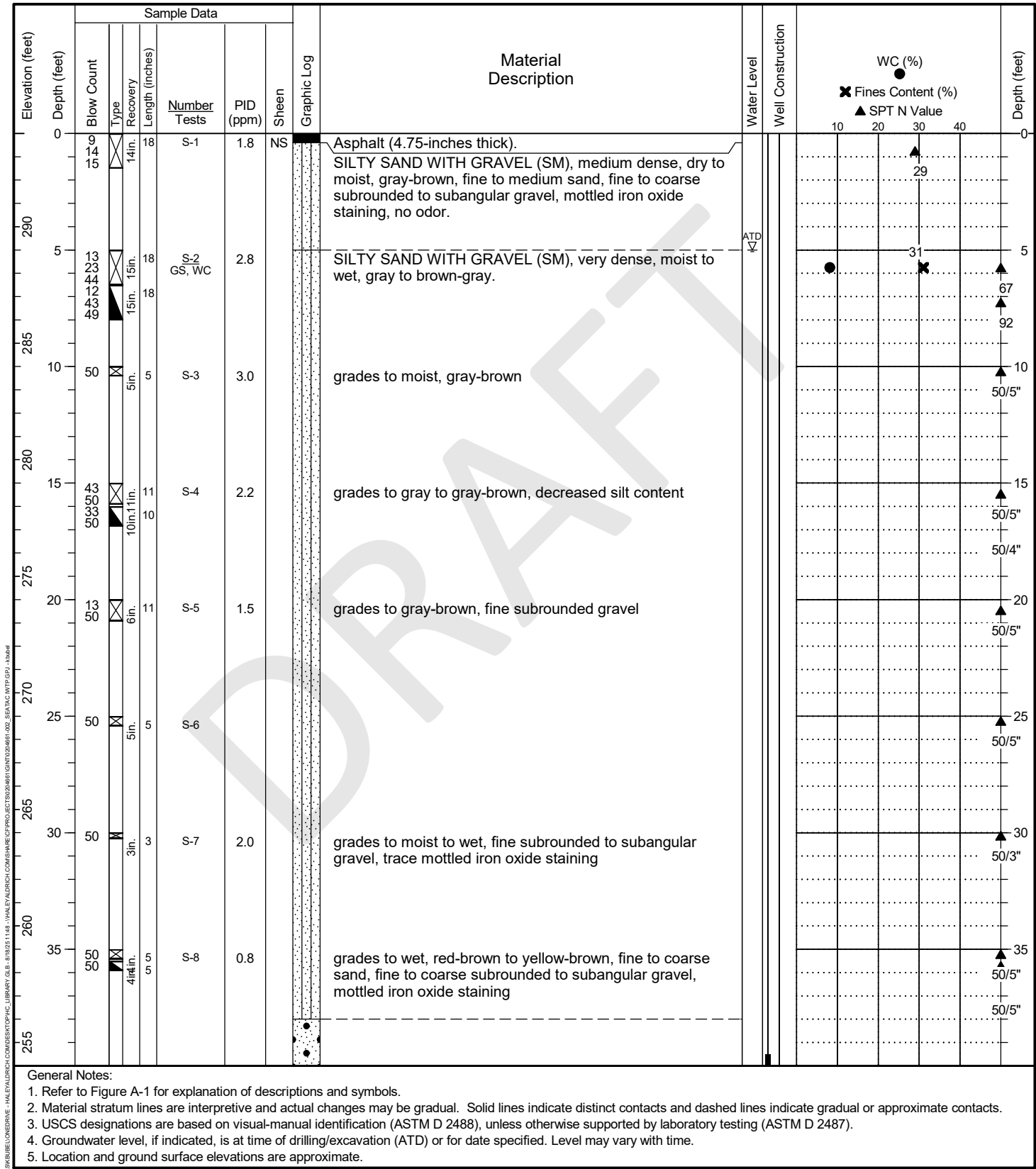
Date Started: 06/03/2025	Date Completed: 06/03/2025	Contractor/Crew: Holt Services, Inc. / Travers
Logged by: T. Scott	Checked by: A. Ung	Rig Model/Type: TSi 150CC / Track-mounted drill rig
Location: Lat: 47.435184 Long: -122.316285 (WGS 84)	Hole Diameter: 6 inches	Well Casing Diameter: ID: 2 inches
Ground Surface Elevation: 295.36 feet (NAVD 88)	Total Depth: 50.8 feet	Depth to Groundwater: Not Identified
Comments:		



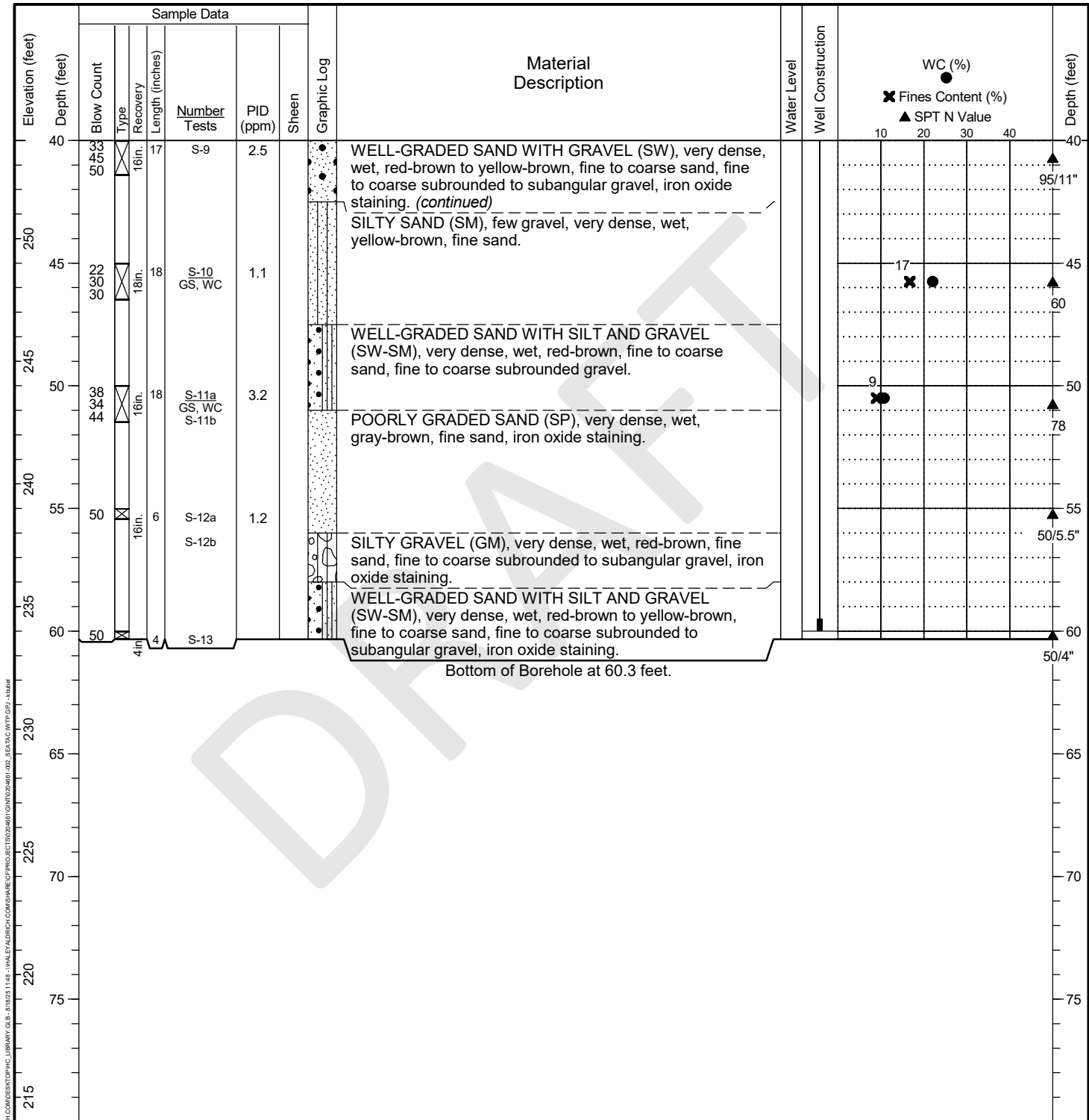
General Notes:

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Material stratum lines are interpretive and actual changes may be gradual. Solid lines indicate distinct contacts and dashed lines indicate gradual or approximate contacts.
3. USCS designations are based on visual-manual identification (ASTM D 2488), unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling/excavation (ATD) or for date specified. Level may vary with time.
5. Location and ground surface elevations are approximate.

Date Started: 06/18/2025	Date Completed: 06/18/2025	Drilling Contractor/Crew: Holt Services, Inc. / A. Causland
Logged by: G. Sebbane	Checked by: A. Ung	Drilling Method: Hollow Stem Auger/Mud Rotary
Location: Lat: 47.435179 Long: -122.316997 (WGS 84)		Rig Model/Type: Mobile B-57 / Track-mounted drill rig
Ground Surface Elevation: 294.00 feet (NAVD 88)		Hammer Type: Auto-hammer
Comments:		Hammer Weight (pounds): 140 Hammer Drop Height (inches): 30
		Measured Hammer Efficiency (%): 84.1
		Hole Diameter: 4 inches Well Casing Diameter: ID: 2 inches
		Total Depth: 60.3 feet Depth to Groundwater: 5 feet



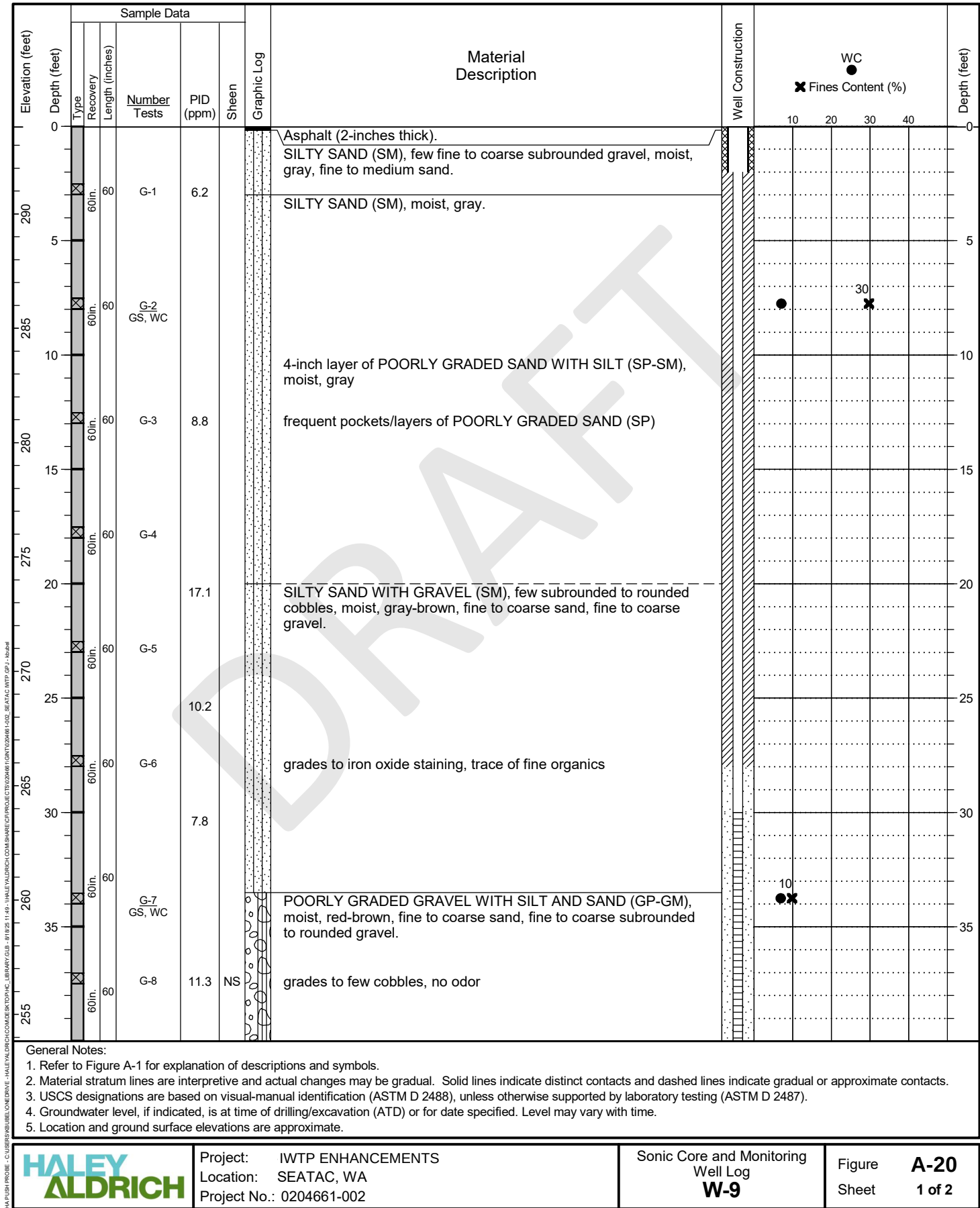
Date Started: 06/18/2025	Date Completed: 06/18/2025	Drilling Contractor/Crew: Holt Services, Inc. / A. Causland
Logged by: G. Sebbane	Checked by: A. Ung	Drilling Method: Hollow Stem Auger/Mud Rotary
Location: Lat: 47.435179 Long: -122.316997 (WGS 84)		Rig Model/Type: Mobile B-57 / Track-mounted drill rig
Ground Surface Elevation: 294.00 feet (NAVD 88)		Hammer Type: Auto-hammer
Comments:		Hammer Weight (pounds): 140 Hammer Drop Height (inches): 30
		Measured Hammer Efficiency (%): 84.1
		Hole Diameter: 4 inches Well Casing Diameter: ID: 2 inches
		Total Depth: 60.3 feet Depth to Groundwater: 5 feet



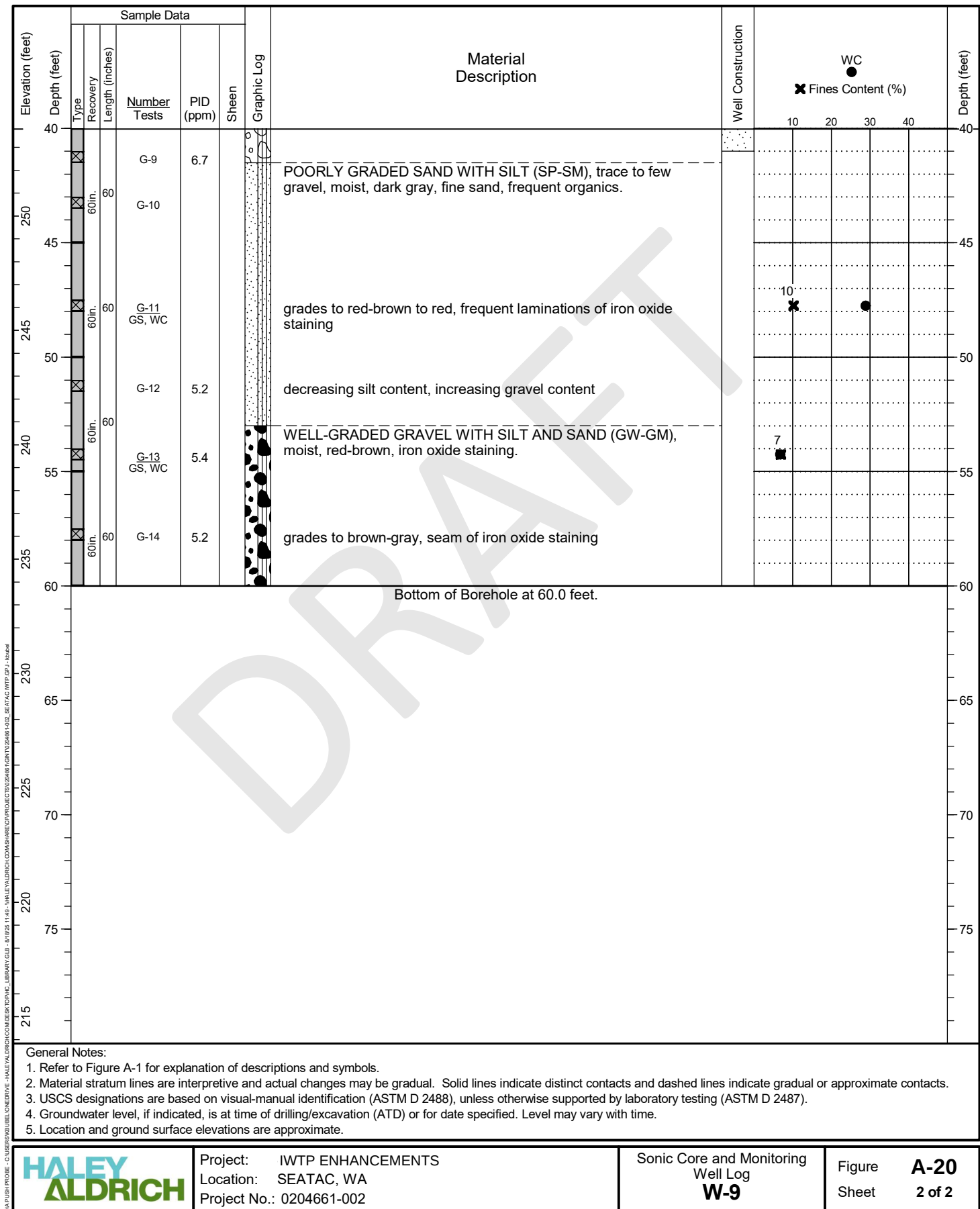
General Notes:

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Material stratum lines are interpretive and actual changes may be gradual. Solid lines indicate distinct contacts and dashed lines indicate gradual or approximate contacts.
3. USCS designations are based on visual-manual identification (ASTM D 2488), unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling/excavation (ATD) or for date specified. Level may vary with time.
5. Location and ground surface elevations are approximate.

Date Started: 06/07/2025	Date Completed: 06/07/2025	Contractor/Crew: Holt Services, Inc. / Travers
Logged by: T. Scott	Checked by: A. Ung	Rig Model/Type: TSi 150CC / Track-mounted drill rig
Location: Lat: 47.435179 Long: -122.316777 (WGS 84)	Hole Diameter: 6 inches	Well Casing Diameter: ID: 2 inches
Ground Surface Elevation: 293.83 feet (NAVD 88)	Total Depth: 60.0 feet	Depth to Groundwater: Not Identified
Comments:		



Date Started: 06/07/2025	Date Completed: 06/07/2025	Contractor/Crew: Holt Services, Inc. / Travers
Logged by: T. Scott	Checked by: A. Ung	Rig Model/Type: TSi 150CC / Track-mounted drill rig
Location: Lat: 47.435179 Long: -122.316777 (WGS 84)	Hole Diameter: 6 inches	Well Casing Diameter: ID: 2 inches
Ground Surface Elevation: 293.83 feet (NAVD 88)	Total Depth: 60.0 feet	Depth to Groundwater: Not Identified
Comments:		



TEST CERTIFICATE

DWT Traceable to certificate no. : V110701 T14D221 TC

Instrument	:	Model EPP-40V Piezometer	Date	: 03.06.2023
Serial number	:	221457	Temperature	: 28°C
Capacity	:	0.7 MPa	Atm. Pressure (MPa)	: 0.100

Zero pressure freq = 2578 Hz

Input pressure (MPa)	Up1 (Digit)	Observed value Down (Digit)	Up2 (Digit)	Average (Digit)	End Point Fit (MPa)	Poly Fit (MPa)	Non Conformance (% FS)
0.000	6645.7	6646.7	6646.7	6646.2	0.000	0.001	0.078
0.140	6106.8	6105.6	6105.0	6105.9	0.137	0.139	0.130
0.280	5552.7	5552.8	5553.3	5553.0	0.277	0.280	0.009
0.420	4998.8	4998.0	4997.7	4998.2	0.417	0.420	0.042
0.560	4440.3	4440.4	4439.7	4440.0	0.559	0.561	0.077
0.700	3883.7	3883.7	3881.8	3882.8	0.700	0.700	0.058

Non linearity (% FS) 0.45 Accuracy(% FS) 0.13

Digit : $f^2 / 1000$
 Linear gage factor (G) : $2.5331E-04$ MPa/digit
 (Use gage factor with minus sign with our read out unit)
 Thermal factor(K) : $2.019E-04$ MPa/°C
 Polynomial constants :
 $A = -1.5640E-09$ $B = -2.3650E-04$ $C = 1.6414E+00$
 Pressure "P" is calculated with the following equation:
 Linear : $P(\text{MPa}) = G(R0 - R1) + K(T1 - T0) - (S1 - S0)$
 Polynomial : $P(\text{MPa}) = A(R1)^2 + B(R1) + C + K(T1 - T0) - (S1 - S0)$
 $R1$ = current reading & $R0$ is initial reading in digit.
 $S1$ and $T1$ = current atmospheric pressure(MPa) and temperature (°C)

Note :

(Zero conditions in the field must be established by recording the reading $R0$ (digit) along with temperature $T0$ (°C) and atmospheric pressure $S0$ (MPa) at the time of installation. If polynomial constants are used, determine value of 'C' as per § 6.2 of user's manual.)

Pin configuration/wiring code:

Red & black : **Signal** **Green & white:** **Thermistor**

Note : The above named Instrument has been calibrated by comparison with standards traceable to National Institute of Standards and Technology (NIST), United States, Certificate no. 1500241918 & 1500241919.



Tested by :



TUNNELS



HYDROELECTRIC



CONSTRUCTION



STRUCTURAL



METRO & RAIL



BRIDGES



MINING

Encardio-Rite Group - India | Bhutan | Nepal | Bahrain | Qatar | Saudi Arabia | UAE | Greece | Spain | UK | USA

TEST CERTIFICATE

DWT Traceable to certificate no. : V110701 T14D221 TC

Instrument	:	Model EPP-40V Piezometer	Date	: 03.06.2023
Serial number	:	221450	Temperature	: 28°C
Capacity	:	0.7 MPa	Atm. Pressure (MPa)	: 0.100

Zero pressure freq = 2620 Hz

Input pressure (MPa)	Up1 (Digit)	Observed value Down (Digit)	Up2 (Digit)	Average (Digit)	End Point Fit (MPa)	Poly Fit (MPa)	Non Conformance (% FS)
0.000	6863.0	6868.7	6868.7	6865.8	0.000	0.000	0.054
0.140	6247.7	6248.2	6247.7	6247.7	0.137	0.139	0.094
0.280	5616.6	5618.3	5619.0	5617.8	0.277	0.280	0.009
0.420	4983.7	4984.3	4984.0	4983.8	0.417	0.420	0.058
0.560	4348.7	4349.2	4348.2	4348.5	0.558	0.560	0.019
0.700	3709.5	3709.5	3707.5	3708.5	0.700	0.700	0.027

Non linearity (% FS) 0.47 Accuracy(% FS) 0.09

Digit : $f^2 / 1000$

Linear gage factor (G) : $2.2171E-04$ MPa/digit
(Use gage factor with minus sign with our read out unit)

Thermal factor(K) : $1.631E-04$ MPa/°C

Polynomial constants :
 $A = -1.2996E-09$ $B = -2.0778E-04$ $C = 1.4882E+00$

Pressure "P" is calculated with the following equation:

Linear : $P(\text{MPa}) = G(R0 - R1) + K(T1 - T0) - (S1 - S0)$

Polynomial : $P(\text{MPa}) = A(R1)^2 + B(R1) + C + K(T1 - T0) - (S1 - S0)$
 $R1$ = current reading & $R0$ is initial reading in digit.
 $S1$ and $T1$ = current atmospheric pressure(MPa) and temperature (°C)

Note :

(Zero conditions in the field must be established by recording the reading $R0$ (digit) along with temperature $T0$ (°C) and atmospheric pressure $S0$ (MPa) at the time of installation. If polynomial constants are used, determine value of 'C' as per § 6.2 of user's manual.)

Pin configuration/wiring code:

Red & black : **Signal** **Green & white:** **Thermistor**

Note : The above named Instrument has been calibrated by comparison with standards traceable to National Institute of Standards and Technology (NIST), United States, Certificate no. 1500241918 & 1500241919.



Tested by :



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DRAFT

APPENDIX B
Laboratory Testing Program

Appendix B

Laboratory Testing Program

A laboratory testing program was performed for this study to evaluate the basic index and geotechnical engineering properties of the site soils. Both disturbed and relatively undisturbed samples were tested. The tests performed and the procedures followed are outlined below.

Soil Classification

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

The classifications of selected samples were checked by laboratory tests such as Atterberg limits determinations and grain size analyses. Classifications were made in general accordance with the Unified Soil Classification (USC) System, ASTM D 2487, as presented on Figure B-1.

Water Content Determinations

Water contents were determined for most samples recovered in the explorations in general accordance with ASTM D 2216, as soon as possible following their arrival in our laboratory. Water contents were not determined for very small samples nor samples where large gravel contents would result in values considered unrepresentative. The results of these tests are plotted at the respective sample depth on the exploration logs. In addition, water contents are routinely determined for samples subjected to other testing. These are also presented on the exploration logs.

Grain Size Analysis (GS)

Grain size distribution was analyzed on representative samples in general accordance with ASTM D 422. Wet sieve analysis was used to determine the size distribution greater than the U.S. No. 200 mesh sieve. The size distribution for particles smaller than the No. 200 mesh sieve was determined by the hydrometer method for a selected number of samples. The results of the tests are presented as curves on Figure B-2 plotting percent finer by weight versus grain size.

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Exploration	Sample ID	Depth	Gravel (%)	Sand (%)	Fines (%)	Liquid Limit	Plastic Limit	Water Content (%)	USCS Group Symbol	Soil Description
B-1	S-1	0.0	38.1	55.4	6.5			8	SW-SM	WELL-GRADED SAND WITH SILT AND GRAVEL
B-1	S-2	5.0								
B-1	S-3	10.0								
B-1	S-4	15.0								
B-1	S-5	20.0	10.1	59.3	30.7			9	SM	SILTY SAND
B-1	S-6	25.0								
B-2	G-1	1.5								
B-2	G-2	2.5								
B-2	S-1	5.0								
B-2	S-2	10.0	25.0	44.3	30.7			8	SM	SILTY SAND WITH GRAVEL
B-2	S-3	15.0								
B-2	S-4	20.0								
B-2	S-5	25.0	6.8	67.2	25.9			16	SM	SILTY SAND
B-3	S-1a	0.0								
B-3	S-1b	0.5								
B-3	S-2	5.0	7.5	81.5	10.9			16	SW-SM	WELL-GRADED SAND WITH SILT
B-3	S-3	10.0								
B-3	S-4	15.0	3.4	52.4	44.2			10	SM	SILTY SAND
B-3	S-5	20.0								
B-3	S-6	25.0								
B-4	S-1	0.0	25.2	48.4	26.4			9	SM	SILTY SAND WITH GRAVEL
B-4	S-2	5.0								
B-4	S-3a	10.0								
B-4	S-3b	10.5								
B-4	S-4	15.0								
B-4	S-5	20.0								
B-4	S-6	25.0								
B-5	S-1	0.0	19.2	62.0	18.8			4	SM	SILTY SAND WITH GRAVEL
B-5	S-2a	5.0								
B-5	S-2b	6.5								
B-5	S-3	10.0								
B-5	S-4	15.0	6.2	58.1	35.8			9	SM	SILTY SAND
B-5	S-5	20.0								
B-5	S-6	25.0								
B-6	S-1a	0.4								
B-6	S-1b	1.9	27.7	55.9	16.4			5	SM	SILTY SAND WITH GRAVEL
B-6	S-2a	5.0								
B-6	S-2b	5.6								
B-6	S-3	10.0								
B-6	S-4	15.0	22.1	50.1	27.9			8	SM	SILTY SAND WITH GRAVEL
B-6	S-5	20.0								
B-6	S-6	25.0								
B-7	S-1	0.0								
B-7	S-2a	5.0								
B-7	S-2b	5.5								
B-7	S-3	10.0	11.6	40.4	48.0			15	SM	SILTY SAND
B-7	S-4	15.0	6.3	60.9	32.8			10	SM	SILTY SAND

SEATTLE - HAL LAB SUMMARY FOR REPORTS - C:\USERS\BELLAWON\DRIVE - HAL VALDRICH\COM\SECT\CHC - LIBRARY\GLB - 81125 14.08 - 1\HAL VALDRICH\COM\SHARE\CF\PROJ\SECT\0204661\0204661-002_SEATAC IWTP (SP) - 1.nelab

Exploration	Sample ID	Depth	Gravel (%)	Sand (%)	Fines (%)	Liquid Limit	Plastic Limit	Water Content (%)	USCS Group Symbol	Soil Description
B-7	S-5	20.0								
B-7	S-6	25.0								
B-8	S-1	0.0								
B-8	S-2	5.0	15.2	46.3	38.5			9	SM	SILTY SAND WITH GRAVEL
B-8	S-3	10.0								
B-8	S-4	15.0								
B-8	S-5	20.0								
B-8	S-6	25.0	6.7	68.3	25.0			11	SM	SILTY SAND
B-9	S-1	0.0	15.6	49.9	34.5			6	SM	SILTY SAND WITH GRAVEL
B-9	S-2	5.0								
B-9	S-3	10.0	24.8	38.8	36.4			8	SM	SILTY SAND WITH GRAVEL
B-9	S-4	15.0								
B-9	S-5	20.0								
B-9	S-6	25.0								
B-10	S-1a	0.0								
B-10	S-1b	1.5	15.0	64.0	21.0			12	SM	SILTY SAND WITH GRAVEL
B-10	S-2	5.0								
B-10	S-3	10.0								
B-10	S-4a	15.0								
B-10	S-4b	15.4								
B-10	S-5	20.0								
B-10	S-6	25.0	1.8	82.1	16.2			18	SM	SILTY SAND
W-1	G-1	2.5								
W-1	G-2	5.5	9.6	56.1	34.3			43	SM	SILTY SAND
W-1	G-3	8.0								
W-1	G-4	12.5								
W-1	G-5	19.0								
W-1	G-6	23.5	30.9	47.1	22.0			5	SM	SILTY SAND WITH GRAVEL
W-1	G-7	27.5								
W-1	G-8	32.5	0.0	91.6	8.4			20	SP-SM	POORLY GRADED SAND WITH SILT
W-1	G-9	37.5								
W-1	G-10	42.5								
W-1	G-11	44.0	0.0	87.2	12.8			23	SM	SILTY SAND
W-2	S-1	0.0								
W-2	G-2	2.5								
W-2	G-3	4.0								
W-2	S-4	5.0								
W-2	G-5	6.0								
W-2	G-6	8.0	1.2	91.5	7.3			22	SP-SM	POORLY GRADED SAND WITH SILT
W-2	S-7	10.0								
W-2	G-8	11.5	29.7	68.9	1.4			14	SP	POORLY GRADED SAND WITH GRAVEL
W-2	G-9	14.0								
W-2	S-10	15.0								
W-2	G-11	17.0								
W-2	S-12	20.0								
W-2	G-13	24.0	13.9	59.3	26.8			6	SM	SILTY SAND
W-2	S-14	25.0								

SEATTLE - HAL LAB SUMMARY (FOR REPORTS) - C:\USERS\BELLANOWE\DRIVE - HALEY\ALDRICH\COM\SECTOPAC - LIBRARY GLOB - 81125 14.08 - 1\HALEY\ALDRICH\COM\SHAWNEE\CP\PROJECTS\0204661\GNT\0204661-002_SEATAC IWTP (SP) - 1\delan

Exploration	Sample ID	Depth	Gravel (%)	Sand (%)	Fines (%)	Liquid Limit	Plastic Limit	Water Content (%)	USCS Group Symbol	Soil Description
W-3	S-1	0.0								
W-3	G-2	2.5	13.0	83.4	3.5			3	SP	POORLY GRADED SAND
W-3	S-3	5.0								
W-3	G-4	6.0								
W-3	G-5	8.0	9.4	32.4	58.2			15	ML	SANDY SILT
W-3	S-6	10.0								
W-3	G-7	12.5								
W-3	S-8	15.0	9.1	66.2	24.7			9	SM	SILTY SAND
W-3	G-9	18.5								
W-3	S-10	20.0								
W-3	G-11	21.0	17.3	56.0	26.6			4	SM	SILTY SAND WITH GRAVEL
W-3	G-12	24.5								
W-3	S-13	25.0								
W-4	S-1a	0.0								
W-4	S-1b	0.6								
W-4	G-2	2.5								
W-4	S-3	5.0								
W-4	G-4	7.5	5.6	47.2	47.2			10	SM	SILTY SAND
W-4	S-5	10.0								
W-4	G-6	12.5								
W-4	S-7	15.0	10.3	50.8	38.9			8	SM	SILTY SAND
W-4	G-8	17.5								
W-4	S-9	20.0								
W-4	G-10	22.5	7.6	62.6	29.8			7	SM	SILTY SAND
W-4	S-11	25.0								
W-4	G-12	27.5								
W-4	S-13	30.0								
W-4	G-14	33.0	17.2	57.1	25.6			7	SM	SILTY SAND WITH GRAVEL
W-4	S-15	35.0								
W-4	G-16	37.5								
W-4	S-17	40.0	48.5	41.8	9.7			11	GP-GM	POORLY GRADED GRAVEL WITH SILT AND SAND
W-5	S-1	0.0	34.5	45.7	19.8			6	SM	SILTY SAND WITH GRAVEL
W-5	G-2	1.5								
W-5	G-3	3.5								
W-5	S-4	5.0								
W-5	G-5	7.5	5.4	52.3	42.3			11	SM	SILTY SAND
W-5	S-6	10.0								
W-5	G-7	12.5								
W-5	S-8	15.0								
W-5	G-9	17.5								
W-5	S-10	20.0								
W-5	G-11	22.5								
W-5	S-12	25.0	5.5	66.3	28.2			11	SM	SILTY SAND
W-5	G-13	27.5	15.2	67.0	17.8			7	SM	SILTY SAND WITH GRAVEL
W-5	S-14	30.0								
W-6	S-1	0.0								
W-6	G-2	2.5								



Project: SEATAC IWTP
Location: SEATAC, WA
Project No.: 0204661-002

Summary of Laboratory Results

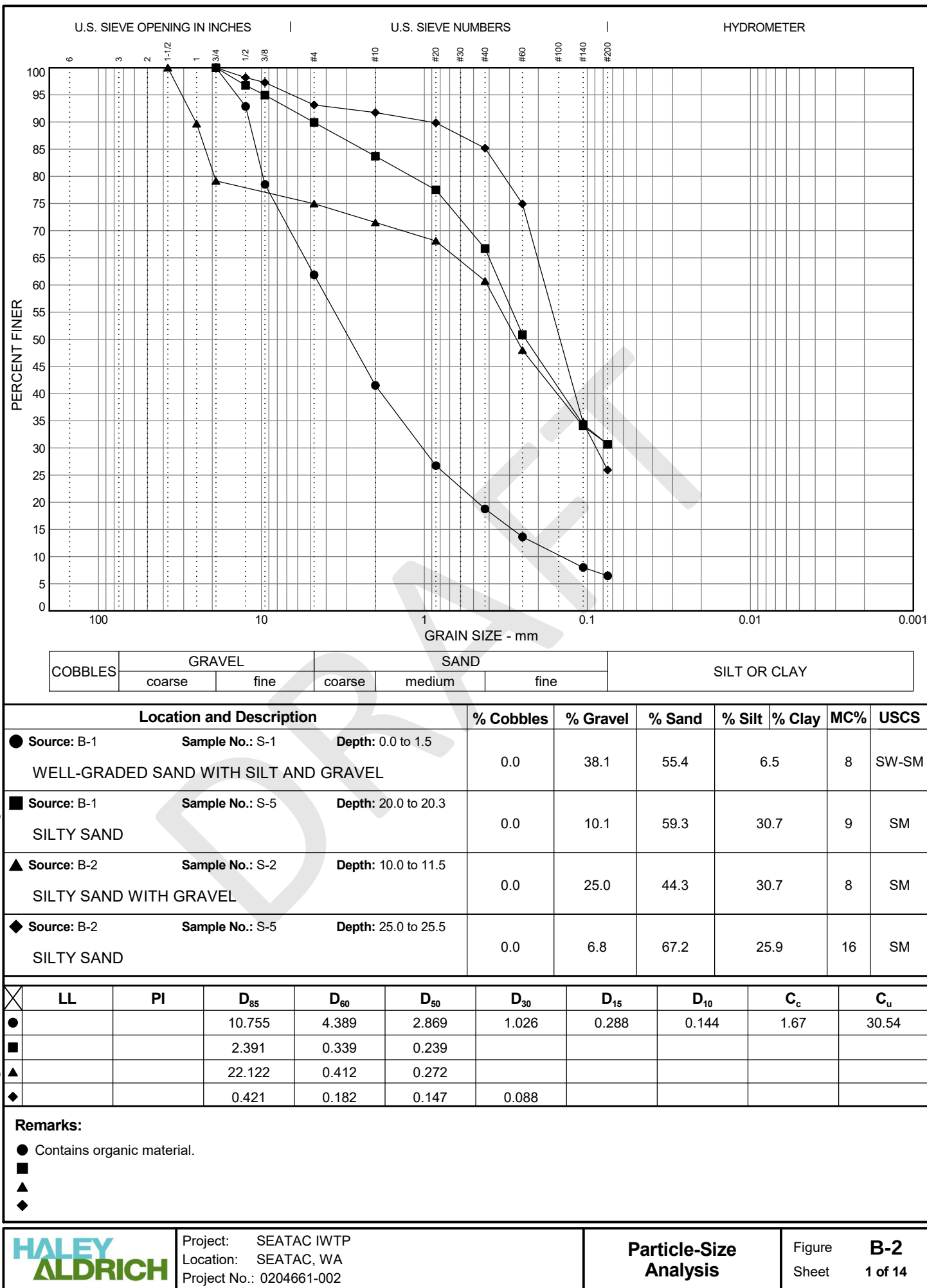
Figure Sheet **B-1**
3 of 5

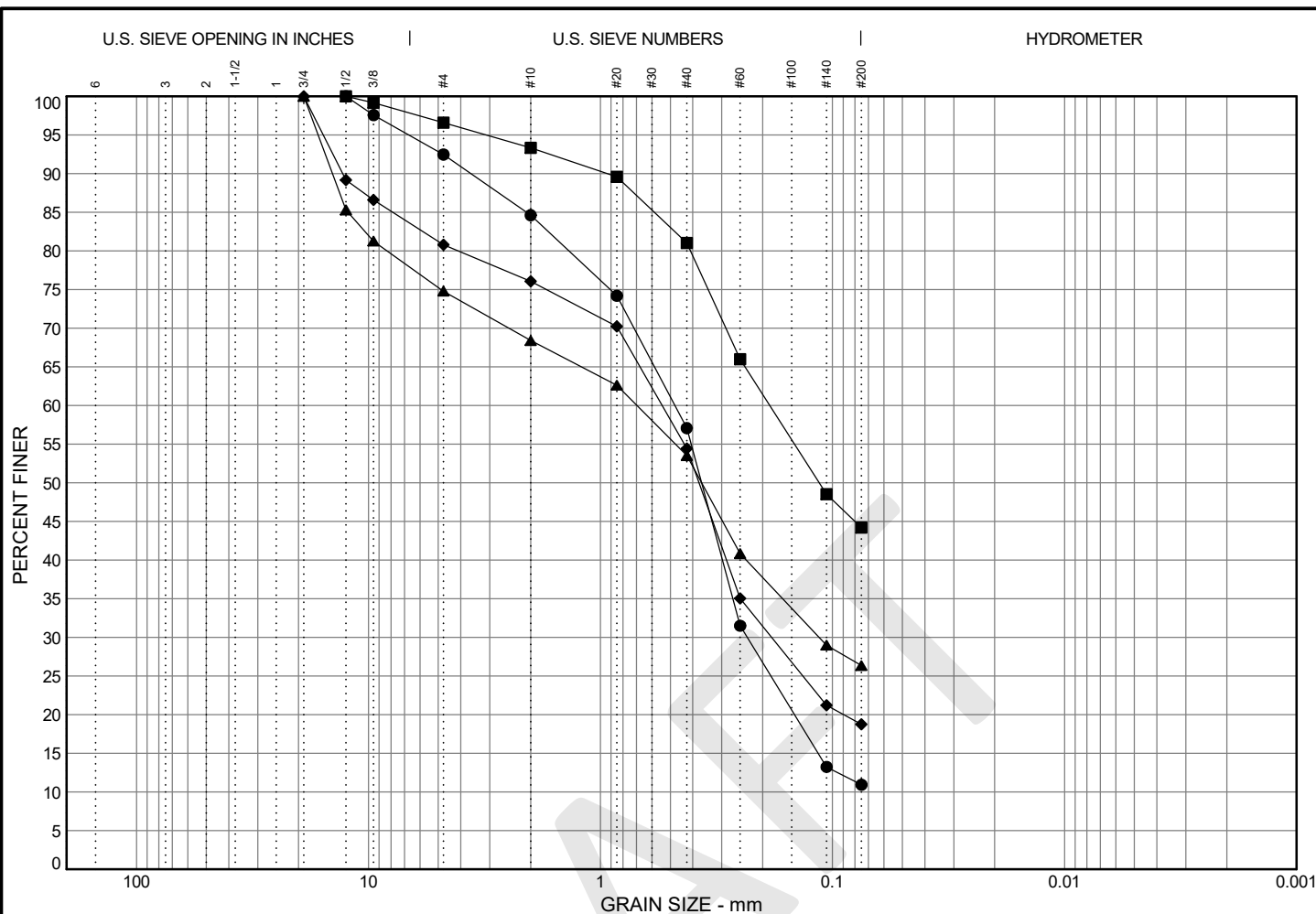
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Exploration	Sample ID	Depth	Gravel (%)	Sand (%)	Fines (%)	Liquid Limit	Plastic Limit	Water Content (%)	USCS Group Symbol	Soil Description
W-6	S-3	5.0								
W-6	G-4	7.5	11.3	56.3	32.4			6	SM	SILTY SAND
W-6	S-5	10.0								
W-6	G-6	12.5								
W-6	S-7	15.0								
W-6	G-8	17.5								
W-6	S-9	20.0								
W-6	G-10	22.5								
W-6	S-11	25.0	3.6	88.9	7.5			14	SP-SM	POORLY GRADED SAND WITH SILT
W-6	G-12	27.5								
W-6	G-13	29.5								
W-6	S-14	30.0								
W-6	G-15	32.5								
W-6	S-16	35.0	38.5	50.8	10.7			9	SP-SM	POORLY GRADED SAND WITH SILT AND GRAVEL
W-7	S-1	0.0								
W-7	G-2	4.0	0.9	92.3	6.7			11	SP-SM	POORLY GRADED SAND WITH SILT
W-7	S-3	5.0								
W-7	G-4	7.5								
W-7	S-5	10.0								
W-7	G-6	11.0								
W-7	G-7	14.0	26.8	52.3	20.9			6	SM	SILTY SAND WITH GRAVEL
W-7	S-8	15.0								
W-7	G-9	16.5								
W-7	G-10	19.0								
W-7	S-11	20.0								
W-7	G-12	22.0								
W-7	S-13	25.0								
W-7	G-14	26.5								
W-7	G-15	29.0	9.0	51.3	39.7			7	SM	SILTY SAND
W-7	S-16	30.0								
W-7	G-17	32.5								
W-7	G-18	34.0								
W-7	S-19	35.0								
W-7	G-20	37.5	53.9	34.5	11.6			7	GW-GM	WELL-GRADED GRAVEL WITH SILT AND SAND
W-7	G-21	39.0								
W-7	S-22	40.0								
W-7	G-23	43.5	54.5	36.1	9.4			9	GW-GM	WELL-GRADED GRAVEL WITH SILT AND SAND
W-7	S-24	45.0								
W-7	G-25	46.0								
W-7	G-26	47.5	49.0	42.0	9.0			8	GW-GM	WELL-GRADED GRAVEL WITH SILT AND SAND
W-7	S-27	50.0								
W-8	S-1	0.0								
W-8	S-2	5.0	21.1	47.9	31.1			8	SM	SILTY SAND WITH GRAVEL
W-8	S-3	10.0								
W-8	S-4	15.0								
W-8	S-5	20.0								
W-8	S-6	25.0								

Exploration	Sample ID	Depth	Gravel (%)	Sand (%)	Fines (%)	Liquid Limit	Plastic Limit	Water Content (%)	USCS Group Symbol	Soil Description
W-8	S-7	30.0								
W-8	S-8	35.0								
W-8	S-9	40.0								
W-8	S-10	45.0	4.2	79.0	16.7			22	SM	SILTY SAND
W-8	S-11a	50.0	19.7	71.4	9.0			11	SW-SM	WELL-GRADED SAND WITH SILT AND GRAVEL
W-8	S-11b	51.0								
W-8	S-12a	55.0								
W-8	S-12b	56.0								
W-8	S-13	60.0								
W-9	G-1	2.5								
W-9	G-2	7.5	10.5	59.8	29.7			7	SM	SILTY SAND
W-9	G-3	12.5								
W-9	G-4	17.5								
W-9	G-5	22.5								
W-9	G-6	27.5								
W-9	G-7	33.5	51.5	38.6	9.8			7	GP-GM	POORLY GRADED GRAVEL WITH SILT AND SAND
W-9	G-8	37.0								
W-9	G-9	41.0								
W-9	G-10	43.0								
W-9	G-11	47.5	7.6	82.2	10.2			29	SP-SM	POORLY GRADED SAND WITH SILT
W-9	G-12	51.0								
W-9	G-13	54.0	59.7	33.3	7.0			7	GW-GM	WELL-GRADED GRAVEL WITH SILT AND SAND
W-9	G-14	57.5								

SEATTLE - HAL LAB SUMMARY (FOR REPORTS) - C:\USERS\BELLANON\DRIVE - HALEY\ALDRICH\COM\SEATTLE\TOP\HMC_LIBRARY\GLB - 81125 14.08 - 1\HALEY\ALDRICH\COM\SHARE\CF\PROJECTS\0204661\0204661-002_SEATAC IWTP\SP - J - belan





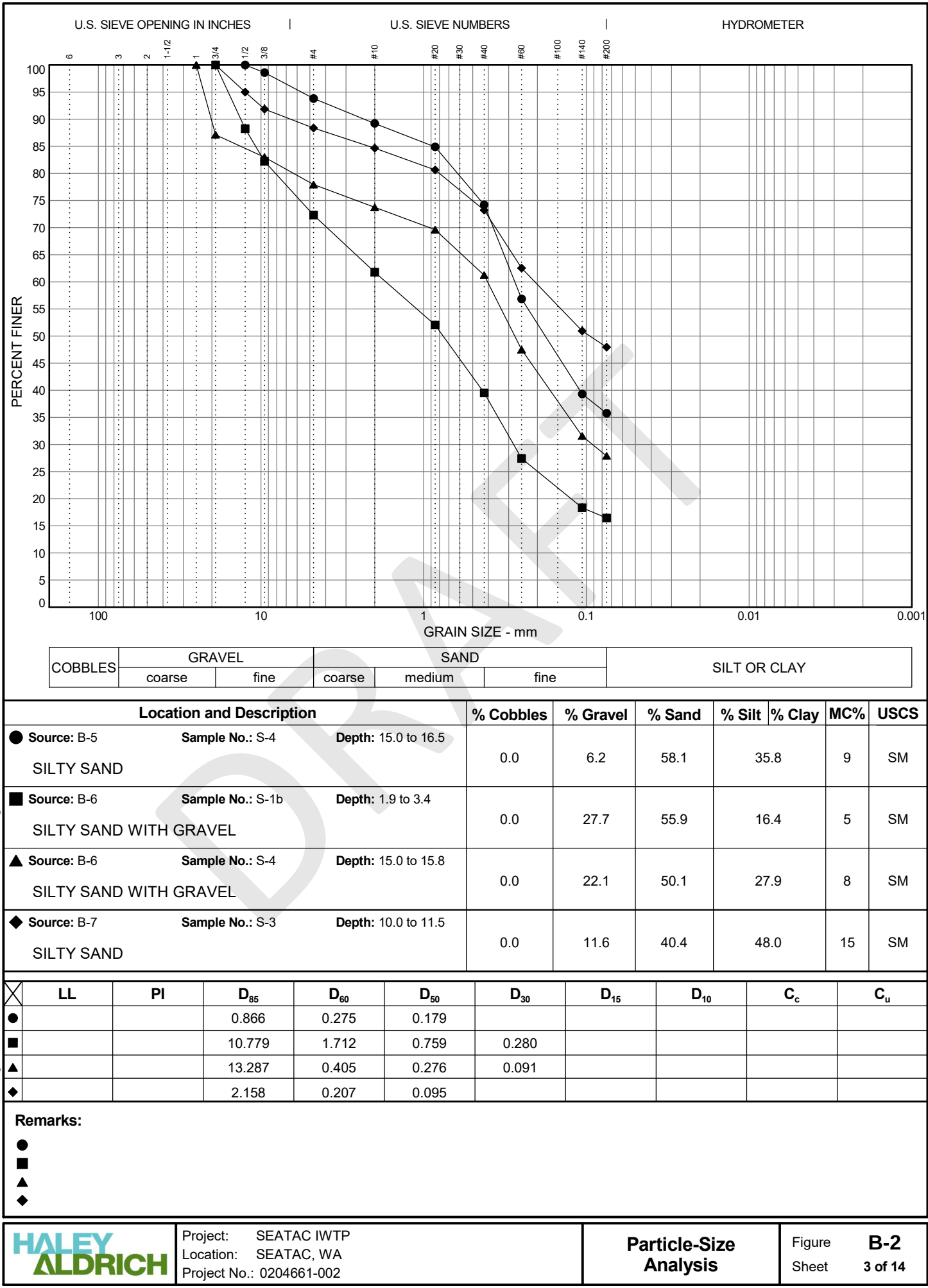
COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Location and Description			% Cobbles	% Gravel	% Sand	% Silt	% Clay	MC%	USCS
● Source: B-3	Sample No.: S-2	Depth: 5.0 to 6.5							
WELL-GRADED SAND WITH SILT			0.0	7.5	81.5	10.9		16	SW-SM
■ Source: B-3	Sample No.: S-4	Depth: 15.0 to 16.5							
SILTY SAND			0.0	3.4	52.4	44.2		10	SM
▲ Source: B-4	Sample No.: S-1	Depth: 0.0 to 1.5							
SILTY SAND WITH GRAVEL			0.0	25.2	48.4	26.4		9	SM
◆ Source: B-5	Sample No.: S-1	Depth: 0.0 to 1.5							
SILTY SAND WITH GRAVEL			0.0	19.2	62.0	18.8		4	SM

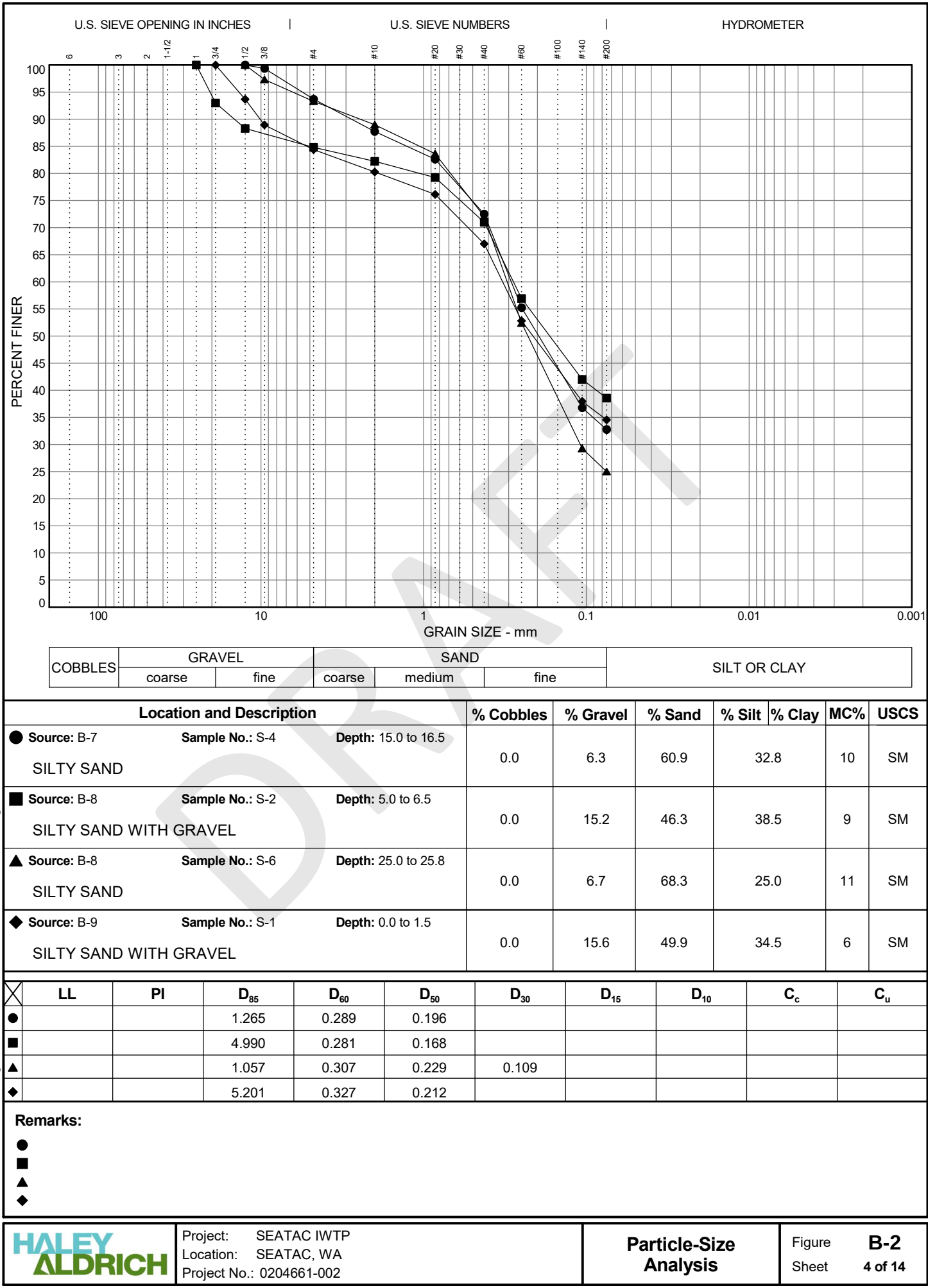
LL	PI	D ₈₅	D ₆₀	D ₅₀	D ₃₀	D ₁₅	D ₁₀	C _c	C _u
●		2.086	0.479	0.367	0.233	0.115		1.74	7.33
■		0.587	0.186	0.114					
▲		12.243	0.696	0.367	0.114				
◆		7.856	0.543	0.377	0.183				

Remarks:

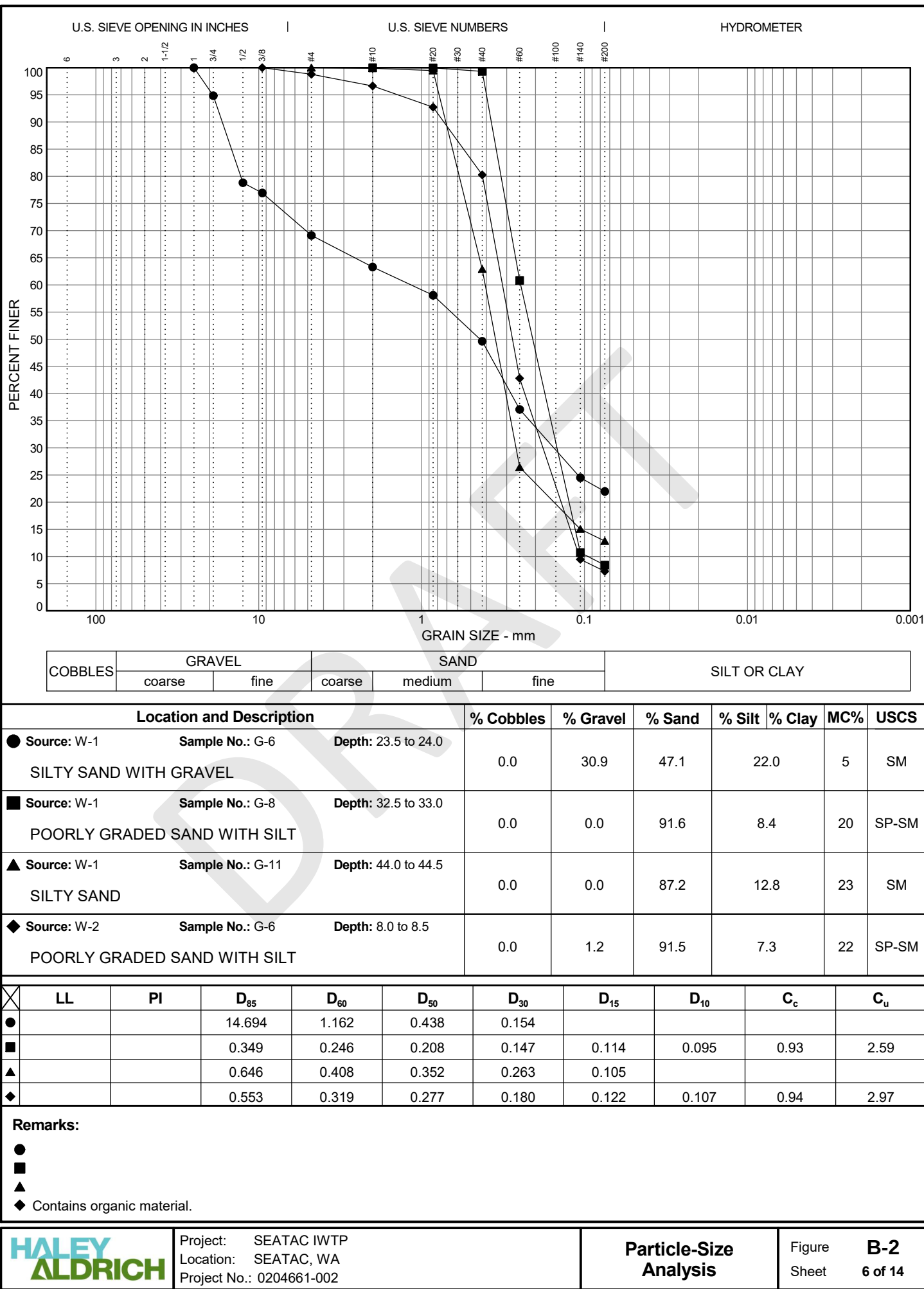
-
- Omit one ~3/4" gravel.
- ▲ Contains organic material.
- ◆

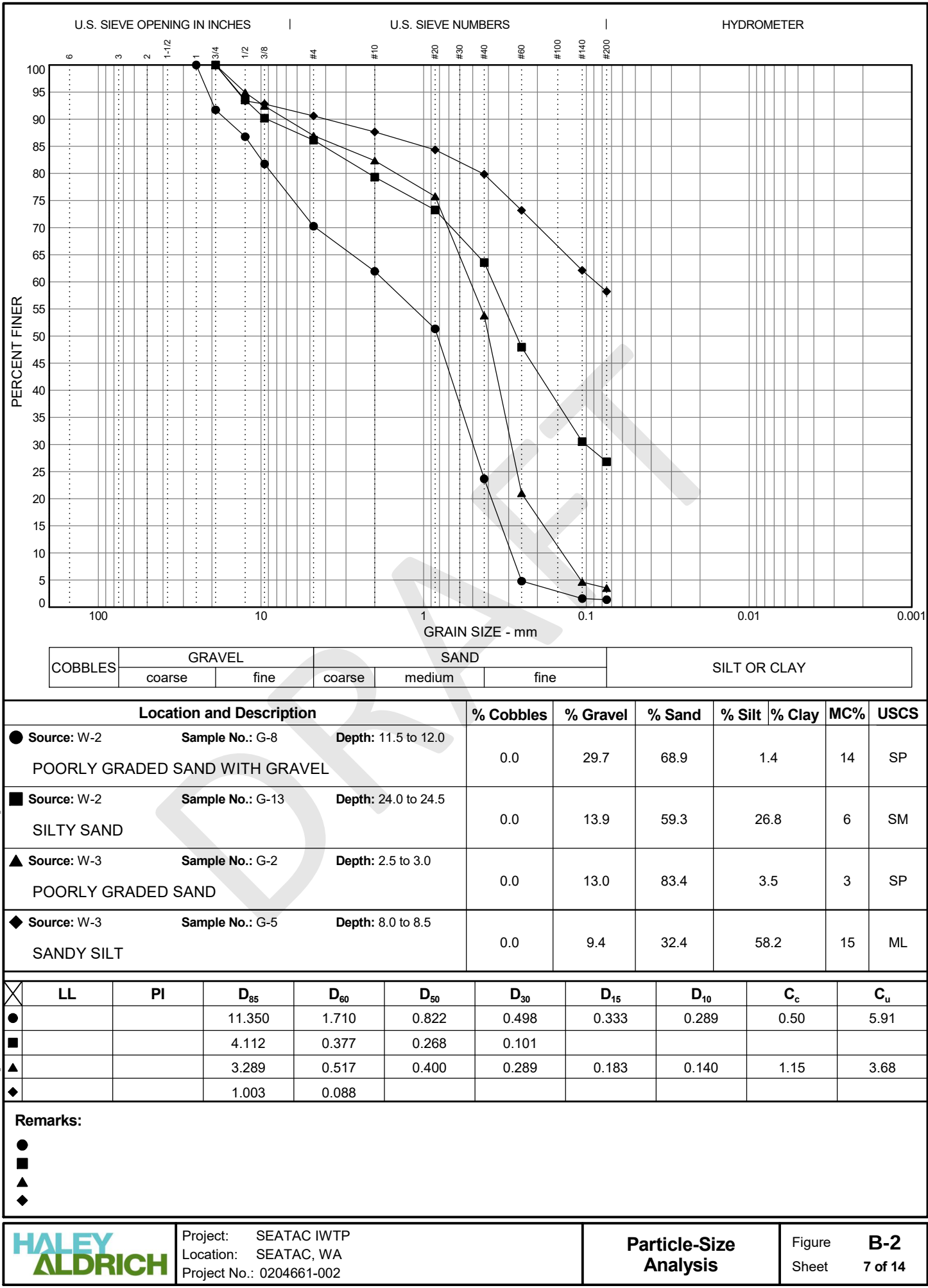


HA GRAB SIZE: C:\USERS\BELA\ONE DRIVE - HALEY\ALDRICH\COMSHANE\PROJECTS\0204661\GINT0204661-002_SEATAC IWTP.GPJ - 10/10/18

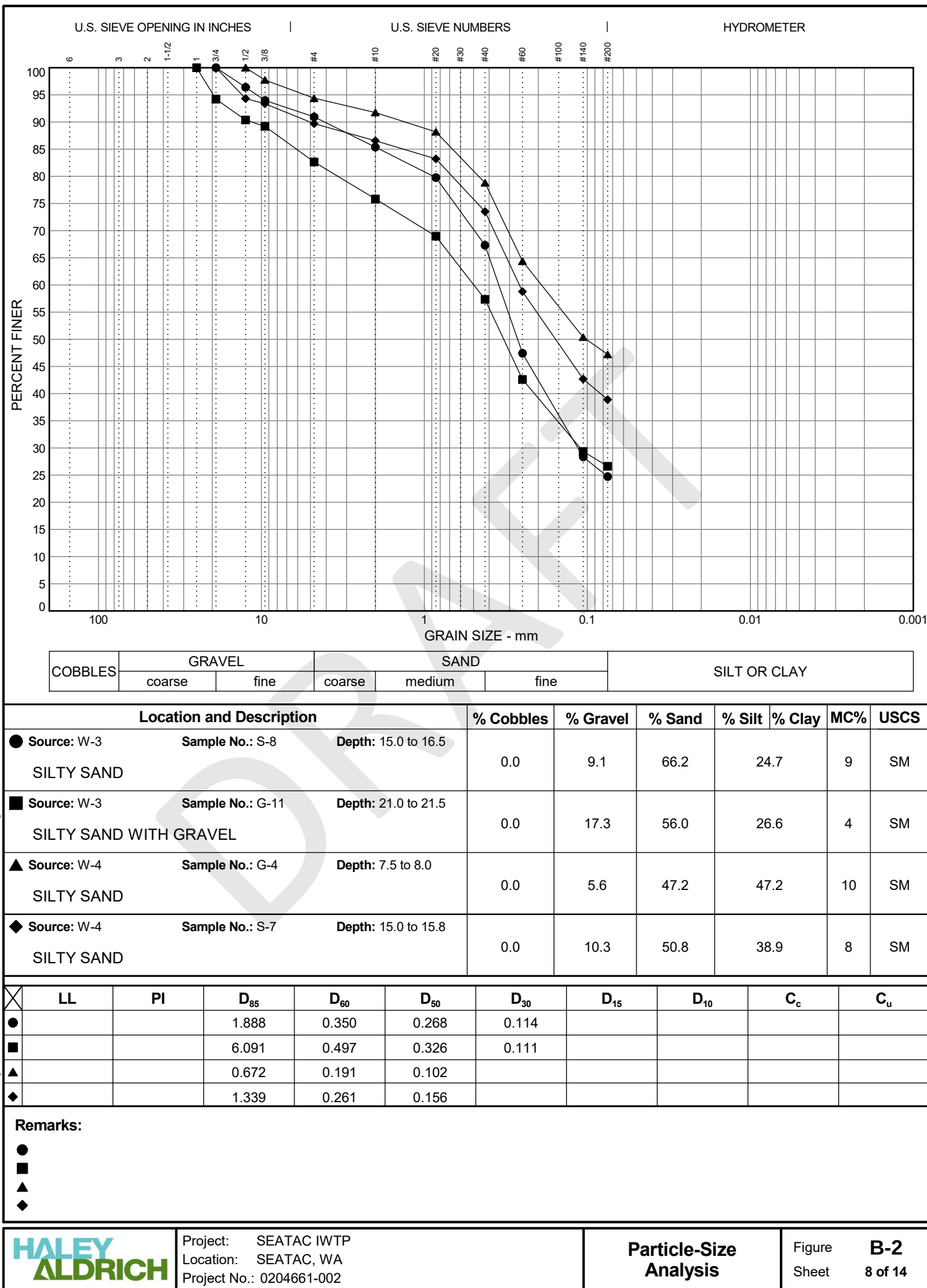


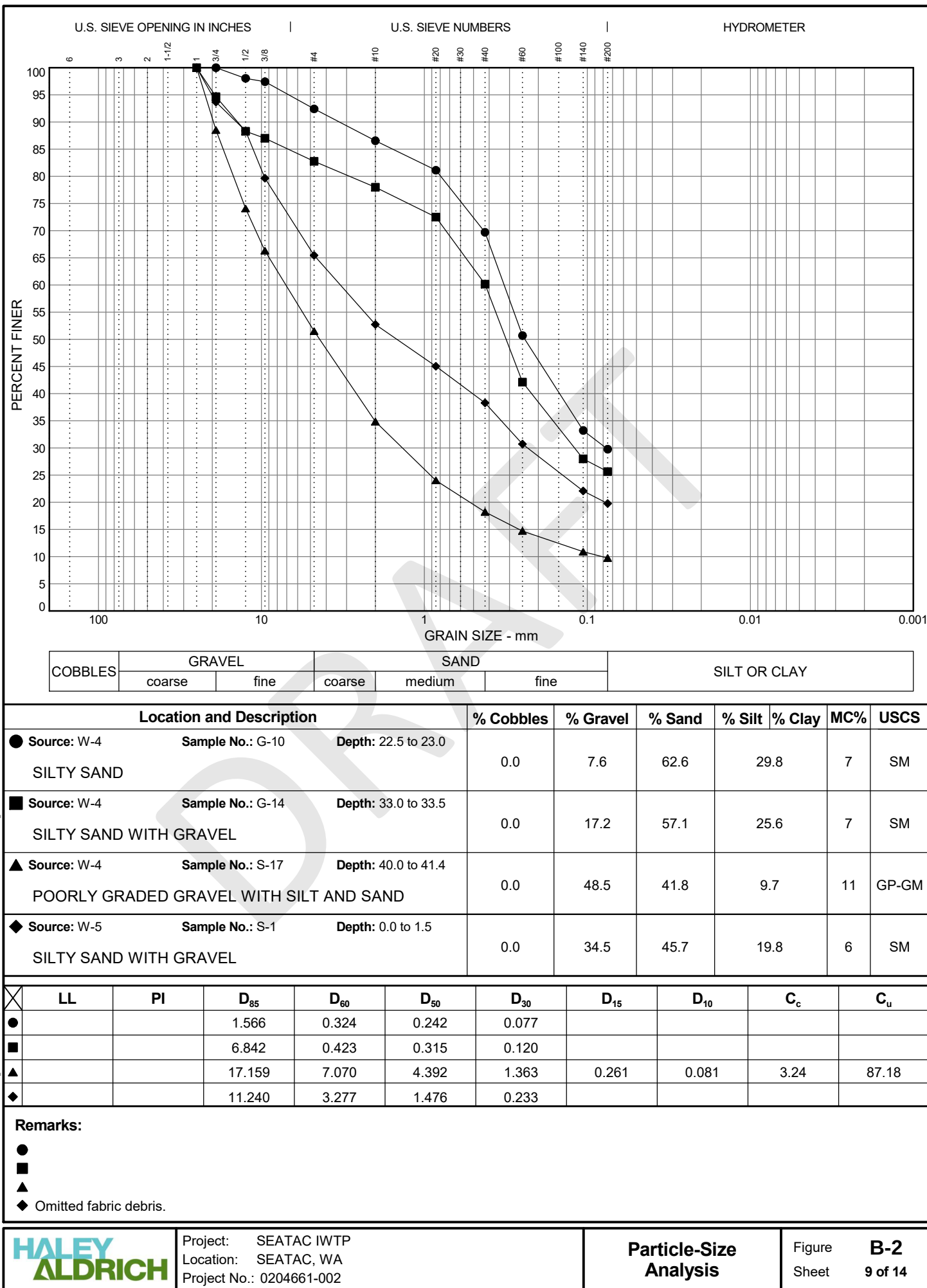
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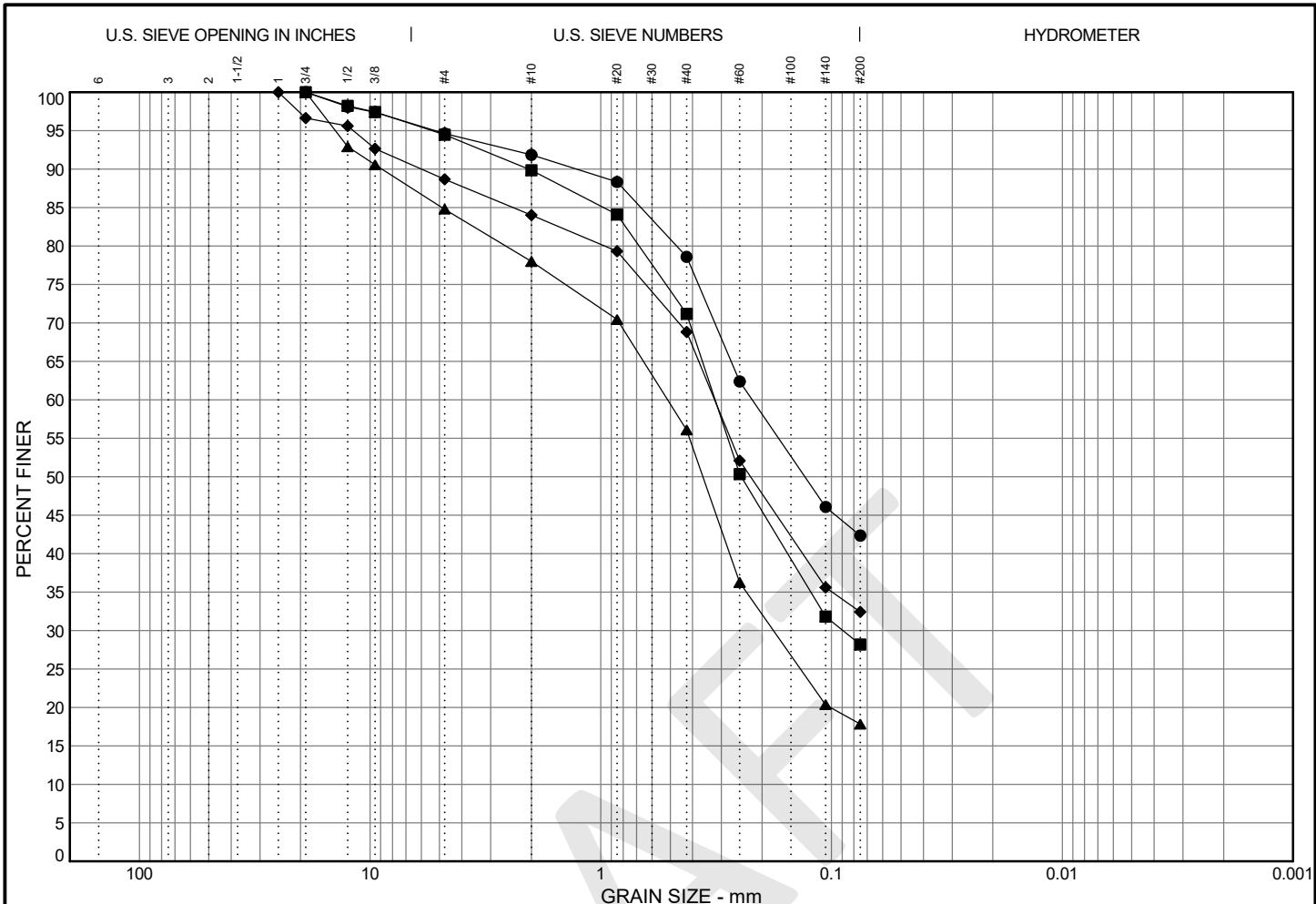




HA GRN SIZE: C:\USERS\BELLAM\ONE DRIVE - HALEY\ALDRICH\COMSHANE\CFPROJECT\0204661\GINT0204661-002_SEATAC IWTP.GPJ - 10/10/18







COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Location and Description			% Cobbles	% Gravel	% Sand	% Silt	% Clay	MC%	USCS
● Source: W-5	Sample No.: G-5	Depth: 7.5 to 8.0							
SILTY SAND			0.0	5.4	52.3	42.3		11	SM
■ Source: W-5	Sample No.: S-12	Depth: 25.0 to 25.9							
SILTY SAND			0.0	5.5	66.3	28.2		11	SM
▲ Source: W-5	Sample No.: G-13	Depth: 27.5 to 28.0							
SILTY SAND WITH GRAVEL			0.0	15.2	67.0	17.8		7	SM
◆ Source: W-6	Sample No.: G-4	Depth: 7.5 to 8.0							
SILTY SAND			0.0	11.3	56.3	32.4		6	SM

LL	PI	D ₈₅	D ₆₀	D ₅₀	D ₃₀	D ₁₅	D ₁₀	C _c	C _u
●		0.671	0.221	0.130					
■		0.971	0.320	0.246	0.089				
▲		4.874	0.514	0.361	0.178				
◆		2.402	0.321	0.224					

Remarks:

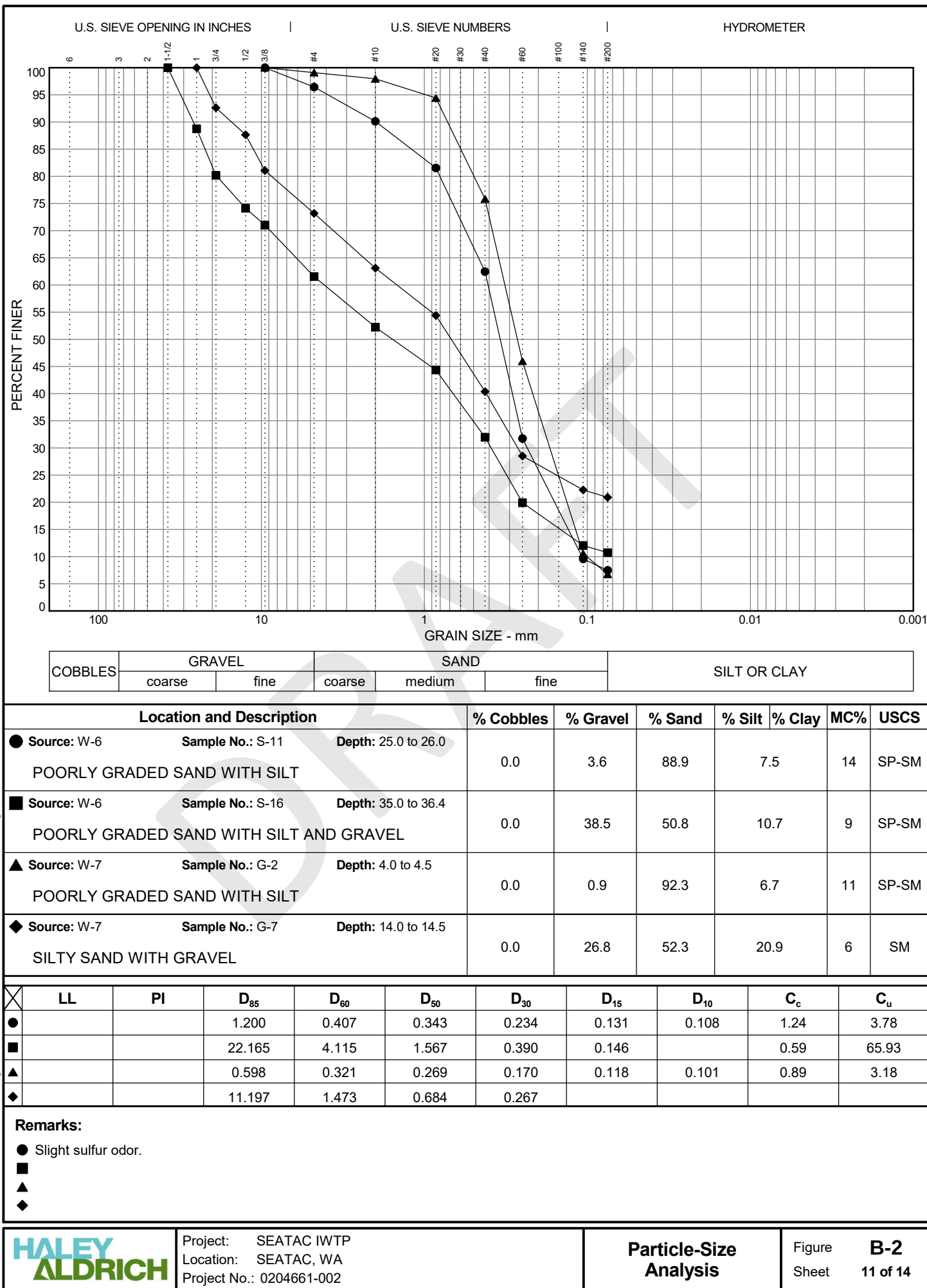
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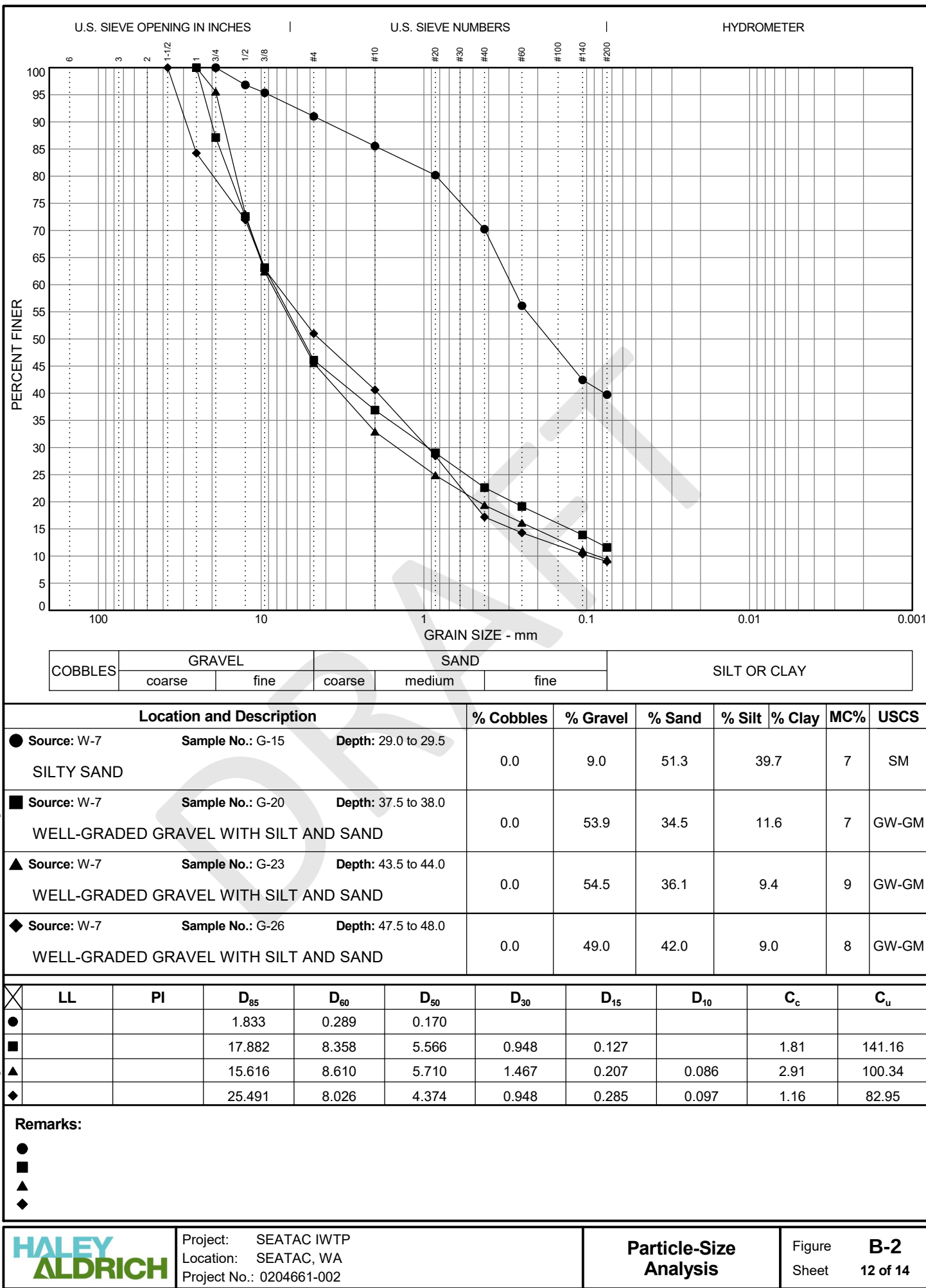
■

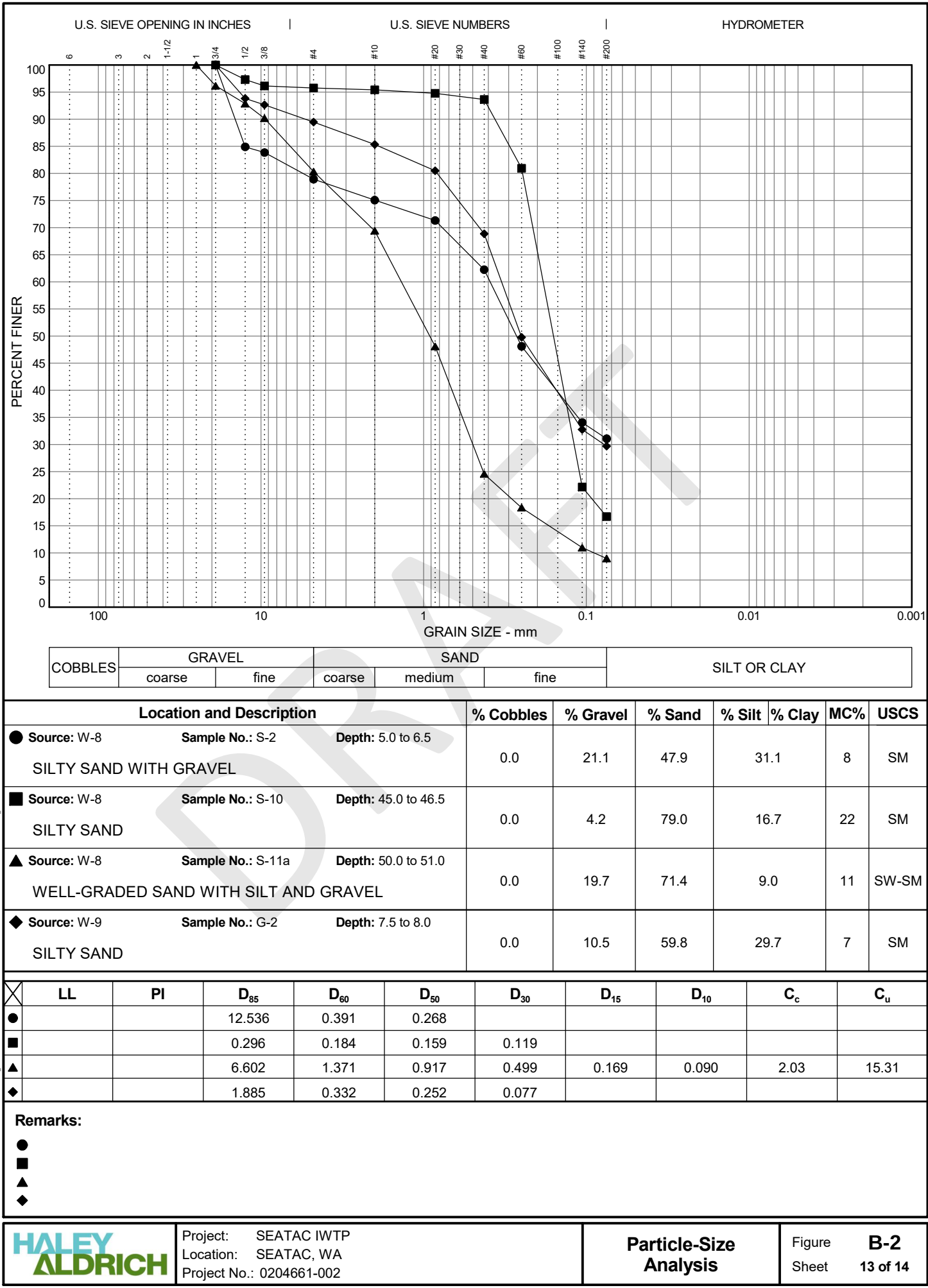
▲

◆

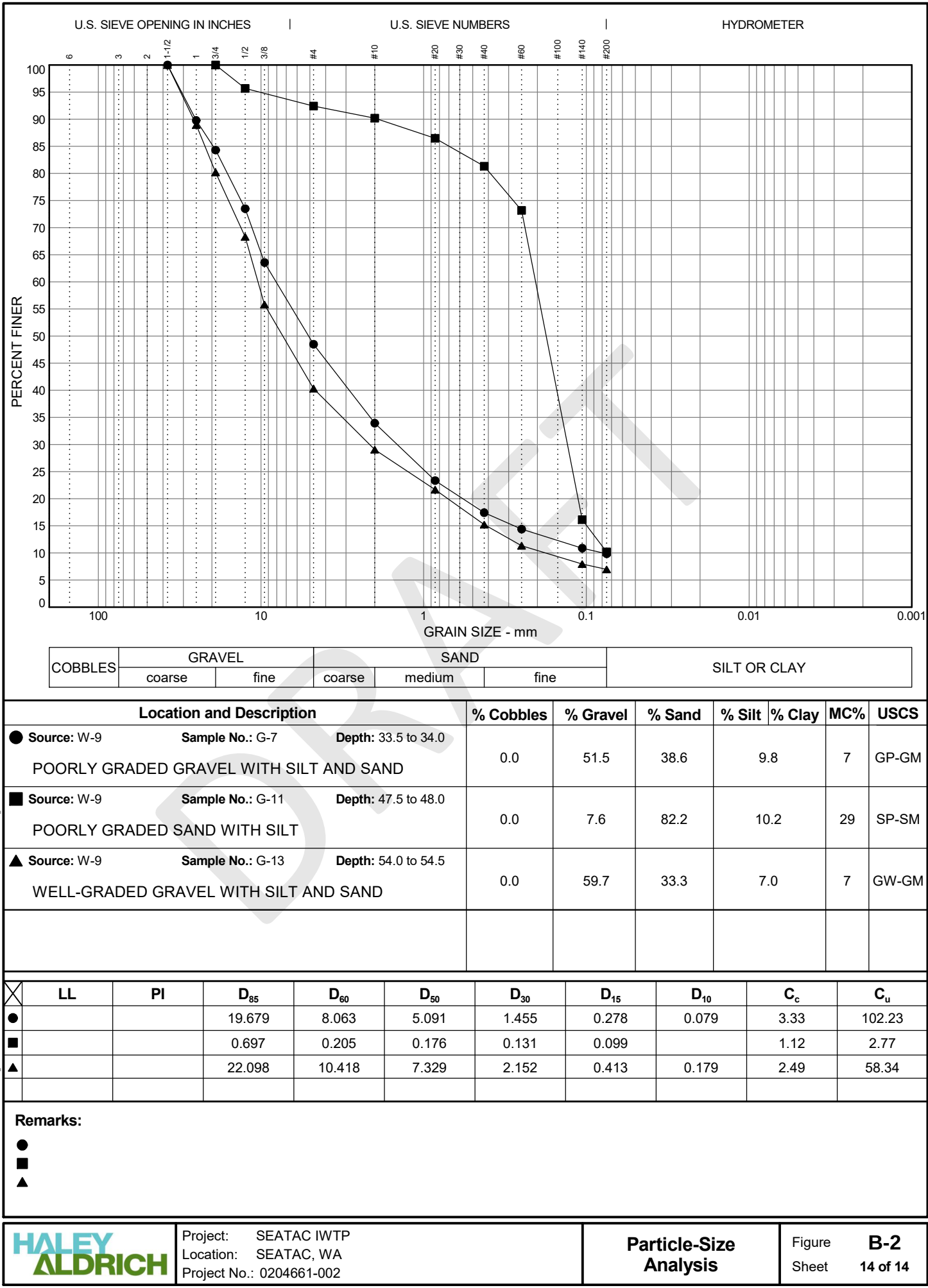
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HA GRANT SIZE: C:\USERS\BELAM\ONE DRIVE - HALEY\ALDRICH\COMSHANE\PROJECTS\0204661\GINT0204661-002_SEATAC IWTP.GPJ - 10/10/19

DRAFT

APPENDIX C

Historical Explorations

Appendix C

Historical Explorations

In addition to the explorations and laboratory test results presented in Appendices A and B, we reviewed previous explorations by Haley & Aldrich (formerly Hart Crowser) and others to gain an understanding of the subsurface conditions within unexplored portions of the site. Logs by others are included as they were produced by others for reference only and Haley & Aldrich is not responsible for the accuracy or completeness of the information presented in the logs. Approximate locations of the previous explorations by others are shown on Figure 2; actual locations may differ from those shown.

Table C-1 – Historical Borings in Vicinity of IWTP Enhancements Project

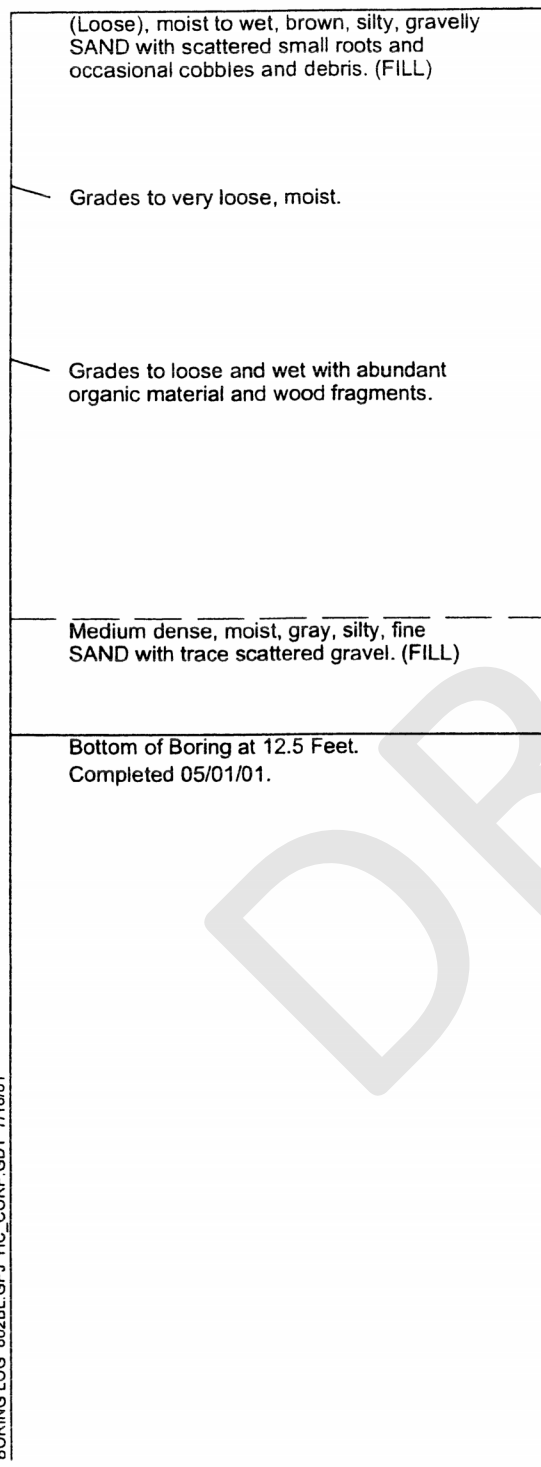
Boring ID	STIA Boring ID	Report	Year Drilled
HC01-B1	3RDRW_B1_1671	Parcel 802, Third Runway South RPZ Project	2001
HC01-B2	3RDRW_B2_1671		2001
HC01-B3	3RDRW_B3_1671		2001
HC01-B4	3RDRW_B4_1671		2001
HC01-B408	3RDRW_B408		2001
HC01-B409	3RDRW_B409		2001
HC01-B410	3RDRW_B410		2001
HC01-B417	3RDRW_B417		2001
HC01-MW1	3RDRW_MW1_1671		2001
HC01-MW2	3RDRW_MW2_1671		2001
HC01-MW3	3RDRW_MW3_1671		2001
HC01-B411	3RDRW_B411	Parcel 803, Third Runway South RPZ Project	2001
HC01-B412	3RDRW_B412		2001
HC01-B401	3RDRW_B401	Parcel 804 and 805, Third Runway South Project	2001
HC01-B402	3RDRW_B402		2001
HC01-B403	3RDRW_B403		2001
HC01-B404	3RDRW_B404		2001
HC01-B405	3RDRW_B405		2001
HC01-B406	3RDRW_B406		2001
HC01-B407	3RDRW_B407		2001
HC01-B414	3RDRW_B414	Parcel 810, Third Runway South RPZ Project	2001
HC01-B415	3RDRW_B415		2001
HC01-B416	3RDRW_B416		2001

HSA Boring Log HC01-B1

|| A_SB1010 ||

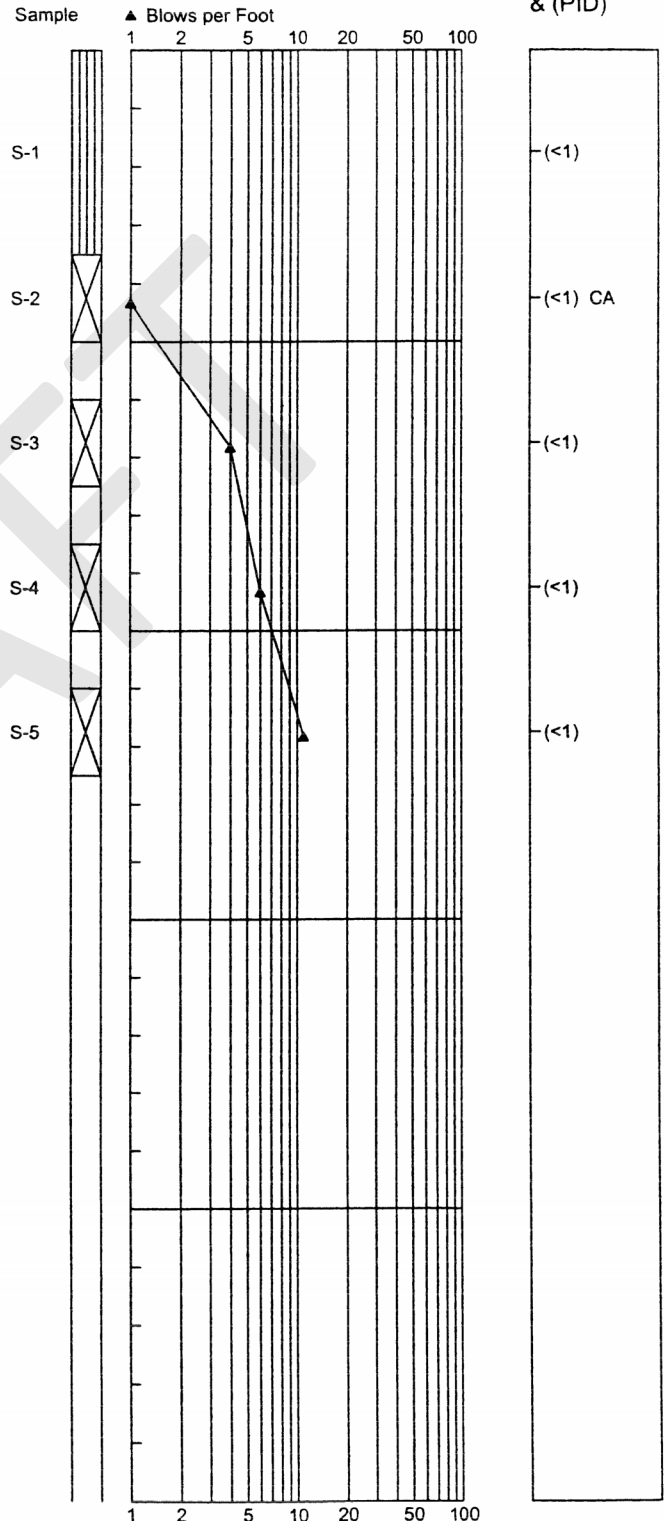
Soil Descriptions
Approximate Ground Surface Elevation in Feet: 299

Depth
in Feet



STANDARD PENETRATION
RESISTANCE

LAB
TESTS
& (PID)



BORING LOG 802BL.GPJ HC CORP.GDT 7/18/01

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date



HARTCROWSER

J-4978-36 (802) 05/01

Figure A-6

HSA Boring Log HC01-B2

Soil Descriptions

Approximate Ground Surface Elevation in Feet: 299

Depth
in Feet

(Loose), moist, brown, slightly silty, sandy
GRAVEL. (FILL)

Loose, wet, dark brown to dark gray, very
silty SAND with organic material, roots, and
trace scattered gravel. (FILL)

Grades to medium dense.

Dense, moist, gray, silty, gravelly, fine to
medium SAND. (TILL-LIKE)

Bottom of Boring at 15.0 Feet.
Completed 05/01/01.

▽
ATD

STANDARD PENETRATION RESISTANCE

Sample

▲ Blows per Foot

1 2 5 10 20 50 100

LAB
TESTS
& (PID)

S-1

S-2

S-3

S-4

S-5

S-6

(<1)

(<1) CA

(<1)

(<1)

(<1)

BORING LOG 802BL.GPJ HC_CORP.GDT 7/18/01



HARTCROWSER

J-4978-36 (802) 05/01

Figure A-7

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. HSA = Hollow-stem auger.

HSA Boring Log HC01-B3

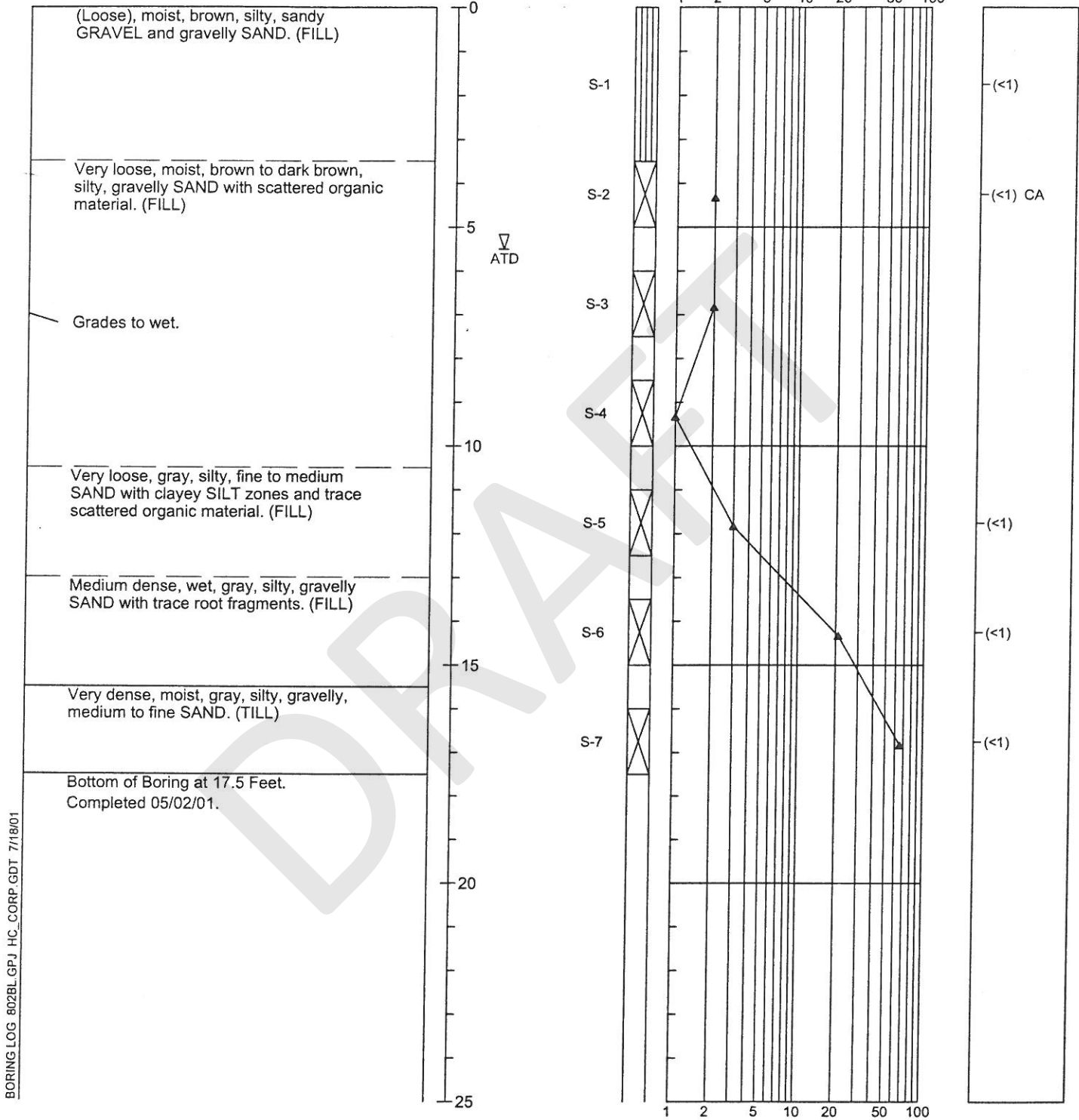
Soil Descriptions

Approximate Ground Surface Elevation in Feet: 299

Depth
in Feet

STANDARD PENETRATION RESISTANCE

LAB
TESTS
& (PID)



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. HSA = Hollow-stem auger.

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J-4978-36 (802) 05/01

Figure A-8

HSA Boring Log HC01-B4

|| A SB1013 ||

STANDARD PENETRATION
RESISTANCE

LAB
TESTS
& (PID)

Soil Descriptions

Approximate Ground Surface Elevation in Feet: 299

Depth
in Feet

Sample

▲ Blows per Foot

1 2 5 10 20 50 100

(Loose), moist, brown to dark brown, silty, sandy GRAVEL to silty, gravelly SAND. (FILL)	0
Very loose, wet, brown, silty, gravelly SAND. (FILL)	5
Very soft, wet, dark gray organic SILT. (FILL)	10
Medium dense, wet, gray, silty SAND with scattered organic material. (FILL)	15
Dense, moist, gray, silty, gravelly, medium to fine SAND. (TILL)	20
Bottom of Boring at 20.0 Feet. Completed 05/02/01.	25

▽
ATD

S-1

S-2

S-3

S-4

S-5

S-6

S-7

S-8

(<1)

(<1) CA

(<1)

(<1)

(<1)

(<1)

BORING LOG 802BL GPJ HC_CORP GDT 7/18/01

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. HSA = Hollow-stem auger.



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J-4978-36 (802) 05/01

Figure A-9

Strataprobe Boring Log HC01-B401

3RDRW-B401
(1574)

Soil Descriptions

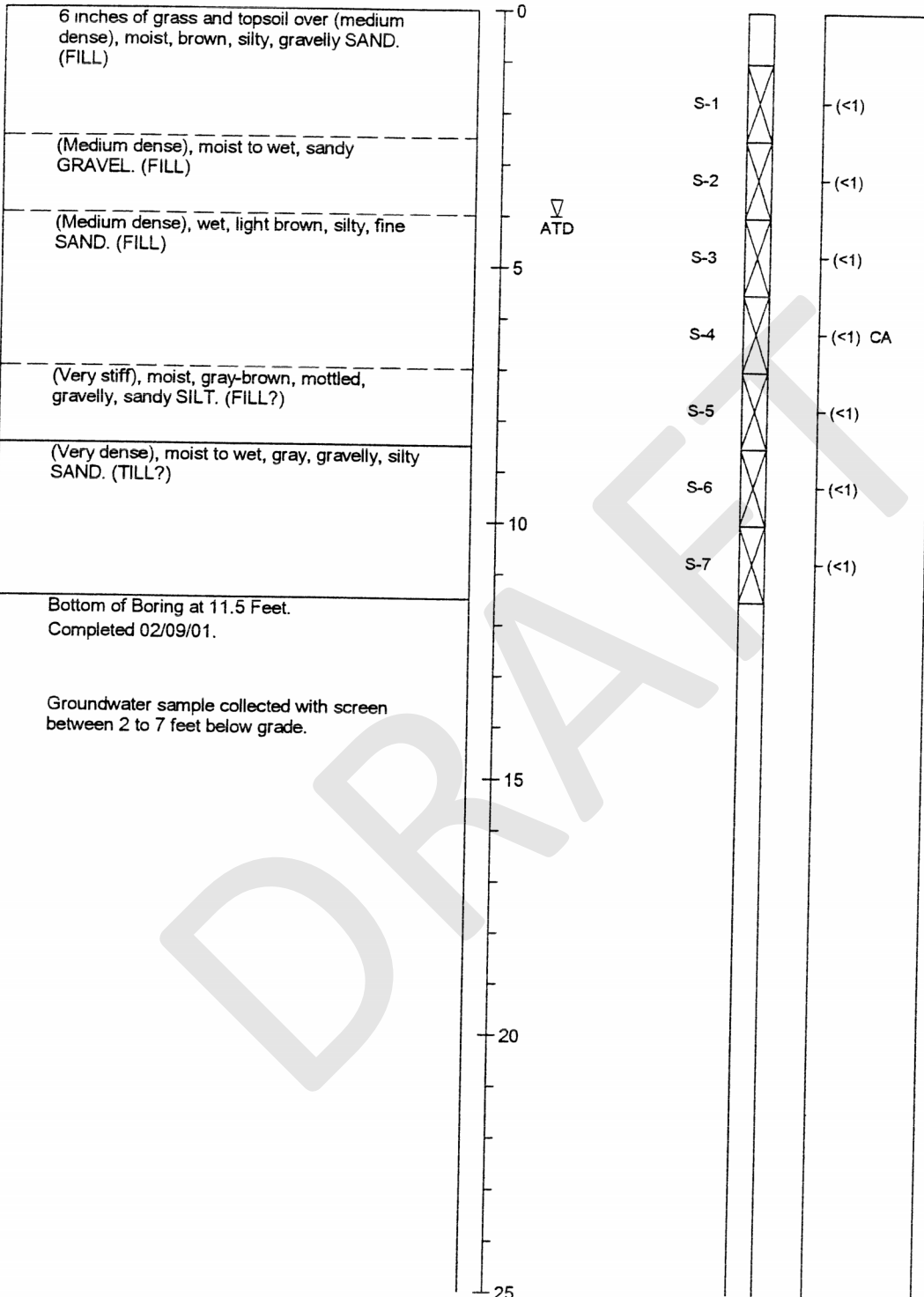
Approx. Ground Surface Elevation in Feet: 305

Depth
in Feet

Sample

LAB
TESTS
& (PID)

|| A_SB899 ||



STRATAPROBE 497836STGPJ HC CORP GDT 10 31 01

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. Ground surface elevation estimated from topo referenced map.

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4978-36 (804/805) 02/01

Figure A-2

Strataprobe Boring Log HC01-B402

3RDRW-B402
(1574)

Soil Descriptions

Approx. Ground Surface Elevation in Feet: 302

Depth
in Feet

Sample

LAB
TESTS
& (PID)

6 inches of grass and topsoil over (loose), moist to wet, dark brown, very silty, fine SAND with roots. (FILL)
(Medium dense), moist, dark brown, slightly gravelly, slightly silty SAND. (FILL)
(Medium dense), wet, brown, slightly silty, slightly gravelly SAND. (FILL?)
(Medium stiff to stiff), moist, gray-brown mottled, gravelly, sandy SILT. (FILL)
(Dense), moist, gray, gravelly, silty SAND. (FILL?)

Bottom of Boring at 8.5 Feet.
Completed 02/09/01.

Groundwater sample collected with screen
between 3.5 to 8.5 feet below grade.



S-1
S-2
S-3
S-4
S-5

(<1)
(<1)
(<1) CA
(<1)
(<1)

|| A_SB900 ||

STRATAPROBE 497836ST GPJ HC CORP GDT 6/19/01

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. Ground surface elevation estimated from topo referenced map.



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4978-36 (804/805)02/01

Figure A-3

Strataprobe Boring Log HC01-B403

3RDRW-B403
(1574)

Soil Descriptions

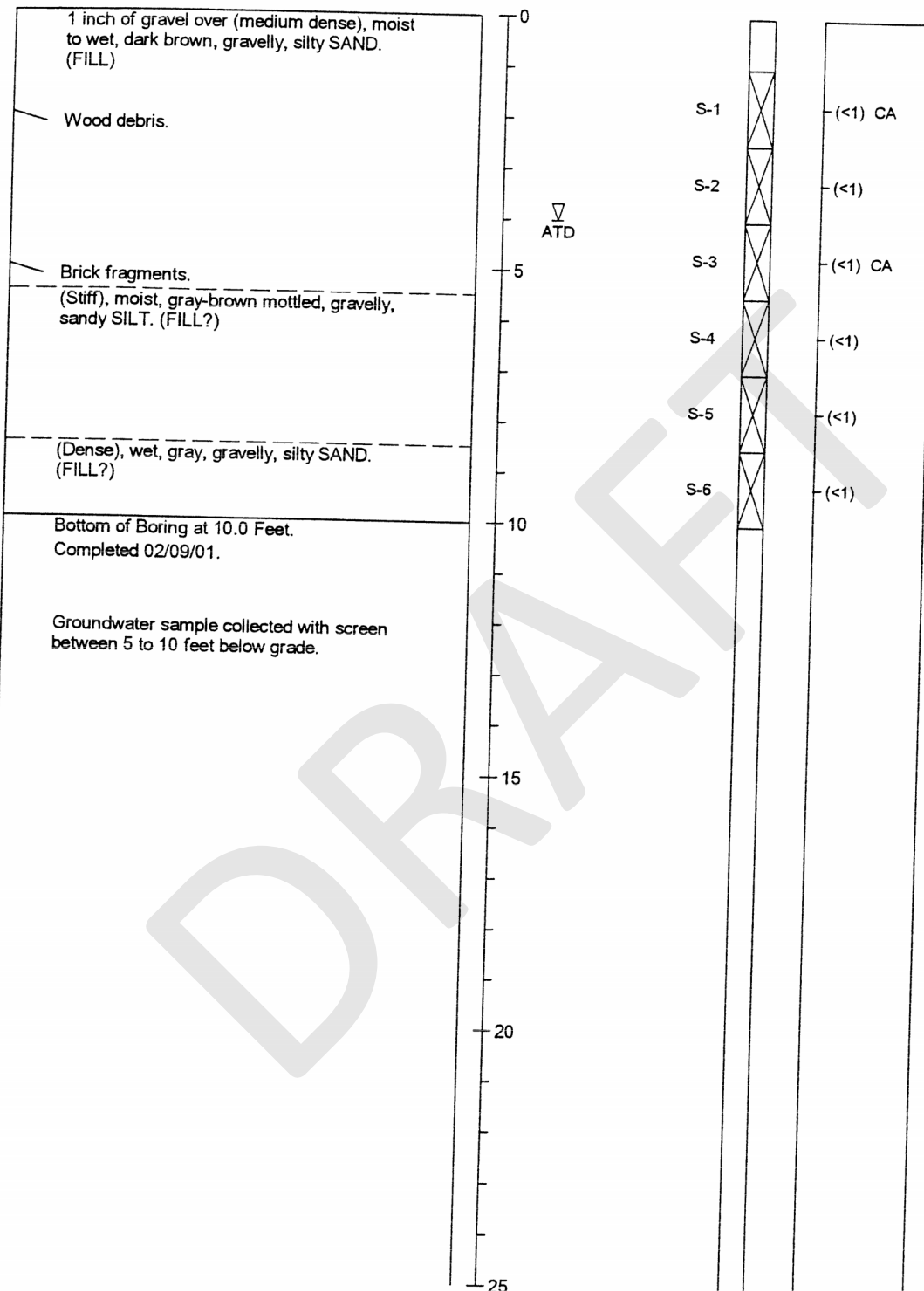
Approx. Ground Surface Elevation in Feet: 304

Depth
in Feet

Sample

LAB
TESTS
& (PID)

|| A_SB901 ||



STRATAPROBE 497836ST.GPJ HC_CORP.GDT 10 31 01

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. Ground surface elevation estimated from topo referenced map.



HARTCROWSER

4978-36 (804/805) 02/01

Figure A-4

Strataprobe Boring Log HC01-B404

3R0RW-B404
(1574)

Soil Descriptions

Approx. Ground Surface Elevation in Feet: 304

Depth
in Feet

Sample

LAB
TESTS
& (PID)

|| A_SB902 ||

1 inch of gravel base over moist, gray-brown, slightly silty, gravelly SAND. (FILL)	0
(Medium stiff), moist to wet, gray-brown mottled, slightly sandy SILT. (FILL)	5
(Medium dense), wet, brown, slightly gravelly, silty SAND. (FILL)	10
(Dense), wet, gray, silty, gravelly SAND. (TILL?)	15
Bottom of Boring at 13.0 Feet. Completed 02/08/01.	20
Groundwater sample collected with screen between 8 to 13 feet below grade.	25

S-1	(<1)
S-2	(<1)
S-3	(<1)
S-4	(<1) CA
S-5	(<1)
S-6	(<1)
S-7	(<1)
S-8	(<1)

STRATAPROBE 497836ST GPJ HC CORP GDT 10 31 01

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. Ground surface elevation estimated from topo referenced map.



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4978-36 (804/805) 02/01

Figure A-5

Strataprobe Boring Log HC01-B405

32DRW - B405
(1574)

Soil Descriptions

Approx. Ground Surface Elevation in Feet: 306

Depth
in Feet

LAB
TESTS
& (PID)

Asphalt over (medium dense), wet, brown, slightly silty, gravelly SAND. (FILL)
(Dense), very gravelly SAND and (medium stiff to stiff), moist, gray-brown mottled, gravelly, sandy SILT. (FILL)
(Dense), wet, gray, silty, gravelly SAND. (TILL?)
Bottom of Boring at 8.5 Feet. Completed 02/12/01.
Groundwater sample collected with screen between 3.5 to 8.5 feet below grade.



S-1
S-2
S-3
S-4
S-5

(<1)
(<1)
(<1) CA
(<1)
(<1)

|| A_SB903 ||

STRATAPROBE 497836ST GPJ HC CORP.GDT 6/19/01

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. Ground surface elevation estimated from topo referenced map.



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4978-36 (804/805)02/01

Figure A-6

Strataprobe Boring Log HC01-B406

3RDRW-B406
(1574)

Soil Descriptions

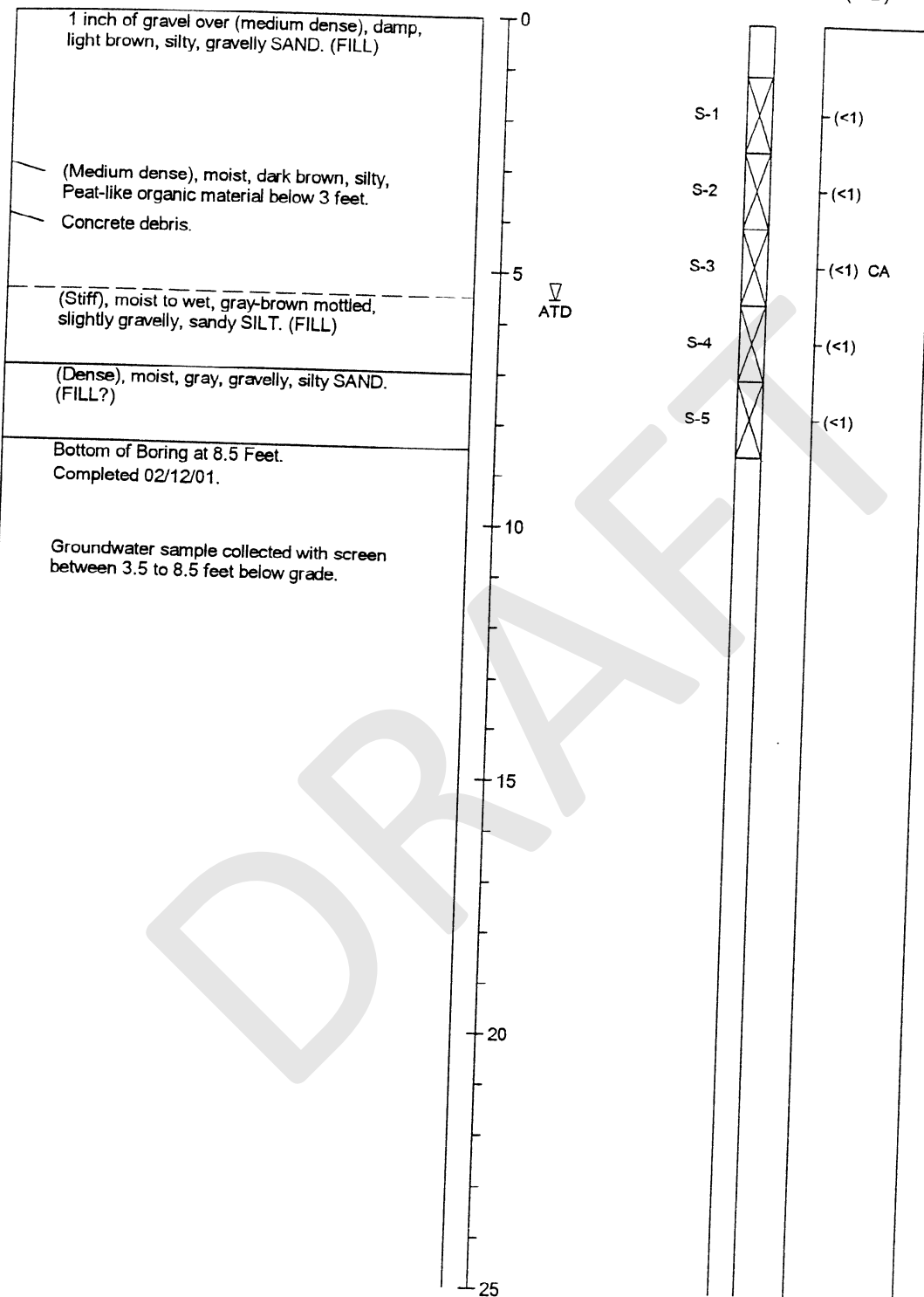
Approx. Ground Surface Elevation in Feet: 302

Depth
in Feet

Sample

LAB
TESTS
& (PID)

|| A_SB904 ||



STRATAPROBE 497836STGPJ HC_CORP GDT 10 31 01

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. Ground surface elevation estimated from topo referenced map.

HARTCROWSER

4978-36 (804/805) 02/01

Figure A-7

Strataprobe Boring Log HC01-B407

3RDRW - B 407
(1574)

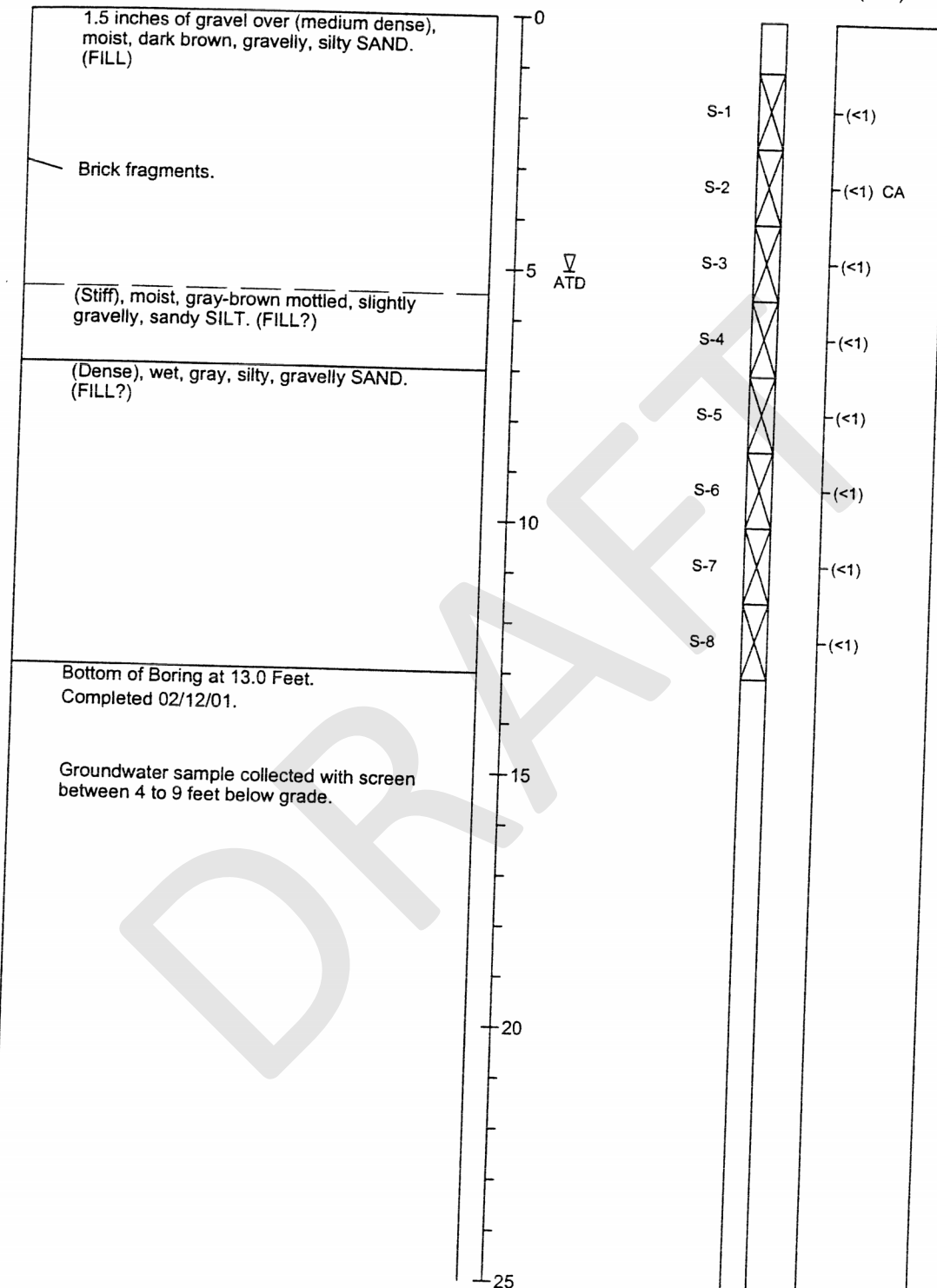
Soil Descriptions

Approx. Ground Surface Elevation in Feet: 301

Depth
in Feet

Sample

LAB
TESTS
& (PID)



STRATAPROBE 497836ST GPJ HC CORP GDT 6/19/01

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.
4. Ground surface elevation estimated from topo referenced map.

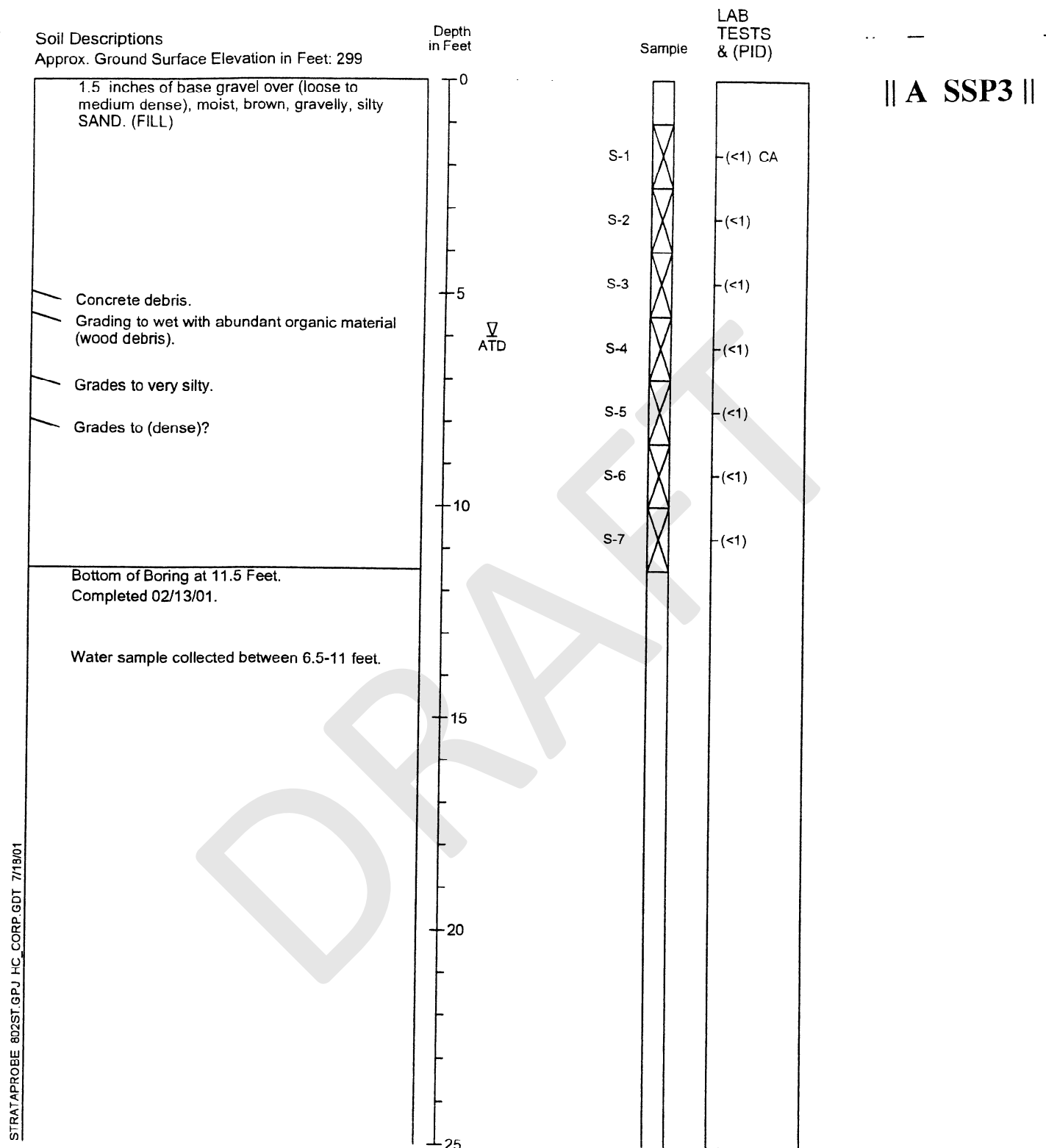


HARTCROWSER

4978-36 (804/805)02/01

Figure A-8

Strataprobe Boring Log HC01-B408



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.


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4978-36 (802) 02/01

Figure A-2

Strataprobe Boring Log HC01-B409

|| A SSP4 ||

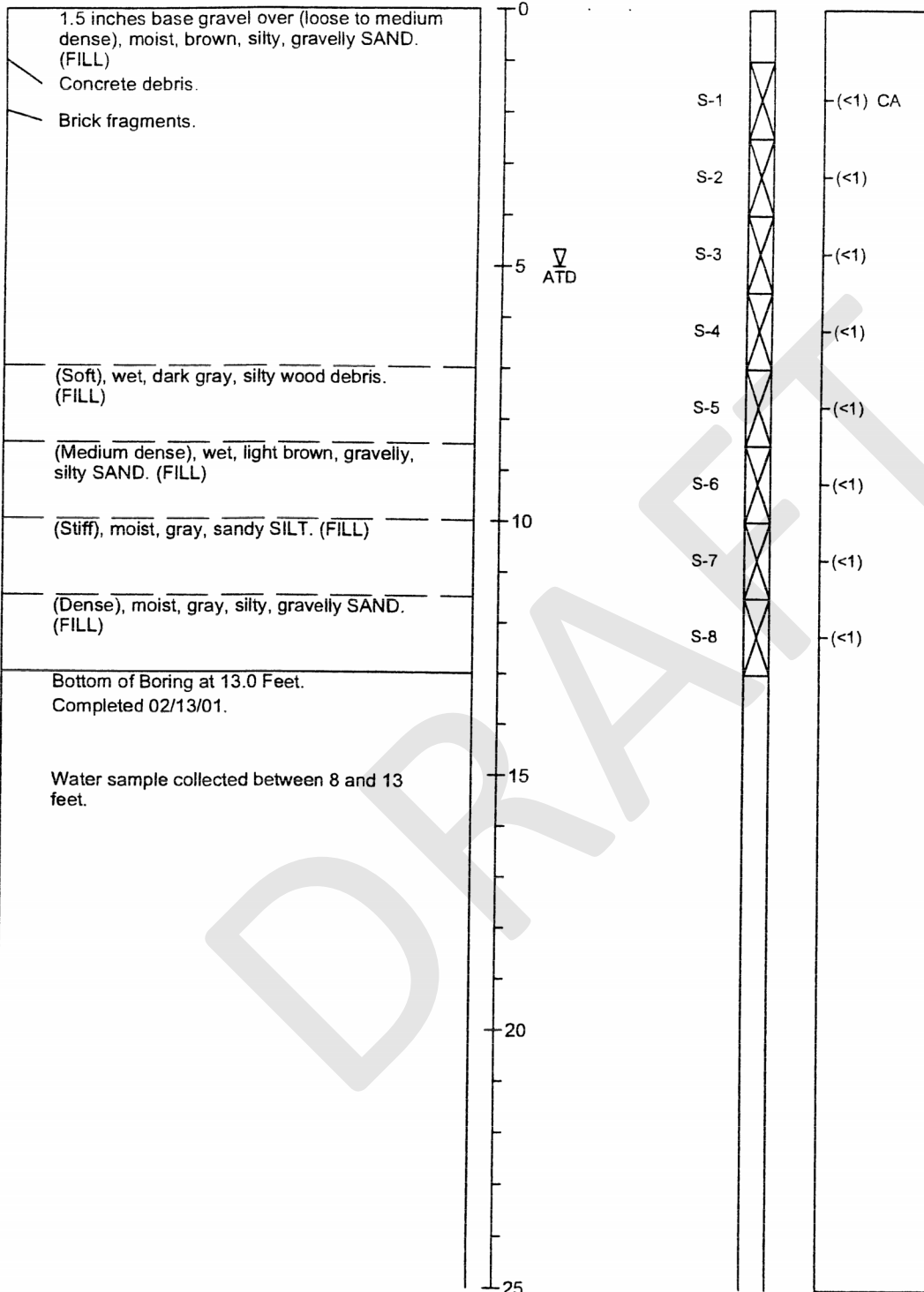
Soil Descriptions

Approx. Ground Surface Elevation in Feet: 299

Depth
in Feet

Sample

LAB
TESTS
& (PID)



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.



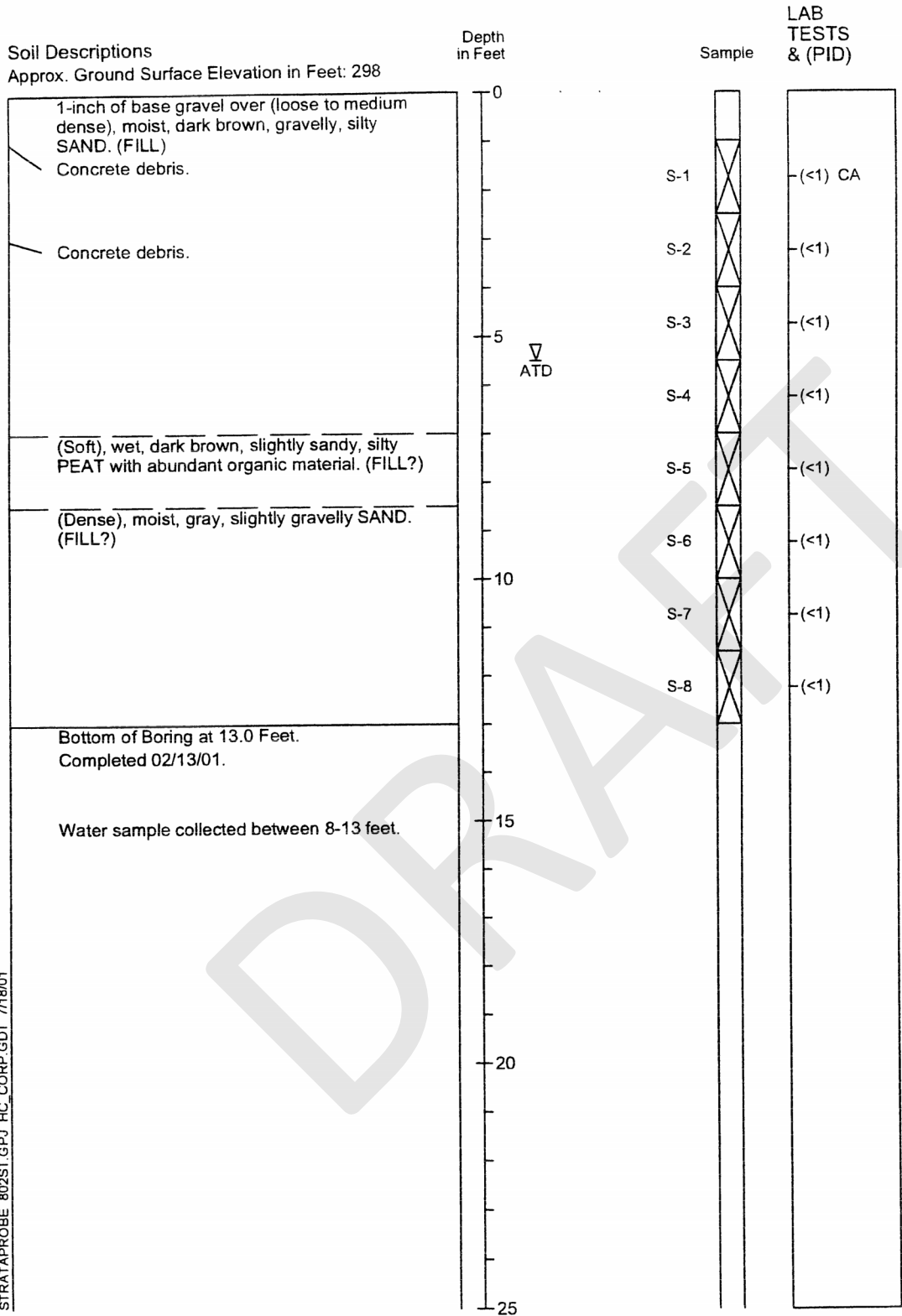
HARTCROWSER

4978-36 (802) 02/01

Figure A-3

Strataprobe Boring Log HC01-B410

|| A SSP5 ||



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

Strataprobe Boring Log HC01-B411

3RDRW-B~~411~~ 411
(1577)

Soil Descriptions

Approx. Ground Surface Elevation in Feet: 290

Depth
in Feet

Sample

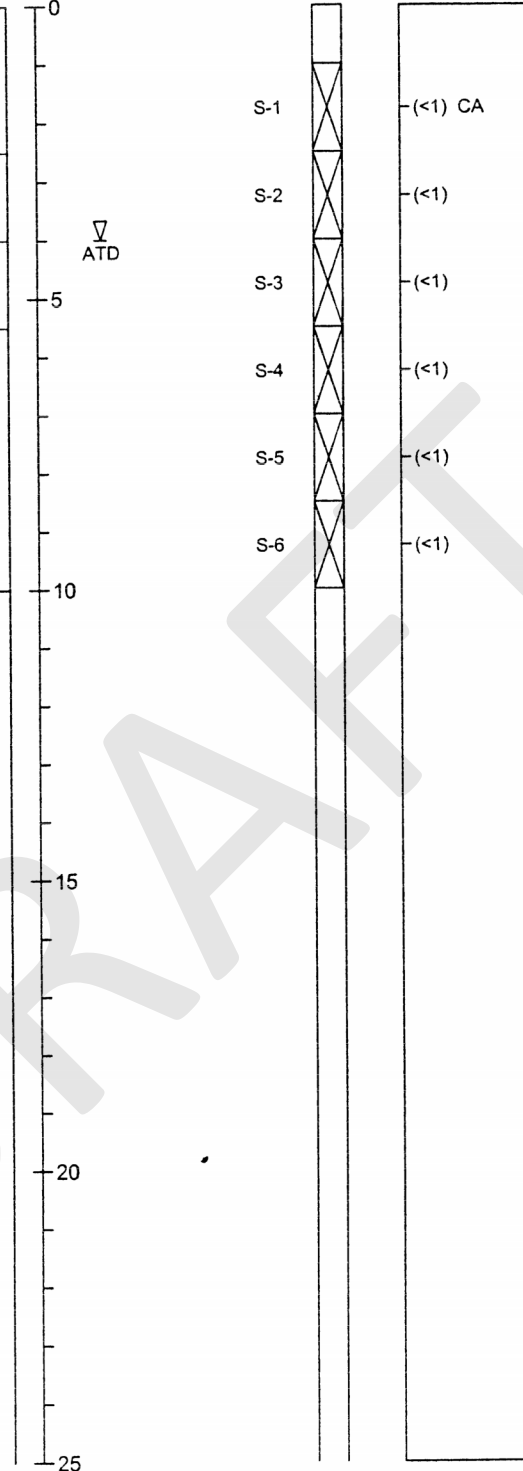
LAB
TESTS
& (PID)

|| A_SB893 ||

1.5 inches of base gravel over (loose to medium dense), moist, gray, silty, gravelly SAND. (FILL)
(Loose to medium dense), moist to wet, dark brown, slightly sandy, silty PEAT. (Fill)
(Medium stiff), moist, gray-brown mottled, slightly gravelly, sandy SILT. (Fill)
(Dense to very dense), gray, moist, silty, gravelly SAND. (TILL)

Bottom of Boring at 10.0 Feet.
Completed 02/13/01.

Groundwater sample collected for chemical analysis with screen at depth of 5 to 10 feet.



STRATAPROBE 497836ST GPJ HC CORP GDT 7/13/01

Appendix B



HARTCROWSER

4978-36 (803) 02/01

Figure A-2

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

Strataprobe Boring Log HC01-B412

3RARW - B412

(1577)

Soil Descriptions

Approx. Ground Surface Elevation in Feet:

Depth
in Feet

Sample

LAB
TESTS
& (PID)

|| A_SB894 ||

1 foot of topsoil and organics over (loose), damp, dark gray, silty, gravelly SAND. (FILL)
Concrete debris.
(Soft), moist, dark brown, slightly silty, sandy PEAT. (FILL)
(Medium stiff to medium dense), wet, gray to gray-brown mottled, very silty SAND to very sandy SILT. (FILL)
(Medium dense to dense), wet, gray, slightly gravelly, slightly silty SAND. (FILL)
(Dense), moist, light gray, very silty, gravelly SAND. (TILL)

0

5
ATD

10

15

20

25

S-1

(<1)

S-2

(<1)

S-3

(<1) CA

S-4

(<1)

S-5

(<1)

S-6

(<1)

S-7

(<1)

Bottom of Boring at 11.5 Feet.
Completed 02/13/01.

Groundwater sample collected for chemical
analysis with screen at depth of 6.5 to 11.5
feet.

STRATAPROBE 497836ST GPJ HC CORP GDT 10 31 01



HARTCROWSER

4978-36 (803) 02/01

Figure A-3

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

Strataprobe Boring Log HC01-B414

3RDRW-B414
(1578)

Soil Descriptions

Approx. Ground Surface Elevation in Feet: 0

Depth
in Feet

Sample

LAB
TESTS
& (PID)

|| A_SB896 ||

Asphalt over (medium dense), moist to wet,
gray, silty, fine SAND. (FILL)

Wood debris.

(Medium dense), wet, dark brown, slightly
silty, gravelly SAND. (FILL)

Wood debris.

(Dense), moist, light brown, gravelly, silty
SAND. (TILL)

Bottom of Boring at 10.0 Feet.
Completed 02/14/01.

Groundwater sample collected for chemical
analysis with screen at depth of 5 to 10 feet.

▽
ATD

S-1

-(<1)

S-2

-(<1)

S-3

-(<1) CA

S-4

-(<1)

S-5

-(<1)

S-6

-(<1)

10

15

20

25

STRATAPROBE 497836ST GPJ HC CORP GDT 6/28/01

APPENDIX D

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.



HARTCROWSER

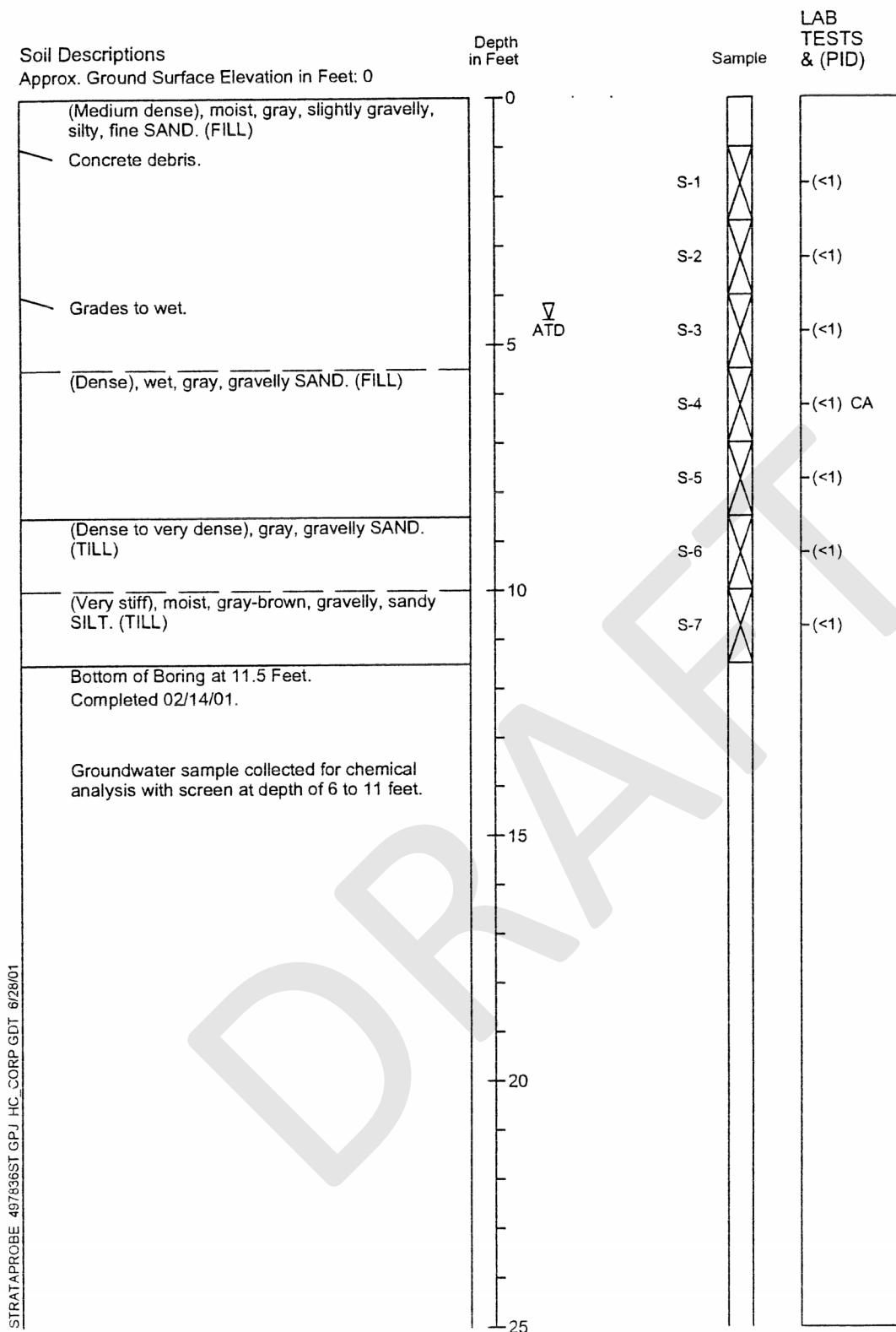
4978-36 (810) 02/01

Figure A-2

Strataprobe Boring Log HC01-B415

3RDRW-B415

(1578)



|| A_SB897 ||



HARTCROWSER

4978-36 (810) 02/01

Figure A-3

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

Strataprobe Boring Log HC01-B416

3RDRW-B416
(# 1578)

Soil Descriptions
Approx. Ground Surface Elevation in Feet: 0

Depth
in Feet

Sample
LAB
TESTS
& (PID)

|| A_SB898 ||

Asphalt over (medium dense), moist, gray-brown, very silty, fine SAND.
(Medium stiff), wet, gray, sandy SILT with trace peat.
(Medium dense), wet, gray, slightly silty, slightly gravelly SAND.
(Very dense), moist, light brown, silty, gravelly SAND. (TILL)

Bottom of Boring at 8.5 Feet.
Completed 02/14/01.

Groundwater sample collected for chemical analysis with screen at depth of 3.5 to 8.5 feet.

0
5
10
15
20
25

▽
ATD

S-1
S-2
S-3
S-4
S-5

(<1)
(<1)
(<1) CA
(<1)
(<1)

STRATAPROBE 497836ST GPJ HC CORP GDT 6/28/01

Annex B



HARTCROWSER

4978-36 (810) 02/01

Figure A-4

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

Hand-Auger Boring Log HC01-B417

|| A_SB1006 ||

Sample

Lab
Tests

PID

Depth
in Feet

SOIL DESCRIPTIONS

Approx. Ground Surface Elevation in Feet: 292

S-1

CA

<1

0
1
2
3
4
5

6 inches Base Gravel over (loose to medium dense), dark brown, gravelly, silty SAND. (FILL)

Bottom of Exploration at 3.0 Feet.
Completed 02/14/01.

DRAFT

2 LOGS PER PAGE 802HA.GPJ HC_CORP.GDT 7/18/01



HARTCROWSER

4978-36 (802)

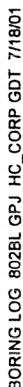
02/01

Figure A-5

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater conditions, if indicated, are at time of excavation. Conditions may vary with time.

Boring Log for Monitoring Well HC01-MW1

|| A MW855 ||



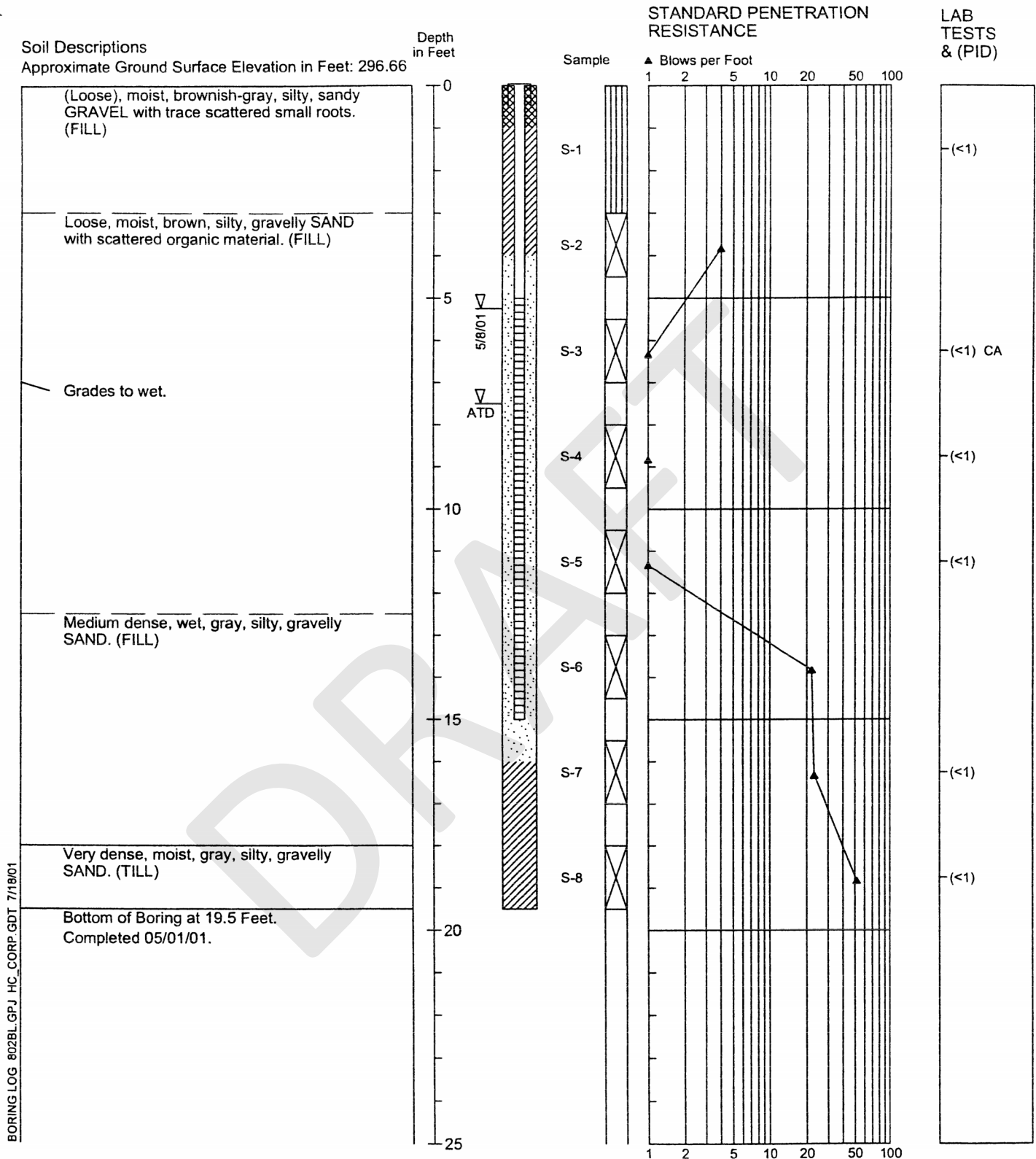
- 

J-4978-36 (802) 04/01

Figure A-10

Boring Log for Monitoring Well HC01-MW2

|| A MW856 ||



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

Boring Log for Monitoring Well HC01-MW3

|| A MW857 ||

Soil Descriptions

Approximate Ground Surface Elevation in Feet: 300

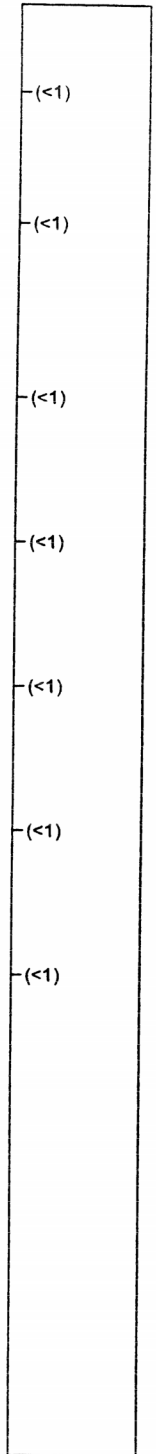
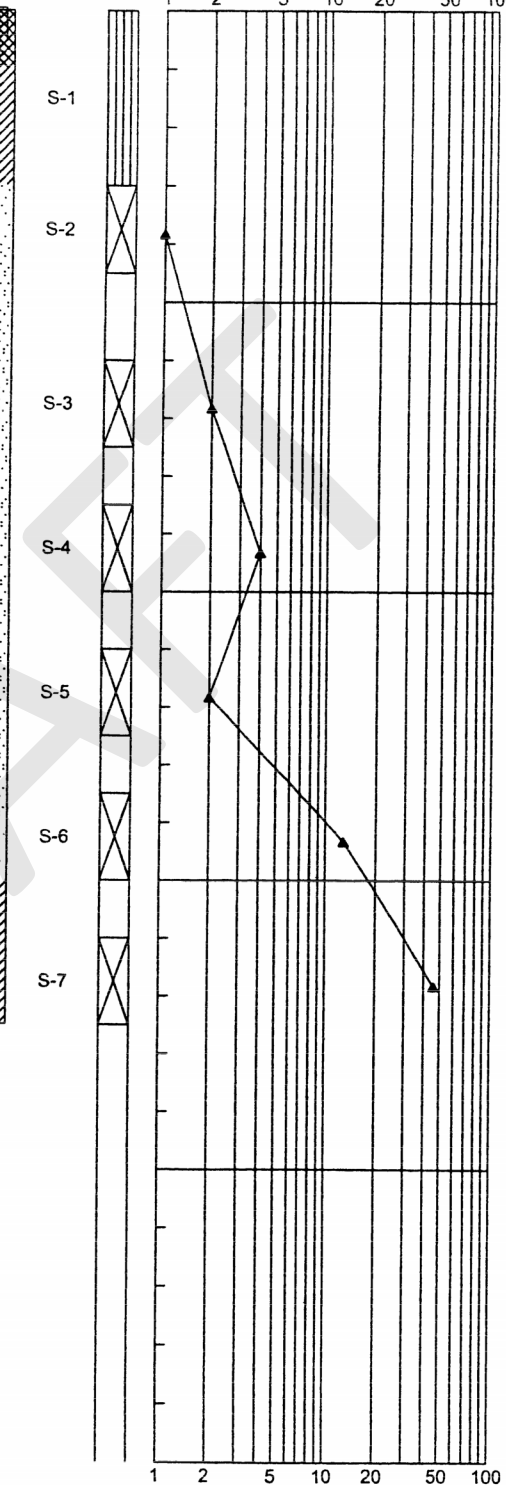
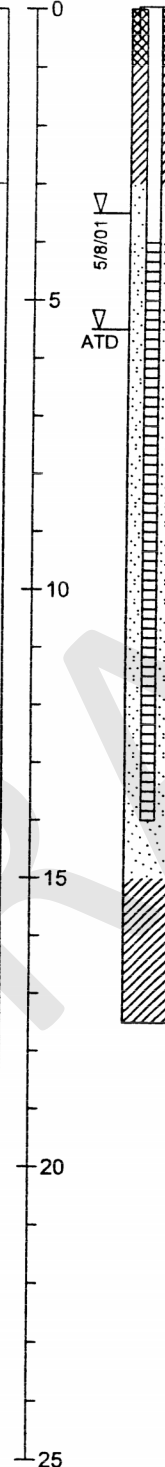
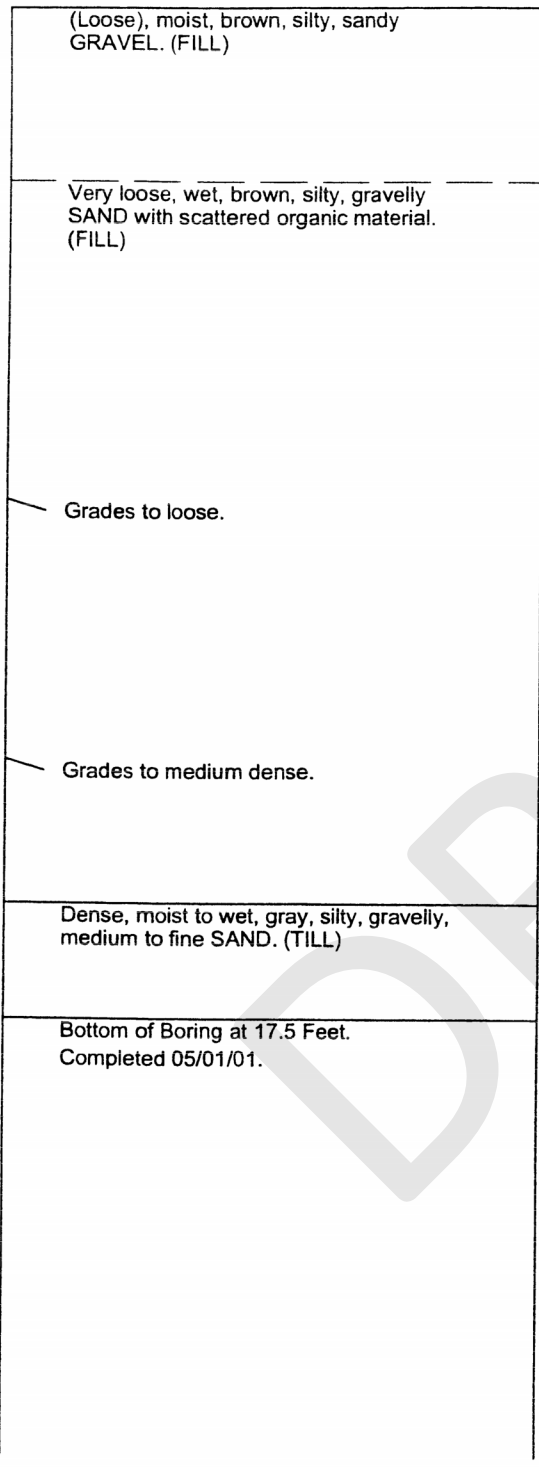
Depth
in Feet

STANDARD PENETRATION RESISTANCE

LAB
TESTS
& (PID)

▲ Blows per Foot
1 2 5 10 20 50 100

Sample



BORING LOG 802BL.GPJ HC CORP.GDT 7/18/01

HARTCROWSER

J-4978-36 (802) 05/01

Figure A-12

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

APPENDIX D
Hydrogeologic Monitoring and Characterization

Appendix D

Hydrogeologic Monitoring and Characterization

This appendix documents the hydrogeological characterization of the Seatac IWTP site to support planning, design, and considerations for construction and operation of the completed facilities. This appendix includes information on the following subjects:

- Groundwater Monitoring Activities;
- Hydraulic Properties of Site Soils;

Groundwater Monitoring Activities

Groundwater conditions were observed during drilling and in monitoring wells and vibrating wire piezometers installed on site. Dedicated monitoring wells were completed in eight borings in June 2025 (W-1, W-2, W-3, W-4, W-5, W-6, W-7, and W-9) and screened from approximately 7 to 50 feet below ground surface (bgs). Two VWP's were installed in boring W-8 at depths of approximately 40 and 59 feet bgs to monitor groundwater pressure within the Glacial Outwash unit. A summary of monitoring well and VWP construction is contained in Table 1 in the main text of this report. VWP calibration sheets are included in Appendix A.

Manual groundwater level measurements were completed during site visits in June to August 2025 during well development, groundwater sampling, slug testing, and groundwater monitoring activities. Manual groundwater level measurements are attached in Table D-1. Detailed description of field activities is included in Appendix A. Long-term groundwater monitoring is being performed using pressure transducers with integrated data loggers installed in monitoring wells (W-2, W-3, W-4, W-5) and with the VWP's installed in W-8. A barometric pressure instrument was installed in W-3's monument to measure atmospheric pressure for compensation of pressure transducers. Groundwater hydrographs depicting precipitation trends and continuous groundwater monitoring data from each monitoring well and from VWP's are shown in Figures D-1 to D-3.

Groundwater was encountered within the Fill unit during drilling at depths of approximately 5 feet bgs. Based on our review and understanding of the available subsurface information at the site, we understand the shallow groundwater is indicative of a perched groundwater table within or at the bottom of the existing Fill unit.

Wet soils were encountered in granular lenses within the Glacial Till unit during drilling and in monitoring wells completed in the Glacial Till. Groundwater within the Glacial Till ranges from approximately 274 to 296 feet elevation.

Pressurized groundwater conditions were encountered within the Glacial Outwash unit at the time of drilling. Groundwater levels within wells screened in the Glacial Outwash unit (W-4, W-6, W-7, W-9) indicate artesian conditions in which the piezometric level is higher than the top of the Glacial Outwash unit. Piezometric levels in the Glacial Outwash unit ranged from approximately 4.5 feet bgs (W-4) to flowing artesian conditions with piezometric levels above the ground surface (W-1, W-6, W-7, W-9). Groundwater pressure in the Glacial Outwash unit ranges from approximately 302 to 309 feet elevation.

Groundwater level hydrographs show generally stable groundwater conditions at all monitoring locations, fluctuating less than 1 foot throughout the monitoring period. Unconfined groundwater generally flows from north to south. Monitoring locations within the Glacial Till unit (W-2, W-3, and

W-5) show the groundwater level was highest at W-3, averaging 295.4 feet elevation, and lowest at W-2, averaging 273.5 feet elevation. The average groundwater level measured by pressure transducer at W-4 within the Glacial Outwash unit was 302.2 feet elevation. Groundwater pressure detected by VWP's at W-8, converted to equivalent head, was highest at the deeper VWP, averaging 308.4 feet equivalent head, and lowest at the shallower VWP, averaging 305.6 feet equivalent head.

MANUAL GROUNDWATER LEVEL MEASUREMENTS

Manual groundwater levels measurements are a measurement and recording of the depth to water present in a well casing. Water level measurements were obtained at each monitoring well prior to purging, prior to slug testing, prior to transducer deployment, and during periodic site visits. All manual groundwater levels were measured using a Waterline Envirotech water level indicator and were recorded to the nearest 0.01 foot. Measurements were taken from the top of the well casing.

A summary of manual water level measurements is included in Table D-1.

LONG-TERM GROUNDWATER MONITORING

Long-term groundwater monitoring is being performed using pressure transducers with integrated data loggers installed in monitoring wells (W-2, W-3, W-4, W-5) and with VWP's installed in W-8. A barometric pressure instrument was installed in W-3's monument to measure atmospheric pressure for compensation of pressure transducers.

Transducer Data Processing

The general workflow for processing transducer data was barometric correction followed by conversion to groundwater elevation relative to the NAVD88 datum. Pressure data were mathematically corrected for barometric effects by subtracting barometric pressure from the total recorded pressure using readings from the BaroTroll located on site. The resulting water pressure was converted to feet of water above the transducer assuming freshwater density. The resulting water level above the transducer was tied to manual groundwater level(s) made at the time of transducer installation and/or during data downloads.

Barometric Efficiency

A barometric efficiency correction was applied to piezometric pressure data from W-4, as groundwater is pressurized at this well. Pressure transducers can inaccurately record real piezometric pressure when installed in a well which is screened within a confined aquifer. This is due to the difference in pressure being transmitted directly to the free surface of a well and the pressure being transmitted to groundwater in the aquifer itself (Ferris et al., 1962). This inaccuracy can be corrected by calculating barometric efficiency and applying it to the pressure transducer piezometric pressure readings (In-Situ, Inc., 2012). Barometric efficiency is the ratio of well water level change to barometric pressure change.

The barometric efficiency of W-4 was calculated by plotting the incremental change in barometric pressure versus the incremental change in water level. The resulting slope of the plot is the well barometric efficiency. The data from W-4 was then corrected using an equation from Gonthier, 2007.

The barometric efficiency at W-4 was calculated to equal -0.85. The negative slope is reflective of the inverse relationship between groundwater levels and atmospheric pressure change (i.e., water levels decline with an increase in atmospheric pressure).

Vibrating Wire Piezometer Data Processing

Measurements of VWP frequency and temperature were automatically converted to pressure by the dataloggers using the equations and constants found in the calibration sheets. Pressure values were converted to groundwater piezometric heads assuming freshwater density.

Results of Long-Term Groundwater Monitoring

Groundwater hydrographs from pressure transducers and VWPs are included in Figures D-1 to D-5.

Vertical Gradient

An upward vertical gradient of approximately 0.3 to 0.9 foot per foot (ft/ft) exists between the Glacial Outwash and Glacial Till units due to the pressurization of the Glacial Outwash. An upward gradient of approximately 0.1 ft/ft was measured within the Glacial Outwash unit between the two VWPs. Tables D-5 and D-6 show calculations for vertical gradient and a summary of results.

Hydraulic Properties of Site Soils

This section documents the processes Haley & Aldrich used to estimate hydraulic properties of water-bearing materials. Hydraulic properties of interest include hydraulic conductivity and storativity. The testing and analysis program included slug testing and grain size analysis.

Hydraulic conductivity of site soils was estimated from correlations with grain size data and from slug testing performed in monitoring wells. Hydraulic conductivity is a measure of the ability of aquifer materials to transmit groundwater and is controlled by the size, amount, and interconnection of void spaces in the water-bearing zones. Hydraulic conductivity is an important parameter in predicting the amount of water produced during potential construction dewatering and depressurization activities.

SLUG TESTING

Slug Testing Methodology

Slug testing is a procedure which involves rapidly displacing water in a well and measuring recovery to the static water level, typically with a solid PVC rod (Fetter, 2001). The rate of recovery is a function of the hydraulic conductivity of the water-bearing materials. A test conducted by raising the water level in the well is referred to as a “falling head” test, and a test which lowers the water level in a well is called a “rising head test”. Air-pressurized pneumatic slug testing is similar to slug testing but displaces water by pumping air into the sealed well casing, followed by release of the air and measuring the recovery to the static water level (Butler et al., 2003; Greene and Shapiro, 1995). As water is displaced below the static level by pressurized air, these tests are considered rising head tests.

Pneumatic slug testing was performed in wells W-2, W-3, W-4, and W-5. Test data were converted to elapsed time and displacement from static water levels. Slug test data were analyzed using the software program Aqtesolv v 4.50 (Duffield, 2007). Slug tests were analyzed using the Bouwer and Rice methodology (Bouwer and Rice, 1976; Bouwer, 1989) to obtain estimated values of hydraulic conductivity. Slug testing analysis parameters are contained in Table D-2.

Slug testing was not performed in W-1, W-6, W-7, or W-9 due to the flowing artesian conditions.

Slug Testing Results

Results of slug testing analysis are summarized in Table D-3. Representative line-fit plots for the Bouwer and Rice analyses are included in Figures D-3 to D-5 and hydrographs from slug testing are included in Figures D-4 and D-6. Mean hydraulic conductivity values were 1.4 feet per day (ft/day) (4.9×10^{-4} centimeters per second [cm/sec]) in the Fill unit, from 0.9 to 7.3ft/day (3×10^{-4} to 2.6×10^{-3} cm/sec) in the Glacial Till unit, and 5.2 feet per day ft/day (1.8×10^{-3} cm/sec) in the Advance Outwash Unit. These values are generally consistent with published ranges (Freeze and Cherry, 1979). In our experience, hydraulic conductivity of glacial till is typically one to two orders of magnitude less than measured. This discrepancy can be explained by the location of well W-2 screen in a cleaner sand lens within the Glacial Till unit.

GRAIN SIZE ANALYSIS

Grain size data for samples collected in the Glacial Outwash were analyzed to provide a range of likely hydraulic conductivity values within the unit to supplement the slug testing program. Estimates of hydraulic conductivity from grain size data were calculated using HydrogeoSieveXL, an Excel-based tool for estimation of hydraulic conductivity from grain size distribution data (Devlin, 2015). This tool uses 14 published relationships between grain size distribution parameters and hydraulic conductivity.

The tool calculates hydraulic conductivity using the empirical relationships and determines which methods are applicable based on the assumptions and limitations of each method. The arithmetic and geometric mean hydraulic conductivity of the applicable results are output by the tool.

Hydraulic conductivity estimates of the Glacial Outwash are contained in Table D-4. Outputs from HydrogeoSieveXL are attached in this appendix. Hydraulic conductivity ranges from 10 to 331 ft/day (3.6×10^{-3} to 1.2×10^{-1} cm/sec) in the Glacial Outwash Unit. Use of grain size methods to estimate hydraulic conductivity is often accurate only to the general order of magnitude (Eggleston and Rojstaczer, 2001). However, this provides insight into the potential variability of hydraulic conductivity within the Glacial Outwash to supplement the slug testing, which was possible only in W-4 screened in the Glacial Outwash.

Attachments:

- Table D-1 – Summary of Manual Groundwater Level Measurements
- Table D-2 – Summary of Slug Testing Analysis Parameters
- Table D-3 – Summary of Slug Testing Results
- Table D-4 – Summary of Grain Size Analysis Results
- Table D-5 – Summary of Groundwater Levels for Vertical Gradient Calculations
- Table D-6 – Summary of Vertical Gradients

- Figure D-1 – Groundwater Hydrographs W-2 and W-3
- Figure D-2 – Groundwater Hydrographs W-4 and W-5
- Figure D-3 – Groundwater Hydrograph W-8
- Figure D-4 – Slug Testing Hydrographs W-2 and W-3
- Figure D-5 – Representative Slug Testing Results W-2 and W-3
- Figure D-6 – Slug Testing Hydrographs W-4 and W-5
- Figure D-7 – Representative Slug Testing Results W-4 and W-5

- Attachment D-1 – HydrogeoSieveXL Outputs

References

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<https://haleyaldrich.sharepoint.com/sites/PortofSeattle/Shared Documents/0204661.POS SeaTac Mech and Elec IDIQ/002 IWTP Treatment Facility/Deliverables In-Basket/Geotech Report/Attachments/Appendices/Appendix D/Appendix D-Text.docx>

TABLE D-1**SUMMARY OF MANUAL GROUNDWATER LEVEL MEASUREMENTS**

SEA-TAC IWTP - AGB SITE

SEATAC, WASHINGTON

WELL ID	DATE AND TIME	REFERENCE ELEVATION (FEET)	DEPTH TO WATER (FEET)	GROUNDWATER ELEVATION (FEET)
W-2	6/27/25 13:23	279	4.88	274.12
W-2	7/9/25 8:22	279	5.06	273.94
W-2	7/9/25 10:18	279	5.06	273.94
W-2	7/10/25 8:16	279	5.08	273.92
W-2	7/10/25 9:53	279	5.19	273.81
W-2	8/4/25 8:46	279	5.34	273.66
W-2	8/4/25 10:21	279	5.36	273.64
W-3	6/27/25 12:37	304	8.08	295.92
W-3	7/9/25 12:36	304	8.38	295.62
W-3	7/9/25 13:26	304	8.38	295.62
W-3	7/10/25 11:45	304	8.37	295.63
W-3	7/10/25 13:15	304	8.52	295.48
W-3	8/4/25 14:15	304	8.78	295.22
W-3	8/4/25 14:25	304	8.73	295.27
W-4	6/27/25 15:42	307	4.42	302.58
W-4	7/9/25 11:35	307	4.50	302.50
W-4	7/9/25 12:27	307	4.49	302.51
W-4	7/10/25 13:30	307	4.49	302.51
W-4	7/10/25 14:57	307	4.48	302.52
W-4	8/4/25 10:31	307	4.69	302.31
W-4	8/4/25 10:45	307	4.67	302.33
W-5	6/27/25 15:42	292	5.12	286.88
W-5	7/9/25 10:26	292	5.26	286.74
W-5	7/9/25 11:22	292	5.21	286.79
W-5	7/10/25 10:09	292	5.29	286.71
W-5	7/10/25 11:26	292	6.10	285.90
W-5	8/4/25 11:01	292	5.39	286.61
W-5	8/4/25 13:47	292	5.48	286.52

Notes:*Elevations are in NAVD88 vertical datum*

TABLE D-2

SUMMARY OF SLUG TESTING ANALYSIS PARAMETERS

SEA-TAC IWTP - AGB SITE

SEATAC, WASHINGTON

WELL INFORMATION										SLUG TEST ANALYSIS INFORMATION (TESTED 7/9/2025)				
WELL ID	REFERENCE ELEVATION (FEET)	BORING DEPTH (FEET BGS)	WELL DEPTH (FEET BGS)	BOREHOLE DIAMETER (INCH)	SCREEN LENGTH (FEET)	SCREENED INTERVAL DEPTH (FEET BGS)	SCREENED INTERVAL ELEVATION (FEET)	SCREENED SOIL CLASSIFICATION(S)	SCREENED UNIT(S)	AQUIFER TYPE	DEPTH TO WATER (FEET BGS)	DEPTH TO SEDIMENT (FEET BGS)	DEPTH TO AQUIFER TOP (FEET BGS)	AQUIFER SATURATED THICKNESS (FEET)
W-2	279	25	23	6	10	13 - 23	256 - 266	Silt with sand (ML), silty sand (SM), poorly-graded sand (SP)	Glacial Till	Unconfined	5.48	23.45	5.48	17.52
W-3	304	25	20	6	10	10 - 20	284 - 294	Silty sand (SM)	Fill, Glacial Till	Unconfined	8.60	20.25	8.60	11.40
W-4	307	45	45	6	5	40 - 45	262 - 267	Poorly-graded sand with silt and gravel (SP-SM)	Glacial Outwash	Confined	4.80	45.13	32.30	12.70
W-5	292	30	12	6	5	7 - 12	280 - 285	Silty sand with gravel (SM)	Glacial Till	Unconfined	5.68	12.35	5.58	6.32

Notes:*bgs = below ground surface**Elevations are in NAVD88 vertical datum*

TABLE D-3

SUMMARY OF SLUG TESTING RESULTS

SEA-TAC IWTP - AGB SITE

SEATAC, WASHINGTON

WELL ID	SCREENED UNIT	TEST NUMBER	BOUWER AND RICE		
				K (FEET/DAY)	K (CM/SEC)
W-2	Glacial Till	1		7.2	2.5E-03
		2		7.6	2.7E-03
		3		7.3	2.6E-03
			G. Mean	7.3	2.6E-03
W-3	Fill, Glacial Till	1		1.3	4.6E-04
		2		1.4	5.1E-04
		3		1.4	5.1E-04
			G. Mean	1.4	4.9E-04
W-4	Glacial Outwash	1		4.9	1.7E-03
		2		5.5	1.9E-03
		3		5.1	1.8E-03
			G. Mean	5.2	1.8E-03
W-5	Glacial Till	1		0.7	2.5E-04
		2		1.0	3.4E-04
		3		0.9	3.1E-04
			G. Mean	0.9	3.0E-04

Notes:*G. mean is the geometric mean value*

TABLE D-4**SUMMARY OF GRAIN SIZE ANALYSIS RESULTS FOR GLACIAL OUTWASH**

SEA-TAC IWTP - AGB SITE

SEATAC, WASHINGTON

EXPLORATION ID	SAMPLE ID	DEPTH	GEOMETRIC MEAN K (CM/SEC)	ARITHMETIC MEAN K (CM/SEC)	GEOMETRIC MEAN K (FEET/DAY)	ARITHMETIC MEAN K (FEET/DAY)
W-1	G-8	32.5	1.3E-02	1.4E-02	36	41
W-1	G-11	44	7.4E-03	2.2E-02	21	63
W-4	S-17	40	6.3E-02	5.6E-01	178	1,593
W-6	S-16	35	2.7E-02	1.0E-01	77	289
W-7	G-20	37.5	4.7E-02	8.3E-01	132	2,339
W-7	G-23	43.5	6.7E-02	8.7E-01	190	2,463
W-7	G-26	47.5	6.7E-02	5.3E-01	191	1,515
W-8	S-10	45	3.6E-03	7.8E-03	10	22
W-8	S-11a	50	2.0E-02	5.5E-02	57	155
W-9	G-7	33.5	7.2E-02	7.3E-01	204	2,065
W-9	G-11	47.5	7.8E-03	1.0E-02	22	29
W-9	G-13	54	1.2E-01	1.3E+00	331	3,659
Arithmetic Mean			4.3E-02	4.2E-01	121	1,186
Geometric Mean			2.8E-02	1.4E-01	80	410

TABLE D-5

SUMMARY OF GROUNDWATER LEVELS FOR VERTICAL GRADIENT CALCULATIONS

SEA-TAC IWTP - AGB SITE

SEATAC, WASHINGTON

LOCATION ID	SCREENED INTERVAL ELEVATION (FEET)	SCREEN MIDPOINT/ VWP ELEVATION (FEET)	SCREENED UNIT(S)	GROUNDWATER ELEVATION (FEET)
W-2	256 - 266	261	Glacial Till	273.61
W-3	284 - 294	289	Fill, Glacial Till	295.55
W-4	262 - 267	264.5	Glacial Outwash	302.3
W-5	280 - 285	282.5	Glacial Till	286.39
W-8	-	235	Glacial Outwash	305.95
	-	254		308.73

Notes:*VWP = Vibrating Wire Piezometer**Elevations are in NAVD88 vertical datum**Groundwater elevations recorded on VWPs and pressure transducers on July 6, 2025 at 10:20*

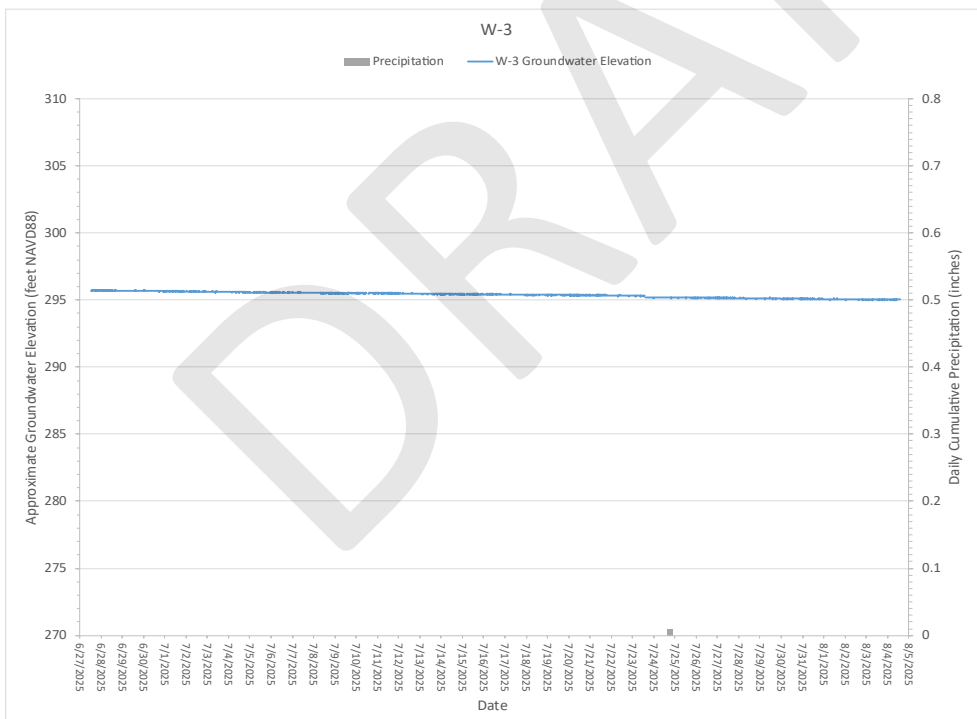
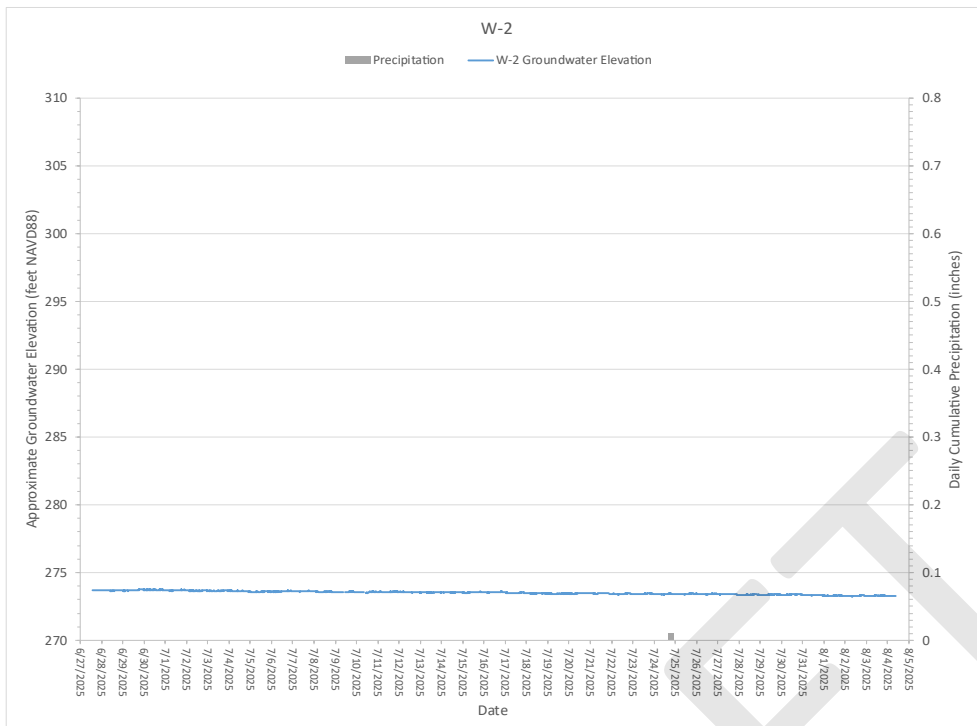
TABLE D-6**SUMMARY OF VERTICAL GRADIENTS**

SEA-TAC IWTP - AGB SITE

SEATAC, WASHINGTON

COMPARED SOIL UNITS	COMPARED LOCATION IDS	VERTICAL DISTANCE (FEET)	DIFFERENCE IN GROUNDWATER ELEVATION (FEET)	VERTICAL GRADIENT
Glacial Outwash to Glacial Outwash	W-4; W-8 (VWP - 235 ft)	29.5	-3.65	-0.1
	W-4; W-8 (VWP - 254 ft)	10.5	-6.43	-0.6
	W-8 (VWP - 235 ft); W-8 (VWP - 254 ft)	19.0	-2.78	-0.1
Glacial Outwash to Glacial Till	W-3; W-4	24.5	-6.76	-0.3
	W-5; W-4	18.0	-15.91	-0.9
	W-3; W-8 (VWP - 235 ft)	54.0	-10.40	-0.2
	W-5; W-8 (VWP - 235 ft)	47.5	-19.56	-0.4
	W-3; W-8 (VWP - 254 ft)	35.0	-13.18	-0.4
	W-5; W-8 (VWP - 254 ft)	28.5	-22.34	-0.8

Notes:*VWP = Vibrating Wire Piezometer**Elevations are in NAVD88 vertical datum**Groundwater elevations measured by VWPs and pressure transducers on July 6, 2025 at 10:20**Vertical distances are calculated as distance between screen midpoint elevation or VWP elevation**Differences in groundwater elevation are calculated from shallower well/VWP to deeper well/VWP**Negative sign on vertical gradients indicates upward direction*



Notes:

Elevations are in NAVD88 vertical datum

IWTP TREATMENT FACILITY
SEATAC, WASHINGTON

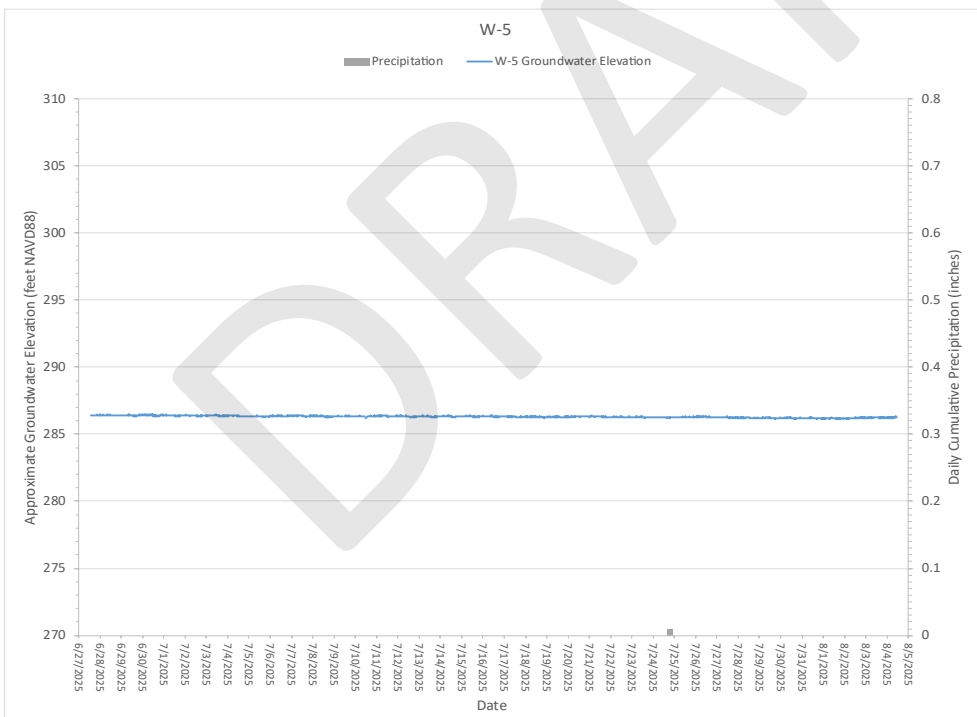
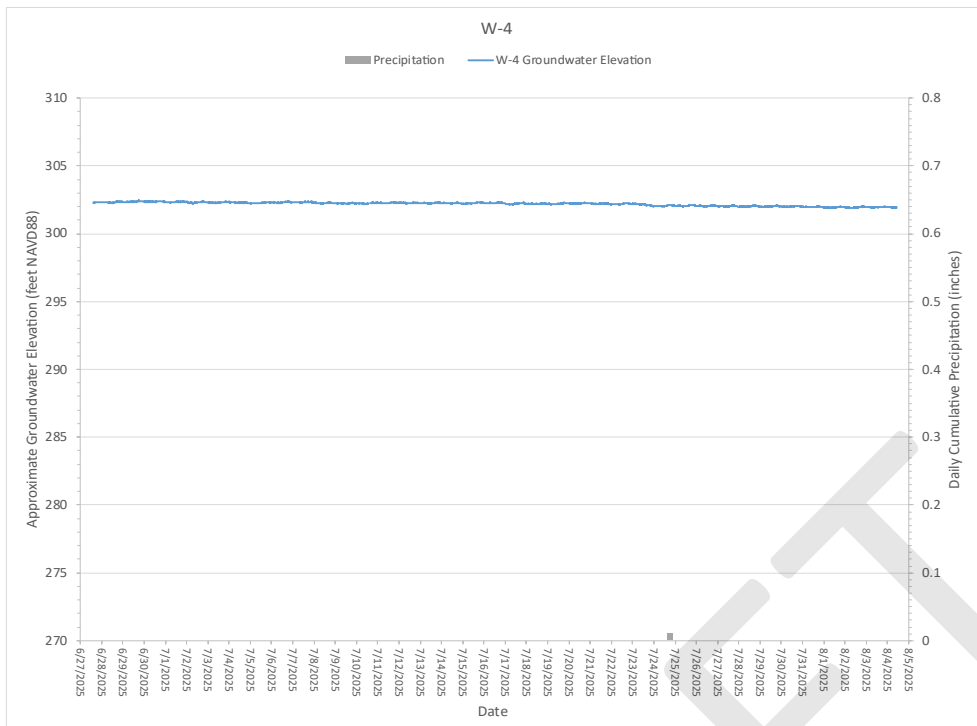
GROUNDWATER HYDROGRAPHS
W-2 AND W-3

AUGUST 2025

**HALEY
ALDRICH**

Figure

D-1



Notes:

Elevations are in NAVD88 vertical datum

IWTP TREATMENT FACILITY
SEATAC, WASHINGTON

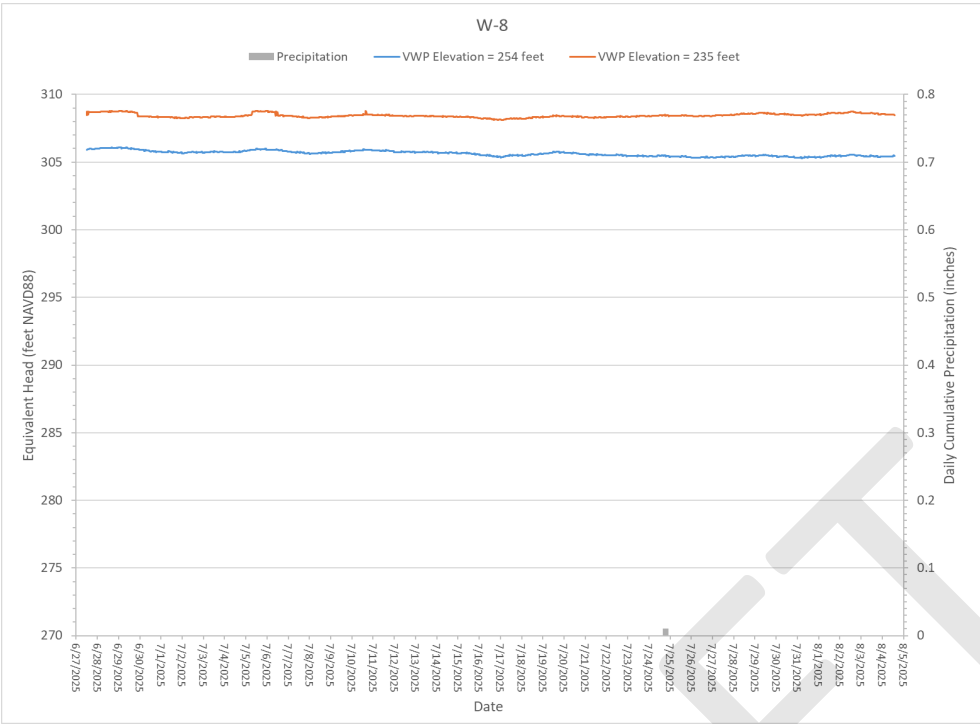
GROUNDWATER HYDROGRAPHS
W-4 AND W-5

AUGUST 2025

**HALEY
ALDRICH**

Figure

D-2



Notes:

Elevations are in NAVD88 vertical datum

IWTP TREATMENT FACILITY
SEATAC, WASHINGTON

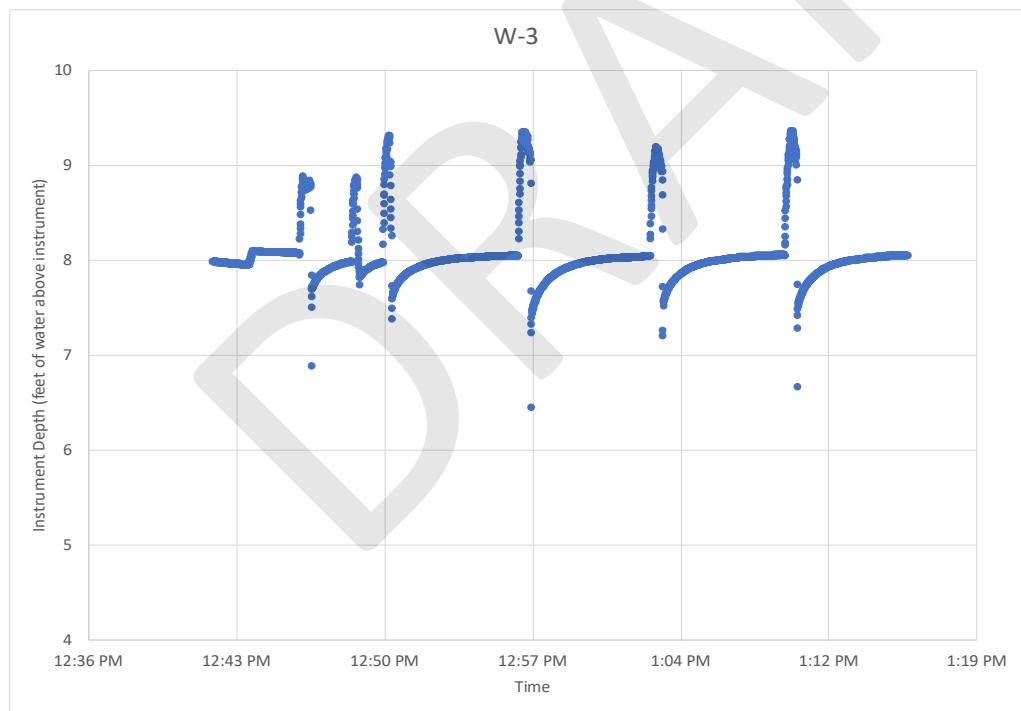
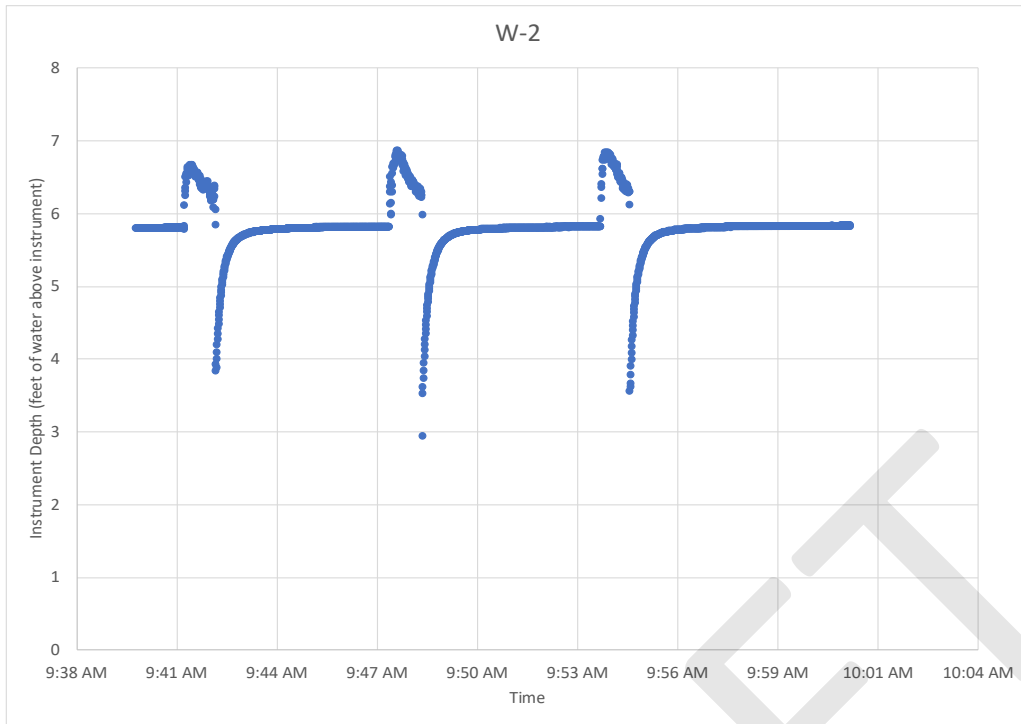
GROUNDWATER HYDROGRAPH
W-8

AUGUST 2025

HALEY
ALDRICH

Figure

D-3



Notes:

Elevations are in NAVD88 vertical datum

IWTP TREATMENT FACILITY
SEATAC, WASHINGTON

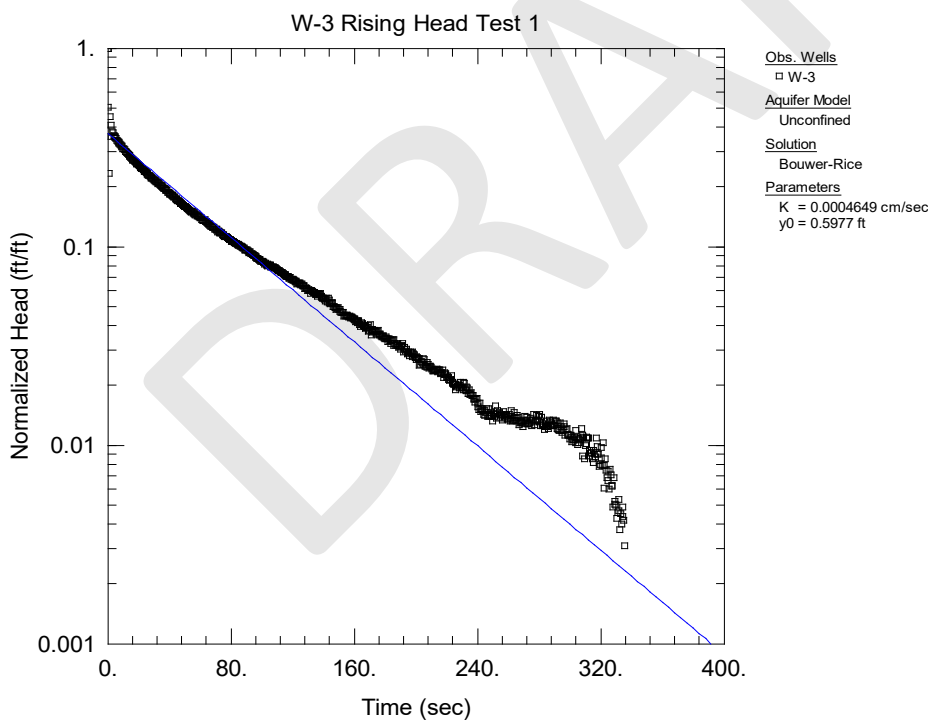
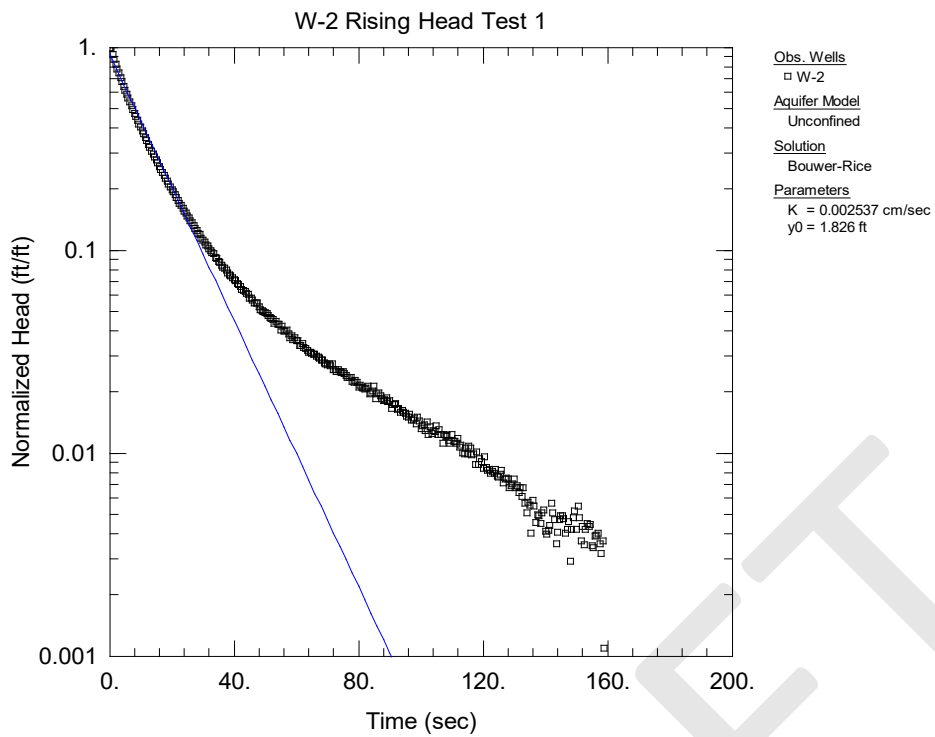
SLUG TESTING HYDROGRAPHS
W-2 AND W-3

AUGUST 2025

**HALEY
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Figure

D-4



Notes:

Elevations are in NAVD88 vertical datum

IWTP TREATMENT FACILITY
SEATAC, WASHINGTON

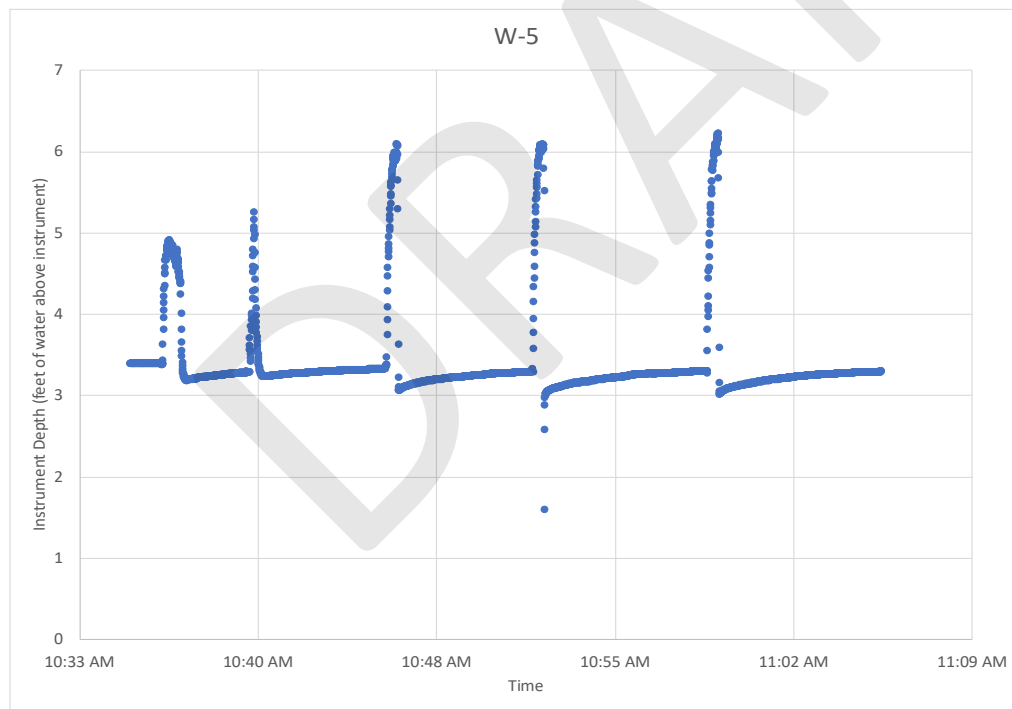
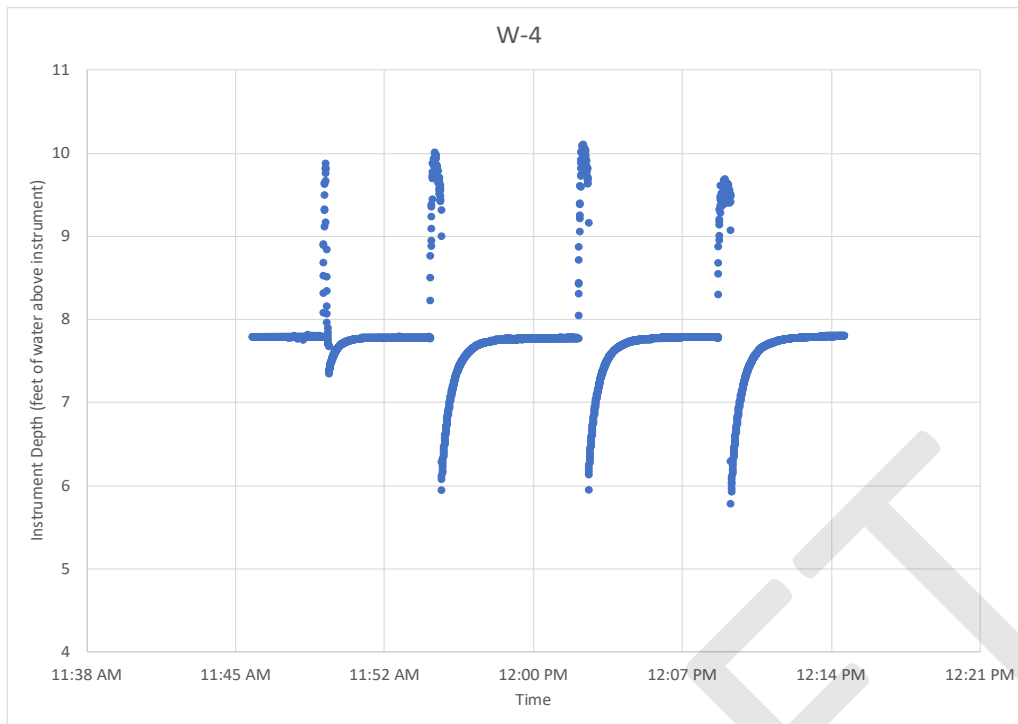
REPRESENTATIVE SLUG TESTING RESULTS
W-2 AND W-3

AUGUST 2025

**HALEY
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Figure

D-5



Notes:

Elevations are in NAVD88 vertical datum

IWTP TREATMENT FACILITY
SEATAC, WASHINGTON

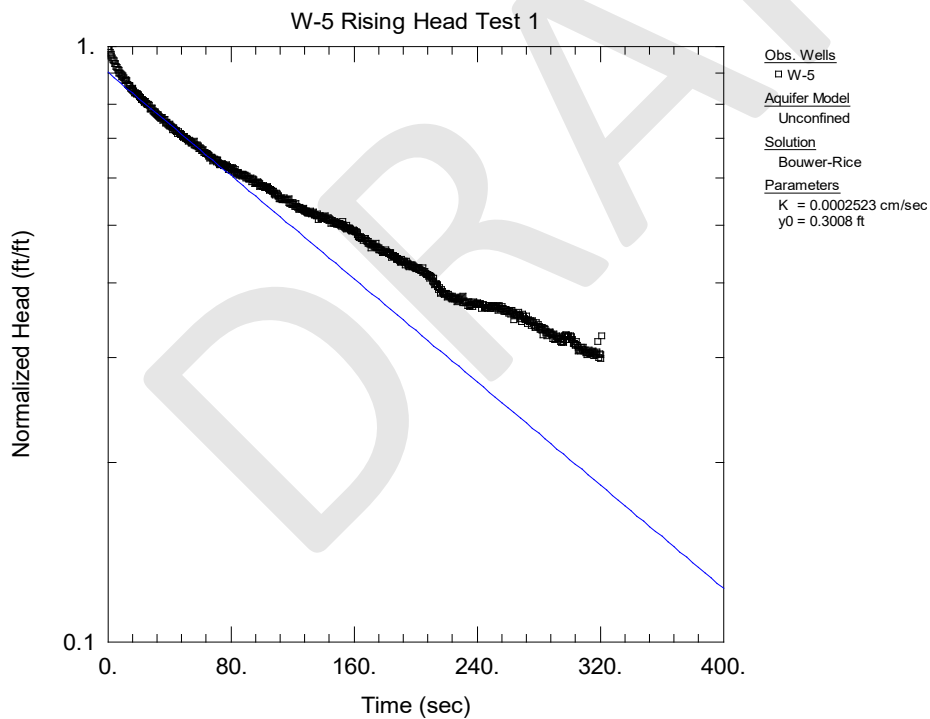
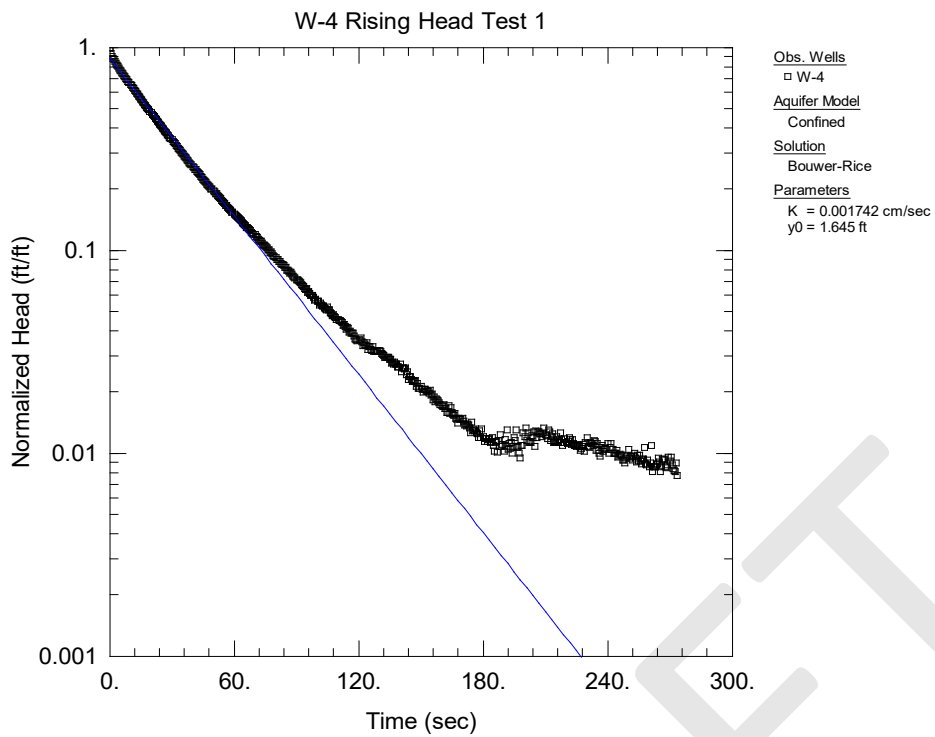
SLUG TESTING HYDROGRAPHS
W-4 AND W-5

AUGUST 2025

**HALEY
ALDRICH**

Figure

D-6



Notes:

Elevations are in NAVD88 vertical datum

IWTP TREATMENT FACILITY
SEATAC, WASHINGTON

REPRESENTATIVE SLUG TESTING RESULTS
W-4 AND W-5

AUGUST 2025

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Figure

D-7



Grain Size Analysis Report

Date:

7/28/2025

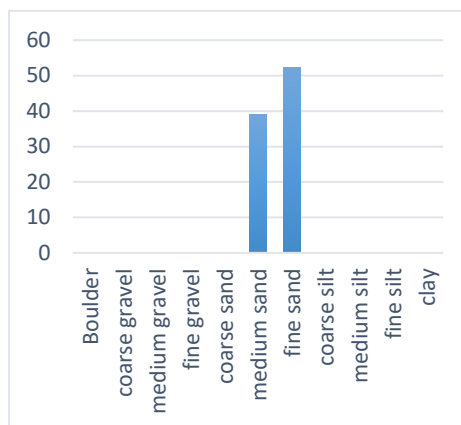
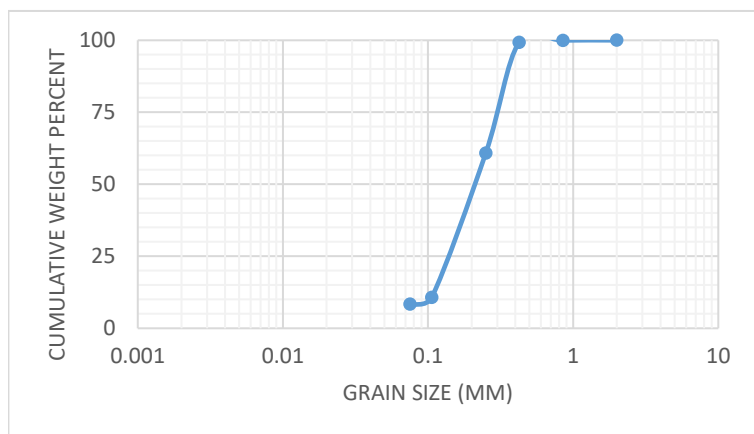
Sample Name: W-1, G-8, 32.5ft

Mass Sample (g): 91.584655

T (oC)

20

Moderately well sorted sand low in fines



Sieve opening (ps) di (mm)	Mass of retained (mr) (g)	mass fraction (mf)	Percent Passing (pp)
2	0	0	100
0.85	0.026981	0.000295	99.97054
0.425	0.593688	0.006482	99.3223
0.25	35.24896	0.384878	60.83446
0.106	45.90837	0.501267	10.70776
0.075	2.0995	0.022924	8.415345

Effective Grain Diameters (mm)		Other Useful Parameters	
d10	0.096	Uniformity Coef.	2.57
d17	0.124	n computed	0.41
d20	0.133	g (cm/s ²)	980.00
d50	0.219	ρ (g/cm ³)	0.9981
d60	0.248	μ (g/cm s)	0.0098
de (Krugger)	0.237	ρg/μ (1/cm s)	9.9327E+04
de (Kozeny)	0.206	tau (Sauerbrei)	1.053
de (Zunker)	0.216	d _{geometric mean}	0.247
de (Zamarin)	0.226	σ _φ	0.871
lo (Alyameni)	0.066		
mm	0	% in sample	
>64	Boulder		
16 - 64	coarse gravel		
8 - 16	medium gravel		
2 - 8	fine gravel	0	
0.5 - 2	coarse sand	0.02946	
0.25 - 0.5	medium sand	39.13608	
0.063 - 0.25	fine sand	52.419115	
0.016 - 0.063	coarse silt		
0.008 - 0.016	medium silt		
0.002 - 0.008	fine silt		
<0.002	clay		



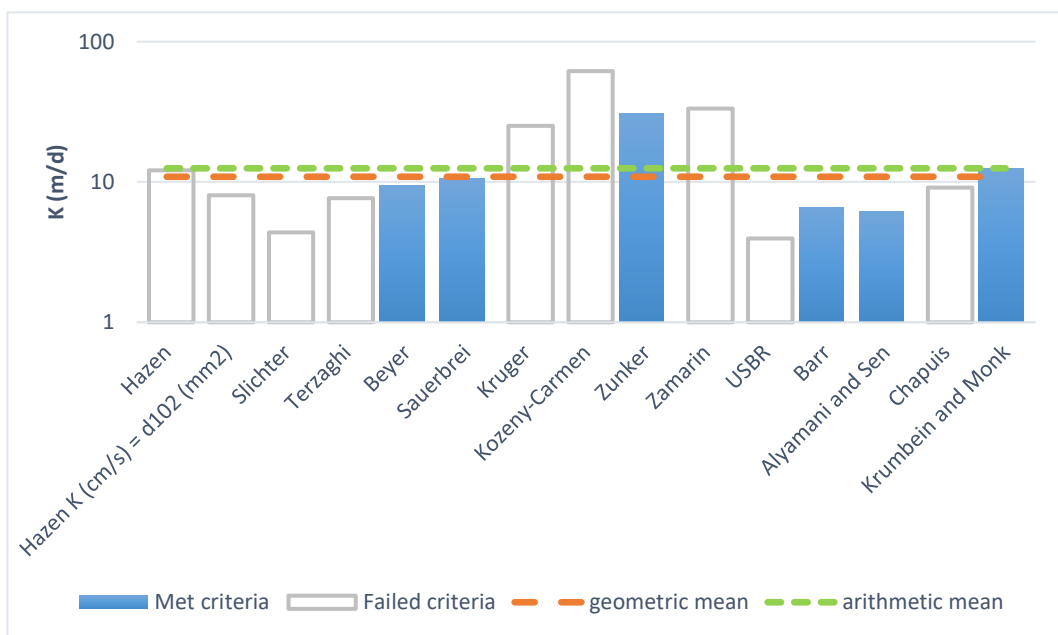
K from Grain Size Analysis Report

Date: 7/28/2025

Sample Name: W-1, G-8, 32.5ft

Mass Sample (g): 91.584655 T (oC) 20

Moderately well sorted sand low in fines



Estimation of Hydraulic Conductivity	cm/s	m/s	m/d	de
Hazen	.140E-01	.140E-03	12.12	
Hazen K (cm/s) = d ₁₀ (mm)	.930E-02	.930E-04	8.03	
Slichter	.505E-02	.505E-04	4.36	
Terzaghi	.887E-02	.887E-04	7.66	
Beyer	.110E-01	.110E-03	9.50	
Sauerbrei	.123E-01	.123E-03	10.67	
Kruger	.291E-01	.291E-03	25.13	
Kozeny-Carmen	.713E-01	.713E-03	61.62	
Zunker	.354E-01	.354E-03	30.61	
Zamarin	.386E-01	.386E-03	33.38	
USBR	.458E-02	.458E-04	3.96	
Barr	.759E-02	.759E-04	6.56	
Alyamani and Sen	.714E-02	.714E-04	6.17	
Chapuis	.106E-01	.106E-03	9.12	
Krumbein and Monk	.145E-01	.145E-03	12.51	
Shepherd	.135E-01	.135E-03	11.64	
geometric mean	.126E-01	.126E-03	10.90	
arithmetic mean	.145E-01	.145E-03	12.52	



Grain Size Analysis Report

Date:

7/28/2025

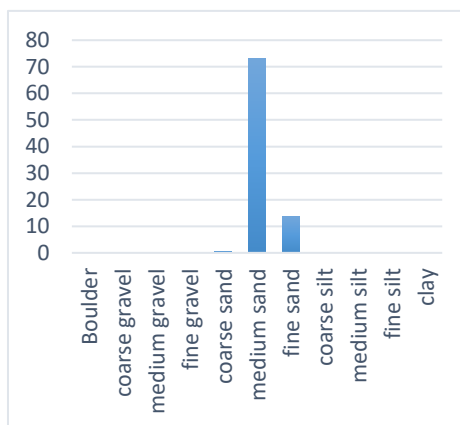
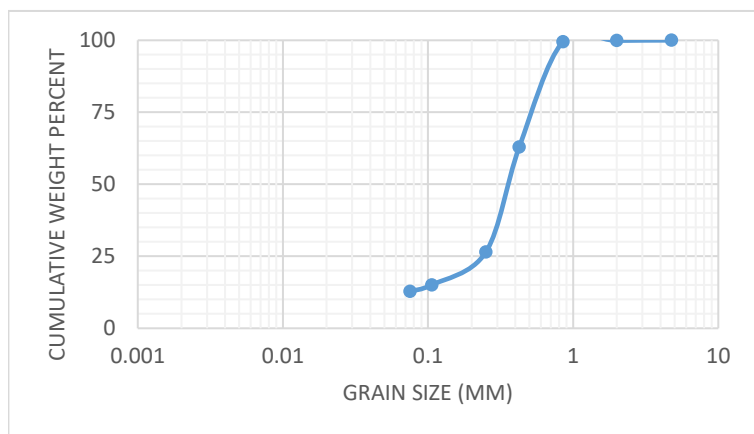
Sample Name: W-1, G-11, 44ft

Mass Sample (g): 531.21

T (oC)

20

Poorly sorted sand low in fines



Sieve opening (ps) di (mm)	Mass of retained (mr) (g)	mass fraction (mf)	Percent Passing (pp)
4.75	0	0	100
2	0.595221	0.00112	99.88795
0.85	2.267417	0.004268	99.46111
0.425	194.2933	0.365756	62.8855
0.25	193.613	0.364476	26.43795
0.106	60.48463	0.113862	15.05175
0.075	11.73411	0.022089	12.84281

Effective Grain Diameters (mm)		Other Useful Parameters	
d10	0.058	Uniformity Coef.	7.04
d17	0.131	n computed	0.32
d20	0.169	g (cm/s ²)	980.00
d50	0.363	ρ (g/cm ³)	0.9981
d60	0.411	μ (g/cm s)	0.0098
de (Kruger)	0.394	ρg/μ (1/cm s)	9.9327E+04
de (Kozeny)	0.354	tau (Sauerbrei)	1.053
de (Zunker)	0.367	d _{geometric mean}	0.426
de (Zamarin)	0.380	σ _φ	1.350
lo (Alyameni)	-0.018		
mm	0	% in sample	
>64	Boulder		
16 - 64	coarse gravel		
8 - 16	medium gravel		
2 - 8	fine gravel	0.11205	
0.5 - 2	coarse sand	0.42684	
0.25 - 0.5	medium sand	73.02316	
0.063 - 0.25	fine sand	13.59514	
0.016 - 0.063	coarse silt		
0.008 - 0.016	medium silt		
0.002 - 0.008	fine silt		
<0.002	clay		



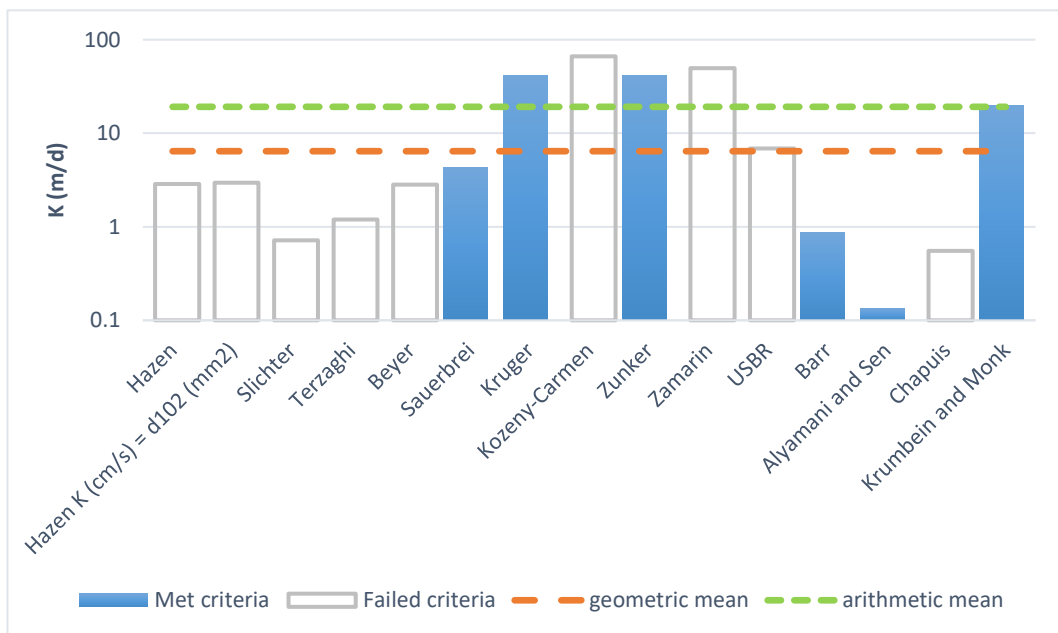
K from Grain Size Analysis Report

Date: 7/28/2025

Sample Name: W-1, G-11, 44ft

Mass Sample (g): 531.21 T (oC) 20

Poorly sorted sand low in fines



Estimation of Hydraulic Conductivity	cm/s	m/s	m/d	de
Hazen	.333E-02	.333E-04	2.87	
Hazen K (cm/s) = d ₁₀ (mm)	.341E-02	.341E-04	2.95	
Slichter	.831E-03	.831E-05	0.72	
Terzaghi	.139E-02	.139E-04	1.20	
Beyer	.326E-02	.326E-04	2.82	
Sauerbrei	.496E-02	.496E-04	4.29	
Kruger	.474E-01	.474E-03	40.92	
Kozeny-Carmen	.767E-01	.767E-03	66.24	
Zunker	.475E-01	.475E-03	41.00	
Zamarin	.574E-01	.574E-03	49.59	
USB	.794E-02	.794E-04	6.86	
Barr	.101E-02	.101E-04	0.87	
Alyamani and Sen	.156E-03	.156E-05	0.13	
Chapuis	.638E-03	.638E-05	0.55	
Krumbein and Monk	.231E-01	.231E-03	19.97	
Shepherd	.311E-01	.311E-03	26.84	
geometric mean	.744E-02	.744E-04	6.42	
arithmetic mean	.222E-01	.222E-03	19.15	



Grain Size Analysis Report

Date:

7/28/2025

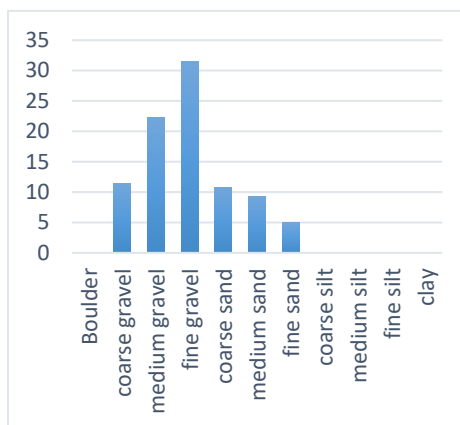
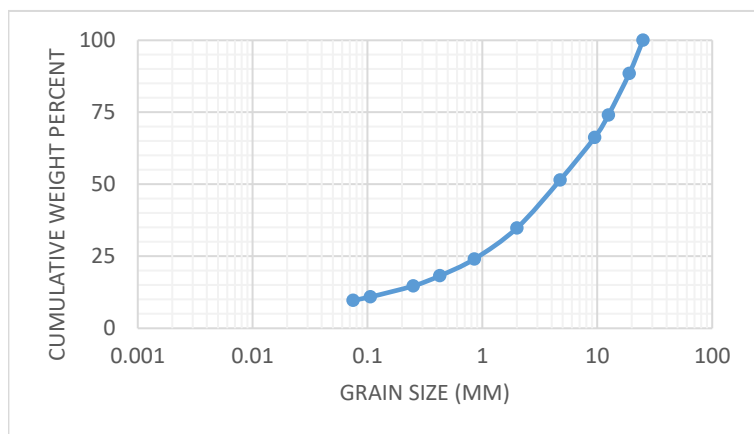
Sample Name: W-4, S-17, 40ft

Mass Sample (g): 2186.82

T (oC)

20

Poorly sorted sandy gravel low in fines



Sieve opening (ps) di (mm)	Mass of retained (mr) (g)	mass fraction (mf)	Percent Passing (pp)
25	0	0	100
19	251.1764	0.114859	88.51408
12.5	315.6554	0.144345	74.07963
9.5	170.0012	0.077739	66.30573
4.75	323.6089	0.147982	51.50758
2	364.2879	0.166583	34.84924
0.85	236.605	0.108196	24.02965
0.425	127.0757	0.05811	18.21867
0.25	76.68259	0.035066	14.71209
0.106	83.36114	0.03812	10.90011
0.075	25.43954	0.011633	9.736798

Effective Grain Diameters (mm)		Other Useful Parameters	
d10	0.082	Uniformity Coef.	91.15
d17	0.364	n computed	0.26
d20	0.555	g (cm/s ²)	980.00
d50	4.501	ρ (g/cm ³)	0.9981
d60	7.476	μ (g/cm s)	0.0098
de (Kruger)	1.418	ρg/μ (1/cm s)	9.9327E+04
de (Kozeny)	1.254	tau (Sauerbrei)	1.053
de (Zunker)	1.306	d _{geometric mean}	3.548
de (Zamarin)	1.362	σ _φ	2.830
lo (Alyameni)	-1.023		
mm		0	% in sample
>64		Boulder	
16 - 64		coarse gravel	11.48592
8 - 16		medium gravel	22.20835
2 - 8		fine gravel	31.45649
0.5 - 2		coarse sand	10.81959
0.25 - 0.5		medium sand	9.31756
0.063 - 0.25		fine sand	4.975292
0.016 - 0.063		coarse silt	
0.008 - 0.016		medium silt	
0.002 - 0.008		fine silt	
<0.002		clay	



K from Grain Size Analysis Report

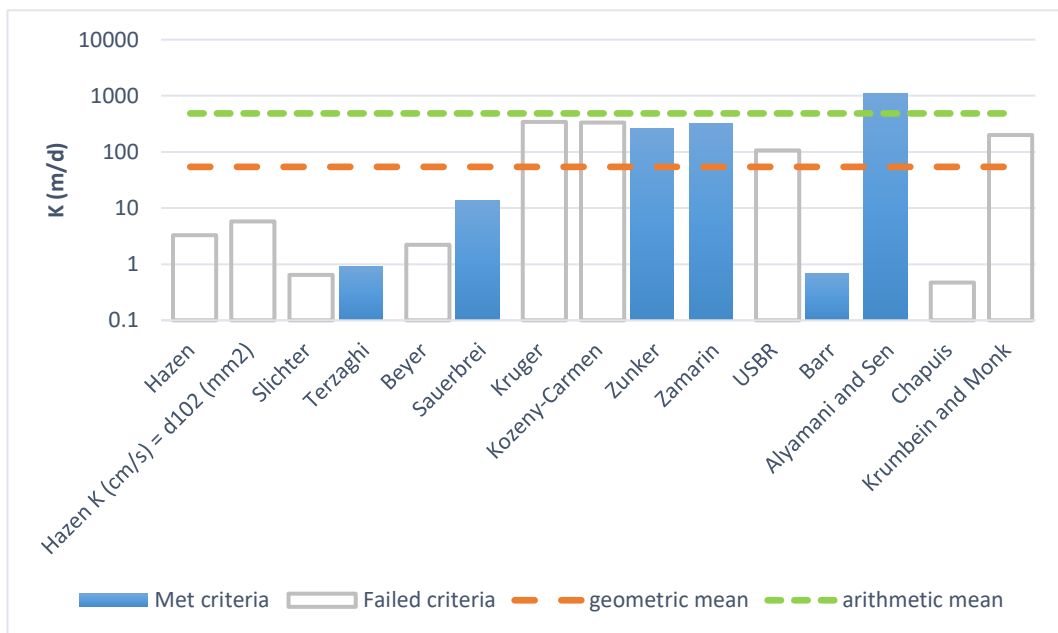
Date: 7/28/2025

Sample Name: W-4, S-17, 40ft

Mass Sample (g): 2186.82

T (oC) 20

Poorly sorted sandy gravel low in fines



Estimation of Hydraulic Conductivity	cm/s	m/s	m/d	de
Hazen	.381E-02	.381E-04	3.29	
Hazen K (cm/s) = d ₁₀ (mm)	.673E-02	.673E-04	5.81	
Slichter	.748E-03	.748E-05	0.65	
Terzaghi	.107E-02	.107E-04	0.92	
Beyer	.257E-02	.257E-04	2.22	
Sauerbrei	.155E-01	.155E-03	13.43	
Kruger	.399E+00	.399E-02	344.83	
Kozeny-Carmen	.387E+00	.387E-02	334.38	
Zunker	.308E+00	.308E-02	265.84	
Zamarin	.379E+00	.379E-02	327.70	
USBR	.123E+00	.123E-02	106.46	
Barr	.802E-03	.802E-05	0.69	
Alyamani and Sen	.125E+01	.125E-01	1081.95	
Chapuis	.547E-03	.547E-05	0.47	
Krumbein and Monk	.230E+00	.230E-02	198.83	
Shepherd	.198E+01	.198E-01	1708.87	
geometric mean	.628E-01	.628E-03	54.25	
arithmetic mean	.562E+00	.562E-02	485.63	



Grain Size Analysis Report

Date:

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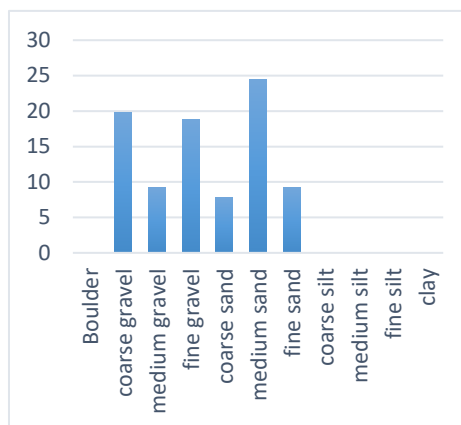
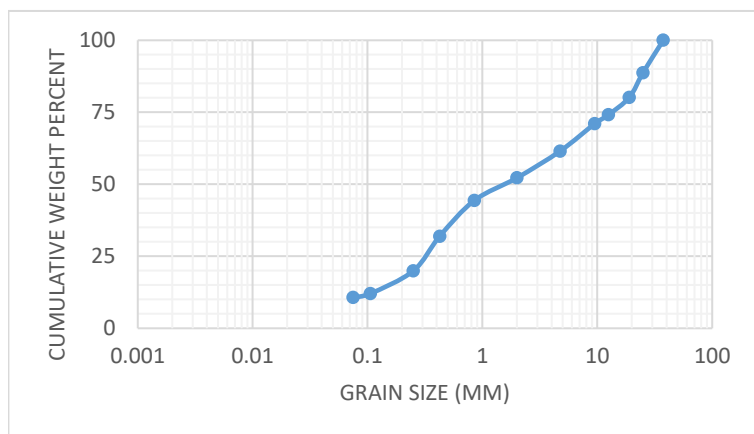
Sample Name: W-6, S-16, 35ft

Mass Sample (g): 2141.37

T (oC)

20

Poorly sorted gravelly sand low in fines



Sieve opening (ps) di (mm)	Mass of retained (mr) (g)	mass fraction (mf)	Percent Passing (pp)
37.5	0	0	100
25	240.6891	0.1124	88.76004
19	183.6139	0.085746	80.18544
12.5	129.7465	0.06059	74.1264
9.5	66.25592	0.030941	71.03231
4.75	203.192	0.094889	61.54343
2	199.1549	0.093004	52.24308
0.85	168.5155	0.078695	44.37356
0.425	265.5211	0.123996	31.97397
0.25	257.7233	0.120354	19.93853
0.106	168.792	0.078824	12.0561
0.075	28.75881	0.01343	10.71309

Effective Grain Diameters (mm)		Other Useful Parameters	
d10	0.070	Uniformity Coef.	61.33
d17	0.196	n computed	0.26
d20	0.251	g (cm/s ²)	980.00
d50	1.672	ρ (g/cm ³)	0.9981
d60	4.294	μ (g/cm s)	0.0098
de (Kruger)	0.798	ρg/μ (1/cm s)	9.9327E+04
de (Kozeny)	0.708	tau (Sauerbrei)	1.053
de (Zunker)	0.737	d _{geometric mean}	2.273
de (Zamarin)	0.768	σ _φ	3.222
lo (Alyameni)	-0.331		
mm		0 % in sample	
>64		Boulder	
16 - 64		coarse gravel	19.81456
8 - 16		medium gravel	9.15313
2 - 8		fine gravel	18.78923
0.5 - 2		coarse sand	7.86952
0.25 - 0.5		medium sand	24.43503
0.063 - 0.25		fine sand	9.22544
0.016 - 0.063		coarse silt	
0.008 - 0.016		medium silt	
0.002 - 0.008		fine silt	
<0.002		clay	



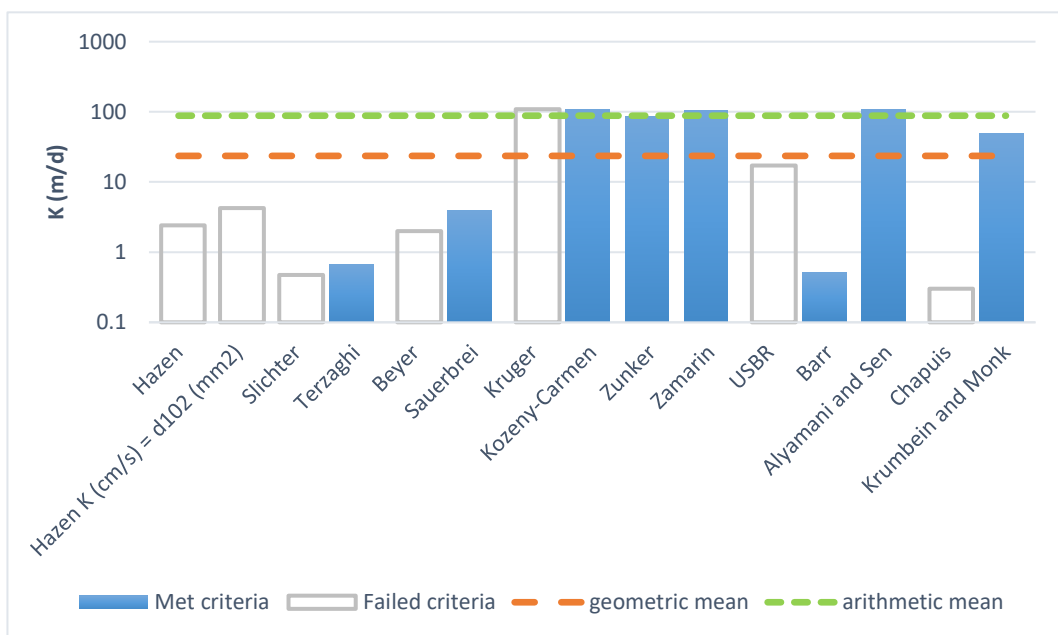
K from Grain Size Analysis Report

Date: 7/28/2025

Sample Name: W-6, S-16, 35ft

Mass Sample (g): 2141.37 T (oC) 20

Poorly sorted gravelly sand low in fines



Estimation of Hydraulic Conductivity	cm/s	m/s	m/d	de
Hazen	.277E-02	.277E-04	2.40	
Hazen K (cm/s) = d ₁₀ (mm)	.490E-02	.490E-04	4.23	
Slichter	.545E-03	.545E-05	0.47	
Terzaghi	.778E-03	.778E-05	0.67	
Beyer	.231E-02	.231E-04	1.99	
Sauerbrei	.452E-02	.452E-04	3.90	
Kruger	.127E+00	.127E-02	109.32	
Kozeny-Carmen	.124E+00	.124E-02	106.73	
Zunker	.980E-01	.980E-03	84.65	
Zamarin	.120E+00	.120E-02	104.10	
USBR	.198E-01	.198E-03	17.13	
Barr	.585E-03	.585E-05	0.51	
Alyamani and Sen	.127E+00	.127E-02	109.70	
Chapuis	.350E-03	.350E-05	0.30	
Krumbein and Monk	.566E-01	.566E-03	48.86	
Shepherd	.386E+00	.386E-02	333.55	
geometric mean	.273E-01	.273E-03	23.55	
arithmetic mean	.102E+00	.102E-02	88.08	



Grain Size Analysis Report

Date:

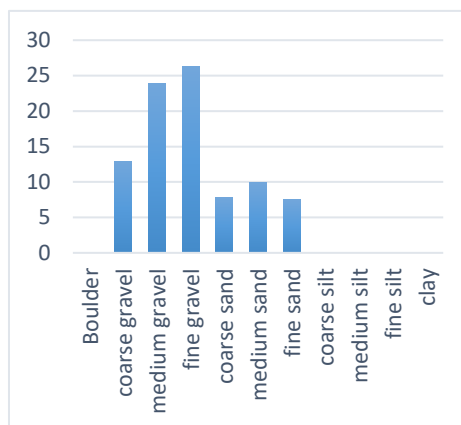
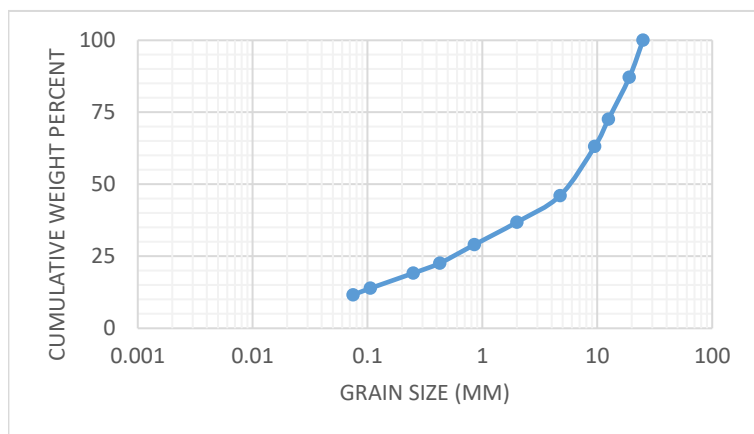
7/28/2025

Sample Name: W-7, G-20, 37.5ft

Mass Sample (g): 1215.26

T (oC) 20

Poorly sorted sandy gravel low in fines



Sieve opening (ps) di (mm)	Mass of retained (mr) (g)	mass fraction (mf)	Percent Passing (pp)
25	0	0	100
19	156.7209	0.128961	87.10392
12.5	176.5727	0.145296	72.5743
9.5	114.5062	0.094224	63.15194
4.75	207.2472	0.170537	46.09821
2	112.0546	0.092206	36.87758
0.85	95.73065	0.078774	29.0002
0.425	77.49348	0.063767	22.6235
0.25	42.45401	0.034934	19.13009
0.106	63.4418	0.052204	13.90966
0.075	28.22283	0.023224	11.58729

Effective Grain Diameters (mm)		Other Useful Parameters	
d10	0.065	Uniformity Coef.	133.21
d17	0.191	n computed	0.26
d20	0.294	g (cm/s ²)	980.00
d50	5.837	ρ (g/cm ³)	0.9981
d60	8.622	μ (g/cm s)	0.0098
de (Kruger)	1.132	ρg/μ (1/cm s)	9.9327E+04
de (Kozeny)	1.012	tau (Sauerbrei)	1.053
de (Zunker)	1.050	d _{geometric mean}	3.479
de (Zamarin)	1.091	σ _φ	3.120
lo (Alyameni)	-1.378		
mm		0	% in sample
>64		Boulder	
16 - 64		coarse gravel	12.89608
8 - 16		medium gravel	23.95198
2 - 8		fine gravel	26.27436
0.5 - 2		coarse sand	7.87738
0.25 - 0.5		medium sand	9.87011
0.063 - 0.25		fine sand	7.5428
0.016 - 0.063		coarse silt	
0.008 - 0.016		medium silt	
0.002 - 0.008		fine silt	
<0.002		clay	



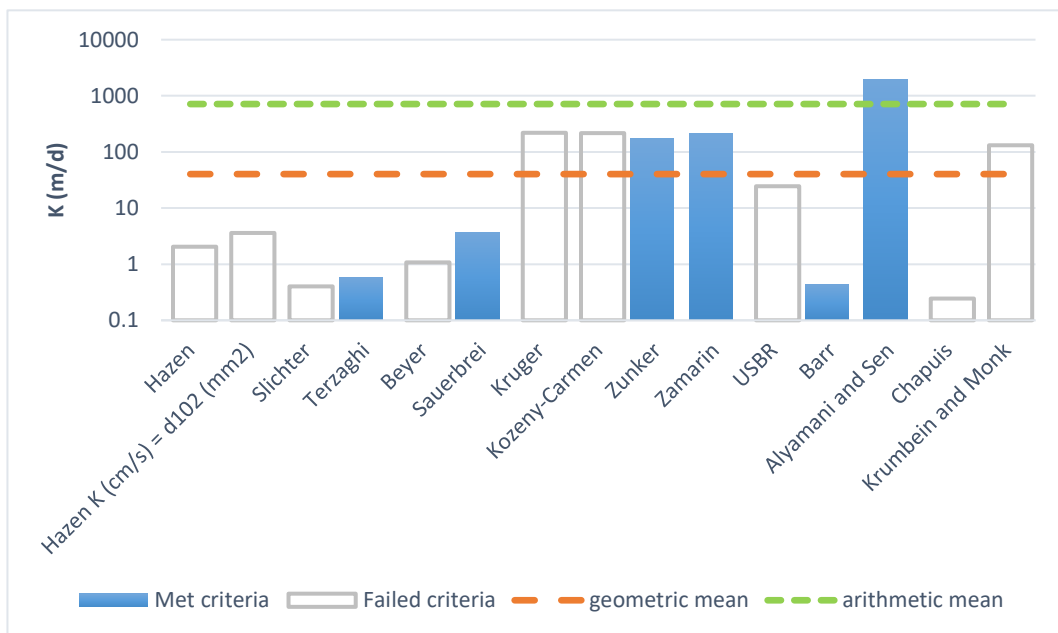
K from Grain Size Analysis Report

Date: 7/28/2025

Sample Name: W-7, G-20, 37.5ft

Mass Sample (g): 1215.26 T (oC) 20

Poorly sorted sandy gravel low in fines



Estimation of Hydraulic Conductivity	cm/s	m/s	m/d	de
Hazen	.237E-02	.237E-04	2.05	
Hazen K (cm/s) = d ₁₀ (mm)	.419E-02	.419E-04	3.62	
Slichter	.466E-03	.466E-05	0.40	
Terzaghi	.665E-03	.665E-05	0.57	
Beyer	.124E-02	.124E-04	1.07	
Sauerbrei	.429E-02	.429E-04	3.70	
Kruger	.254E+00	.254E-02	219.67	
Kozeny-Carmen	.252E+00	.252E-02	217.75	
Zunker	.199E+00	.199E-02	171.88	
Zamarin	.243E+00	.243E-02	210.29	
USBR	.284E-01	.284E-03	24.58	
Barr	.500E-03	.500E-05	0.43	
Alyamani and Sen	.229E+01	.229E-01	1979.53	
Chapuis	.281E-03	.281E-05	0.24	
Krumbein and Monk	.151E+00	.151E-02	130.87	
Shepherd	.304E+01	.304E-01	2623.69	
geometric mean	.466E-01	.466E-03	40.29	
arithmetic mean	.825E+00	.825E-02	712.87	



Grain Size Analysis Report

Date:

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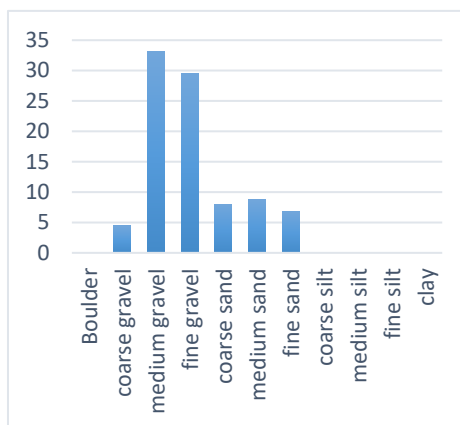
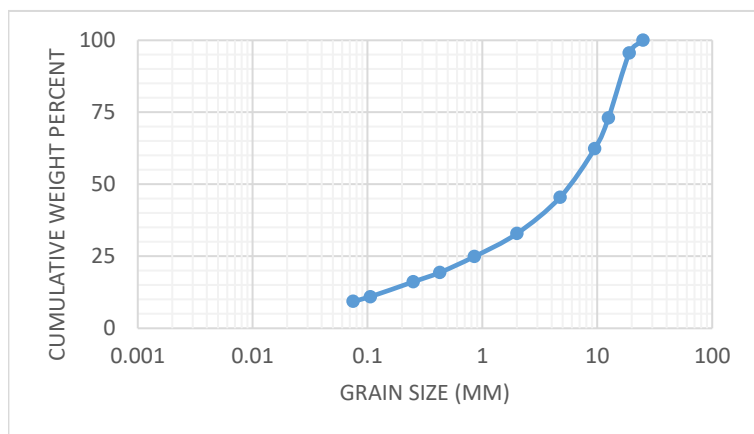
Sample Name: W-7, G-23, 43.5ft

Mass Sample (g): 1843.14

T (oC)

20

Poorly sorted sandy gravel low in fines



Sieve opening (ps) di (mm)	Mass of retained (mr) (g)	mass fraction (mf)	Percent Passing (pp)
25	0	0	100
19	81.78307	0.044372	95.56284
12.5	415.6244	0.225498	73.01304
9.5	195.7064	0.106181	62.39494
4.75	311.0931	0.168784	45.51651
2	232.4203	0.1261	32.90649
0.85	147.8316	0.080206	24.88585
0.425	101.7258	0.055192	19.36669
0.25	59.64512	0.032361	16.13063
0.106	94.89517	0.051486	10.98207
0.075	29.63961	0.016081	9.373966

Effective Grain Diameters (mm)		Other Useful Parameters	
d10	0.087	Uniformity Coef.	101.37
d17	0.297	n computed	0.26
d20	0.474	g (cm/s ²)	980.00
d50	6.012	ρ (g/cm ³)	0.9981
d60	8.826	μ (g/cm s)	0.0098
de (Kruger)	1.261	ρg/μ (1/cm s)	9.9327E+04
de (Kozeny)	1.118	tau (Sauerbrei)	1.053
de (Zunker)	1.164	d _{geometric mean}	3.651
de (Zamarin)	1.213	σ _φ	2.843
lo (Alyameni)	-1.394		
mm	0	% in sample	
>64	Boulder		
16 - 64	coarse gravel		4.43716
8 - 16	medium gravel		33.1679
2 - 8	fine gravel		29.48845
0.5 - 2	coarse sand		8.02064
0.25 - 0.5	medium sand		8.75522
0.063 - 0.25	fine sand		6.756664
0.016 - 0.063	coarse silt		
0.008 - 0.016	medium silt		
0.002 - 0.008	fine silt		
<0.002	clay		



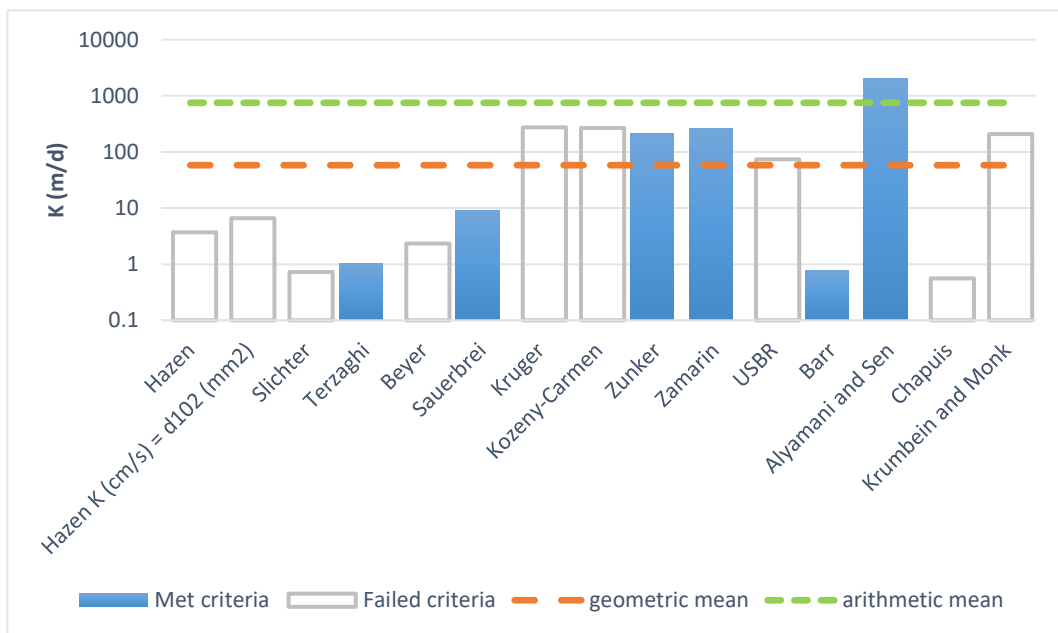
K from Grain Size Analysis Report

Date: 7/28/2025

Sample Name: W-7, G-23, 43.5ft

Mass Sample (g): 1843.14 T (oC) 20

Poorly sorted sandy gravel low in fines



Estimation of Hydraulic Conductivity	cm/s	m/s	m/d	de
Hazen	.429E-02	.429E-04	3.71	
Hazen K (cm/s) = d ₁₀ (mm)	.758E-02	.758E-04	6.55	
Slichter	.844E-03	.844E-05	0.73	
Terzaghi	.120E-02	.120E-04	1.04	
Beyer	.271E-02	.271E-04	2.34	
Sauerbrei	.103E-01	.103E-03	8.93	
Kruger	.316E+00	.316E-02	272.94	
Kozeny-Carmen	.308E+00	.308E-02	265.89	
Zunker	.244E+00	.244E-02	211.08	
Zamarin	.301E+00	.301E-02	259.79	
USBR	.855E-01	.855E-03	73.90	
Barr	.904E-03	.904E-05	0.78	
Alyamani and Sen	.234E+01	.234E-01	2018.23	
Chapuis	.648E-03	.648E-05	0.56	
Krumbein and Monk	.240E+00	.240E-02	207.06	
Shepherd	.319E+01	.319E-01	2754.74	
geometric mean	.671E-01	.671E-03	58.01	
arithmetic mean	.869E+00	.869E-02	750.66	



Grain Size Analysis Report

Date:

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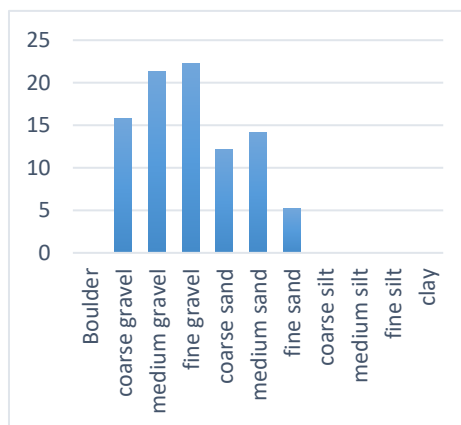
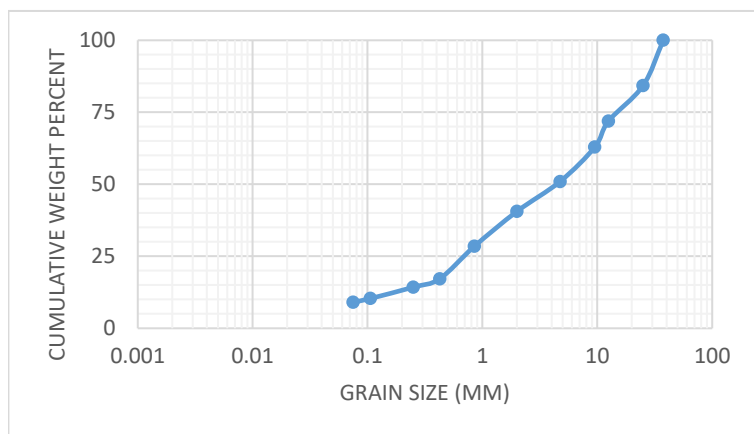
Sample Name: W-7, G-26, 47.5ft

Mass Sample (g): 1985.47

T (oC)

20

Poorly sorted sandy gravel low in fines



Sieve opening (ps) di (mm)	Mass of retained (mr) (g)	mass fraction (mf)	Percent Passing (pp)
37.5	0	0	100
25	312.8338	0.157562	84.24384
12.5	244.5692	0.12318	71.92589
9.5	179.2937	0.090303	62.8956
4.75	236.3946	0.119062	50.98937
2	206.1361	0.103822	40.60714
0.85	241.5189	0.121643	28.44282
0.425	223.2175	0.112426	17.20027
0.25	58.19889	0.029312	14.26903
0.106	77.84234	0.039206	10.34843
0.075	26.23217	0.013212	9.027223

Effective Grain Diameters (mm)		Other Useful Parameters	
d10	0.098	Uniformity Coef.	85.30
d17	0.413	n computed	0.26
d20	0.531	g (cm/s ²)	980.00
d50	4.488	ρ (g/cm ³)	0.9981
d60	8.345	μ (g/cm s)	0.0098
de (Kruger)	1.279	ρg/μ (1/cm s)	9.9327E+04
de (Kozeny)	1.131	tau (Sauerbrei)	1.053
de (Zunker)	1.178	d _{geometric mean}	3.638
de (Zamarin)	1.228	σ _φ	2.996
lo (Alyameni)	-1.000		
mm	0	% in sample	
>64	Boulder		
16 - 64	coarse gravel		15.75616
8 - 16	medium gravel		21.34824
2 - 8	fine gravel		22.28846
0.5 - 2	coarse sand		12.16432
0.25 - 0.5	medium sand		14.17379
0.063 - 0.25	fine sand		5.241807
0.016 - 0.063	coarse silt		
0.008 - 0.016	medium silt		
0.002 - 0.008	fine silt		
<0.002	clay		



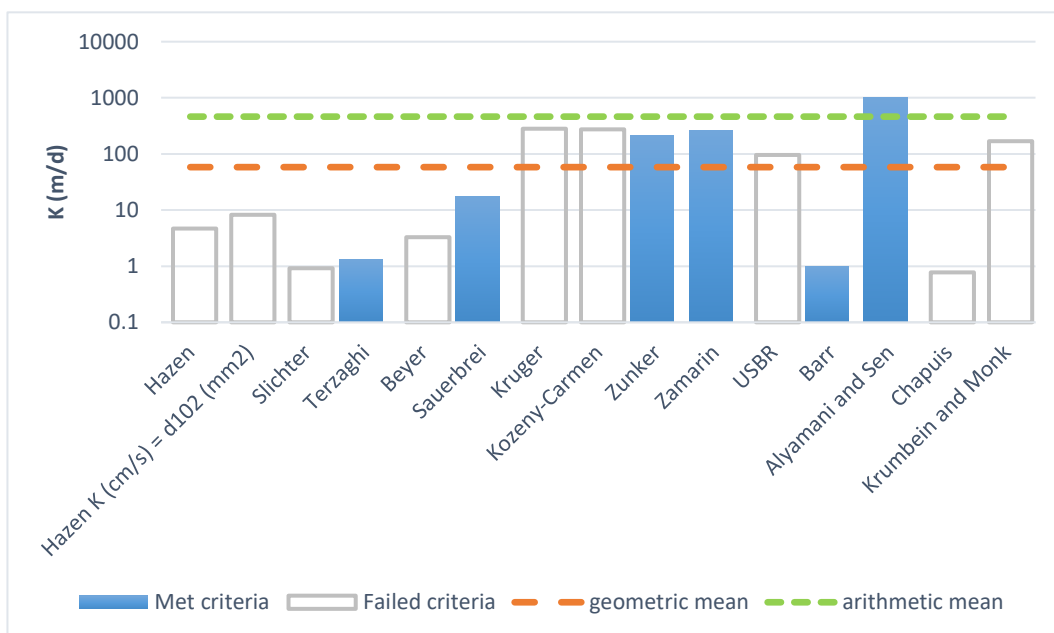
K from Grain Size Analysis Report

Date: 7/28/2025

Sample Name: W-7, G-26, 47.5ft

Mass Sample (g): 1985.47 T (oC) 20

Poorly sorted sandy gravel low in fines



Estimation of Hydraulic Conductivity	cm/s	m/s	m/d	de
Hazen	.542E-02	.542E-04	4.68	
Hazen K (cm/s) = d ₁₀ (mm)	.957E-02	.957E-04	8.27	
Slichter	.106E-02	.106E-04	0.92	
Terzaghi	.152E-02	.152E-04	1.31	
Beyer	.380E-02	.380E-04	3.28	
Sauerbrei	.200E-01	.200E-03	17.27	
Kruger	.325E+00	.325E-02	280.39	
Kozeny-Carmen	.315E+00	.315E-02	272.36	
Zunker	.250E+00	.250E-02	216.40	
Zamarin	.309E+00	.309E-02	266.59	
USBR	.111E+00	.111E-02	95.99	
Barr	.114E-02	.114E-04	0.99	
Alyamani and Sen	.119E+01	.119E-01	1029.62	
Chapuis	.899E-03	.899E-05	0.78	
Krumbein and Monk	.195E+00	.195E-02	168.25	
Shepherd	.197E+01	.197E-01	1700.61	
geometric mean	.673E-01	.673E-03	58.18	
arithmetic mean	.535E+00	.535E-02	461.83	



Grain Size Analysis Report

Date:

7/28/2025

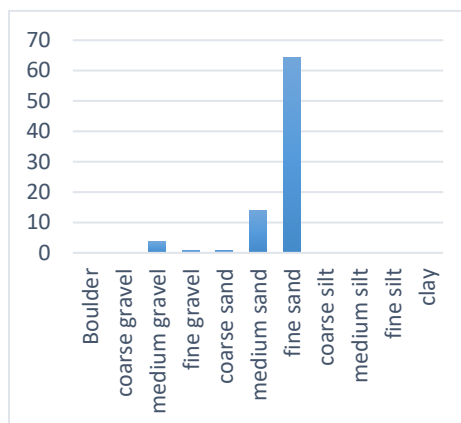
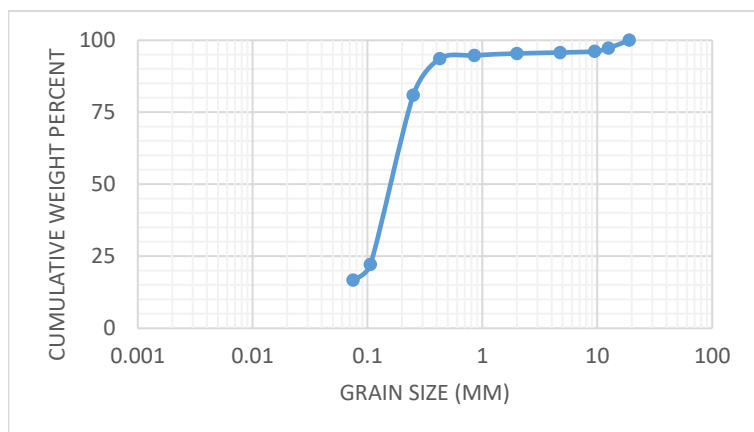
Sample Name: W-8, S-10, 45ft

Mass Sample (g): 524.09

T (oC)

20

Moderately well sorted sand low in fines



Sieve opening (ps) di (mm)	Mass of retained (mr) (g)	mass fraction (mf)	Percent Passing (pp)
19	0	0	100
12.5	14.12931	0.02696	97.30403
9.5	6.111676	0.011662	96.13788
4.75	2.009571	0.003834	95.75444
2	1.760995	0.00336	95.41843
0.85	3.439131	0.006562	94.76222
0.425	5.987309	0.011424	93.6198
0.25	66.48239	0.126853	80.9345
0.106	307.9446	0.58758	22.17654
0.075	28.61081	0.054591	16.7174

Effective Grain Diameters (mm)		Other Useful Parameters	
d10	0.045	Uniformity Coef.	4.43
d17	0.077	n computed	0.37
d20	0.094	g (cm/s ²)	980.00
d50	0.174	ρ (g/cm ³)	0.9981
d60	0.199	μ (g/cm s)	0.0098
de (Kruger)	0.232	ρg/μ (1/cm s)	9.9327E+04
de (Kozeny)	0.200	tau (Sauerbrei)	1.053
de (Zunker)	0.210	d _{geometric mean}	0.292
de (Zamarin)	0.221	σ _φ	1.388
lo (Alyameni)	0.013		
mm	0	% in sample	
>64	Boulder		
16 - 64	coarse gravel		0
8 - 16	medium gravel		3.86212
2 - 8	fine gravel		0.71945
0.5 - 2	coarse sand		0.65621
0.25 - 0.5	medium sand		13.82772
0.063 - 0.25	fine sand		64.2171
0.016 - 0.063	coarse silt		
0.008 - 0.016	medium silt		
0.002 - 0.008	fine silt		
<0.002	clay		



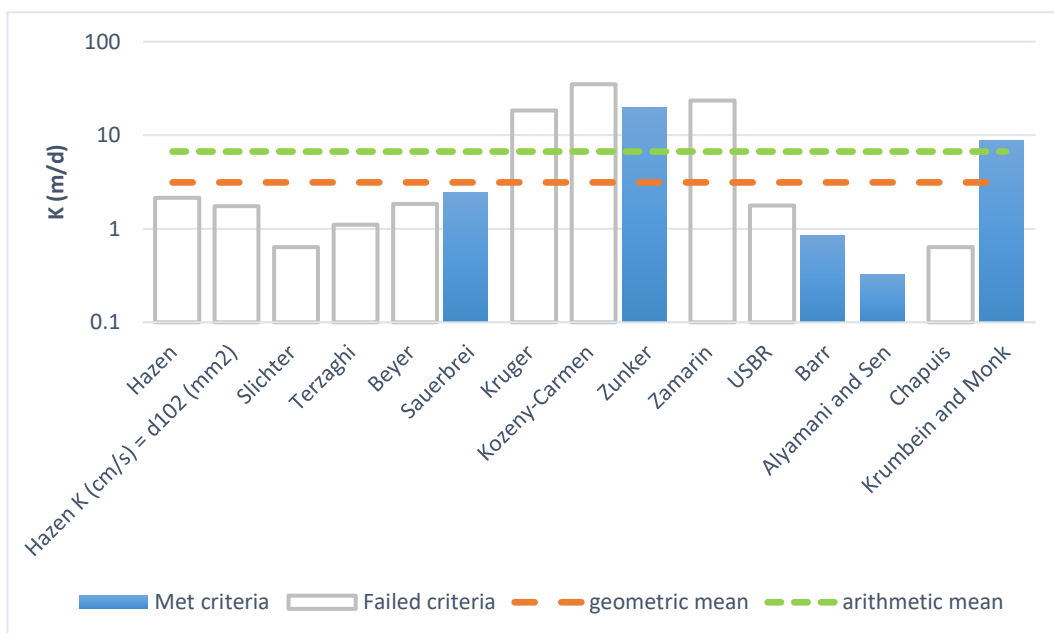
K from Grain Size Analysis Report

Date: 7/28/2025

Sample Name: W-8, S-10, 45ft

Mass Sample (g): 524.09 T (oC) 20

Moderately well sorted sand low in fines



Estimation of Hydraulic Conductivity	cm/s	m/s	m/d	de
Hazen	.248E-02	.248E-04	2.14	
Hazen K (cm/s) = d ₁₀ (mm)	.201E-02	.201E-04	1.74	
Slichter	.739E-03	.739E-05	0.64	
Terzaghi	.128E-02	.128E-04	1.10	
Beyer	.213E-02	.213E-04	1.84	
Sauerbrei	.283E-02	.283E-04	2.45	
Kruger	.213E-01	.213E-03	18.40	
Kozeny-Carmen	.405E-01	.405E-03	35.02	
Zunker	.228E-01	.228E-03	19.69	
Zamarin	.271E-01	.271E-03	23.45	
USBR	.205E-02	.205E-04	1.77	
Barr	.988E-03	.988E-05	0.85	
Alyamani and Sen	.374E-03	.374E-05	0.32	
Chapuis	.738E-03	.738E-05	0.64	
Krumbein and Monk	.103E-01	.103E-03	8.88	
Shepherd	.924E-02	.924E-04	7.99	
geometric mean	.362E-02	.362E-04	3.13	
arithmetic mean	.775E-02	.775E-04	6.70	



Grain Size Analysis Report

Date:

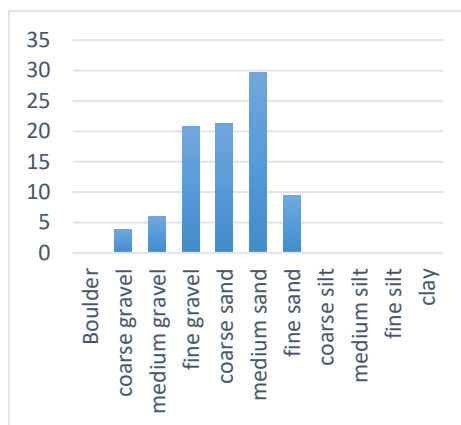
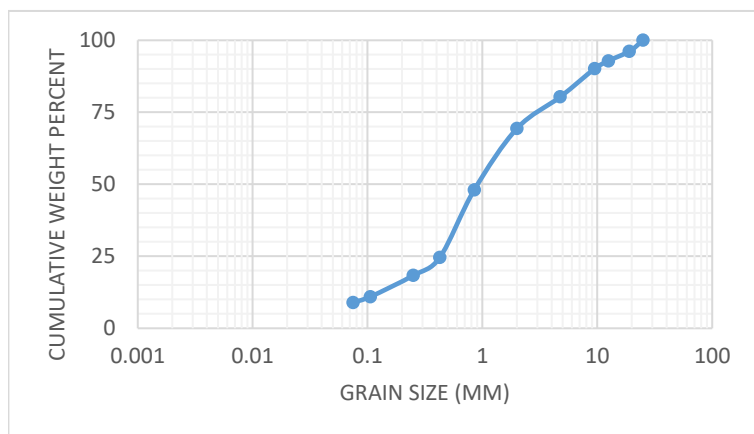
7/28/2025

Sample Name: W-8, S-11a, 50ft

Mass Sample (g): 1242.86

T (oC) 20

Poorly sorted gravelly sand low in fines



Sieve opening (ps) di (mm)	Mass of retained (mr) (g)	mass fraction (mf)	Percent Passing (pp)
25	0	0	100
19	47.76162	0.038429	96.15712
12.5	40.76755	0.032801	92.87698
9.5	33.72762	0.027137	90.16327
4.75	122.2108	0.09833	80.33024
2	135.8308	0.109289	69.40135
0.85	264.7594	0.213024	48.09892
0.425	292.6893	0.235497	24.54926
0.25	77.16396	0.062086	18.34068
0.106	91.52011	0.073637	10.97701
0.075	24.89309	0.020029	8.974122

Effective Grain Diameters (mm)		Other Useful Parameters	
d10	0.091	Uniformity Coef.	16.42
d17	0.224	n computed	0.27
d20	0.297	g (cm/s ²)	980.00
d50	0.953	ρ (g/cm ³)	0.9981
d60	1.492	μ (g/cm s)	0.0098
de (Kruger)	0.719	ρg/μ (1/cm s)	9.9327E+04
de (Kozeny)	0.635	tau (Sauerbrei)	1.053
de (Zunker)	0.662	d _{geometric mean}	1.308
de (Zamarin)	0.691	σ _φ	2.559
lo (Alyameni)	-0.125		
mm		0	% in sample
>64		Boulder	
16 - 64		coarse gravel	3.84288
8 - 16		medium gravel	5.99385
2 - 8		fine gravel	20.76192
0.5 - 2		coarse sand	21.30243
0.25 - 0.5		medium sand	29.75824
0.063 - 0.25		fine sand	9.366558
0.016 - 0.063		coarse silt	
0.008 - 0.016		medium silt	
0.002 - 0.008		fine silt	
<0.002		clay	



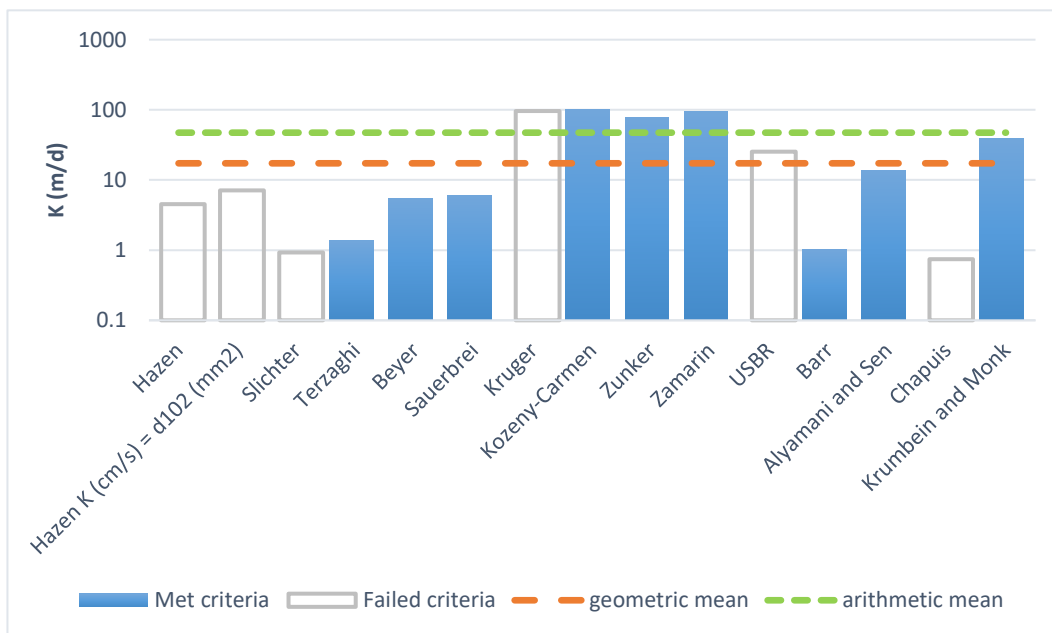
K from Grain Size Analysis Report

Date: 7/28/2025

Sample Name: W-8, S-11a, 50ft

Mass Sample (g): 1242.86 T (oC) 20

Poorly sorted gravelly sand low in fines



Estimation of Hydraulic Conductivity	cm/s	m/s	m/d	de
Hazen	.526E-02	.526E-04	4.55	
Hazen K (cm/s) = d ₁₀ (mm)	.826E-02	.826E-04	7.14	
Slichter	.107E-02	.107E-04	0.92	
Terzaghi	.159E-02	.159E-04	1.37	
Beyer	.633E-02	.633E-04	5.47	
Sauerbrei	.695E-02	.695E-04	6.01	
Kruger	.111E+00	.111E-02	95.94	
Kozeny-Carmen	.118E+00	.118E-02	101.69	
Zunker	.894E-01	.894E-03	77.28	
Zamarin	.111E+00	.111E-02	95.85	
USBR	.292E-01	.292E-03	25.20	
Barr	.117E-02	.117E-04	1.01	
Alyamani and Sen	.160E-01	.160E-03	13.80	
Chapuis	.861E-03	.861E-05	0.74	
Krumbein and Monk	.446E-01	.446E-03	38.53	
Shepherd	.153E+00	.153E-02	131.81	
geometric mean	.200E-01	.200E-03	17.30	
arithmetic mean	.547E-01	.547E-03	47.28	



Grain Size Analysis Report

Date:

7/28/2025

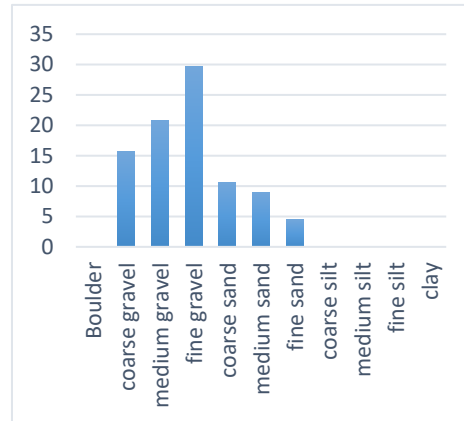
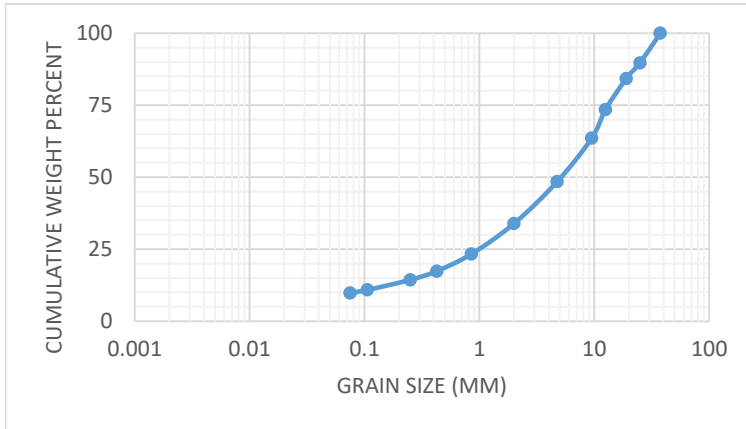
Sample Name: W-9, G-7, 33.5ft

Mass Sample (g): 1948.74

T (oC)

20

Poorly sorted sandy gravel low in fines



Sieve opening (ps) di (mm)	Mass of retained (mr) (g)	mass fraction (mf)	Percent Passing (pp)
37.5	0	0	100
25	199.3824	0.102314	89.76865
19	106.5643	0.054684	84.30028
12.5	210.5434	0.108041	73.4962
9.5	193.5183	0.099304	63.56577
4.75	293.777	0.150752	48.49054
2	283.6882	0.145575	33.93302
0.85	206.3186	0.105873	23.34574
0.425	115.4552	0.059246	17.42113
0.25	59.08326	0.030319	14.38926
0.106	68.35264	0.035075	10.88173
0.075	20.11472	0.010322	9.849539

Effective Grain Diameters (mm)		Other Useful Parameters	
d10	0.080	Uniformity Coef.	105.34
d17	0.401	n computed	0.26
d20	0.610	g (cm/s ²)	980.00
d50	5.226	ρ (g/cm ³)	0.9981
d60	8.376	μ (g/cm s)	0.0098
de (Kruger)	1.529	ρg/μ (1/cm s)	9.9327E+04
de (Kozeny)	1.350	tau (Sauerbrei)	1.053
de (Zunker)	1.407	d _{geometric mean}	3.965
de (Zamarin)	1.468	σ _φ	2.912
lo (Alyameni)	-1.207		
mm	0	% in sample	
>64	Boulder		
16 - 64	coarse gravel		15.69972
8 - 16	medium gravel		20.73451
2 - 8	fine gravel		29.63275
0.5 - 2	coarse sand		10.58728
0.25 - 0.5	medium sand		8.95648
0.063 - 0.25	fine sand		4.539721
0.016 - 0.063	coarse silt		
0.008 - 0.016	medium silt		
0.002 - 0.008	fine silt		
<0.002	clay		



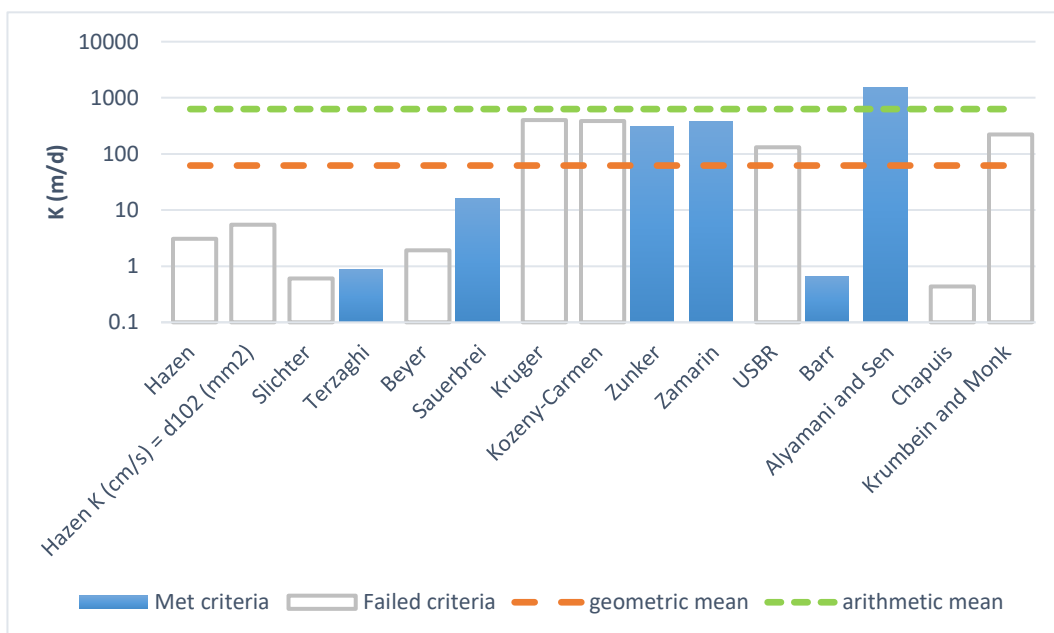
K from Grain Size Analysis Report

Date: 7/28/2025

Sample Name: W-9, G-7, 33.5ft

Mass Sample (g): 1948.74 T (oC) 20

Poorly sorted sandy gravel low in fines



Estimation of Hydraulic Conductivity	cm/s	m/s	m/d	de
Hazen	.358E-02	.358E-04	3.09	
Hazen K (cm/s) = d ₁₀ (mm)	.632E-02	.632E-04	5.46	
Slichter	.704E-03	.704E-05	0.61	
Terzaghi	.100E-02	.100E-04	0.87	
Beyer	.221E-02	.221E-04	1.91	
Sauerbrei	.188E-01	.188E-03	16.25	
Kruger	.464E+00	.464E-02	400.86	
Kozeny-Carmen	.449E+00	.449E-02	388.04	
Zunker	.357E+00	.357E-02	308.68	
Zamarin	.441E+00	.441E-02	380.72	
USBR	.153E+00	.153E-02	132.15	
Barr	.754E-03	.754E-05	0.65	
Alyamani and Sen	.175E+01	.175E-01	1511.70	
Chapuis	.502E-03	.502E-05	0.43	
Krumbein and Monk	.258E+00	.258E-02	223.04	
Shepherd	.253E+01	.253E-01	2186.02	
geometric mean	.719E-01	.719E-03	62.11	
arithmetic mean	.728E+00	.728E-02	629.27	



Grain Size Analysis Report

Date:

7/28/2025

Sample Name: W-9, G-11, 47.5ft

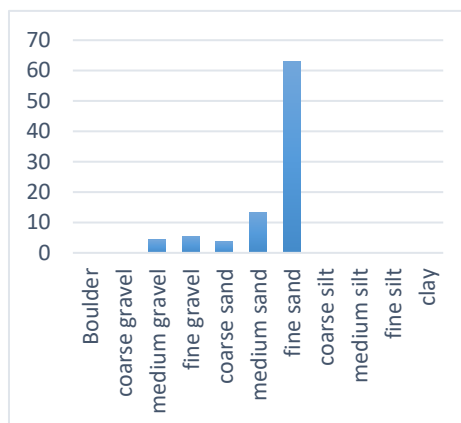
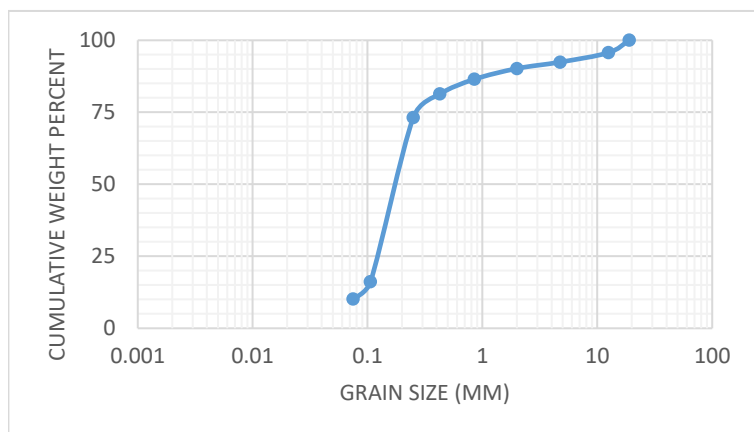
Mass Sample (g):

444.56

T (oC)

20

Moderately well sorted sand low in fines



Sieve opening (ps) di (mm)	Mass of retained (mr) (g)	mass fraction (mf)	Percent Passing (pp)
19	0	0	100
12.5	19.12964	0.043031	95.69695
4.75	14.55067	0.032731	92.4239
2	9.89555	0.022259	90.19798
0.85	16.58573	0.037308	86.46716
0.425	22.84363	0.051385	81.32868
0.25	36.27507	0.081598	73.16891
0.106	253.5945	0.570439	16.12497
0.075	26.30319	0.059167	10.20829

Effective Grain Diameters (mm)		Other Useful Parameters	
d10	0.073	Uniformity Coef.	2.95
d17	0.108	n computed	0.40
d20	0.116	g (cm/s ²)	980.00
d50	0.192	ρ (g/cm ³)	0.9981
d60	0.217	μ (g/cm s)	0.0098
de (Kruger)	0.237	ρg/μ (1/cm s)	9.9327E+04
de (Kozeny)	0.204	tau (Sauerbrei)	1.053
de (Zunker)	0.214	d _{geometric mean}	0.341
de (Zamarin)	0.226	σ _φ	1.897
lo (Alyameni)	0.044		
mm	0	% in sample	
>64	Boulder		
16 - 64	coarse gravel		0
8 - 16	medium gravel		4.30305
2 - 8	fine gravel		5.49897
0.5 - 2	coarse sand		3.73082
0.25 - 0.5	medium sand		13.29825
0.063 - 0.25	fine sand		62.96062
0.016 - 0.063	coarse silt		
0.008 - 0.016	medium silt		
0.002 - 0.008	fine silt		
<0.002	clay		



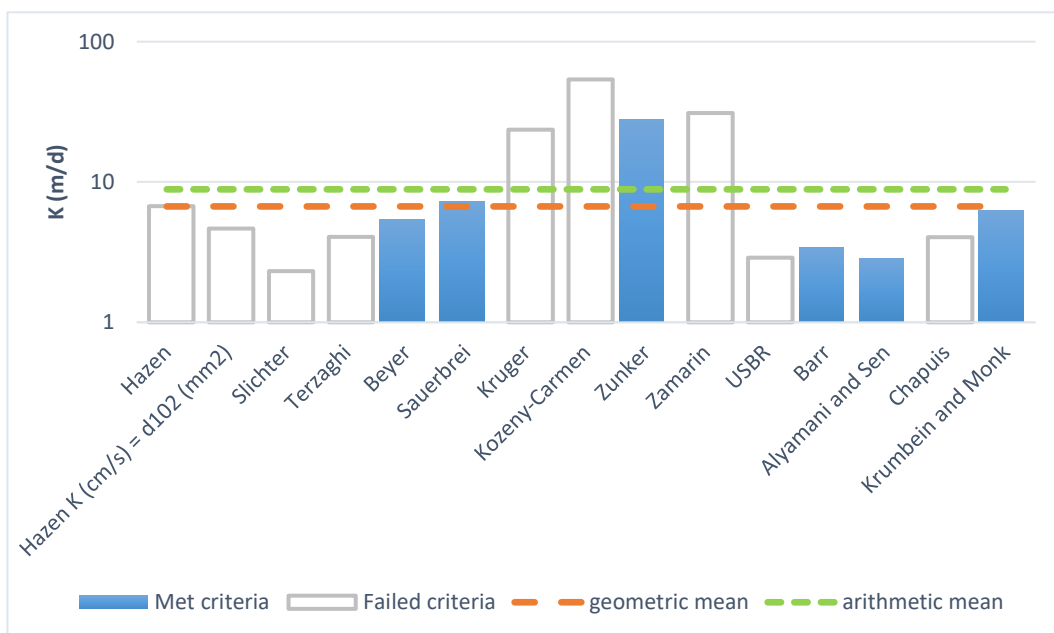
K from Grain Size Analysis Report

Date: 7/28/2025

Sample Name: W-9, G-11, 47.5ft

Mass Sample (g): 444.56 T (oC) 20

Moderately well sorted sand low in fines



Estimation of Hydraulic Conductivity	cm/s	m/s	m/d	de
Hazen	.779E-02	.779E-04	6.73	
Hazen K (cm/s) = d ₁₀ (mm)	.540E-02	.540E-04	4.66	
Slichter	.269E-02	.269E-04	2.32	
Terzaghi	.470E-02	.470E-04	4.06	
Beyer	.621E-02	.621E-04	5.37	
Sauerbrei	.836E-02	.836E-04	7.22	
Kruger	.273E-01	.273E-03	23.59	
Kozeny-Carmen	.624E-01	.624E-03	53.95	
Zunker	.320E-01	.320E-03	27.67	
Zamarin	.359E-01	.359E-03	31.03	
USB	.335E-02	.335E-04	2.89	
Barr	.392E-02	.392E-04	3.39	
Alyamani and Sen	.331E-02	.331E-04	2.86	
Chapuis	.468E-02	.468E-04	4.04	
Krumbein and Monk	.720E-02	.720E-04	6.22	
Shepherd	.108E-01	.108E-03	9.34	
geometric mean	.775E-02	.775E-04	6.70	
arithmetic mean	.103E-01	.103E-03	8.87	



Grain Size Analysis Report

Date:

7/28/2025

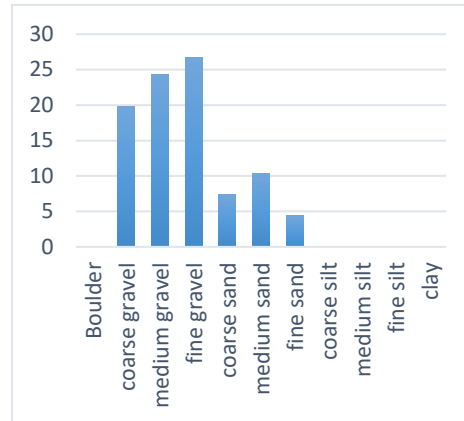
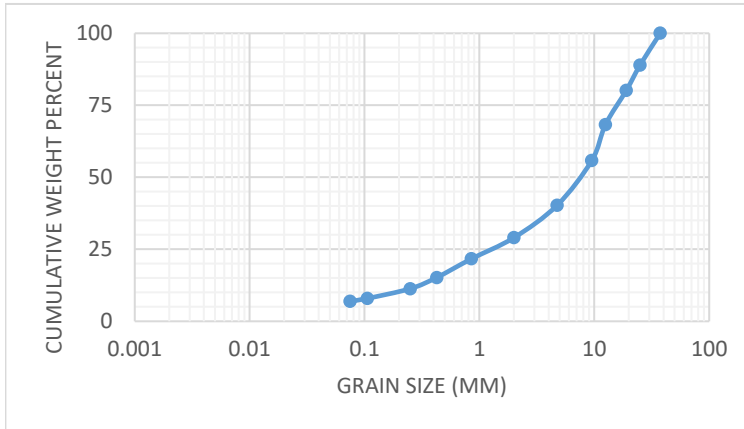
Sample Name: W-9, G-13, 54ft

Mass Sample (g): 2287.15

T (oC)

20

Poorly sorted sandy gravel low in fines



Sieve opening (ps) di (mm)	Mass of retained (mr) (g)	mass fraction (mf)	Percent Passing (pp)
37.5	0	0	100
25	253.1463	0.110682	88.9318
19	200.0083	0.087449	80.18693
12.5	272.0277	0.118937	68.29319
9.5	285.7167	0.124923	55.80093
4.75	354.4993	0.154996	40.30132
2	257.462	0.112569	29.04443
0.85	168.7192	0.073768	21.6676
0.425	147.6799	0.064569	15.21066
0.25	88.87773	0.03886	11.3247
0.106	77.27896	0.033788	7.945868
0.075	22.65774	0.009907	6.955214

Effective Grain Diameters (mm)		Other Useful Parameters	
d10	0.194	Uniformity Coef.	54.29
d17	0.543	n computed	0.26
d20	0.740	g (cm/s ²)	980.00
d50	7.722	ρ (g/cm ³)	0.9981
d60	10.508	μ (g/cm s)	0.0098
de (Kruger)	1.541	ρg/μ (1/cm s)	9.9327E+04
de (Kozeny)	1.369	tau (Sauerbrei)	1.053
de (Zunker)	1.424	d _{geometric mean}	4.719
de (Zamarin)	1.482	σ _φ	2.770
lo (Alyameni)	-1.689		
mm	0	% in sample	
>64	Boulder		
16 - 64	coarse gravel		19.81307
8 - 16	medium gravel		24.386
2 - 8	fine gravel		26.7565
0.5 - 2	coarse sand		7.37683
0.25 - 0.5	medium sand		10.3429
0.063 - 0.25	fine sand		4.369486
0.016 - 0.063	coarse silt		
0.008 - 0.016	medium silt		
0.002 - 0.008	fine silt		
<0.002	clay		



K from Grain Size Analysis Report

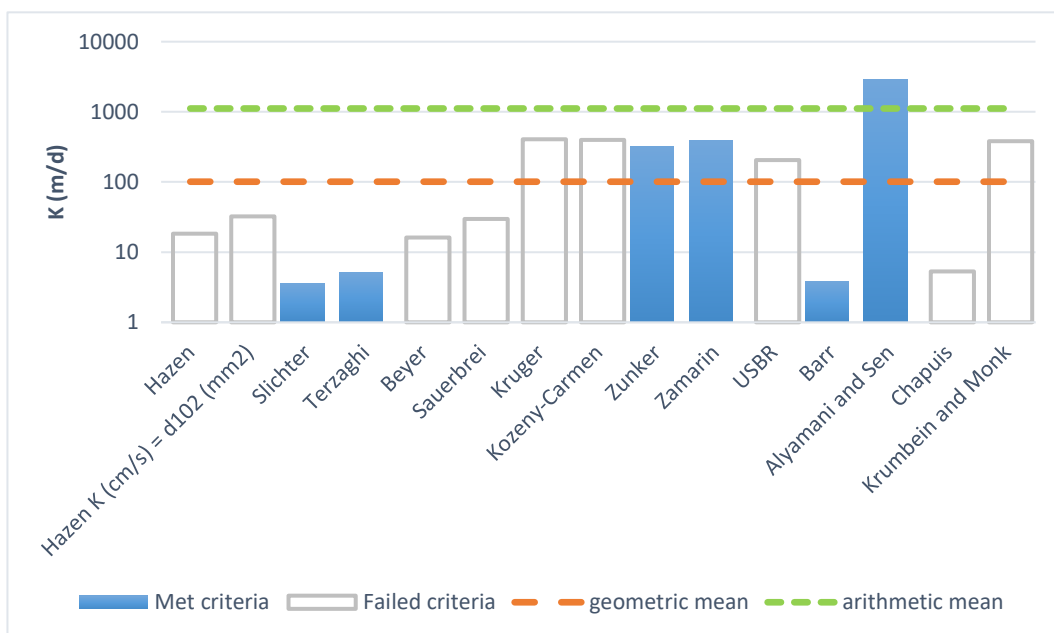
Date: 7/28/2025

Sample Name: W-9, G-13, 54ft

Mass Sample (g): 2287.15

T (oC) 20

Poorly sorted sandy gravel low in fines



Estimation of Hydraulic Conductivity	cm/s	m/s	m/d	de
Hazen	.212E-01	.212E-03	18.33	
Hazen K (cm/s) = d ₁₀ (mm)	.375E-01	.375E-03	32.36	
Slichter	.417E-02	.417E-04	3.60	
Terzaghi	.594E-02	.594E-04	5.14	
Beyer	.187E-01	.187E-03	16.12	
Sauerbrei	.345E-01	.345E-03	29.83	
Kruger	.471E+00	.471E-02	407.21	
Kozeny-Carmen	.461E+00	.461E-02	398.71	
Zunker	.366E+00	.366E-02	315.97	
Zamarin	.449E+00	.449E-02	388.21	
USBR	.239E+00	.239E-02	206.24	
Barr	.447E-02	.447E-04	3.86	
Alyamani and Sen	.339E+01	.339E-01	2926.62	
Chapuis	.615E-02	.615E-04	5.31	
Krumbein and Monk	.440E+00	.440E-02	380.41	
Shepherd	.482E+01	.482E-01	4163.95	
geometric mean	.117E+00	.117E-02	100.94	
arithmetic mean	.129E+01	.129E-01	1115.34	

APPENDIX E
Dewatering and Depressurization Analysis

Appendix E

Dewatering and Depressurization Analysis

This appendix documents the methodology to evaluate dewatering and depressurization requirements for the Sea-Tac IWTP project. Construction of the aerated gravel bed (AGB) tank and pumping station will require excavation below the water table. Subsurface investigations at the site indicate that a unit of Glacial Outwash has confined artesian pressures which extend near or beyond ground surface across the site. In addition, zones of perched groundwater and saturated conditions may be encountered within the Fill and Glacial Till units overlying the Glacial Outwash. Dewatering will be required when the excavation extends below groundwater. Depressurization of the Glacial Outwash will be necessary to reduce hydrostatic uplift forces acting on the overlying soil to maintain a stable working surface in excavations.

This appendix includes information on the following subjects:

- Uplift Calculations;
- Dewatering and Depressurization Assessment Modeling;
- Results and Conclusions of Dewatering and Depressurization Assessment

Uplift Calculations

Hydrostatic uplift may affect the subbase of an excavation. When an excavation is constructed at a depth where the groundwater is present, or piezometric pressures are present, the potential for adverse impacts on the excavation must be taken into account. A significant concern for stability of the construction excavation is the elevated piezometric heads in the Glacial Outwash aquifer. The heads in this aquifer provide a source of recharge to the Fill and Glacial Till units and reduction of these heads will be necessary for dewatering of the excavations. If not lowered, the heads in the Glacial Outwash aquifer can also create instability of the base of the excavations.

To identify if the groundwater pressures in the Glacial Outwash aquifer are sufficient to cause instability or heave in the excavations, factor of safety calculations were performed for the excavations. Four cases were evaluated, which include excavation for the AGB tank with and without additional shoring below the excavation, and excavation for the pumping station with and without additional shoring below the excavation. The calculation inputs and results are provided in Table E-1. The following provides an example of the factor of safety calculation method for the AGB tank excavation:

Base of Excavation Elevation: 278 feet

Glacial Outwash Groundwater Elevation: 310 feet

Top of Glacial Outwash unit Elevation: 256 feet

Thickness of soil between subgrade and top of Glacial Outwash: 22 feet

Acting head on base of aquitard: (310 feet – 256 feet) = 54 feet

Factor of Safety (FS) = $F_{gl}/F_{hw} = 1.3$

$FS = Y_s b / Y_w h = 125 \text{ lbs/ft}^3 (22 \text{ feet}) / 62.4 \text{ lbs/ft}^3 (54 \text{ feet}) = 2,750 / 3,370 = 0.8$

For basal stability ($FS \geq 1.3$)

Required head = $h = Y_s b / Y_w (1.3) = 125 \text{ lbs/ft}^3 (22 \text{ feet}) / 62.4 \text{ lb/ft}^3 (1.3) = 2,750 / 81 = 34 \text{ feet}$
Required Groundwater Elevation = El 256 feet + 34 feet = 290 feet
Required Drawdown = 310 feet – 290 feet = 20 feet

Where:

F_{gl} = downforce resulting from the weight of soil
 F_{hw} = hydrostatic uplift force
 Y_s = unit weight of soil
 b = thickness of soil plug
 Y_w = unit weight of water
 h = piezometric head acting on the base of the Glacial Till

Geologic unit elevations were determined from borings W-8 and W-9 for the AGB tank area, and from boring W-7 for the pumping station area. Parameters used for uplift calculations and resulting factors of safety and depressurization targets are contained in Table E-1. A factor of safety of 1.3 was used to determine depressurization targets.

The excavation depth of the pumping station will likely extend into the Glacial Outwash unit. In this case, there is no factor of safety calculated against the uplift forces and it is assumed that dewatering of the Glacial Outwash unit will be required.

Dewatering and Depressurization Assessment Modeling

A groundwater model was developed to estimate likely water volumes and flow rates generated during construction dewatering and depressurization activities. The groundwater flow model was constructed using the United States Geological Survey (USGS) MODFLOW-2005 code (Harbaugh, 2005). The software package Groundwater Vistas Version 8 (Environmental Simulations, Inc., 2020) was used to prepare the input files and to post-process the model results.

Assumptions made in the groundwater flow simulations are based on our review of available conceptual plans for the AGB tank and pumping station and our experience with similar projects. A general summary of model construction and assumptions used in the groundwater models is provided below.

- The model domain encompassed an area 5,120 feet east-west and 5,120 feet north-south. The rectangular grid consisted of 368 rows, 305 columns, and 4 layers, with a variable grid spacing of 2 to 172 ft. The layer thickness varied from 1 to 15 ft. Grid spacing was smaller near the AGB tank and pumping station.
- Elevation (EL) is assumed to be in feet in the NAVD88 vertical datum.
- The top of the model (Layer 1) was flat and generally corresponds to ground surface at the location of the AGB tank with EL 295 feet. Layer 1, which represents the Fill unit, had bottom of EL 290 feet. Layer 2, which represents the Glacial Till unit, had bottom at EL 258 feet. Layers 3 and 4 represent the Glacial Outwash unit. Layer 3 had bottom at EL 225 feet. The bottom of the model (Layer 4) was assigned EL 200 feet.
- Groundwater flow was simulated under steady-state conditions.
- Layers 1 and 2 were assigned unconfined layer types. Layers 3 and 4 were assigned confined layer types.

- The northern and southern edges of the model were defined as a constant-head boundary with head at EL 295 feet in Layers 1 and 2 and EL 310 feet in Layers 3 and 4. This creates a baseline condition for all simulations with an upward vertical gradient between the Glacial Outwash and overlying layers.
- The eastern and western boundaries and the bottom of the model were no flow boundaries.
- Hydraulic conductivity is the most critical parameter in determining groundwater flow and the amount of water captured by dewatering and depressurization systems. Hydraulic conductivity values used in the model were based on slug testing and grain size analysis (see Appendix D). These methods are typically accurate only to the order of magnitude (Eggleson and Rojstaczer, 2001; Herzog, 1994). In our experience, the slug testing results generally indicated higher than typical hydraulic conductivity values for the Glacial Till, thus a lower value was used in the model. Hydraulic conductivity estimates for the Glacial Outwash from grain size analysis varied over several orders of magnitude. Values were selected to represent likely low, moderate, and high hydraulic conductivity cases. Table E-1 contains hydraulic conductivity values used in the model. A 10:1 ratio of horizontal to vertical hydraulic conductivity was used for all units.

Table E-2. Summary of Model Hydraulic Conductivity Values		
Unit	Horizontal Hydraulic Conductivity (feet/day)	Vertical Hydraulic Conductivity (feet/day)
Fill	5	0.5
Glacial Till	0.3	0.03
Glacial Outwash - Low	10	1
Glacial Outwash - Moderate	50	5
Glacial Outwash - High	500	50

- The AGB tank and pumping station excavations and depressurization were modeled independently.
- Shoring will likely be necessary to maintain open excavations. The shoring was not modeled as providing hydraulic cutoff. Likely construction scenarios include shoring installed to the bottom of excavation and below the bottom of excavation. Models were created for scenarios in which depressurization extends to approximately 2 feet below the bottom excavations and for depressurization extending to 10 feet below the bottom of excavation to provide additional depressurization for shoring. Table E-3 contains depressurization targets for each scenario.

Table E-3. Summary of Excavation Dimensions and Depressurization Targets		
Scenario	Dimensions (W x H) (feet)	Depressurization Target in Layer 3 (feet)
AGB tank	220 x 220	287
Pumping station	220 x 220	267.5
AGB tank with deep shoring	25 x 80	272
Pumping station with deep shoring	25 x 80	256

- Dewatering and depressurization systems were modeled using the Drain package. Drains were assigned to cells around the perimeter of the excavation in Layers 1 to 3. Drain elevations in Layers 1 and 2 were assigned 0.1 feet above the bottom of the cell. Drain elevations in Layer 3

were specified to achieve the depressurization targets contained in Table E-3 across the excavation footprint. Drain hydraulic conductivity of 1,000 feet/day was assumed.

- Drain cell fluxes from Layers 1 and 2 were summed to estimate dewatering flow rates in the Fill and Glacial Till. Drain cell fluxes from Layer 3 were summed to estimate depressurization rates in the Glacial Outwash.

Results and Conclusions of Dewatering and Depressurization Assessment

A summary of predicted flow rates required to achieve depressurization targets and safety factors is contained in Table E-3. Predicted depressurization flow rates are plotted against hydraulic conductivity in the attached Figure E-1. Predicted flow rates to dewater the Fill and Glacial Till units were less than 10 gallons per minute (gpm). Predicted flow rates to depressurize the Glacial Outwash varied from approximately 130 to approximately 10,000 gpm. Depressurization to accommodate deep shoring may increase these rates to approximately 220 to approximately 12,000 gpm. Flow rates increase with hydraulic conductivity, as illustrated in Figure E-1.

Dewatering of the Fill and Glacial Till units is not likely to produce significant volumes of water. Coarse granular lenses within the Glacial Till may temporarily produce greater volumes of water but flow rates are expected to reduce as the lenses are dewatered. Dewatering may likely be achieved by combinations of trenches and sumps within the excavation. If the coarser lenses are hydraulically connected to the Glacial Outwash, they may act as conduits for groundwater flow and produce greater volumes than predicted in this analysis.

The modeling results suggest depressurization within the Glacial Outwash to the required levels to mitigate uplift pressures may be achieved by pumping from the perimeter of the excavations.

Explorations completed on site did not encounter the bottom of the Glacial Outwash unit. The bottom elevation of Layer 4 was varied from EL 200 to EL 150 feet to assess how the unit thickness would affect predicted flow rates. Using the hydraulic conductivity of 500 feet/day, the predicted flow rate increased by about 45 percent, from approximately 7,000 gpm to 10,000 gpm.

We recommend a pumping test in the Glacial Outwash unit for determination of aquifer properties and feasibility of depressurizing the unit to the required levels. We recommend further explorations to determine the thickness of the Glacial Outwash unit.

Attachments:

Table E-1 – Hydrostatic Uplift and Factor of Safety Calculations

Table E-4 – Summary of Dewatering/Depressurization Modeling Results

Figure E-1 – Predicted Depressurization Flow Rates

References

1. Eggleston, J., and Rojstaczer, S., 2001. The Value of Grain-size Hydraulic Conductivity Estimates: Comparison with High Resolution In-situ Field Hydraulic Conductivity. American Geophysical Union, Geophysical Research Letters, vol. 28, no. 22, pages 4255-4258.
2. Environmental Simulations, Inc., 2020. Groundwater Vistas Version 8.
3. Harbaugh, A.W., 2005. MODFLOW-2005, the U.S. Geological Survey modular ground-water model -- the Ground-Water Flow Process: U.S. Geological Survey Techniques and Methods 6-A16.
4. Herzog, Beverly L., 1994. Slug tests for determining hydraulic conductivity of natural geologic deposits. Proceedings of the Symposium on Hydraulic Conductivity and Waste Contaminant Transport in Soil, ASTM Special Technical Publication, Issue 1142. Accessed from USGS Publications Warehouse, <https://pubs.usgs.gov/publication/70017474>.

<https://haleyaldrich.sharepoint.com/sites/PortofSeattle/Shared Documents/0204661.POS SeaTac Mech and Elec IDIQ/002 IWTP Treatment Facility/Deliverables In-Basket/Geotech Report/Attachments/Appendices/Appendix E/Appendix E-text.docx>

TABLE E-1

HYDROSTATIC UPLIFT AND FACTOR OF SAFETY CALCULATIONS

SEA-TAC IWTP - AGB SITE

SEATAC, WASHINGTON

Parameter	Unit	Tank		Tank with Deep Shoring		Pumping Station	Pumping Station with Deep Shoring
		W-8	W-9	W-8	W-9	W-7	W-7
Surface Elevation	feet	295	295	295	295	295	295
Groundwater Elevation	feet	310	310	310	310	310	310
Bottom of Excavation Elev	feet	278	278	268	268	266	256
Bottom of Fill Elev	feet	288	290	288	290	294	294
Bottom of Till Unit Elev	feet	256	260	256	260	263	263
Top of Outwash Elev	feet	256	260	256	260	263	263
Unit weight of Fill	lb/ft ³	120	120	120	120	120	120
Unit weight of Till	lb/ft ³	125	125	125	125	125	125
Unit weight of water	lb/ft ³	62.4	62.4	62.4	62.4	62.4	62.4
Calculated							
Thickness Fill	feet	0	0	0	0	0	0
Thickness Till	feet	22	18	12	8	3	0
Water Column	feet	54	50	54	50	47	47
Weight of Soil Plug	lb/ft ³	2750	2250	1500	1000	375	0
Water Column Pressure	lb/ft ³	3370	3120	3370	3120	2933	2933
Calc Factor of safety (FS)		0.82	0.72	0.45	0.32	0.13	--
Drawdown	feet	20	23	36	38	42.5	44
Depressurization Goal (FS)	1.3	1.30	1.34	1.34	1.34	1.34	--
Dewatering Goal Elevation	feet	290	287	274	272	267.5	256

Notes:

Excavations for pumping station with deep shoring extend into Glacial Outwash, no factor of safety calculated

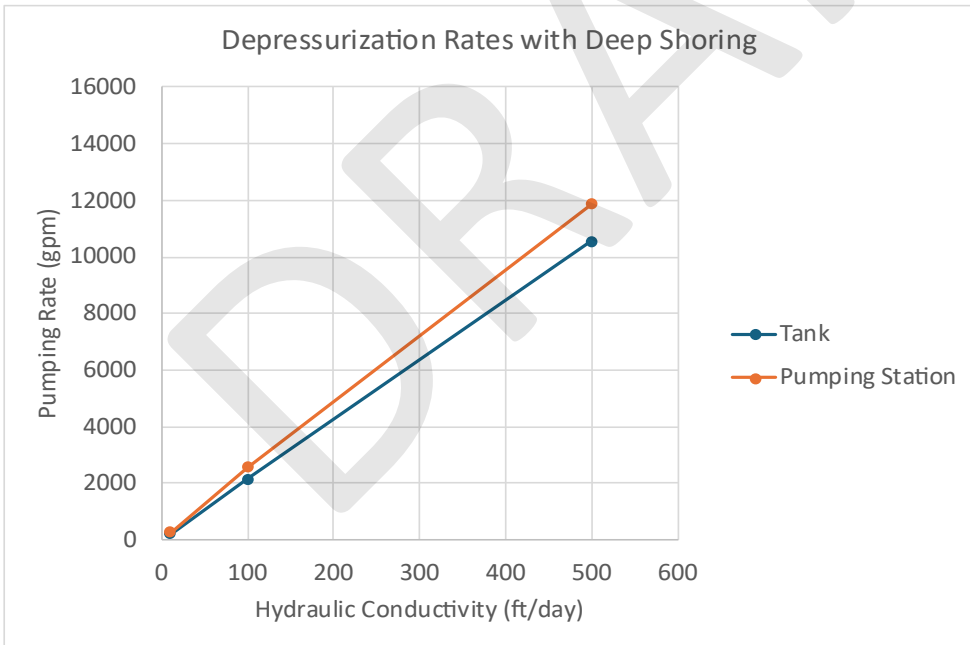
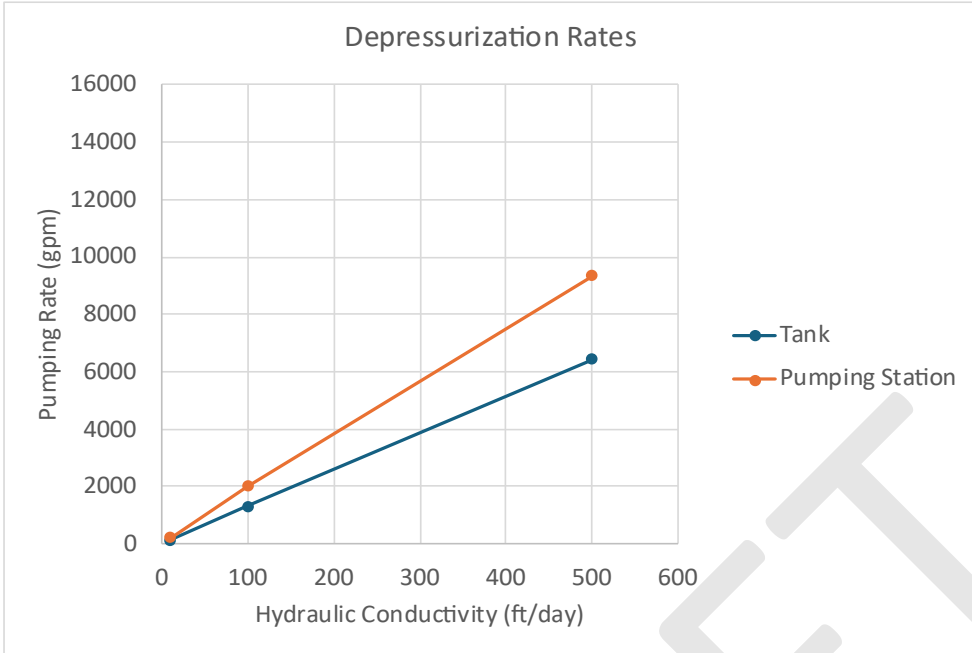
TABLE E-4

SUMMARY OF DEWATERING/DEPRESSURIZATION MODELING RESULTS

SEA-TAC IWTP - AGB SITE

SEATAC, WASHINGTON

Scenario	Description	Head in Outwash feet	Depressurization Target feet	Kh feet/day	Kv feet/day	Kh:Kv Ratio	Fill/Glacial Till Dewatering Flow Rate		Glacial Outwash Depressurization Flow Rate	
							cubic feet/day	gpm	cubic feet/day	gpm
A	AGB tank	310	287	10	1	10:1	1,270	7	24,500	130
		310	287	100	10	10:1	1,280	7	253,000	1,320
		310	287	500	50	10:1	1,300	7	1,237,000	6,430
B	Pumping station	310	267.5	10	1	10:1	150	1	39,800	210
		310	267.5	100	10	10:1	160	1	388,100	2,020
		310	267.5	500	50	10:1	180	1	1,800,000	9,330
C	AGB tank with deep shoring	310	272	10	1	10:1	550	3	42,000	220
		310	272	100	10	10:1	560	3	416,000	2,160
		310	272	500	50	10:1	600	3	2,030,000	10,600
D	Pumping station with deep shoring	310	256	10	1	10:1	110	1	51,000	270
		310	256	100	10	10:1	130	1	493,000	2,600
		310	256	500	50	10:1	130	1	2,283,000	11,900



Notes:
gpm = gallons per minute

IWTP TREATMENT FACILITY
SEATAC, WASHINGTON

PREDICTED DEPRESSURIZATION FLOW RATES

AUGUST 2025

HALEY
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Figure

E-1