PanGEO
INCORPORATED
Geotechnical & Earthquake
Engineering Consultants

April 16, 2019
File No. 18-371

Mr. Ryan Yuan
3611 W. Mercer Way
Mercer Island WA 98040

Subject: **Geotechnical Engineering Study**
Proposed Residence
3611 West Mercer Way, Mercer Island, WA

Dear Mr. Yuan,

As requested, PanGEO, Inc. has completed a geotechnical engineering study for the proposed residence at the above-referenced site. This study was performed in general accordance with our mutually agreed scope of work outlined in our proposal dated October 11, 2018, which you approved on October 30, 2018. Our service scope included reviewing readily-available geologic data, reviewing preliminary design plans, conducting a site reconnaissance, drilling three test borings, and developing the conclusions and recommendations presented in this report.

SITE AND PROJECT DESCRIPTION

The 17,535-square foot lot is located on a southwesterly facing slope that leads down to the shoreline of Lake Washington. There is about 66 feet of topographic relief across the site. As currently planned, the proposed new house will be built overlapping the footprint of the existing house as shown on Figure 2. This location will require demolition of the existing house and excavating into the hillside on east side. Cuts with heights up to 10 to 12 feet may be needed for the new construction. The City of Mercer Island maps several geologic hazards for this site, including seismic, steep slope, potential landslide and erosion hazards.

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The conclusions and recommendations outlined in this report are based on our understanding of the proposed development, which is in turn based on the project information provided. If the above project description is incorrect, or the project information changes, we should be consulted to review the recommendations contained in this study and make modifications, if needed.

SUBSURFACE EXPLORATIONS

Three borings (PG-1 to PG-3) were drilled at the site on November 14, 2018, using a hand-operated portable drill rig owned and operated by CN Drilling of Seattle, Washington. The approximate boring locations were measured in the field from on-site features and are shown on Figure 2. The borings were drilled to depths of about 26½, 16½ and 21½ feet in PG-1 PG-2 and PG-3, respectively.

The drill rig was equipped with 6-inch outside diameter hollow stem augers. Soil samples were obtained from the borings at 2½-foot depth intervals in general accordance with Standard Penetration Test (SPT) sampling methods (ASTM test method D-1586) in which the samples are obtained using a 2-inch outside diameter split-spoon sampler. The sampler 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 achieve the last 12 inches of sample penetration 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.

A geologist from PanGEO were present to observe the drilling, assist in sampling, and to describe and document the soil samples obtained from the borings. The soil samples were described and field classified in general accordance with the symbols and terms outlined in Figure A-1, and the summary boring logs are included as Figures A-2 to A-4.

SITE GEOLOGY AND SUBSURFACE CONDITIONS

SITE GEOLOGY

The Geologic Map of Mercer Island (Troost and Wisher, 2006) mapped a complex of surficial geologic units at the subject site. At the level of West Mercer Way and just below the geology is mapped as Pre-Olympia Nonglacial Deposits (Qpon). Beneath the non-glacial deposits and around mid-slope, the geologic map shows Pre-Olympia Coarse-Grained Deposits (Qpoc), followed by Pre-Olympia Fine-grained deposits (Qpof) in the lower portion of the slope. Lake Deposits (Ql) are mapped along the lakeshore. Pre-Olympia Nonglacial deposits are described by Troost, et al. as stiff to hard, laminated to massive, silt and clay with sand interbeds to clean to silty sand and gravel with silt and peat interbeds that had been overridden by Olympia Interglaciation. Pre-Olympia Coarse-Grained deposits typically consist of dense, clean to silty, sand and gravel with occasional silty layers that had been overridden by Olympia Interglaciation. The Pre-Olympia fine grained strata consist of hard, laminated to massive, silt and clay. Lake Deposits (Ql) typically consist of very loose to loose sand to very soft to medium stiff silt and clay with peat and other organic sediments deposited adjacent to Lake Washington.

Landsliding in the area is typical, with several old slide scarps mapped above and around the subject site.

SUBSURFACE AND GROUNDWATER CONDITIONS

The soils observed in the borings consisted of fill or mass wasting deposits over Lake Deposits and Glaciolacustrine beds. N-values for both the cohesive and non-cohesive beds were lower than might be expected for native, glacially over-ridden soils, suggesting that slope processes have disturbed the original condition of the soil units. The following is a description of the soils encountered in the test borings advanced at the site. Please refer to the boring summary logs (Figures A-2 to A-4) for a detailed description of the conditions encountered at each boring location.

UNIT 1: Fill – Loose, silty fine sand and soft to medium stiff, silty, lean clay was encountered at the top of PG-1. The fill occurs on three layers, 2 feet of silty sand at the top, followed by 7½ feet of clay, then 2½ feet of non-plastic silt. PG-2 also encountered 2 feet of medium dense, silty sand fill at the surface. The soils were moist to very moist, with mixed textures. One piece of glass, organics, and wood debris were recovered in the sample from 10 to 11½ feet in boring PG-1, confirming that the soil was fill, most likely resulting from the driveway construction.

UNIT 2: Mass Wasting Deposit –Underlying the surficial fill in boring PG-2 was 5 feet of stiff, light brown, silty clay. The unit was low plastic and was characterized by broken textures, with an occasional gravel. At the base of the unit was a dark gray, organic bearing bed. Based on the textures and the location of the boring on the uphill side of the driveway, the unit was interpreted as a mass wasting deposit.

UNIT 3: Lake Beds – All three borings appeared to contain deposits that appeared to have been deposited in Lake Washington and then buried by mass wasting and other deposits. In PG-1, beneath the fill the boring penetrated 2½ feet of medium dense or stiff, silty clay to clayey silt. The soil varies from slightly plastic to low plastic, with slow dilatancy, and well-developed laminae. In PG-2 the mass wasting unit was underlain by nearly 1 ½ feet of fine to coarse sand, perhaps more of a beach deposit, medium dense, and grading finer downward. PG-3 was located on the relatively flat area above the lake, that would have been lake bottom prior to the construction of the Lake Washington ship canal, so lake beds were encountered from the surface. In PG-3 the lake beds consisted of roughly 4½ feet of non-plastic, laminated silt and silt with fine sand, over a 1½ foot bed of fine to coarse sand with gravel. Below the sand bed was 7½ feet of soft to medium stiff, laminated, green, silty, lean clay.

UNIT 4: Glaciolacustrine Deposits **–** The deepest soil encountered in the borings was an interbedded sequence of green gray, loose to medium dense, slightly plastic, clayey silt and low plastic, silty, lean clay, with occasional gravel. The unit was very homogeneous, laminated to massive, containing occasional light gray partings and occasional zones of hackly fracturing. The textures are consistent with glaciolacustrine sediments, so the unit is interpreted as such, though the N-values are relatively lower than would be expected.

Groundwater was encountered at various levels in the borings, general perched in coarser beds within the sequence. It should be noted that groundwater elevations and seepage rates are likely to vary depending on the season, local subsurface conditions, and other factors. Groundwater levels and seepage rates are normally highest during the winter and early spring.

GEOLOGY HAZARDS ASSESSMENT

Landslide Hazards and Steep Slopes

According to the City of Mercer Island's Geologic Hazards Map, the site lies within a potential landslide hazard area where numerous landslides have occurred in the past. Based on our field observations and the results of our field exploration, it is our opinion that the site is globally stable in its current configuration. It is also our opinion that the planned construction will not adversely impact the overall stability of the site and surrounding properties, provided that the recommendations presented in this report are properly incorporated into the design and construction of the project.

Erosion Hazards

The site also lies within a mapped potential erosion hazard area. Based on the results of our test borings, the silty and clayey soils exposed at the surface of the site are anticipated to exhibit moderate to low erosion potential. In our opinion, the erosion hazard at the site can be effectively mitigated with the best management practice during construction and with properly designed and implemented landscaping for permanent erosion control. During construction, the temporary erosion hazard can be effectively managed with an appropriate erosion and sediment control plan, including but not limited to installing a silt fence at the construction perimeter, limiting removal of vegetation to the construction area, placing rocks or hay bales at the disturbed/traffic areas and on the downhill side of the project, covering all stockpiled soil or cut slopes with plastic sheets, constructing a temporary drainage pond to control surface runoff and sediment traps if needed, placing rocks at the construction entrance, etc. Permanent erosion control measures should include establishing vegetation, landscape plants, and hardscape established at the end of project.

Seismic Hazards

The site also lies with a mapped potential seismic hazard area, which may be susceptible to risk of damage from earthquake-induced ground shaking, slope failure, soil liquefaction, or surface faulting. While the site is contained within the area mapped as having a known or suspected seismic hazard, the mapped area is not rated as having either a high or moderate potential. Potential damage from liquefation may be mitigated by supporting the house on driven pin pile foundations. Additionally, the risk of slope failure should be low because of the use of permanent walls to retain the hillside slopes. These remedial measures are subsequently discussed in the engineering design recommendations.

GEOTECHNICAL DESIGN RECOMMENDATIONS

SEISMIC DESIGN PARAMETERS

Table 1 below provides seismic design parameters for the site that are in conformance with 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), and the 2008 USGS seismic hazard maps:

Table 1 – 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	1.402	0.540	1.00	1.50	0.935	0.540

HOUSE FOUNDATIONS

We recommend that the house be supported on driven pin piles to avoid potential adverse settlement associated with loose mass wasting material underlying the site and potential liquefaction in the scattered saturated sand deposits underlying the site. The following presents our recommendation for pin piles foundations.

***Pin Pile Sizes* -** In our opinion, 3-, 4-, or 6-inch diameter, Schedule 40, galvanized, steel pipes (pin piles) may be used to support the new structure. Three, four, and six-inch diameter pin piles are typically installed using small hammers mounted on a small excavator.

***Pin Pile Capacity* -** The number of piles required depends on the magnitude of the design load. Allowable axial compression capacities of 6, 10, and 15 tons may be used for the 3-, 4-, and 6-inch diameter pin piles, respectively, with an approximate factor of safety of 2 for piles driven to refusal. Penetration resistance required to achieve the (refusal) capacities will be determined based on the hammer used to install the pile. Tensile capacity of pin piles should be ignored in design calculations.

It is our experience that the driven pipe pile foundations should provide adequate support with total settlements on the order of ½-inch or less.

The criterion for driving refusal is defined as the minimum amount of time (in seconds) required to achieve one inch of penetration, and it varies with the size of hammer used for pile driving.

For 3-, 4-, and 6-inch pin piles, the following table is a summary of driving refusal criteria for different hammer sizes that are commonly used:

Summary of Commonly-Accepted Driving Criteria for 3-, 4-, and 6-inch Pin Pile with a 6, 10, and 15-ton Allowable Axial Compression Load

Hammer Model	Hammer Weight (lb) / Blows per minute	3” Pile Refusal Criteria (seconds per inch of penetration)	4” Pile Refusal Criteria (seconds per inch of penetration)	6” Pile Refusal Criteria (seconds per inch of penetration)
Hydraulic TB 325	850 / 900	10	16	
Hydraulic TB 425	1,100 / 900	6	10	20
Hydraulic TB 725X	2,000 / 600	3	4	10
Hydraulic TB 830X	3,000 / 500			6

Please note that these refusal criteria were established empirically based on previous load tests on 3-, 4-, and 6-inch pin piles. Contractors may select a different hammer for driving these piles and propose a different driving criterion. In this case, it is the contractor’s responsibility to demonstrate to the Engineer’s satisfaction that the design load can be achieved based on their selected equipment and driving criteria.

Pin Pile Specifications - We recommend that the following specifications be included on the foundation plan:

1. All piles should consist of galvanized Schedule-40, ASTM A-53 Grade “A” pipe.

2. All piles shall be driven to refusal (see above table).

3. Piles shall be driven in nominal sections and connected with compression fitted sleeve couplers (i.e. no welding of pipe segments).

4. The geotechnical engineer of record or his/her representative shall observe pin pile installation.

The quality of a pin pile foundation is dependent, in part, on the experience and professionalism of the installation company. We recommend that a company with experienced personnel be selected to install the piles.

Lateral Forces **-** The capacity of pin pipes to resist lateral loads is very limited and should not be used in design. Therefore, lateral forces from wind or seismic loading should be resisted by the passive earth pressures acting against the pile caps and below-grade walls or from battered piles (batter no steeper than 3(H):12(V)). ***Friction at the base of pile-supported concrete grade beams should be ignored in the design calculations.*** Passive resistance values may be determined using an equivalent fluid weight of 400 pounds per cubic foot (pcf). This value includes a safety factor of about 1.5 assuming that properly compacted granular fill will be placed adjacent to and surrounding the pile caps and grade beams.

Grade Beam/Pile Cap Embedment **-** We recommend that the base of perimeter grade beams extend at least 18 inches below the adjacent exterior ground surface and that the base of interior grade beams extend at least 12 inches below interior floor slabs.

Estimated Pile Length **–** The subsurface conditions at the site will likely vary substantially across the site. Based on the soil conditions at the site and our experience in the project area, for planning and cost estimating purposes, we estimate that pile length may range from about 25 to 30 feet.

PERIMETER FOOTING DRAIN AND INTERCEPTOR TRENCH DRAIN

Perimeter drains should be installed around the building at or just below the invert of the footing or pile caps. Under no circumstances should roof downspout drain lines be connected to the footing drain systems. Roof downspouts must be separately tightlined to appropriate discharge locations. Cleanouts should be installed at strategic locations to allow for periodic maintenance of the footing drain and downspout tightline systems.

CONCRETE SLAB-ON-GRADE

In our opinion, conventional slab-on-grade construction may be utilized for the floor slabs. All soil beneath the floor slabs should be compacted to a dense and unyielding condition prior to placing capillary break material for the floor slabs. On-site soils that cannot be compacted to a dense and unyielding condition should be removed and replaced with compacted structural fill.

Slab-on-grade floors should be underlain by a capillary break consisting of at least of 4 inches of ¾-inch, clean crushed rock (less than 3 percent fines) compacted to a firm and unyielding condition. The capillary break should be placed on subgrade that has been compacted to a dense and unyielding condition. The capillary break should be placed on a suitable subgrade as confirmed by PanGEO. A 10-mil polyethylene vapor barrier should also be placed directly below the slab. We also recommend that control joints be incorporated into the floor slab to control cracking.

RETAINING AND BASEMENT WALL DESIGN PARAMETERS

Retaining and basement walls should be properly designed to resist the lateral earth pressures exerted by the soils behind the wall. Proper drainage provisions should also be provided behind the walls to intercept and remove groundwater that may be present behind the wall. Our geotechnical recommendations for the design and construction of the retaining/below-grade walls are presented below.

Lateral Earth Pressures

Concrete cantilever walls should be designed for an active pressure of 35 pcf for level backfills behind the walls assuming the walls are free to rotate or for an equivalent fluid weight of 50 pcf for rigid or unyielding walls. Walls with a 1(H):1(V) backslope should be designed for an active equivalent fluid weight of 45 pcf. Permanent walls should be designed for an additional uniform lateral pressure of 6H psf for seismic loading, where H corresponds to the buried depth of the wall. These recommendations assume that the wall backfill will consist of a free draining and properly compacted fill with adequate drainage provisions.

Surcharge

Surcharge loads, where present, should also be included in the design of retaining walls. We recommend that a lateral load coefficient of 0.3 be used to compute the lateral pressure on the wall face resulting from surcharge loads located within a horizontal distance of one-half wall height.

Lateral Resistance

Lateral forces from seismic loading and unbalanced lateral earth pressures may be resisted by a combination of passive earth pressures acting against the embedded portions of the foundations and by friction acting on the base of the foundations. Passive resistance values may be determined using an equivalent fluid weight of 400 pcf. This value includes a factor of safety of 1.5, assuming the footing is poured against dense native sand, re-compacted on-site sandy soil or properly compacted structural fill adjacent to the sides of footing. A friction coefficient of 0.5 may be used to determine the frictional resistance at the base of the footings. The coefficient includes a factor safety of 1.5.

Wall Drainage

Provisions for wall drainage should consist of a 4-inch diameter perforated drainpipe behind and at the base of the wall footings, embedded in 12 to 18 inches of clean crushed rock and pea gravel wrapped with a layer of filter fabric. We recommend a composite drainage material, such as Miradrain 6000, be used for drainage on exterior walls. The drainpipe at the base of the wall should be graded to direct water to a suitable outlet.

Wall Backfill

In our opinion, imported structural fill should be used for wall backfill, and should consist of granular material, such as WSDOT Gravel Borrow or approved equivalent. In areas where the space is limited between the wall and the face of excavation, pea gravel or clean crushed rock may be used as backfill without compaction.

Wall backfill should be moisture conditioned to within about 3 percent of 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. Within 5 feet of the wall, the backfill should be compacted with hand-operated equipment to at least 90 percent of the maximum dry density.

CONSTRUCTION CONSIDERATIONS

SITE PREPARATION

Site preparation for the proposed project mainly includes site clearing and excavations to the design subgrade. All debris resulted from site clearing should be hauled away from the site. The stripped surface materials should be properly disposed off-site or be "wasted" on site in non-structural landscaping areas.

Following site clearing and excavations, the adequacy of the subgrade where structural fill, foundations, slabs, or pavements are to be placed should be verified by a representative of PanGEO. The subgrade soil in the improvement areas, if recompacted and still yielding, may need to be over-excavated and replaced with compacted structural fill or lean-mix concrete. The need for overexcavation should be determined by PanGEO.

TEMPORARY EXCAVATIONS

According to the revised plans (dated 3/20/19), the proposed construction will require excavations up to about 7½ to 8 feet deep. These excavations will occur in the area of the daylight basement and will be highest at the southeast corner of the house. We anticipate the excavations to mainly encounter loose to medium dense silty sand and soft to medium stiff silt and/or clay, which may be fill from the driveway. All temporary excavations should be performed in accordance with Part N of WAC (Washington Administrative Code) 296-155. The contractor is responsible for maintaining safe excavation slopes and/or shoring.

Based on the soil conditions at the site and the steep slope above the planned house location, for planning purposes, it is our opinion that where space is available, open cut excavations maybe used for the proposed construction and may be sloped 1½(H):1(V).

The temporary excavations and cut slopes should be re-evaluated in the field during construction based on actual observed soil conditions and may need to be modified in the winter. The cut slopes should be covered with plastic sheets in the raining season. We also recommend that heavy construction equipment, building materials, excavated soil, and vehicular traffic should not be allowed within a distance equal to 1/3 the slope height from the top of any excavation.

SOLDIER PILE WALLS

We anticipate that permanent soldier pile walls will be required to support the existing driveway (see Figure 2) and that the deep portion of the basement excavation may require construction shoring to support the neighboring property to the north.

A soldier pile wall consists of vertical steel beams, typically spaced from 6 to 8 feet apart along the proposed excavation wall, with timber lagging spanning between the flanges of the soldier piles to provide lateral restraint to the exposed soil. Prior to the start of excavation, the steel beams are installed into holes drilled to a design depth and then backfilled with lean mix concrete. As the excavation proceeds downward and the steel piles are subsequently exposed, the timber lagging is installed between the piles to further stabilize the walls of the excavation.

Design Lateral Pressures – For a cantilevered soldier pile wall or a soldier pile wall with one level of tiebacks, the earth pressures depicted on Figure 4 should be used for design. We recommend that tiebacks be used where the wall height exceeds 10 feet. Tiebacks should be designed with an allowable resistance of 1 kip per linear foot, or alternatively helical anchors may be used for tiebacks. The lateral earth pressures shown on Figure 4 should be increased for any surcharge loads resulting from traffic, construction equipment, building loads or excavated soil if they are located within the height dimension of the wall. In addition, if a soldier pile wall is constructed below a basement wall of an adjacent property, the surcharge pressure from the wall and backfill should be used in design of the soldier pile wall. Finally, any walls used for permanent support should also include a uniform pressure of 6H for seismic loading where H represents the exposed height of the wall (in feet).

Vertical Capacity – Soldier piles may be designed using an allowable skin friction value of 1.0 ksf for the portion of the pile below the bottom of the excavation and an allowable end bearing value of 20 ksf.

Lagging - Lagging design recommendations for general conditions are presented on Figure 8. Lagging located within 10 feet of the top of the shoring which may be subjected to surcharge loads from construction equipment or material storage should include an additional uniform surcharge pressure of 200 psf. Point loads located close to the top of the wall, such as outriggers of heavy cranes, may apply additional loads to the lagging. These loads may need to be individually analyzed. However, lagging designed for a uniform load of 600 psf in the top 10 feet of the wall should be able to accommodate most crane outrigger loads.

CONSTRUCTION DEWATERING

Perched groundwater will likely be present within the sand beds, especially in the wet season. As such, the contractor should be prepared to provide temporary dewatering systems. Based on our understanding of the project and site conditions, we anticipate that a conventional dewatering system consisting of trenches, sumps and pumps will be adequate to dewater the temporary excavation. We also anticipate that the seepage quantities should be relatively small, likely less than 10 gallons per minute.

PERMANENT CUT AND FILL SLOPES

Based on the soil conditions underlying the site, we recommend permanent cut and fill slopes be constructed no steeper than 2(H):1(V).

MATERIAL REUSE

In the context of this report, structural fill is defined as compacted fill placed under footings, concrete stairs and landings, and slabs, or other load-bearing areas. In our opinion, the on-site soil is not suitable as structural fill. The structural fill should consist of imported, well-grade, granular material, such as WSDOT Gravel Borrow (WSDOT 9-03.14(1)) or approved equivalent. The on-site fill may be used as general fill in the non-structural and landscaping areas. If use of the on-site soil is planned, the excavated soil should be stockpiled and protected with plastic sheeting to prevent softening from rainfall in the wet season.

STRUCTURAL FILL PLACEMENT AND COMPACTION

Structural fill should be moisture conditioned to within about 3 percent of 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.

Depending on the type of compaction equipment used and depending on the type of fill material, it may be necessary to decrease the thickness of each lift in order to achieve adequate compaction. PanGEO can provide additional recommendations regarding structural fill and compaction during construction.

WET WEATHER EARTHWORK

In our opinion, the proposed site construction may be accomplished during wet weather (such as in winter) without adversely affecting the site stability. However, earthwork construction performed during the drier summer months likely will be more economical. Winter construction will require the implementation of best management erosion and sedimentation control practices to reduce the risk of off-site sediment transport. Most of the site soils within the anticipated depth of excavation contain a high percentage of fines and are moisture sensitive. Any footing subgrade soils that become softened either by disturbance, groundwater or rainfall should be removed and replaced with structural fill, Controlled Density Fill (CDF), or lean-mix concrete.

General recommendations relative to earthwork performed in wet conditions are presented below:

- Site stripping, excavation and subgrade preparation should be followed promptly by the placement and compaction of clean structural fill or CDF;
- The size and type of construction equipment used may have to be limited to prevent soil disturbance;
- The ground surface within the construction area should be graded to promote run-off of surface water and to prevent the ponding of water;
- Geotextile silt fences and bales of straw should be strategically located to control erosion and the movement of soil;
- Structural fill should consist of less than 5% fines; and
- Excavation slopes should be covered with plastic sheets.

SURFACE DRAINAGE CONSIDERATIONS

Surface runoff can be controlled during construction by careful grading practices. Typically, this includes the construction of shallow, upgrade perimeter ditches or low earthen berms in conjunction with silt fences to collect runoff and prevent water from entering excavations or to prevent runoff from the construction area from leaving the immediate work site.

Permanent control of surface water should be incorporated in the final grading design. Adequate surface gradients and drainage systems should be incorporated into the design such that surface runoff is directed away from slopes and structures. Water from roof drains and other impervious areas should be properly collected and discharged into a storm drain system and should not be discharged on to the slope areas.

ADDITIONAL SERVICES

To confirm that our recommendations are properly incorporated into the design and construction of the proposed residence, PanGEO should be retained to conduct a review of the final project plans and specifications, and to monitor the construction of geotechnical elements. The City of Mercer Island, as part of the permitting process, will also require geotechnical construction inspection services. PanGEO can provide you a cost estimate for construction monitoring services at a later date.

We anticipate that the following additional services will be required:

- Review final project plans and specifications
- Verify implementation of erosion control measures;
- Verify adequacy of footing subgrade;
- Monitor pin pile installation;
- Monitor temporary excavation;
- Monitor the installation of temporary and permanent soldier pile walls
- Verify the adequacy of subsurface drainage installation;
- Confirm the adequacy of the compaction of structural backfill; and
- Other consultation as may be required during construction

Modifications to our recommendations presented in this report may be necessary, based on the actual conditions encountered during construction.

CLOSURE

We have prepared this report for Ryan Yuan, 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. We are not mold consultants nor are our recommendations to be interpreted as being preventative of mold development. A mold specialist should be consulted for all mold-related issues.

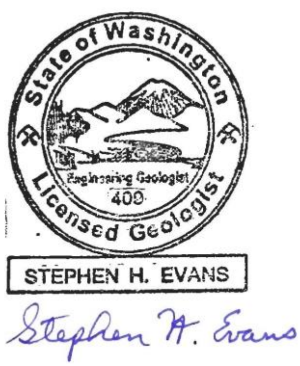
This report has been prepared for planning and design purposes for specific application to the proposed project in accordance with the generally accepted standards of local practice at the time this report was written. No warranty, express or implied, is made.

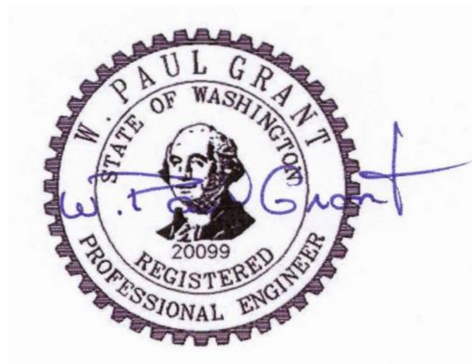
This report may be used only by the client and for the purposes stated, within a reasonable time from its issuance. Land use, site conditions (both off and on-site), or other factors including advances in our understanding of applied science, may change over time and could materially affect our findings. 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,





Stephen H. Evans, L.E.G.
Senior Engineering Geologist

W. Paul Grant, P.E.
Principal Geotechnical Engineer

Enclosures:

Figure 1	Vicinity Map
Figure 2	Site and Exploration Map
Figure 3	Generalized Subsurface Profile Section A-A'
Figure 4	Shoring Design Parameters

Appendix A

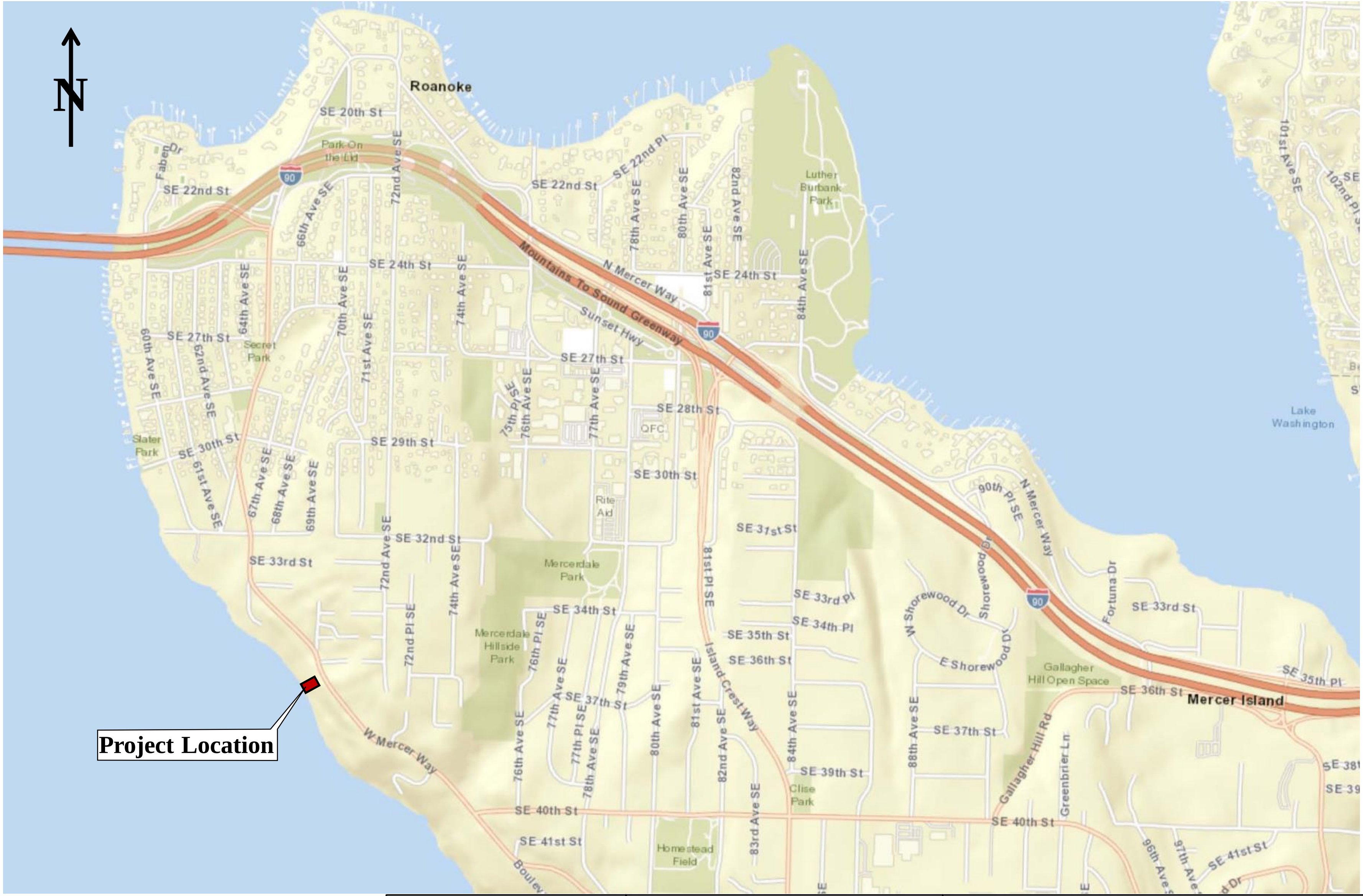
A-1	Terms and Symbols for Boring and Test Pit Logs
A-2	Log of Boring PG-1
A-3	Log of Boring PG-2
A-4	Log of Boring PG-3

REFERENCES

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

Troost, K.G., and Wisher, A. P, 2006. *Geologic Map of Mercer Island, Washington, scale 1:24,000*.

WSDOT, 2014, *Standard Specifications for Road, Bridge and Municipal Construction, M 41-10.*



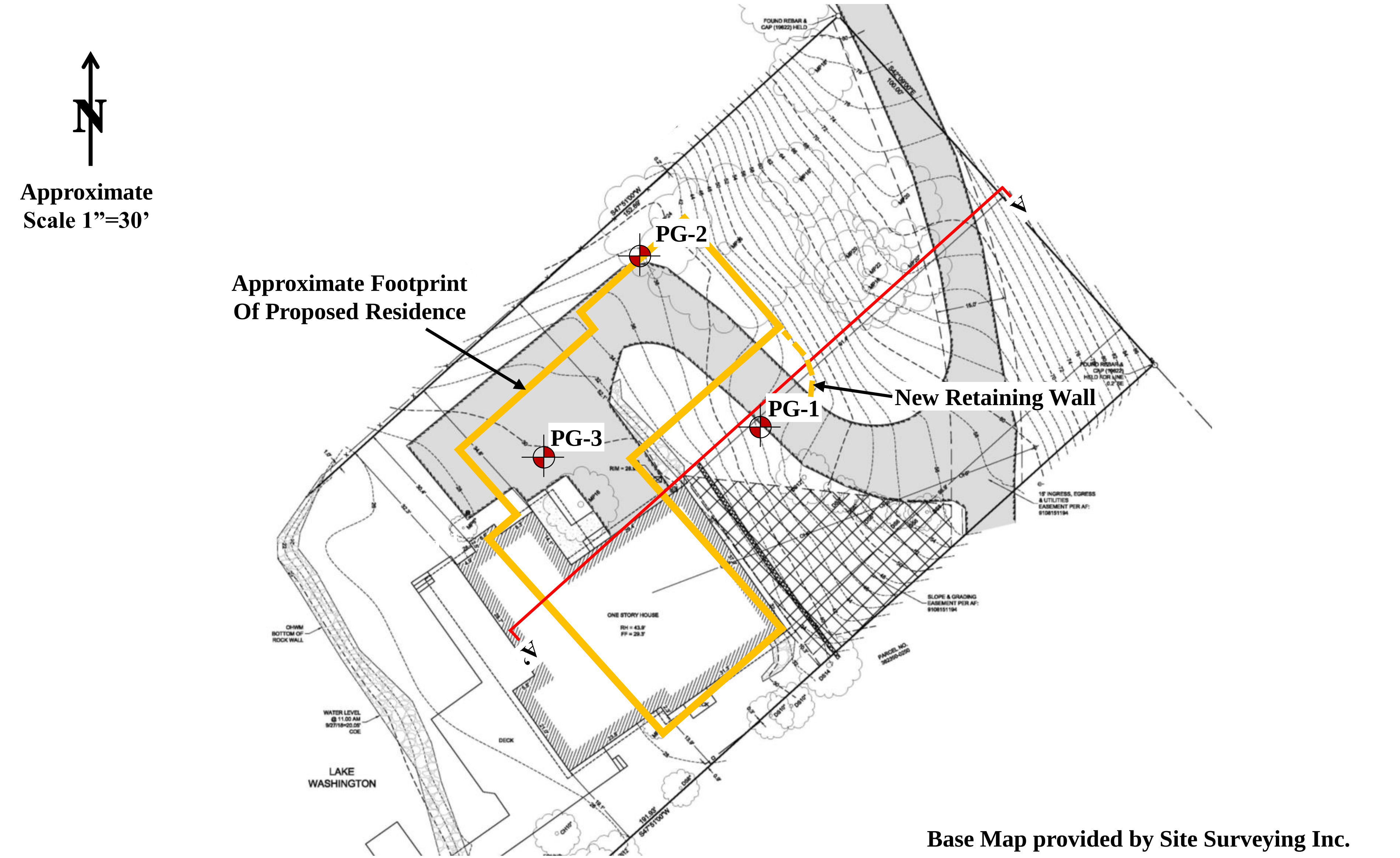
Map not to Scale
Base Map from
Dept of Natural
Resources Geological
Information Portal

PanGEO INCORPORATED

Proposed Residence
3611 West Mercer Way
Mercer Island, WA

VICINITY MAP

Project No.	Figure No.
18-371	1



Legend:

PG-1 PanGEO Boring

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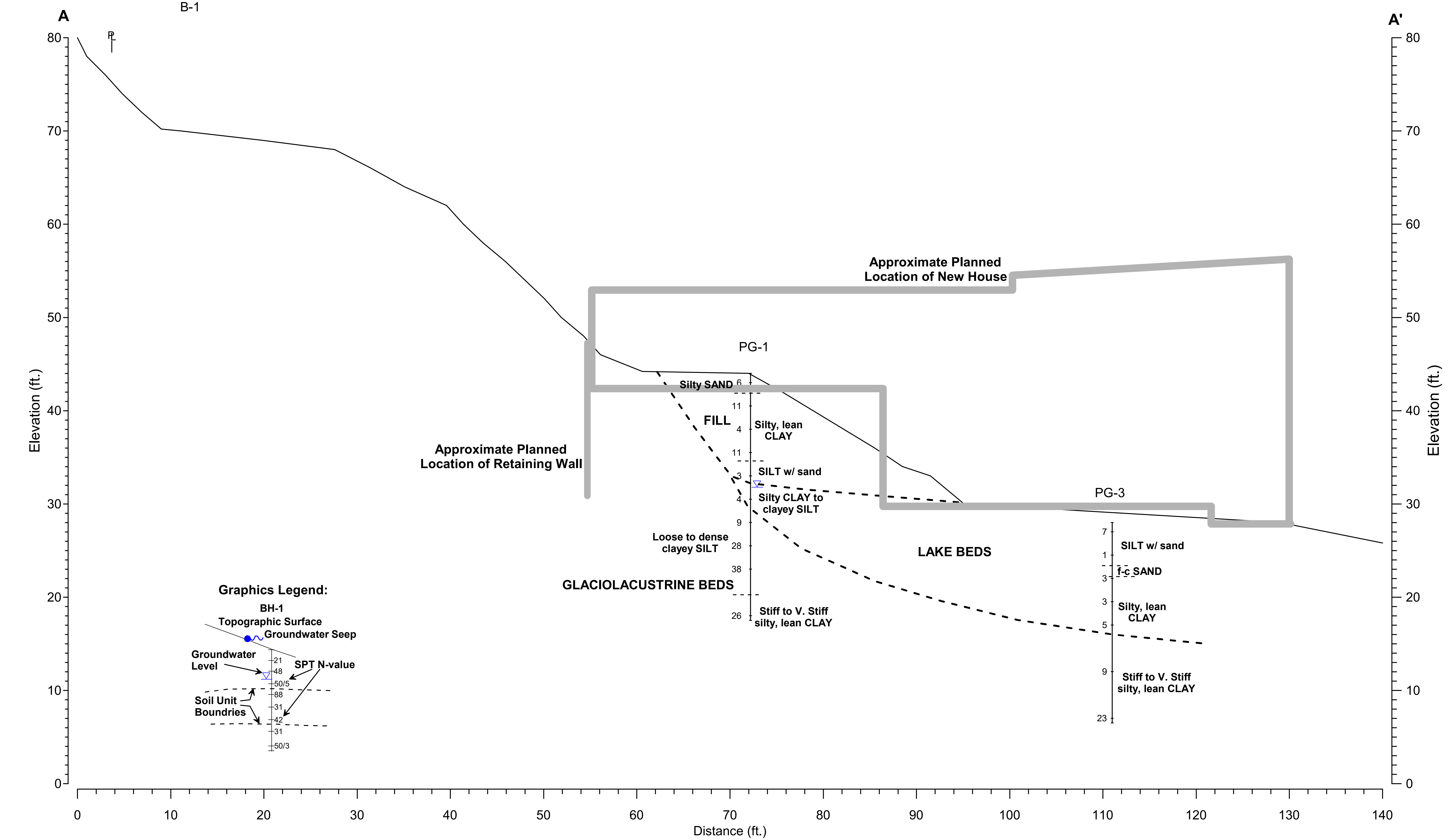
Proposed Residence 3611 West Mercer Way Mercer Island, WA	SITE AND EXPLORATION PLAN	
	Project No. 18-371	Figure No. 2

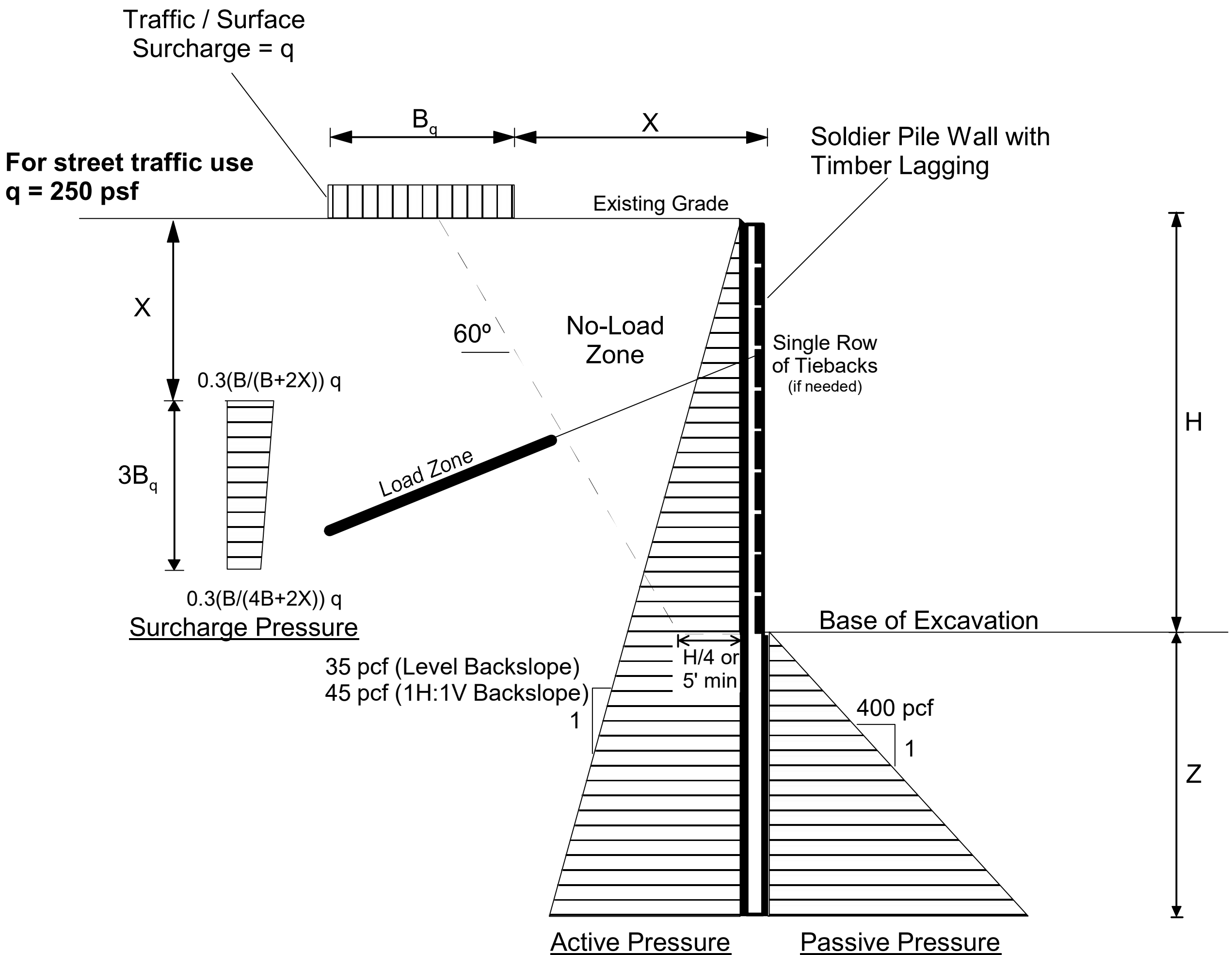


Notes:

1. Site topography from SIte Surveying.
2. Elevations based on NAVD 88.

PanGEO INCORPORATED	Proposed Residence 3611 W. Mercer Way Mercer Island, Wa.	GENERALIZED SUBSURFACE PROFILE SECTION A-A'
		Project No. 18-371 / Figure No. 3

18-371 Profile A.grf w/ 18-371 Stick Log and Profile Data.xls 4/16/19 (10:40) SHE



Notes:

1. Embedment (Z) should be determined by summation of moments at the bottom of the soldier piles or at ground anchor location if present. Minimum pile embedment shall be 10 feet.
2. A factor of safety of 1.5 has been applied to the recommended passive earth pressure value. No factor of safety has been applied to the recommended active earth pressure values.
3. Active and surcharge pressures should be applied over the full width of the pile spacing above the base of the excavation and over one pile diameter below the base of the excavation.
4. Passive pressure should be applied to two times the diameter of the soldier piles.
5. Use uniform earth pressure of 200 psf and 250 psf for lagging design with soldier piles spaced at less than or equal to 8 feet and greater than 8 feet, respectively.
6. Refer to report for additional discussions.

PanGEO INCORPORATED	**Proposed New Residence** **3611 West Mercer Way** **Mercer Island, Washington**	**SHORING DESIGN PARAMETERS** Project No. **18-371** Figure No. **4**

APPENDIX A

SUMMARY TEST 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

Laminated: Layers of soil typically 0.05 to 1mm thick, max. 1 cm

Lens: Layer of soil that pinches out laterally

Interlayered: Alternating layers of differing soil material

Pocket: Erratic, discontinuous deposit of limited extent

Homogeneous: Soil with uniform color and composition throughout

Fissured: Breaks along defined planes

Slickensided: Fracture planes that are polished or glossy

Blocky: Angular soil lumps that resist breakdown

Disrupted: Soil that is broken and mixed

Scattered: Less than one per foot

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
TV	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

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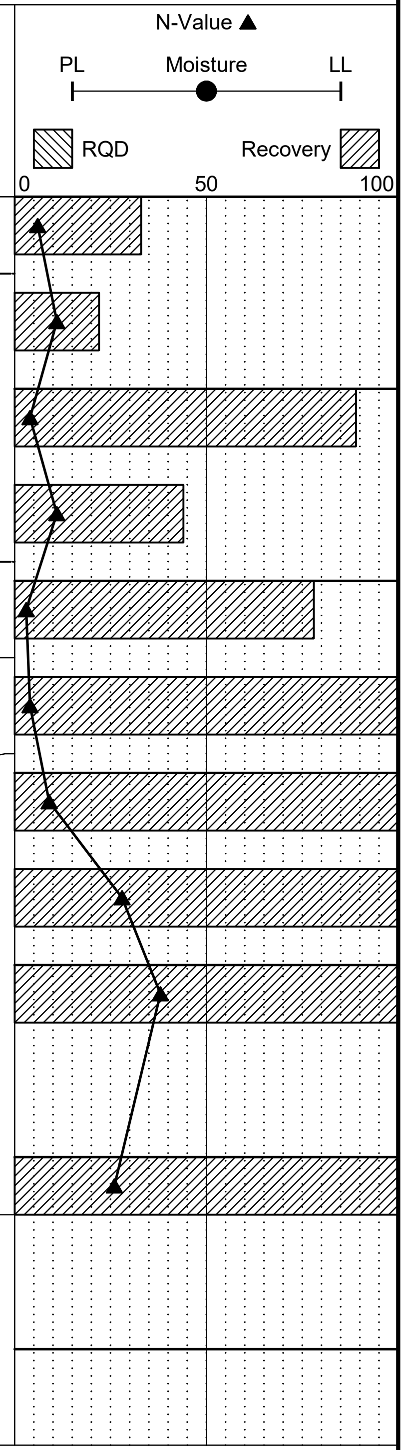
Terms and Symbols for Boring and Test Pit Logs

Figure A-1

Project:	Proposed Residence	Surface Elevation:	
Job Number:	18-371	Top of Casing Elev.:	
Location:	3611 West Mercer Way, Mercer Island, WA	Drilling Method:	HWA
Coordinates:	Northing: , Easting:	Sampling Method:	SPT

Depth, (ft)	Sample No.	Sample Type	Blows / 6 in.	Other Tests	Symbol	MATERIAL DESCRIPTION
0	S-1		3 4 2			Loose, brown, silty, fine SAND with gravel: moist, non-plastic to slightly plastic fines, organics at top, mixed texture, massive. (Fill).
	S-2		4 5 6			Soft to stiff, red brown to brown gray, silty, lean CLAY: moist, slight to low plastic, slow to no dilatancy, some sand and gravel, mixed textures, occasional woody material, oxide staining. (Fill).
5	S-3		3 2 2			Trace sand, wood debris, soft.
	S-4		4 5 6			Scattered charcoal, becoming stiff, massive to laminated with organic laminae, trace to some fine sand.
10	S-5		1 1 2			Loose, dark brown to light brown gray SILT with fine sand: moist, abundant wood debris, one piece of glass and other debris, laminated, slightly plastic. (Fill).
	S-6		2 1 3			Loose or medium stiff, green gray, silty CLAY to clayey SILT: very moist, slight to low plastic, slow dilatancy, homogeneous, laminated with occasional sand laminae, occasional fine organic blades. (Lake Beds).
15	S-7		3 5 4			Medium dense to loose, green gray, clayey SILT: moist to wet, slightly plastic, with rapid dilatancy, homogeneous, occasional fine gravel, massive. (GlacioLake Beds).
	S-8		9 12 16			Grading to clayey SILT with fine sand, massive, occasional gravel.
20	S-9		7 5 33			Clayey SILT, slightly plastic, rapid dilatancy, occasional fine gravel.
25	S-10		7 12 14			Grading to silty, lean CLAY, slight to low plastic, slow dilatancy, massive, wavy laminae.
						Bottom of Boring.
30						



Completion Depth:	26.5ft
Date Borehole Started:	11/14/18
Date Borehole Completed:	11/14/18
Logged By:	S. Evans
Drilling Company:	CN Drilling

Remarks: Groundwater observed during drilling, and may be encountered in perched zones above static water level.

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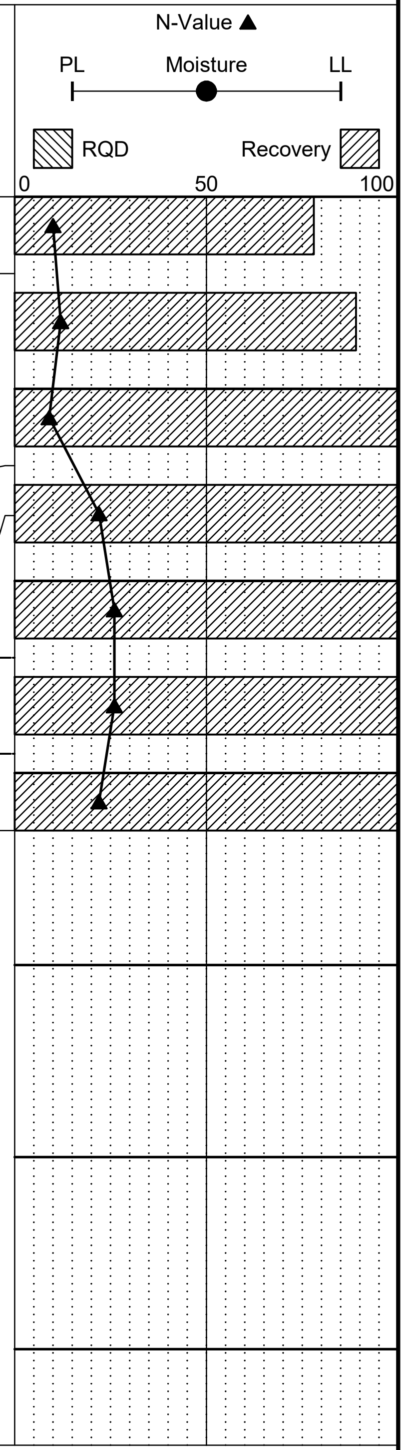
LOG OF TEST BORING PG-1

Figure A-2

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

Project:	Proposed Residence	Surface Elevation:	
Job Number:	18-371	Top of Casing Elev.:	
Location:	3611 West Mercer Way, Mercer Island, WA	Drilling Method:	HWA
Coordinates:	Northing: , Easting:	Sampling Method:	SPT

Depth, (ft)	Sample No.	Sample Type	Blows / 6 in.	Other Tests	Symbol	MATERIAL DESCRIPTION
0	S-1		4 4 6			Medium dense, brown SILT: moist, slight plastic, trace to some fine sand, occasional subangular and blocky gravel, some organics, mixed texture. (Fill).
	S-2		6 6 6			Stiff, light brown, silty CLAY: moist, low plastic, homogeneous, occasional gravel, broken textures, trace organics, massive. (Mass Wasting Deposit).
5	S-3		3 6 3			Dark gray organic bed in sample tip.
	S-4		7 12 10			Medium dense, brown, fine to coarse SAND: moist, trace to some silt, grades finer downward, finer/coarser layers, laminated, two black organic beds, rusty bed at bottom contact. (Beach Deposit).
10	S-5		7 11 15			Medium dense, green gray SILT: very moist, non-plastic to slight plastic, rapid dilatancy, homogeneous, massive. (Glaciolacustrine Bed). Occasional light gray laminae or partings.
	S-6		8 12 14			Very stiff, green gray, silty, lean CLAY: moist, low plastic, homogeneous, slightly hackly fracture, occasional light gray parting or gravel. (Glaciolacustrine Bed).
15	S-7		12 10 12			Medium dense / very stiff, green gray, clayey SILT: moist, slight plastic, slow dilatancy, homogeneous, massive. (Glaciolacustrine Bed).
						Bottom of Boring.
20						
25						
30						



Completion Depth:	16.5ft
Date Borehole Started:	11/14/18
Date Borehole Completed:	11/14/18
Logged By:	S. Evans
Drilling Company:	CN Drilling

Remarks: Groundwater was not observed in the borings, but can be expected in perched zones.

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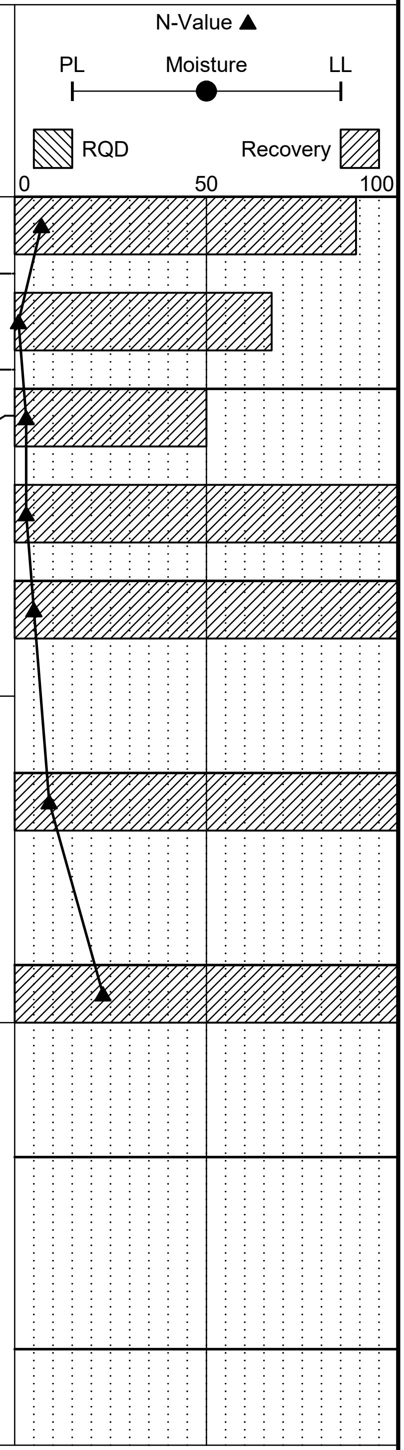
LOG OF TEST BORING PG-2

Figure A-3

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

Project:	Proposed Residence	Surface Elevation:	
Job Number:	18-371	Top of Casing Elev.:	
Location:	3611 West Mercer Way, Mercer Island, WA	Drilling Method:	HWA
Coordinates:	Northing: , Easting:	Sampling Method:	SPT

Depth, (ft)	Sample No.	Sample Type	Blows / 6 in.	Other Tests	Symbol	MATERIAL DESCRIPTION
0	S-1		7 3 4			Loose, brown gray, SILT with fine sand: moist, non-plastic, homogeneous, laminated with rusty laminae. (Lake Beds).
	S-2		1 0 1			Very loose, brown SILT: moist, non-plastic, trace to some fine sand, laminated with sandy laminae, occasional fine organics. (Lake Beds).
5	S-3		1 1 2			Loose, brown, fine to coarse SAND: moist, some silt, gravel. (Lake Beds).
						Soft to medium stiff, green, silty, lean CLAY with clayey silt beds: moist to wet, low plastic, homogeneous, laminated. (Lake Beds).
	S-4		1 1 2			Grading to SILT with fine sand, occasional coarse sand or fine gravel, speckly texture, massive.
10	S-5		2 2 3			Grading to green gray, lighter / darker beds, slightly hackly fracture some zones, dark gray silt with fine sand interbed at 10 feet.
						Stiff, gray, silty, lean CLAY: very moist to moist, low plastic, homogeneous, massive with zones of hackly fracture. (Glaciolacustrine Bed).
15	S-6		2 3 6			
20	S-7		6 10 13			Massive.
						Bottom of Boring.
25						
30						



Completion Depth:	21.5ft
Date Borehole Started:	11/14/18
Date Borehole Completed:	11/14/18
Logged By:	S. Evans
Drilling Company:	CN Drilling

Remarks: Groundwater was not observed in the borings, but can be expected in perched zones.

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LOG OF TEST BORING PG-3

Figure A-4

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