EXHIBIT I
GEOTECHNICAL REPORT

PanGEO
INCORPORATED
Geotechnical & Earthquake Engineering Consultants

August 8, 2016
PanGEO File No. 16-134

Mr. Eric Delfel, P.E.
Gray & Osborne, Inc.
701 Dexter Avenue North, Suite 200
Seattle, Washington 98109

Subject: **Geotechnical Report**
MWWD Lift Station No. 10 Replacement
Mukilteo, Washington
G&O #16429

Dear Mr. Delfel,

PanGEO has completed a geotechnical study for the proposed lift station replacement project for the Mukilteo Water and Wastewater District. The results of our study are presented in the attached report. In summary, the subsurface conditions in the vicinity of the wet well consist of loose to medium dense existing fill overlying medium dense to dense glacial soils. Temporary shoring will likely be needed to accomplish the wet well excavation. It is our opinion that the glacial site soils are adequate for supporting the wet well provided the recommendations in the attached geotechnical report are incorporated into design and construction of the project. Up to approximately 7½ feet of loose soil was encountered on the west side of the pump station building. Provided the loose soil is overexcavated and replaced with structural fill, the pump station building may be supported on a conventional foundation. We appreciate the opportunity to assist you with this project. Please call if you have any questions.

Sincerely,

Siew L. Tan, P.E.
Principal Geotechnical Engineer

3213 Eastlake Avenue East, Suite B
Seattle, WA 98102
Tel (206) 262-0370

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF APPENDICES

GEOTECHNICAL REPORT
MWWD LIFT STATION NO. 10 REPLACEMENT
MUKILTEO, WASHINGTON

1.0 GENERAL

PanGEO completed a geotechnical study to assist the project team with the design and construction to replace the Mukilteo Water and Wastewater District's lift station No. 10 in Mukilteo, Washington. Our work was performed in accordance with our proposal dated January 11, 2016. The purpose of our geotechnical study was to evaluate subsurface conditions at the site and to provide geotechnical engineering recommendations pertinent to design and construction of the replacement lift station. Our services included a site reconnaissance, drilling four test borings, and developing the conclusions and recommendations contained in this report.

2.0 SITE AND PROJECT DESCRIPTION

The existing lift station facility is located near the northwest corner of the intersection of Mukilteo Speedway (State Route 525) and Goat Trail Road in Mukilteo, Washington. The project site is approximately as shown on Figure 1, Vicinity Map. We understand that the lift station replacement project will include installing a new 10-foot dimeter wet well that may extend approximately 16 feet below grade, constructing a new pump station building, and associated new utility pipes/force mains.

Plate 1. Boring BH-1 drilled in general vicinity of proposed wet well, facing south.

Topography at the site consists of an upper, relatively level 20- to 30-foot wide bench located adjacent to Mukilteo Speedway. The existing wet well, dry pit, control vault, and generator are located within this upper bench and the new wet well is planned in this area as shown in Plate 1 and on the attached Figure 2. Given the proximity to the new wet well to Mukilteo Speedway and the depth of the excavation, excavation shoring will likely be needed to accomplish the wet well excavation.

The top of an approximately 10- to 14-foot high west-facing slope that descends at an approximately 2H:1V inclination is located on the west side of the upper bench. An approximately 30-foot wide lower bench is located at the toe of the slope. The new pump station building is planned within the lower bench. We understand the pump station building will be an at-grade structure of CMU construction with a concrete slab-on-grade floor.

The top of a west-facing slope that descends at an inclination of 2H:1V or less is located on the west side of the lower bench. To achieve design grade for the pump station building, a retaining wall will be constructed on the west side of the building to retain up to approximately 8 feet of fill approximately at shown on the attached Figure 3.

3.0 SUBSURFACE EXPLORATION

On May 27, 2016, four test borings (BH-1 through BH-4) were drilled at the approximate locations shown on Figure 2. The borings were drilled to depths between 11½ and 36½ feet below the existing ground surface using a limited access track-mounted drill rig owned and operated by Boretec1, Inc. of Bellevue, Washington. Boring BH-1 was drilled using nominal 8-inch outside diameter hollow stem augers and the remaining borings were drilled using nominal 6-inch outside diameter hollow stem augers.

Soil samples were obtained from the borings at 2½- and 5-foot depth intervals using Standard Penetration Test (SPT) sampling methods which were performed in general accordance with ASTM test method D-1586. The sampling was conducted using a 2-inch outside diameter split-spoon sampler that was driven into the soil a distance of 18 inches using a 140-pound weight freely falling a distance of 30 inches. The number of blows required for each 6-inch increment of sampler penetration was recorded. The number of blows required to drive the sampler between incremental depths of 6 and 18 inches is defined as the SPT N-value. The N-value provides an empirical measure of the relative density of cohesionless soil or the relative consistency of fine-grained soils. The N-values from the boring are noted and plotted on the individual boring logs.

A two-inch diameter groundwater monitoring well was installed in BH-1. The groundwater monitoring well will need to be decommissioned per the Washington State Department of Ecology's standards prior to or during construction.

A geologist from PanGEO was present during the field exploration program to observe the drilling, assist in sampling, and to describe the soil samples using the system outlined on Figure A-1 in Appendix A. Logs of the borings drilled for this study are presented in Figures A-2 to A-5 of Appendix A.

In addition, a hand boring (HB-1) was excavated to 4 feet below grade to supplement the test borings. The approximate location of the hand boring is indicated on Figure 2. The hand boring was excavated using hand tools and the relative density and consistency of the underlying soil were estimated based on probing the walls of the excavation and the difficulty of completing the excavation. A description of the conditions encountered in the hand boring is provided in the *Subsurface Conditions* section of this report.

4.0 SUBSURFACE CONDITIONS

4.1 SITE GEOLOGY AND SOIL CONDITIONS

Review of the *Distribution and Description of Geologic Units in the Mukilteo Quadrangle, Washington* (Minard, 1982) indicates that the surficial geologic unit in the vicinity of the subject site is Vashon advance outwash (Map Unit Qva). In addition, Vashon glacial till (Qvt) is mapped upslope to the east and Fraser to pre-Fraser aged transitional beds (Qtb) are mapped downslope to the west of the site. Minard describes advance outwash deposits as mostly clean, gray, pebbly sand with increasing amounts of gravel higher in the section. Glacial till is a very dense heterogeneous mixture of silt, sand, and gravel laid down at the base of an advancing glacial ice sheet. Minard describes the transitional beds as thick beds of gray clay, silt, and fine- to very-fine sand occurring beneath advance outwash sand.

In summary, based on the subsurface conditions encountered in our test borings, the subject site is underlain by a sequence of existing fill, glacial till, advance outwash, and transitional beds. Please refer to the summary boring logs in Appendix A for additional details. A generalized subsurface profile depicting the subsurface conditions encountered in our borings is provided on Figure 3. The following is a description of the soils encountered in our borings.

Fill – At borings BH-1 and BH-4, 6 to 7½ feet of very loose to loose existing fill consisting of silty sand with gravel was encountered. In addition, loose to medium dense silty sand existing fill was encountered to 4 feet below grade at hand boring HB-1. The existing contained varying amounts of organic debris. We suspect the existing fill encountered at BH-1 and HB-1 is related to road grading for Mukilteo Speedway and the fill encountered at BH-4 is likely due to cut and fill grading to establish the lower bench area.

Glacial Till – Underlying the existing fill at BH-1 and BH-4 and near the surface at BH-2 and BH-3, medium dense to very dense silty sand with gravel that we interpret to be glacial till was encountered. Based on drilling action, the glacial till may contain cobbles or small boulders. The glacial till encountered at each of the borings appears to be consistent with the mapped geology for the area. The glacial till soils were encountered to approximately 15 feet below grade at BH-1, 7½ feet below grade at BH-2, and to the maximum exploration depth of 11½ feet below grade at BH-3 and BH-4.

Advance Outwash – Underlying the glacial till soils at BH-1 and BH-2, medium dense to dense silty sand to poorly graded sand with silt that we interpret to be advance outwash deposits were encountered. The advance outwash soils were encountered from 7½ to 15 feet below grade at BH-1 and from 7½ to 10 feet below grade at BH-2.

Transitional Beds – Underlying the advance outwash deposits at BH-1 and BH-2, very stiff to hard clayey silt to silt that we interpret to be transitional beds were encountered. The transitional beds were typically laminated and contained occasional sand seams and fractured/diced zones.

4.2 GROUNDWATER

Groundwater was encountered about 35 feet below grade in BH-1 and 11 feet below grade at BH-2 at the time of drilling. Groundwater was not encountered at BH-3, BH-4, or HB-1 at the time of drilling. However, iron-oxide and manganese-oxide staining indicative of seasonal groundwater conditions were noted at varying depths in the glacial till, advance outwash, and transitional bed soil units.

A groundwater monitoring well that was screened from 15 to 20 feet below grade was installed in BH-1 to monitor for potential groundwater in the proposed wet well excavation. On July 12, 2016 we visited the site to measure the groundwater level in the well and no groundwater was detected at that time.

Groundwater elevations and seepage rates are likely to vary depending on the season, local subsurface conditions, and other factors. Groundwater levels are normally highest during the winter and early spring.

5.0 GEOTECHNICAL RECOMMENDATIONS

5.1 NEW WET WELL

5.1.1 Design Lateral Earth Pressure

The wet well should be designed to resist lateral loads imposed by the surrounding soils and applicable surcharge loads. For a circular wet well structure, we recommend that the lateral earth pressure be calculated using an equivalent fluid pressure of 50 pcf. The earth pressure will be partially offset by the hydrostatic pressure exerted by the water inside the structure. The hydrostatic pressure inside the wet well should be calculated based on a unit weight for water of 62.4 pcf.

5.1.2 Buoyancy Force

Based on the subsurface conditions encountered at BH-1 and the absence of groundwater in the BH-1 monitoring well on July 12, 2016, the groundwater table is not anticipated to be encountered in the wet well excavation. As such, the proposed wet well need not be designed to resist hydrostatic uplift forces. If surfacewater or groundwater seepage accumulates adjacent to the wet well, we anticipate that the water would infiltrate into the underlying advance outwash soils and/or drain into utility pipe bedding.

5.1.3 Foundation Support

Assuming the excavation for the wet well will extend on the order of 16 feet below the existing site grade, we anticipate medium dense to dense glacial till or advance outwash soils will be encountered at the bottom of the excavation. The glacial till and advance outwash soils are anticipated to provide adequate support for the wet well. To provide a firm working and bearing surface, a leveling course consisting of at least one foot of crushed surfacing base course (CSBC, WSDOT 9-03.9(3)) should be placed below the base of the structure. For design purposes, an allowable bearing pressure of 4,000 psf may be used for sizing the foundation. A representative of Gray & Osborne or PanGEO should verify the adequacy of the subgrade prior to placing forms or reinforcing steel.

5.1.4 Wet Well Backfill

The contractor should be aware that the site soils encountered at our borings contain a relatively high fines content and are considered moisture sensitive. As such, the onsite soil will likely become difficult or impossible to adequately compact if it becomes too wet. If import material is needed for backfill, we recommend that wall backfill consist of granular soils such as Gravel Borrow (WSDOT 9.03.14(1)).

Structural fill should be moisture conditioned to near its optimum moisture content, placed in loose, horizontal lifts less than 8 inches in thickness, and systematically compacted to a dense and relatively unyielding condition and to at least 95 percent of the maximum dry density, as determined using test method ASTM D 1557.

5.2 PUMP STATION BUILDING

5.2.1 Seismic Considerations

We understand the seismic design of the pump station building will be accomplished using the 2015 edition of the International Building Code (IBC), which specifies a design earthquake having a 2% probability of occurrence in 50 years (return interval of 2,475 years). The table below presents the seismic design parameters in accordance with the 2015 IBC, which are consistent with the 2008 USGS seismic hazard maps.

Table 1 - 2015 IBC Summary Seismic Design Parameters

Site Class	Spectral Acceleration at 0.2 sec. (g)	Spectral Acceleration at 1.0 sec. (g)	Site Coefficients		Design Spectral Response Parameters	
	S_S	S_1	F_a	F_v	S_{DS}	S_{D1}
D	1.465	0.569	1.000	1.500	0.977	0.569

Soil liquefaction is a condition where saturated cohesionless soils undergo a substantial loss of strength due to the build-up of excess pore water pressures resulting from cyclic stress applications induced by earthquakes. Soils most susceptible to liquefaction are loose, uniformly graded sands and loose silts with little cohesion. In our opinion, liquefaction is not a design consideration for this site because of the dense nature of the soils underlying the site and the depressed groundwater level.

5.2.2 Pump Station Building Foundation

Based on the subsurface conditions encountered in our borings drilled at the site, it is our opinion that a conventional spread footings are an appropriate foundation type to support the proposed pump station building, provided that the foundation bears on medium dense to dense glacial till soils or on structural fill placed upon competent native soil. Based on the subsurface conditions encountered at BH-4, competent native soils may be as deep as approximately 7½ feet below grade on the west side of the pump station building. The following recommendations should be incorporated into design and construction of the building foundation.

> ***Overexcavation*** – Competent bearing soils may be on the order of 7½ feet below existing grade in the western portion of the building. Possible foundation alternatives in this area would be overexcavating to competent bearing soils and replacing the

overexcavated material with 1½ sack lean-mix concrete or granular structural fill such as Gravel Borrow (WSDOT 9-03.14(1)) or CSBC (WSDOT 9-03.9(3), or extending the footings down to competent glacial till soils. The overexcavation width should extend at least one-half the overexcavation depth beyond the edges of the footings, unless lean-mix concrete is used as backfill. With lean-mix concrete backfill, the width of overexcavation may be limited to the footing width. Footings should be founded upon either the competent native soil or on structural fill or lean-mix concrete placed on native undisturbed competent soil.

Allowable Bearing Pressure – We recommend that a maximum allowable bearing pressure of 2,500 pounds per square foot (psf) be used to size foundation elements bearing on competent glacial till deposits or on structural fill. For allowable stress design, the recommended bearing pressure may be increased by one-third for transient loading, such as wind or seismic forces. Continuous and individual spread footings should have minimum widths of 18 and 24 inches, respectively.

Footing Embedment – To prevent the pump station building from surcharging the new site retaining wall, bottom of the pump station footings should be positioned below a 1H:1V upward projection from the toe of the site retaining wall.

For frost heave considerations, exterior footings should be placed at a minimum depth of 18 inches below final exterior grade. Interior spread foundations should be placed at a minimum depth of 12 inches below the top of slab.

Estimated Settlement - Footings designed and constructed in accordance with the above recommendations should experience total settlement of less than one inch and differential settlement less than about ½ inch. Most of the anticipated settlement should occur during construction as dead loads are applied.

Lateral Load Resistance - Lateral loads on the structure may be resisted by passive earth pressure developed against the embedded near-vertical faces of the foundation system and by frictional resistance developed between the bottom of the foundation and the supporting subgrade soils. For footings bearing on granular soils, a frictional coefficient of 0.4 may be used to evaluate sliding resistance developed between the concrete and the subgrade soil. Passive soil resistance may be calculated using an equivalent fluid weight of 350 pcf, assuming the footings are backfilled with structural fill. The above values include a factor of safety of 1.5. Unless covered by pavements or slabs, the passive resistance in the upper 12 inches of soil should be neglected.

Footing Excavation and Subgrade Protection - All footing excavations should be carefully prepared. Any loose or softened soil should be removed from the footing excavations and replaced with granular structural fill such as CSBC. On-site soils should not be used as structural fill below the footings.

The site soils are moisture sensitive and the footing subgrade will likely become disturbed or softened when exposed to moisture and/or construction activities such as forming or placing reinforcing steel. As a result, it may be necessary to place 2 to 3 inches of lean-mix concrete or about 4 inches of clean, crushed rock to protect the subgrade.

Footing excavations should be observed by Gray & Osborne or PanGEO to confirm that the exposed footing subgrade is consistent with the expected conditions and adequate to support the proposed building.

5.3 FLOOR SLABS

It is our opinion that conventional concrete slab-on-grade floors are appropriate for this site. We recommend that the slab be underlain by 12 inches minimum of properly compacted CSBC placed on existing fill compacted to a firm and unyielding condition or on competent native soils. The subgrade should be compacted to a dense and unyielding condition before placing the CSBC.

5.4 RETAINING WALLS

To achieve design grade for the pump station building, a retaining wall will be constructed on the west side of the site to retain up to approximately 8 feet of new fill. Our recommendations for selection, design, and construction of retaining walls follow.

5.4.1 Selection of Wall Types

Given the limited height of fill planned in the vicinity of the pump station building, several wall options may be considered. The selection of wall type depends on several factors, including cost, performance, aesthetics, and constructability. For this project, it is our opinion that gravity walls such as a pre-cast concrete block walls or gabion walls are appropriate. Although a conventional cast-in-place concrete wall is also considered appropriate, a gravity wall is likely the more economical wall option.

5.4.2 Gravity Walls

The principal advantage of a gravity wall is the ease and speed of construction, and the relatively low construction cost. If a gravity wall will be used for this project, we recommend either a concrete block wall or a rock-filled gabion wall be used.

Concrete blocks should have a minimum dimension of 2½ feet by 2½ feet by 5 feet (Lock-Blocks or Ultrablocks www.ultrablocks.com) and be made of new concrete. Blocks made of returned concrete, or having dimensions of 2 feet by 2 feet by 6 feet (i.e. ecology blocks) should not be used. Concrete blocks can be made with various finishes or textures to provide the desired aesthetics. Typical block layouts for walls up to 4-blocks high are shown on Figure 4.

Gabion walls should be constructed in accordance with WSDOT Standard Plan Sheet D-6, and Section 8-24.3(3) Gabion Cribbing of the 2016 *WSDOT Standard Specifications*. Each gabion basket should be placed horizontally and with a minimum of 6 inches of setback from the basket below, hence creating an average wall face inclination of no steeper than 1H:6V. Dimensions of gabion baskets may vary depending on the supplier.

> ***Minimum Width*** – In general, as a minimum, all gabion baskets and concrete blocks should have a minimum width equal to the greater of 2½ feet or one-third the wall height. For walls with a retained height greater than 4 feet, we recommend that the bottom row of gabion or concrete blocks have a minimum width of 5 feet (i.e. measured perpendicular to wall face).
>
> ***Minimum Embedment*** - Walls should have a minimum of one foot of embedment. All walls should be founded on competent native soils or properly compacted fill.

If needed, a 6-inch layer of granular structural fill such as crushed rock may be placed as a leveling course before placing the base course.

Foundation Preparation – Based on the subsurface conditions encountered in BH-2 and BH-3, competent glacial till is anticipated to be encountered in the foundation excavations for the proposed retaining wall.

Surcharge - Lateral pressures from surface surcharges located within a distance equal to the exposed wall height should be estimated using a lateral pressure coefficient of 0.3 (i.e. the ratio of lateral pressure to vertical pressure). Where applicable, a lateral uniform pressure of 80 psf should be used to account for traffic surcharge.

5.4.3 Cast-In-Place Concrete Walls

Concrete retaining walls may be designed for an earth pressure based upon an equivalent fluid weight of 35 pcf. The recommended lateral pressures assume that adequate wall drainage provisions will be incorporated into the design and construction of the walls, and that properly compacted free-draining structural fill will be used for wall backfill. On-site soils should not be used as wall backfill because of its poor drainage characteristics. Weep holes may be placed near the base of the wall.

Wall footings should be supported on relatively undisturbed native soils or on structural fill placed on native soils. As such, an allowable bearing pressure of 2,500 psf may be used to size the footing. Recommendations outlined in Section 5.2 of this report are also applicable for cast-in-place walls.

Lateral resistance may be computed using an allowable friction coefficient of 0.4 at the base of footings, and an allowable passive resistance of 350 pcf against the embedded portion of the foundation element.

Lateral pressures from surface surcharges located within a distance equal to the exposed wall height should be estimated using a lateral pressure coefficient of 0.3 (i.e. the ratio of lateral pressure to vertical pressure). Where applicable, a lateral uniform pressure of 80 psf should be used to account for traffic surcharge.

5.5 ASPHALT PAVING

We understand that the access drive and the area around the pump station building will be paved. Site traffic will consist of passenger vehicles and vactor trucks. For site paving, we recommend at least 3 inches of hot mixed asphalt (HMA, WSDOT 9-03.8(2)) placed on at least 4 inches of crushed surfacing base course (CSBC, WSDOT 9-03.9(3)). Prior to placing the CSBC, the upper 12 inches of the subgrade should be compacted to at least 95% of its maximum dry density (Modified Proctor, ASTM D1557). After compaction, but prior to placing the CSBC, the pavement subgrade should be proof-rolled with a fully-loaded dump truck to verify the subgrade is stable and unyielding. If unstable areas are identified during the proof-roll that cannot be adequately compacted, the unstable area should be overexcavated to competent soil and backfilled with CSBC.

Please note that the near surface site soils are moisture sensitive, and can become difficult to compact when wet. In the event that the subgrade becomes unstable and compaction criteria cannot be achieved due to excess moisture content of the subgrade, we recommend that a geogrid layer (Tensar TX140, or better) be placed on the subgrade before placing the CSBC.

5.6 NEW UTILITIES

5.6.1 Trench Excavation

Trench excavations may be accomplished using conventional excavation equipment. All excavations should be sloped in accordance with Washington Administrative Code (WAC) 296-155, or be shored. It is contractor's responsibility to maintain safe working conditions, including temporary excavation stability.

5.6.2 Pipe Support and Bedding

Based on our field explorations, we anticipate medium dense to very dense silty sand with gravel will be encountered in utility trench excavations. Utility installation should be conducted in accordance with the 2016 WSDOT Standard Specifications or other applicable specifications for placement and compaction of pipe bedding and backfill. In general, pipe bedding should be placed in loose lifts not exceeding 6 inches in thickness, and compacted to a firm and unyielding condition. Bedding materials and thicknesses provided should be suitable for the utility system and materials installed, and in accordance with any applicable manufacturers' recommendations. Pipe bedding materials should be placed on relatively undisturbed native soil. Soft soils, if present, should be removed from the bottom of the trench and replaced with pipe bedding material.

5.6.3 Trench Backfill

The onsite soils may be utilized for trench backfill provided they can be compacted to the project specifications. If the onsite soils cannot be adequately compacted, trench backfill should consist of select granular material, meeting the requirements for Gravel Borrow as specified in Section 9-03.14(1) of the 2016 WSDOT *Standard Specifications,* or an approved equivalent. The trench backfill should be placed in 8- to 12-inch, loose lifts and compacted using mechanical equipment to at least 90 percent maximum dry density, per ASTM D1557. In paved areas, the upper 2 feet of the backfill should be compacted to at least 95 percent maximum dry density, per ASTM D1557. Heavy compaction equipment should not be permitted to operate directly over utilities until a minimum of 2 feet of backfill has been placed.

5.7 TEMPORARY EXCAVATION SLOPES, TEMPORARY SHORING, AND DEWATERING

We recommend that the excavation plan, dewatering plan, and shoring system selection and design be made the contractor's responsibility. The shoring should be designed in accordance with the current requirements of WISHA to provide adequate protection for the workers, adjacent structures, utilities, and other facilities. Our recommendations for temporary excavations, temporary shoring, and dewatering follow:

Temporary Excavation Slopes – The excavation for the wet well, including our recommended minimum 1-foot of CSBC for foundation support, is anticipated to extend about 17 feet below grade and expected to encounter loose to medium dense fill soils that are prone to caving over medium dense to dense glacial till and advance outwash deposits. Based on the depth of excavation and the proximity to Mukilteo Speedway, we do not envision it will be feasible to accomplish the wet well excavation utilizing only unsupported temporary excavation slopes. However, a combination of temporary shoring on the east side of the excavation and unsupported temporary excavation slopes on the west side of the excavation may be feasible.

All temporary excavations should be performed in accordance with Part N of the WAC (Washington Administrative Code) 296-155. The contractor is responsible for maintaining safe excavation slopes and/or shoring. For planning purposes, the temporary excavations in existing fill may be sloped as steep as 1H:1V and excavations in dense glacial till may be sloped as steep as ¾H:1V. During wet weather, the cut slopes may need to be flattened to reduce potential erosion.

Temporary Shoring – The design of the temporary shoring system should be the contractor's responsibility. However, based on the soil conditions encountered in BH-1, and the close proximity of Mukilteo Speedway, we envision that the wet well excavation can be accomplished using temporary soldier piles with timber or steel plate lagging. As previously discussed, it may be feasible to accomplish the wet well excavation using a combination of temporary shoring near Mukilteo Speedway and unsupported excavation slopes on the west side of the excavation. Because the anticipated excavation will be about 17 feet deep, internal bracing will likely be needed to provide a more economical design than a cantilevered wall, and to limit excessive lateral movements near the top of the walls. Other feasible temporary excavation shoring methods to install the wet well may include using trench boxes, caisson construction, or other proprietary methods such as the Slide-Rail system (http://www.speedshore.com) or equivalent. However, it is our opinion that these methods may have a higher risk for ground movements outside of the excavation.

Given the cobbles and boulders anticipated to be encountered in the site soils, sheet piles may not be a practical shoring option, unless pre-drilling is performed before sheetpile installation. Selection of installation methods should consider the potential impacts to existing nearby structures and utilities and the presence of large cobbles and boulders.

All excavations should be conducted in accordance with all applicable federal, state, and other local safety requirements. As a minimum, we recommend that the following soil parameters be used to evaluate the earth pressures for sizing the shoring system. Please refer to the log of boring BH-1 for the anticipated depth intervals of the various soil units.

Soil unit weight (Fill):	120 pcf
Soil unit weight (Glacial Till):	130 pcf
Soil Friction Angle (ϕ):	32 degrees (Fill)
	36 degrees (Glacial Till)

Lateral loads due to construction equipment traffic or sloping ground conditions adjacent to the excavations should also be added to the recommended earth pressures for design purposes.

The adequacy and safety of the shoring installation should be made the sole responsibility of the contractor. A qualified geotechnical engineer/shoring designer should be retained by the contractor to design and evaluate the shoring system used. The excavation support and shoring system used must comply with all applicable safety requirements.

During construction, the ground adjacent to excavations should be monitored for cracks or dips and other indications of movements and possible sloughing of the excavation walls. Such monitoring is particularly critical in areas adjacent to existing structures and utilities.

Dewatering – Groundwater was not encountered within the anticipated wet well excavation depth in BH-1 at the time of drilling. Furthermore, groundwater was not detected in the monitoring well installed in BH-1. If groundwater seepage is encountered in the wet well excavation, we anticipate that sumps and pumps will be adequate for controlling the groundwater. It should be noted that the level and flow of the groundwater seepage will fluctuate depending on the season, amount of rainfall, surface water runoff, and other factors. Dewatering for construction is the responsibility of the contractor. The selection of equipment and methods of dewatering should be left up to the contractor provided they are in accordance with the recommendations in this report and the project specifications. The contractor should be aware that modifications to the dewatering system may be required during construction depending on the conditions encountered. The dewatering method selected should have minimal impact on the groundwater level surrounding the proposed excavations.

6.0 LIMITATIONS

We have prepared this report for Gray & Osborne, Inc., the Mukilteo Water and Wastewater District, and the project design team. Recommendations contained in this report are based on a site reconnaissance, a subsurface exploration program, review of pertinent subsurface information, and our understanding of the project. The study was performed using a mutually agreed-upon scope of work.

Variations in soil conditions may exist between the locations of the explorations and the actual conditions underlying the site. The nature and extent of soil variations may not be evident until construction occurs. If any soil conditions are encountered at the site that are different from those described in this report, we should be notified immediately to review the applicability of our recommendations. Additionally, we should also be notified to review the applicability of our recommendations if there are any changes in the project scope.

The scope of our work does not include services related to construction safety precautions. Our recommendations are not intended to direct the contractors' methods, techniques, sequences or procedures, except as specifically described in our report for consideration in design. Additionally, the scope of our work specifically excludes the assessment of environmental characteristics, particularly those involving hazardous substances.

This report has been prepared for planning and design purposes for specific application to the proposed project in accordance with the generally accepted standards of local practice at the time this report was written. No warranty, express or implied, is made.

This report may be used only by the client and for the purposes stated, within a reasonable time from its issuance. Land use, site conditions (both off and on-site), or other factors including advances in our understanding of applied science, may change over time and could materially affect our findings. Therefore, this report should not be relied upon after 24 months from its issuance. PanGEO should be notified if the project is delayed by more than 24 months from the date of this report so that we may review the applicability of our conclusions considering the time lapse.

It is the client's responsibility to see that all parties to this project, including the designer, contractor, subcontractors, etc., are made aware of this report in its entirety. The use of information contained in this report for bidding purposes should be done at the contractor's option and risk. Any party other than the client who wishes to use this report shall notify PanGEO of such intended use and for permission to copy this report. Based on the intended use of the report, PanGEO may require that additional work be performed and that an updated report be reissued. Noncompliance with any of these requirements will release PanGEO from any liability resulting from the use this report.

We appreciate the opportunity to be of service.

Sincerely,

SIEW LAN TAN
30342

Aug 8, 2016

Steven T. Swenson, L.G.
Project Geologist

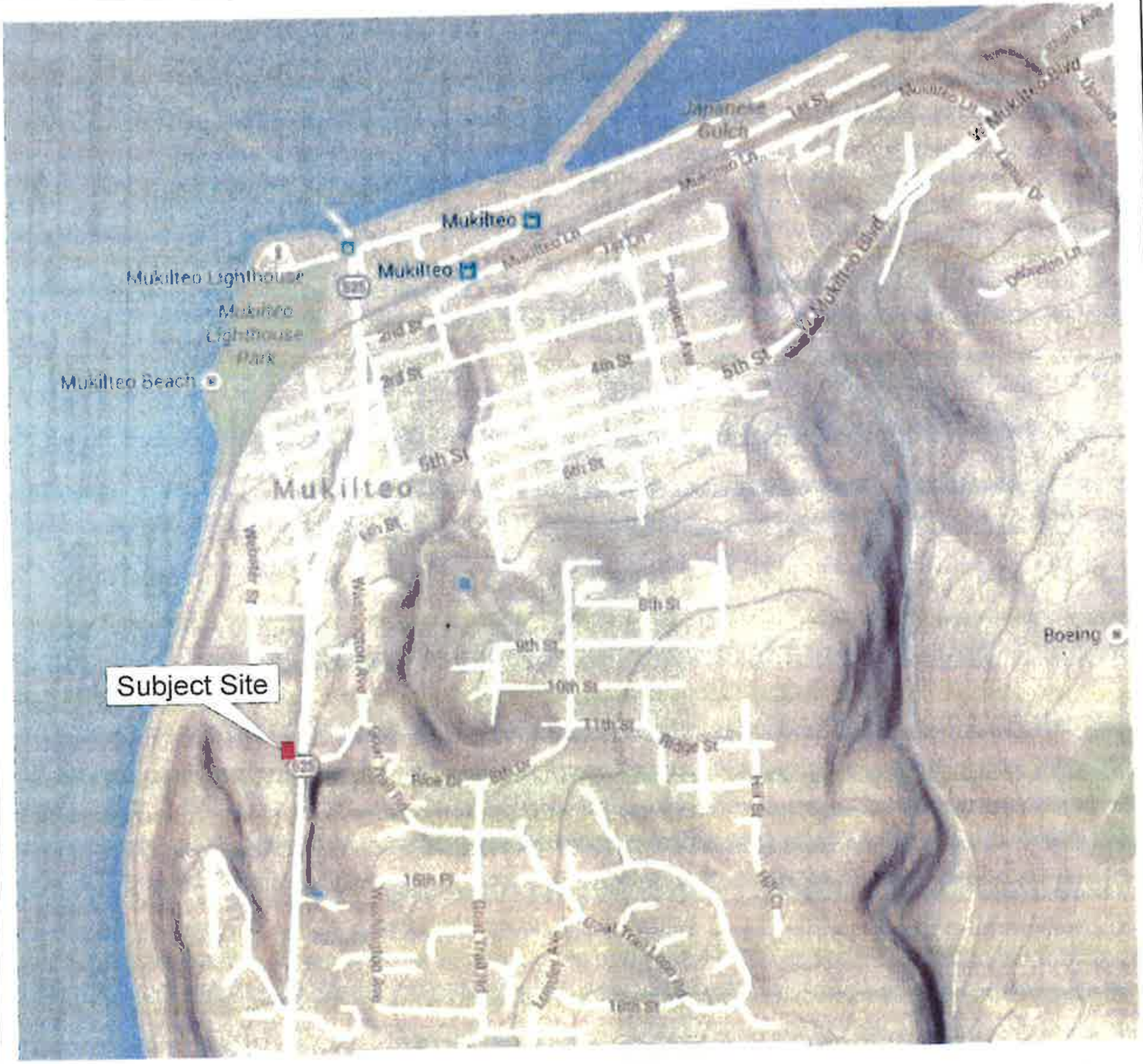
Siew L. Tan, P.E.
Principal Geotechnical Engineer

7.0 LIST OF REFERENCES

International Building Code (IBC), 2015, International Code Council

Minard, J. P., 1982, Distribution and description of geologic units in the Mukilteo quadrangle, Washington: U.S. Geological Survey Miscellaneous Field Studies Map MF-1438, 1 sheet, scale 1:24,000.

WSDOT, (2016). *Standard Specifications for Road, Bridges, and Municipal Construction.*

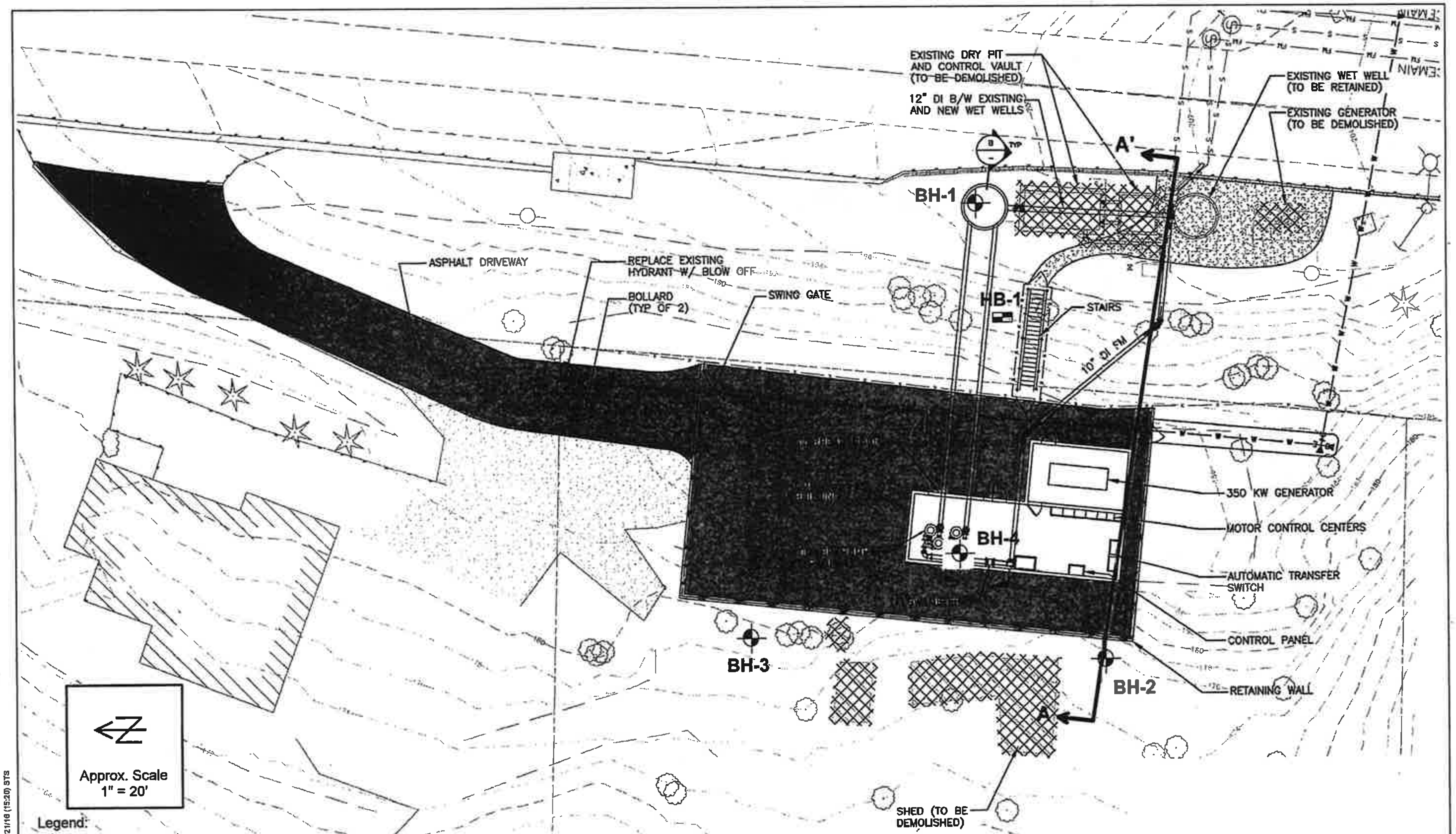


Note: Base map obtained and modified from Google Maps.

Not to Scale

16-134 Fig 1 Vicinity Map.grf 7/21/16 (15:18) STS

PanGEO INCORPORATED	**MWWD Lift Station No. 10** **Mukilteo Speedway and** **Goat Trail Road** **Mukilteo, Washington**	**VICINITY MAP** Project No. **16-134** Figure No. **1**



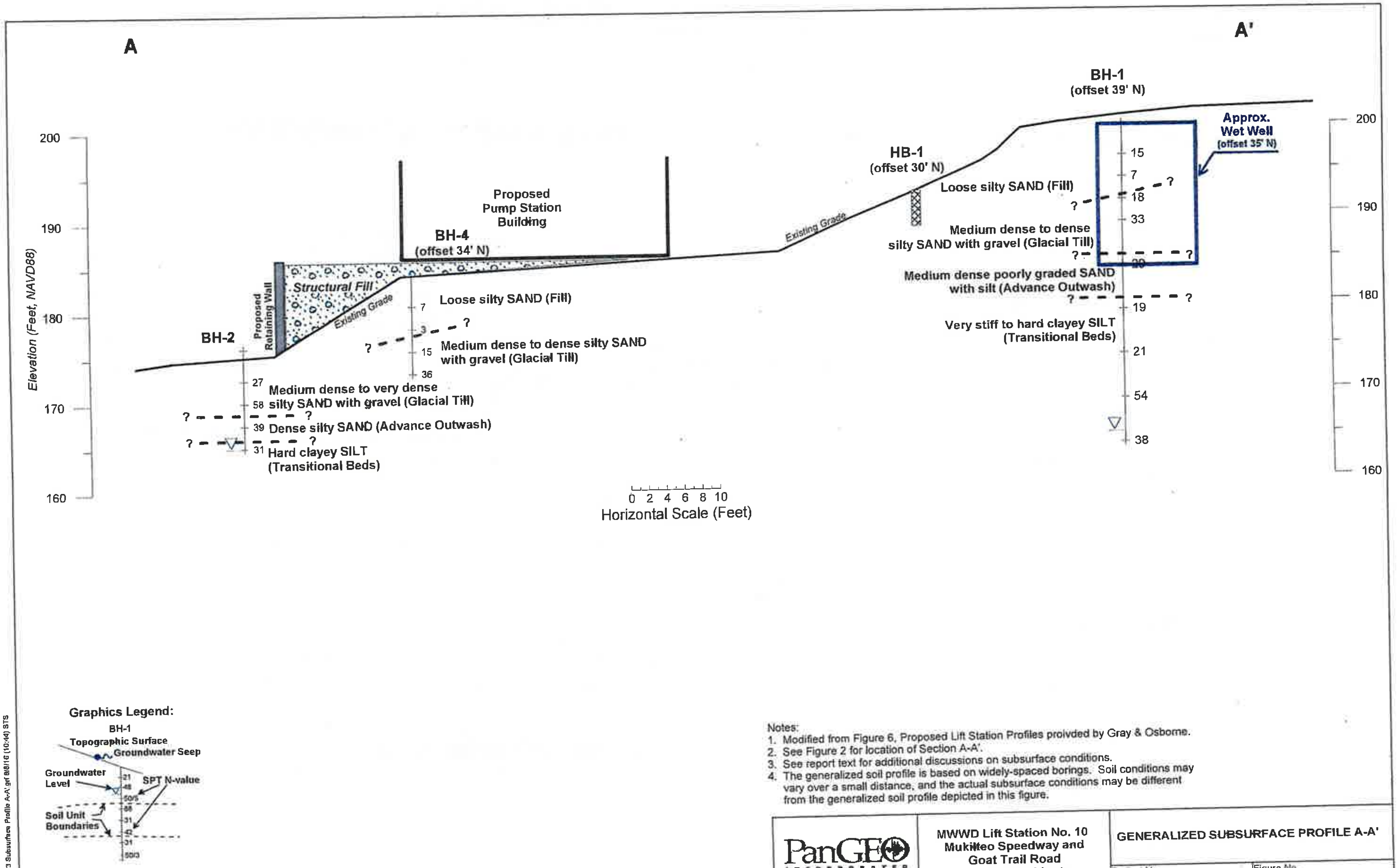
Legend:

- ⊕ Approx. Borehole Location
- ▬ Approx. Hand Boring Location
- ↥↥ Location of Subsurface Profile (see Figure 3)

Note: Base map modified from a proposed site plan provided by Gray & Osborne. Elevation contours are approximate and based on the NAVD88 Datum.

PanGEO INCORPORATED	MWWD Lift Station No. 10 Mukilteo Speedway and Goat Trail Road Mukilteo, Washington	SITE AND EXPLORATION PLAN
		Project No. 16-134	Figure No. 2

16-134 Fig 2 Site Plan.grf 7/21/16 (15:20) STS

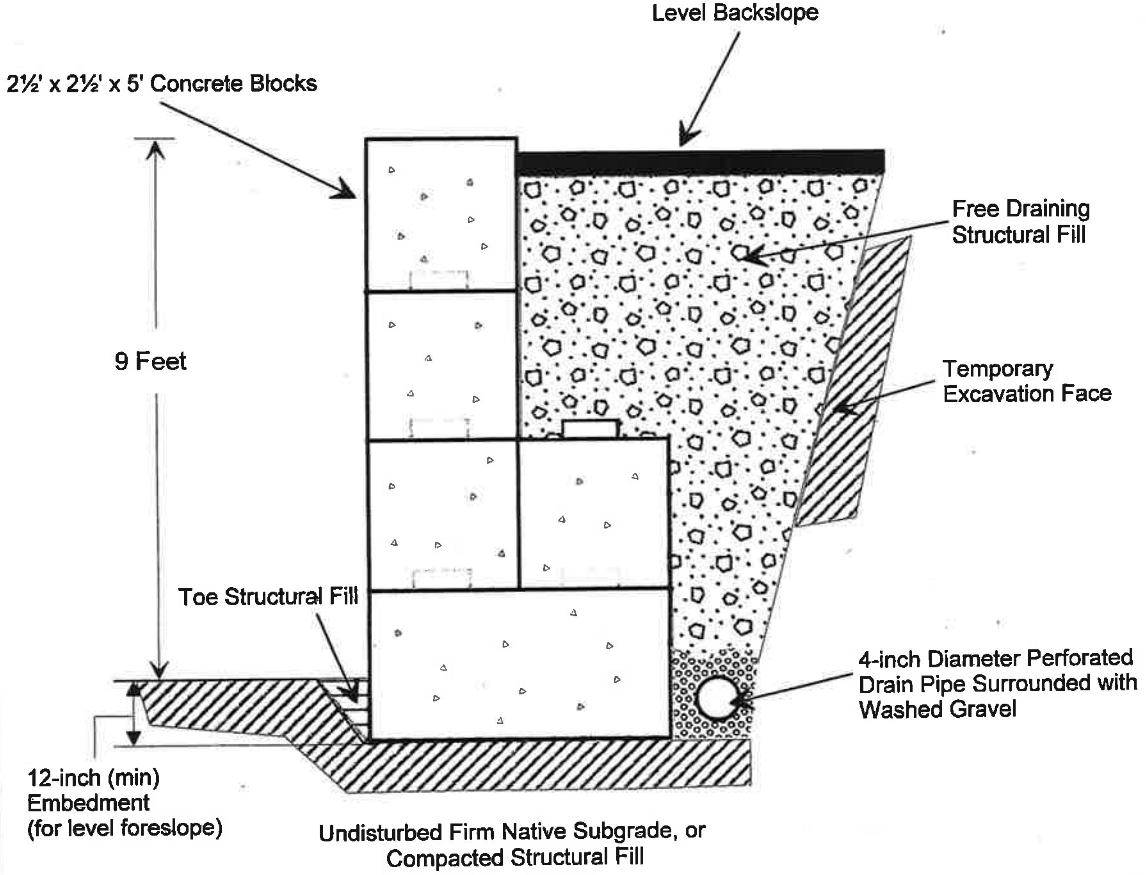


Notes:
1. Modified from Figure 6, Proposed Lift Station Profiles proivded by Gray & Osborne.
2. See Figure 2 for location of Section A-A'.
3. See report text for additional discussions on subsurface conditions.
4. The generalized soil profile is based on widely-spaced borings. Soil conditions may vary over a small distance, and the actual subsurface conditions may be different from the generalized soil profile depicted in this figure.

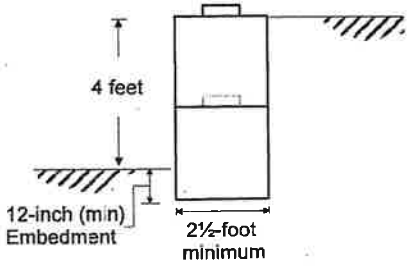
PanGEO INCORPORATED	MWWD Lift Station No. 10 Mukilteo Speedway and Goat Trail Road Mukilteo, Washington	GENERALIZED SUBSURFACE PROFILE A-A' Project No. 16-134 Figure No. 3

16-134 Fig 3 Subsurface Profile A-A'.grf 8/8/16 (10:44) STS

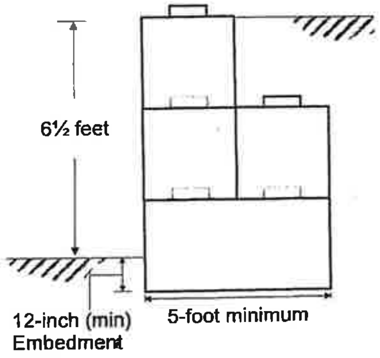
16-134 Fig 4 Ultrablock.grf 7/21/16 (15:22) STS



Typical Modular Block Wall Schematic



2-Block Configuration



3-Block Configuration

Typical Modular Block Wall Configurations

PanGEO
INCORPORATED

MWWD Lift Station No. 10
Mukilteo Speedway and
Goat Trail Road
Mukilteo, Washington

CONCRETE BLOCK (ULTRABLOCK)
GRAVITY WALL SCHEMATIC

Project No.	Figure No.
16-134	4

APPENDIX A

SUMMARY BORING LOGS

RELATIVE DENSITY / CONSISTENCY

SAND / GRAVEL			SILT / CLAY		
Density	SPT N-values	Approx. Relative Density (%)	Consistency	SPT N-values	Approx. Undrained Shear Strength (psf)
Very Loose	<4	<15	Very Soft	<2	<250
Loose	4 to 10	15 - 35	Soft	2 to 4	250 - 500
Med. Dense	10 to 30	35 - 65	Med. Stiff	4 to 8	500 - 1000
Dense	30 to 50	65 - 85	Stiff	8 to 15	1000 - 2000
Very Dense	>50	85 - 100	Very Stiff	15 to 30	2000 - 4000
			Hard	>30	>4000

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS		GROUP DESCRIPTIONS	
Gravel 50% or more of the coarse fraction retained on the #4 sieve. Use dual symbols (eg. GP-GM) for 5% to 12% fines.	GRAVEL (<5% fines)	GW	Well-graded GRAVEL
		GP	Poorly-graded GRAVEL
	GRAVEL (>12% fines)	GM	Silty GRAVEL
		GC	Clayey GRAVEL
Sand 50% or more of the coarse fraction passing the #4 sieve. Use dual symbols (eg. SP-SM) for 5% to 12% fines.	SAND (<5% fines)	SW	Well-graded SAND
		SP	Poorly-graded SAND
	SAND (>12% fines)	SM	Silty SAND
		SC	Clayey SAND
Silt and Clay 50%or more passing #200 sieve	Liquid Limit < 50	ML	SILT
		CL	Lean CLAY
		OL	Organic SILT or CLAY
	Liquid Limit > 50	MH	Elastic SILT
		CH	Fat CLAY
		OH	Organic SILT or CLAY
Highly Organic Soils		PT	PEAT

Notes: 1. Soil exploration logs contain material descriptions based on visual observation and field tests using a system modified from the Uniform Soil Classification System (USCS). Where necessary laboratory tests have been conducted (as noted in the "Other Tests" column), unit descriptions may include a classification. Please refer to the discussions in the report text for a more complete description of the subsurface conditions.

2. The graphic symbols given above are not inclusive of all symbols that may appear on the borehole logs. Other symbols may be used where field observations indicated mixed soil constituents or dual constituent materials.

DESCRIPTIONS OF SOIL STRUCTURES

Layered:	Units of material distinguished by color and/or composition from material units above and below	**Fissured:**	Breaks along defined planes
Laminated:	Layers of soil typically 0.05 to 1mm thick, max. 1 cm	**Slickensided:**	Fracture planes that are polished or glossy
Lens:	Layer of soil that pinches out laterally	**Blocky:**	Angular soil lumps that resist breakdown
Interlayered:	Alternating layers of differing soil material	**Disrupted:**	Soil that is broken and mixed
Pocket:	Erratic, discontinuous deposit of limited extent	**Scattered:**	Less than one per foot
Homogeneous:	Soil with uniform color and composition throughout	**Numerous:**	More than one per foot
		BCN:	Angle between bedding plane and a plane normal to core axis

COMPONENT DEFINITIONS

COMPONENT	SIZE / SIEVE RANGE	COMPONENT	SIZE / SIEVE RANGE
Boulder:	> 12 inches	Sand	
Cobbles:	3 to 12 inches	Coarse Sand:	#4 to #10 sieve (4.5 to 2.0 mm)
Gravel		Medium Sand:	#10 to #40 sieve (2.0 to 0.42 mm)
Coarse Gravel:	3 to 3/4 inches	Fine Sand:	#40 to #200 sieve (0.42 to 0.074 mm)
Fine Gravel:	3/4 inches to #4 sieve	Silt	0.074 to 0.002 mm
		Clay	<0.002 mm

TEST SYMBOLS

for In Situ and Laboratory Tests listed in "Other Tests" column.

ATT	Atterberg Limit Test
Comp	Compaction Tests
Con	Consolidation
DD	Dry Density
DS	Direct Shear
%F	Fines Content
GS	Grain Size
Perm	Permeability
PP	Pocket Penetrometer
R	R-value
SG	Specific Gravity
IV	Torvane
TXC	Triaxial Compression
UCC	Unconfined Compression

SYMBOLS

Sample/In Situ test types and intervals

☒	2-inch OD Split Spoon, SPT (140-lb. hammer, 30" drop)
⧗	3.25-inch OD Spilt Spoon (300-lb hammer, 30" drop)
▚	Non-standard penetration test (see boring log for details)
■	Thin wall (Shelby) tube
✋	Grab
▯	Rock core
◫	Vane Shear

MONITORING WELL

▽	Groundwater Level at time of drilling (ATD)
▼	Static Groundwater Level


Cement / Concrete Seal

Bentonite grout / seal

Silica sand backfill

Slotted tip

Slough

Bottom of Boring

MOISTURE CONTENT

Dry	Dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water

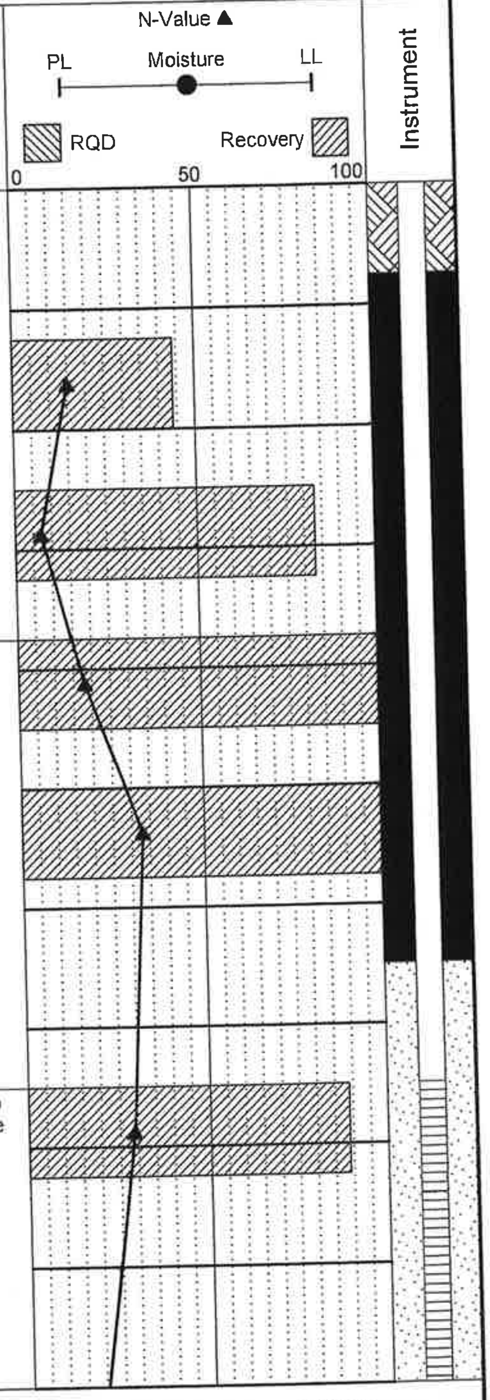
Terms and Symbols for Boring and Test Pit Logs

Figure A-1

Project: MWWD Lift Station No. 10 Replacement
Job Number: 16-134
Location: Mukilteo Speedway & Goat Trail Road, Mukilteo, WA
Coordinates: Northing: , Easting:

Surface Elevation: 200.0ft
Top of Casing Elev.: Not Available
Drilling Method: HSA (8" OD)
Sampling Method: SPT

Depth, (ft)	Sample No.	Sample Type	Blows / 6 in.	Other Tests	Symbol	MATERIAL DESCRIPTION
0						Loose to medium dense, brown, silty SAND with gravel, moist. (Fill).
2						
	S-1	☒	6 7 8			-Trace fine organics.
4						
	S-2	☒	6 4 3			
6						
						Medium dense to dense, light brownish-gray, silty SAND with gravel, moist. Weathered, diamict, gravel subround. (Glacial Till).
8	S-3	☒	7 8 10			
						-Rough drilling, large gravel or cobbles likely.
10						-Trace completely weathered gravels.
	S-4	☒	16 17 16			
12						-Auger grinding on a large gravel or cobble, rough drilling.
14						
						Medium dense, light brown, poorly graded SAND with silt to silty SAND, moist. Fine to medium grained sand, iron-oxide staining, fine gray silt pockets. (Advance Outwash).
16	S-5	☒	8 14 15			
18						
						-No groundwater present in monitoring well on July 12, 2016.
20						



Completion Depth: 36.5ft
Date Borehole Started: 5/27/16
Date Borehole Completed: 5/27/16
Logged By: STS
Drilling Company: Boretec1

Remarks: Boring drilled with a EC 95 track-mounted drill rig. Drill rig equipped with a safety hammer (cathead mechanism) for SPT. Elevation based on topographic information on a site plan provided by Gray & Osborne.

PanGEO INCORPORATED

LOG OF TEST BORING BH-1

Figure A-2

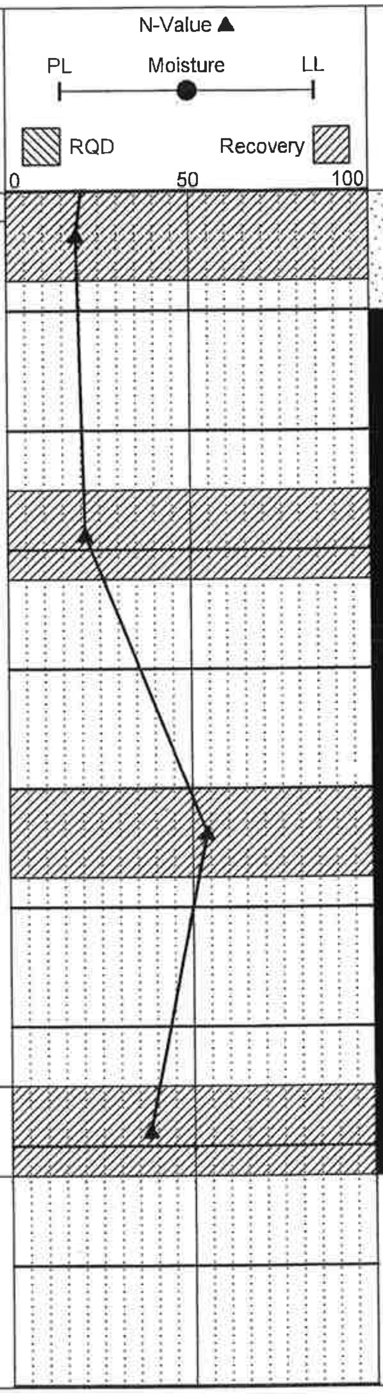
Sheet 1 of 2

The stratification lines represent approximate boundaries. The transition may be gradual.

Project: MWWD Lift Station No. 10 Replacement
Job Number: 16-134
Location: Mukilteo Speedway & Goat Trail Road, Mukilteo, WA
Coordinates: Northing: , Easting:

Surface Elevation: 200.0ft
Top of Casing Elev.: Not Available
Drilling Method: HSA (8" OD)
Sampling Method: SPT

Depth, (ft)	Sample No.	Sample Type	Blows / 6 in.	Other Tests	Symbol	MATERIAL DESCRIPTION
20						-Increase in iron oxide staining, moist to wet.
	S-6	☒	7 9 10			Very stiff to hard, brownish-gray, clayey SILT, moist. Weathered, subhorizontal laminae, one fractured/diced zone with manganese-oxide staining. (Transitional Beds).
22						
24						
	S-7	☒	8 9 12			-Becomes gray, horizontal to subhorizontal laminae, fine sand partings, some sand partings heavily iron-oxide stained.
26						
28						
30						
	S-8	☒	13 25 29			-Becomes brown with iron-oxide and manganese-oxide stained zones, sand partings fine to medium grained, occasional vertical partings, fractured/diced zone.
32						
34						
	S-9	☒	7 16 22		▽	Hard, brown, SILT with fine sand, wet. (Transitional Beds).
36						
						Boring terminated approximately 36.5 feet below grade. Groundwater was first encountered around 35 feet below grade at the time of drilling. No groundwater present in monitoring well on July 12, 2016.
38						
40						



Instrument

Completion Depth: 36.5ft
Date Borehole Started: 5/27/16
Date Borehole Completed: 5/27/16
Logged By: STS
Drilling Company: Boretec1

Remarks: Boring drilled with a EC 95 track-mounted drill rig. Drill rig equipped with a safety hammer (cathead mechanism) for SPT. Elevation based on topographic information on a site plan provided by Gray & Osborne.

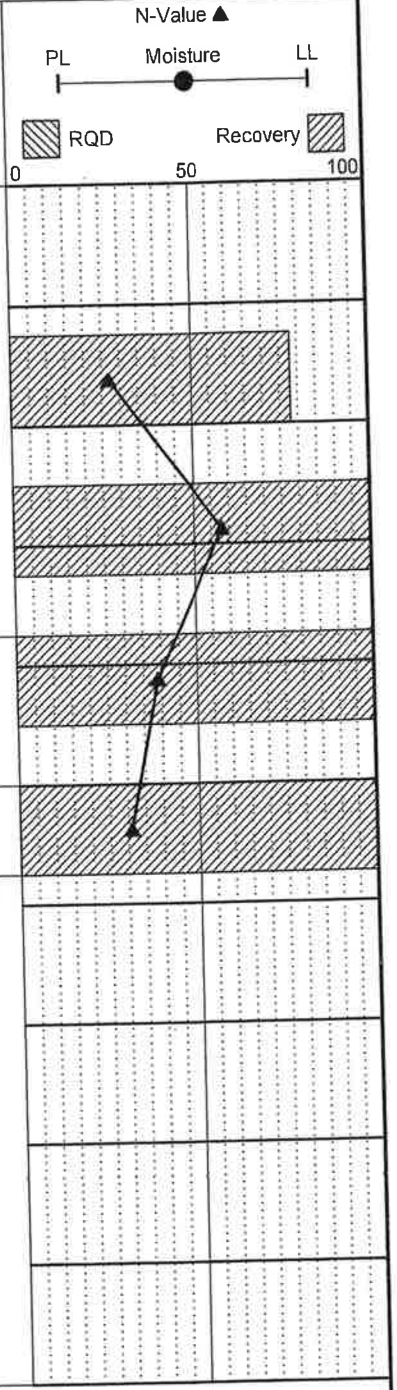
LOG OF TEST BORING BH-1

Figure A-2

The stratification lines represent approximate boundaries. The transition may be gradual.

Project:	MWWD Lift Station No. 10 Replacement	Surface Elevation:	176.0ft
Job Number:	16-134	Top of Casing Elev.:	Not Applicable
Location:	Mukilteo Speedway & Goat Trail Road, Mukilteo, WA	Drilling Method:	HSA (6" OD)
Coordinates:	Northing: , Easting:	Sampling Method:	SPT

Depth, (ft)	Sample No.	Sample Type	Blows / 6 in.	Other Tests	Symbol	MATERIAL DESCRIPTION
0						Medium dense to very dense, brownish-gray, silty SAND with gravel, moist. Weathered with orange pockets, trace fine organics, diamict, iron-oxide staining, gravel subround. (Glacial Till). -Auger grinding on a large gravel or cobble.
	S-1	☒	11 10 17			
	S-2	☒	26 29 29			-Becomes gray.
	S-3	☒	12 18 21			Dense, brown, silty SAND, moist. Fine to medium grained sand. (Advance Outwash).
	S-4	☒	8 15 16		⊻	Hard, brownish-gray, clayey SILT, moist. Subhorizontal laminae, interlayered wet silty sand lenses, manganese-oxide staining. (Transitional Beds).
						Boring terminated approximately 11.5 feet below grade. Groundwater was first encountered around 11 feet below grade at the time of drilling.



Completion Depth:	11.5ft
Date Borehole Started:	5/27/16
Date Borehole Completed:	5/27/16
Logged By:	STS
Drilling Company:	Boretec1

Remarks: Boring drilled with a EC 95 track-mounted drill rig. Drill rig equipped with a safety hammer (cathead mechanism) for SPT. Elevation based on topographic information on a site plan provided by Gray & Osborne.

PanGEO
INCORPORATED

LOG OF TEST BORING BH-2

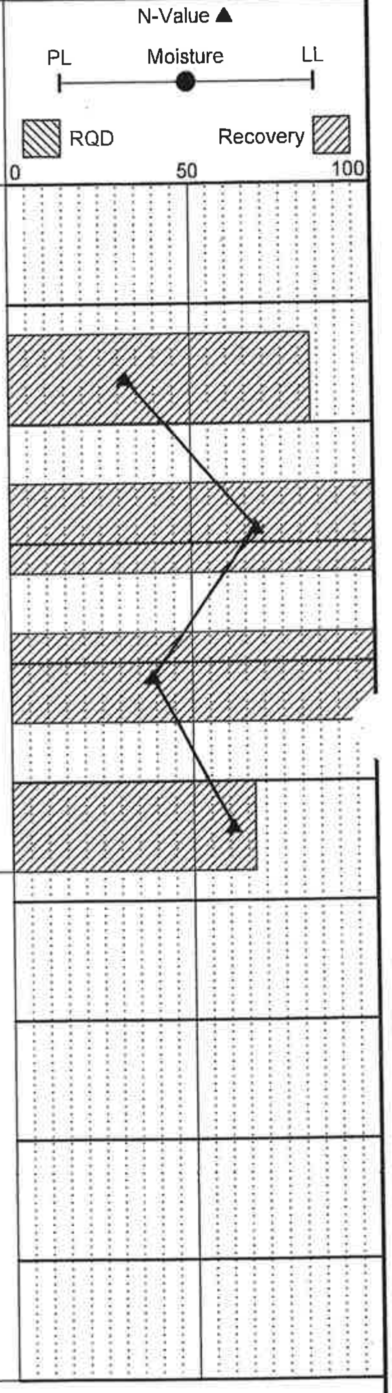
Figure A-3

The stratification lines represent approximate boundaries. The transition may be gradual.

Sheet 1 of 1

Project:	MWWD Lift Station No. 10 Replacement	Surface Elevation:	180.0ft
Job Number:	16-134	Top of Casing Elev.:	Not Applicable
Location:	Mukilteo Speedway & Goat Trail Road, Mukilteo, WA	Drilling Method:	HSA (6" OD)
Coordinates:	Northing: , Easting:	Sampling Method:	SPT

Depth, (ft)	Sample No.	Sample Type	Blows / 6 in.	Other Tests	Symbol	MATERIAL DESCRIPTION
0						Dense to very dense, brownish-gray, silty SAND with gravel, moist. Weathered, diamict, gravel subround. (Glacial Till).
2	S-1	☒	12 15 17			-Iron-oxide staining.
4						
6	S-2	☒	23 35 33			
						-Rough drilling, auger grinding on a large cobble or small boulder.
8	S-3	☒	16 17 22			-Lenses of gray clean sand.
						-Rough drilling.
10	S-4	☒	18 23 38			
12						Boring terminated approximately 11.5 feet below grade. Groundwater was not encountered at the time of drilling.
14						
16						
18						
20						



Completion Depth:	11.5ft
Date Borehole Started:	5/27/16
Date Borehole Completed:	5/27/16
Logged By:	STS
Drilling Company:	Boretec1

Remarks: Boring drilled with a EC 95 track-mounted drill rig. Drill rig equipped with a safety hammer (cathead mechanism) for SPT. Elevation based on topographic information on a site plan provided by Gray & Osborne.

PanGEO INCORPORATED

LOG OF TEST BORING BH-3

Figure A-4

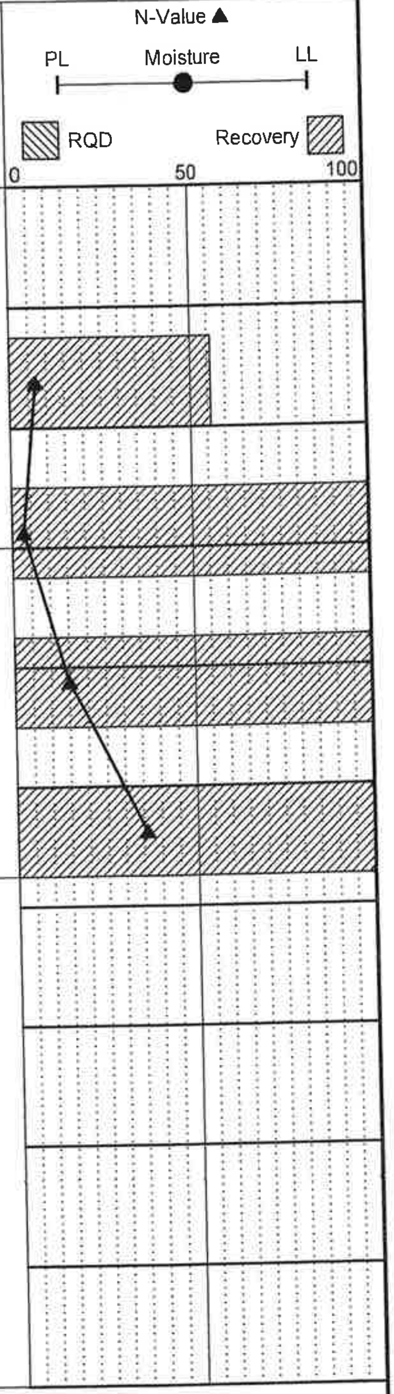
The stratification lines represent approximate boundaries. The transition may be gradual.

Sheet 1 of 1

Project: MWWD Lift Station No. 10 Replacement
Job Number: 16-134
Location: Mukilteo Speedway & Goat Trail Road, Mukilteo, WA
Coordinates: Northing: , Easting:

Surface Elevation: 184.0ft
Top of Casing Elev.: Not Applicable
Drilling Method: HSA (6" OD)
Sampling Method: SPT

Depth, (ft)	Sample No.	Sample Type	Blows / 6 in.	Other Tests	Symbol	MATERIAL DESCRIPTION
0						Very loose to loose, dark brown, silty SAND with gravel with pockets of poorly graded SAND with silt, moist. Contains roots. (Fill).
2	S-1	☒	4 4 3			
4	S-2	☒	1 1 2			
6						Medium dense to dense, orangish-brown, silty SAND with gravel, moist. Weathered, diamict, iron-oxide staining, gravel subround. (Glacial Till).
8	S-3	☒	7 7 8			
10	S-4	☒	11 16 20			-Increase in gravel.
12						Boring terminated approximately 11.5 feet below grade. Groundwater was not encountered at the time of drilling.
14						
16						
18						
20						



Completion Depth: 11.5ft
Date Borehole Started: 5/27/16
Date Borehole Completed: 5/27/16
Logged By: STS
Drilling Company: Boretec1

Remarks: Boring drilled with a EC 95 track-mounted drill rig. Drill rig equipped with a safety hammer (cathead mechanism) for SPT. Elevation based on topographic information on a site plan provided by Gray & Osborne.

PanGEO INCORPORATED

LOG OF TEST BORING BH-4

Figure A-5

The stratification lines represent approximate boundaries. The transition may be gradual.

Sheet 1 of 1