GEO Group Northwest, Inc.
Geotechnical Engineers, Geologists
& Environmental Specialists

October 31, 2022 G-5770

Gerald Yuen
4624 E Mercer Way
Mercer Island, WA 98040

Subject: **Geotechnical Engineering Investigation**
Proposed Driveway Modification
4624 – East Mercer Way
Mercer Island, Washington 98040

Dear Mr. Yuen:

In accordance with our contract with you dated September 7th, 2022, we have investigated the subsurface conditions at the subject property and prepared the following geotechnical report for the proposed modifications to your driveway at the subject property.

SITE AND PROJECT DESCRIPTION

Site Description

The project site (Parcel No. 755870-0020) is located in Mercer Island, Washington as shown on the attached *Plate 1 – Vicinity Map*. The project site is approximately rectangular-shaped, with the major axis oriented approximately east-west. The project site is approximately 39,303 square feet (0.90 acres) in size.

The project site steeply then gently slopes downwards towards the east, with a maximum elevation of approximately 140 feet near the site's southwest corner and a minimum elevation of approximately 20 feet near the site's eastern limit. The project site is currently developed, consisting of an approximately 2,930 square feet large single-family residence constructed in 1990 with an approximately 720 square feet large attached garage, and an approximately 700 square feet attached deck. Undeveloped areas of the project site consist of moderately to heavily forested terrain near the western perimeter of the project site, and a partially cleared region near the center of the project site.

The project site is accessed by a private access road to the northwest. The project site is bounded by developed residential lots to the north & south, by East Mercer Way to the west, and by Lake Washington to the east.

Project Description

Based upon our discussions with you, and our review of the preliminary landscape plans, we understand that modifications to the existing driveway are proposed near the center of the project site. Proposed driveway modifications include widening the paved areas near the split in the driveway that are shared with the adjacent properties (4616 & 4632 E Mercer Wy), and removal of the easternmost pavement that reconnects the driveway. Driveway modifications are illustrated on the attached *Plate 2 – Site Plan*.

Based on the project's preliminary plans, we anticipate construction of retaining walls or rockeries may be required to achieve the proposed design grades for the project.

GEOLOGIC CONDITIONS

The published geologic map (Geologic Map of Mercer Island, Washington, Troost et al., 2006) for the site's vicinity indicates that the soils at the project site consist of Quaternary-age pre-Olympia nonglacial (Qpon) deposits. Pre-Olympia nonglacial deposits typically consist of sand, gravel, silt, and organic sediments that were deposited before the last glacial advance of the Puget lobe of the cordilleran ice sheet approximately 15,000 years ago. Lake deposits typically consist of silt with localized sand, peat, and other organic sediments deposited in a subaqueous environment. Based on Mercer Island's Landslide Hazard Assessment (Troost & Wisher, 2009), the project site and vicinity are overlain by mass wastage (Qmw) deposits.

SUBSURFACE INVESTIGATION

Subsurface Investigation

On September 28th, 2022, a geologist with our firm visited the subject property to perform a visual reconnaissance of the property and investigate the subsurface soil conditions. Three exploratory borings were excavated with hand operated boring equipment. The approximate locations of each boring are illustrated on the attached *Plate 2- Site Plan*.

Soils encountered in boring HA-1 consisted of loose light brown silty sand to a depth of approximately 1.0 feet below ground surface (bgs), underlain by medium stiff to stiff light gray silt with sand to a depth of approximately 3.0 feet bgs. Boring HA-1 was terminated at a depth of approximately 3.0 feet bgs. Soils encountered in boring HA-2 consisted of very loose reddish-brown silty sand to a depth of approximately 2.0 bgs. Loose dark brown silty sand was encountered from depths of approximately 2.0 to 2.2 feet bgs, and was underlain by stiff light gray sandy silt to a depth of approximately 3.5 feet bgs in boring HA-2. Boring HA-2 was terminated at a depth of approximately 3.5 feet bgs. Soils encountered in boring HA-3 consisted of a surficial layer of dark brown mulch underlain by loose grayish brown silty sand with gravel to a depth of approximately 2.0 feet bgs. Boring HA-3 was terminated at a depth of approximately 2.0 feet bgs due to equipment refusal. No groundwater seepage was encountered during our subsurface investigation. For a more detailed description of the soils encountered during our subsurface investigation, please refer to the boring logs on the attached Appendix A – *USCS Soil Classification & Boring Logs*.

We interpret the surficial very loose and loose soils encountered in borings HA-2 and HA-3 as artificial fill soils that were placed during previous construction activity at the site. Medium stiff to stiff soils encountered in borings HA-1 and HA-2 are interpreted as nonglacial deposits, consistent with published mapping of the site.

GEOLOGICAL HAZARD AREA INVESTIGATION AND EVALUATION

Geological Hazard Area Investigation

The City of Mercer Island's definitions for geological hazard areas are provided in Mercer Island's City Code Chapter 19.16.010 (MICC 19.16.010). It is our understanding that the proposed driveway modifications are located in areas mapped by Mercer Island as erosion, landslide, and seismic geological hazard areas. A map illustrating locations of the mapped geological hazard areas are provided on *Plate 3 – Geologic Hazard Map* (MICC 19.07.160.C).

Erosion Hazard Area

Approximately ninety-three (93) percent of the project site is mapped as an erosion hazard area. Areas mapped by Mercer Island as an erosion hazard area includes the entire project site except for the areas below approximately 25 feet in elevation near the site's eastern limit. The established erosion hazard area extends beyond the project site to the developed properties to the north and south, as well as beyond East Mercer Way to the west. Current mapping of erosion hazard areas is based upon past regional soils mapping by several government agencies and is generalized. For this reason, site specific evaluations are necessary to quantify the actual nature and degree of erosion hazard.

During our visual reconnaissance of the project site, we observed areas mapped as erosion hazard areas by Mercer Island where modifications to the existing driveway are proposed to have grades ranging from approximately 15 to 40 percent, and a maximum vertical relief of approximately 25 feet. Slopes near the north central and south-central limits of the project site were observed to be moderately vegetated with grass & moss groundcover, bushes, and near medium to large trees. Approximately 30 percent of the area mapped as an erosion hazard area at the project site is overlain by impermeable surfaces (residence, carport, and driveway). We did not observe any evidence of soil instability or erosion during our visual reconnaissance of the project site.

Landslide Hazard Area

According to Mercer Island's geological hazard mapping, the project site and adjacent properties are mapped as landslide hazard areas. Published mapping of the project site provided by Mercer Island's Landslide Hazard Assessment indicates no recent landslides have occurred on the project site. During our visual reconnaissance of the project site, we did not observe any evidence of recent slope instability.

Seismic Hazard Area

Seismic hazard areas are locations considered by Mercer Island to have a severe risk of damage as a result of earthquake induced ground shaking, slope failure, settlement, soil liquefaction or surface faulting. According to the U.S. Geological Survey Active Faults Database, the project site is located within the Seattle Fault Zone. The Seattle Fault Zone extends from Bainbridge

Island to the west, to beyond Issaquah to the east. No fault traces are mapped on the project site, and the closest known or suspected fault trace is located approximately 1.25 miles north of the project site. During our visual reconnaissance of the project site, we did not observe any evidence of previous slope failure, settlement, soil liquefaction, or surface faulting at the project site.

Steep Slope Hazard Area

Approximately twenty (20) percent of the project site is mapped as a potential steep slope geological hazard area. The area mapped by Mercer Island as a steep slope hazard area consists of slopes above approximately 100 feet in elevation near the site's northwestern limits, and slopes above approximately 80 feet in elevation near the site's southwestern and southcentral limits. Slopes mapped by Mercer Island as a steep slope hazard area at the project site have grades ranging from approximately 40 to 55 percent, and approximately 30 to 50 feet of vertical relief. The mapped steep slope hazard area extends into the properties north and south of the project site.

During our visual reconnaissance of the project site, we observed slopes mapped as steep slope hazard areas to be undisturbed and well vegetated with shrubbery and medium to large trees. During our visual reconnaissance, we did not observe any evidence of recent soil movement or earth loss. Based on our understanding of the proposed project, we anticipate some areas of the proposed driveway modifications would be located within the toe of slope buffer for the steep slope hazard area mapped by Mercer Island at the project site.

Geological Hazard Areas Evaluation

Per MICC 19.07.100, we anticipate overall impacts to the mapped geological hazard areas to be mitigated by the project's proposed measures to reduce impacts to the most critical parts of the geological hazard areas present, including no proposed disturbance to the mapped steep slope hazard area, and re-stabilization of disturbed areas within the mapped geological hazard areas to be completed post-construction. The application of appropriate construction methods and Best Management Practices (BMPs) are also anticipated to minimize impacts to the mapped geological hazard areas during the construction of the proposed driveway modifications. It is our opinion that the potential for soil erosion at the project site can be mitigated through temporary and permanent erosion control measures and control of surface water runoff. Our recommendations for appropriate construction BMPs and erosion control are provided in the Conclusions and Recommendations section of this report.

Based on our understanding and interpretation of subsurface conditions at the site and our understanding of the proposed driveway modifications, it is our opinion that the proposed construction will not increase the potential for slope instability on the project site or adjacent properties. The proposed driveway modifications are to be constructed on relatively flat areas at the project site, and subsurface soils supporting the proposed driveway modifications are anticipated to consist of dense, nonglacial soils, that, in our opinion, are not susceptible to landslide activity (MICC 19.07.160.B2).

Based on the results of our subsurface investigation, it is our opinion that the risk for soil liquefaction resulting from seismic events is minimal for the project site. Soils encountered during our subsurface investigation consisted of unsaturated silts and fine-grained sands, which, in our opinion, are not susceptible to liquefaction.

CONCLUSIONS AND RECOMMENDATIONS

Based upon the results of our study, it is our professional opinion that the site is geotechnically suitable for the proposed driveway modifications without increasing the risk of soil instability at the project site or adjacent properties. Based on the results of our subsurface investigation, the property is underlain with stiff, nonglacial deposits that are consistent with available geologic mapping of the vicinity. These competent soils are anticipated to be found below approximately 2.0 feet bgs at the project site. Additionally, no groundwater seepage was observed during our subsurface investigation and is not anticipated during construction. In our opinion, the proposed driveway modifications can be designed that the risk to the project site and adjacent properties is mitigated such that the site is determined to be safe (MICC 19.07.160.B3). Details of our recommendations regarding the geotechnical aspects of the proposed driveway modifications are described in the following sections of this report.

Site Preparation and General Earthwork

Grading work for the project should be restricted to the minimum needed to achieve proposed final grades. At the start of construction, the proposed driveway areas should be stripped and cleared of all surface vegetation, organic soils, and debris, if present. These materials should be hauled off site or used for landscaping as appropriate; they should not be used as structural fill for the project.

Erosion Control

During demolition and clearing, temporary erosion and sedimentation controls (TESCs) should be installed to prevent the flow of sediment-laden runoff from the site and to minimize the potential for on-site soil erosion. Temporary erosion and sedimentation controls, such as silt fences, should be installed down-gradient of areas disturbed during construction activity to prevent sediment-laden surface runoff from being discharged off the project site. During wet weather, any exposed soils that are subject to erosion should be compacted and covered with plastic sheeting or straw mulch. Stockpiled soils should be covered with plastic sheeting. The temporary erosion and sediment controls should be maintained during the progress of the project until the ground disturbance activities have been completed and the disturbed areas are stabilized.

Concentrated surface water should not be allowed to flow over exposed slopes or into excavations. During wet weather, exposed slopes should be covered with plastic sheeting to minimize erosion, and accumulated surface water should be directed toward temporary settlement or collection points for treatment and discharge, as appropriate for the site conditions, per a construction stormwater management plan. Water also should not be allowed to stand in any area where concrete slabs, or pavements are to be constructed. During construction, loose surfaces should be sealed at night by compacting the surface to reduce the potential for moisture infiltration into the soils.

For permanent erosion control, disturbed soils should be landscaped and mulched upon completion of the site work.

Excavations and Slopes

Based upon the preliminary plans, we anticipate that relatively shallow excavations may be made from the existing grade at the proposed driveway areas. Based on the findings from our subsurface investigation, water seepage is not anticipated for excavations shallower than approximately 3.5 feet bgs at the property. If water seepage or other adverse conditions are encountered, the geotechnical engineer should observe and evaluate these conditions, and temporary cuts in these soils may need to be made at shallower inclinations when recommended by the geotechnical engineer.

Under no circumstances should temporary excavation slopes be greater than the limits specified in local, state, and national government safety regulations. We recommend temporary cuts greater than four feet in height should be sloped at an inclination no steeper than 1H:1V (Horizontal: Vertical) in the overlying very loose to medium dense site soils. Temporary excavations in very dense soils can be sloped near vertical under the observation of the geotechnical engineer. If groundwater seepage is encountered at the excavation, slopes should have inclinations no steeper than 2H:1V for the temporary construction time period. Permanent slopes should be inclined no steeper than 2.5H:1V. Permanent slopes that are to be maintained or mowed should be sloped at 3H:1V, or less.

Subgrade Preparation

Soils in areas to receive structural fill or concrete slabs should be prepared to a firm, unyielding condition. The prepared subgrade should be observed and approved by the geotechnical engineer. Any detected soft spots or disturbed areas should be compacted or excavated and replaced with compacted structural fill or crushed rock as directed by the geotechnical engineer.

Structural Fill

All fill material used to achieve design site elevations below retaining walls or driveways should meet the requirements for structural fill. During wet weather conditions, material to be used as structural fill should have the following specifications:

1. Be free draining, granular material containing no more than five (5) percent fines (silts and clay-size particles passing a No. 200 mesh sieve);
2. Be free of organic material and other deleterious substances, such as construction debris and garbage;
3. Have a maximum particle size of three (3) inches in diameter.

All fill material should be placed at or slightly above the optimum moisture content. The optimum moisture content is the water content in soil that enables the soil to be compacted to the greatest dry density for a given compaction effort.

Based upon our subsurface investigation, some of the sites near surface soils consisted of silty soils which are not recommended for use as structural fill due to their fine-grained gradation and anticipated moisture content, both of which will retard compaction efforts. If structural fills are required to achieve design site elevations, then we recommend the use of an imported granular fill material which may provide more uniformity and be easier to compact to the required structural fill specifications, especially during periods of wet weather.

Structural fill underneath driveways, should be compacted to at least ninety (90) percent of the material's maximum dry density, as determined by ASTM Test Designation D-1557-91 (Modified Proctor). Structural fill placed within twelve (12) inches of finish grade underneath driveways should be compacted to at least ninety-five (95) percent of the material's maximum dry density.

Structural fill material should be spread and compacted in lifts that are ten (10) inches or less in thickness in an uncompacted state. The compacted fill material should be field tested by using ASTM Designations D2922 and D3017, Nuclear probe method, to verify that the required degree of compaction has been achieved.

We recommend that GEO Group Northwest, Inc. be retained to evaluate the suitability of structural fill material and to monitor the compaction of structural fill material during construction for quality assurance of the earthwork.

Soil Retaining Structures

Based on our review of the preliminary plans, we anticipate that the proposed driveway modifications may require retaining structures to achieve proposed design grades. As such, we have provided our recommendations for design of retaining structures below.

Segmental Block Retaining Walls

We recommend that walls should be constructed on a compacted crushed rock pad that is at least 6 inches thick, and should have a minimum embedment of 6 inches below grade along the front of the walls. Tiered walls should be separated by a horizontal distance at least equal to the height of the lower wall (as measured from the front of the upper wall to the back of the lower wall). We recommend that the exposed height of the wall(s) be limited to not more than approximately

4.0 feet. Backfill behind the wall(s) should include a minimum 12-inches wide zone of free-draining crushed rock. This backfill should extend upward to near the top of the wall and downward to the base of the wall. We also recommend that a layer of geotextile filter fabric be placed above the crushed rock if topsoil surfacing will be placed behind the wall(s). These recommendations are illustrated in the attached *Plate 4 – Segmental Block Wall Drainage.*

Heavy compaction machines should not be allowed within horizontal distance to the wall equivalent to one half of the wall height, unless the walls are designed to accommodate the added surcharge.

Rockeries

Rockeries can be constructed against cuts into competent native soils to prevent soil sloughing or erosion. We recommend that rockeries are constructed in conformance with the guidelines described in the attached *Appendix B – ARC Standard Rockery Construction Guidelines*. We recommend that rockeries should be constructed on a subgrade that has been compacted to a firm and unyielding condition. If soft or unstable areas develop in the rockery subgrade, such areas should be over-excavated and replaced with crushed rock. During placement of the first course of stone, a minimum 4-inch diameter rigid perforated PVC drainpipe should be placed below and behind the first course. The drainpipe should be bedded on and surrounded by free-draining crushed rock, and should have sufficient grade for water to flow towards an approved stormwater collection system. We recommend that the first course of stones have a minimum embedment of 12 inches below grade along the front of the rockeries. Rockeries should include a minimum 12-inches wide zone of clean 2-inch quarry rock, or an equivalent free-draining material approved by the geotechnical engineer. Rockeries should have a maximum inclination of 1H:6V. These recommendations are illustrated in the attached page *Plate 5 – Rockery Section Detail*.

Pavements

The performance of pavement is directly related to the condition of the underlying subgrade, if there is post-construction settlement of the subgrade, it will be reflected up through the pavement. To avoid this situation, pavements should be constructed on subgrade that has been compacted to a firm and unyielding condition. If soft or unstable areas develop in the subgrade, such areas should be over-excavated and replaced with compacted structural fill or crushed rock.

Structural fill placed in pavement areas should be compacted in accordance with the requirement in the structural fill section of this report.

The final subgrade should be proof-rolled with heavy rolling equipment (or equivalent) under the observation of the geotechnical engineer shortly before the start of placing the pavement section. It is possible that some localized areas of soft, wet, or unstable subgrade may still exist after this process. If so, these areas nay require over-excavation of the unsuitable material and replacement with compacted structural fill material or crushed rock.

For heavy traffic loading conditions, we recommend that an asphalt pavement section for the site consist of three (3) inches of asphalt-concrete (placed in two lifts) over six (6) inches of clean crushed rock base.

Alternatively, concrete drive slabs can be designed for the site by a structural engineer. For geotechnical consideration, we recommend that concrete drive slabs to receive heavy traffic have a thickness of at least six inches and be reinforced with #4 rebar grid laid out at a twelve (12) inch spacing. The slabs should be underlain with at least six inches of clean crushed rock base.

Surface Drainage

We do not anticipate an adverse impact to the site’s stormwater drainage will result from the proposed driveway modifications. We recommend that storm water drainage from the proposed driveway modifications (including retaining wall and/or rockery drains) be collected and directed to the existing tight-line system which conveys the water to an approved stormwater system.

The existing stormwater drainage system should continue to be maintained and mitigate concentrated flows on the ground surface from developing, as these flows can lead to increased soil erosion and rutting. Final site grades should direct surface water away from rockeries and retaining walls.

LIMITATIONS

This report has been prepared for the specific application to this site for the exclusive use of Mr. Yuen, and their authorized representatives. Any use of this report by other parties is solely at that party's own risk. We recommend that this report be included in its entirety in the project contract documents for reference during construction.

Our findings and recommendations stated herein are based on field observations, our experience and judgement. The recommendations are our professional opinion derived in a manner consistent with the level of care and skill ordinarily exercised by other members of the profession currently practicing under similar conditions in this area, and within the budget constraint. No warranty is expressed or implied. In the event that soil conditions not anticipated in this report are encountered during site development, GEO Group Northwest, Inc. should be notified and the above recommendations should be re-evaluated.

ADDITIONAL SERVICES

GEO Group Northwest recommends that it be retained to perform a review of the final design and specifications of the proposed driveway modifications to verify that our geotechnical recommendations are properly interpreted and incorporated into the design and construction documents and are appropriate for the finalized configuration of the proposed construction.

We also recommend that we be retained to provide geotechnical monitoring and testing services during construction to verify that construction work is completed in compliance with the recommendations in this report and the project plans. As part of these services, will be available to discuss and recommend design changes, if needed, in the event that unanticipated site conditions are encountered or occur during construction.

CLOSING

We appreciate the opportunity to provide you with geotechnical engineering services for this project. If you have any questions, or if we may be of further service, please do not hesitate to contact us.

Sincerely,
GEO GROUP NORTHWEST, INC.

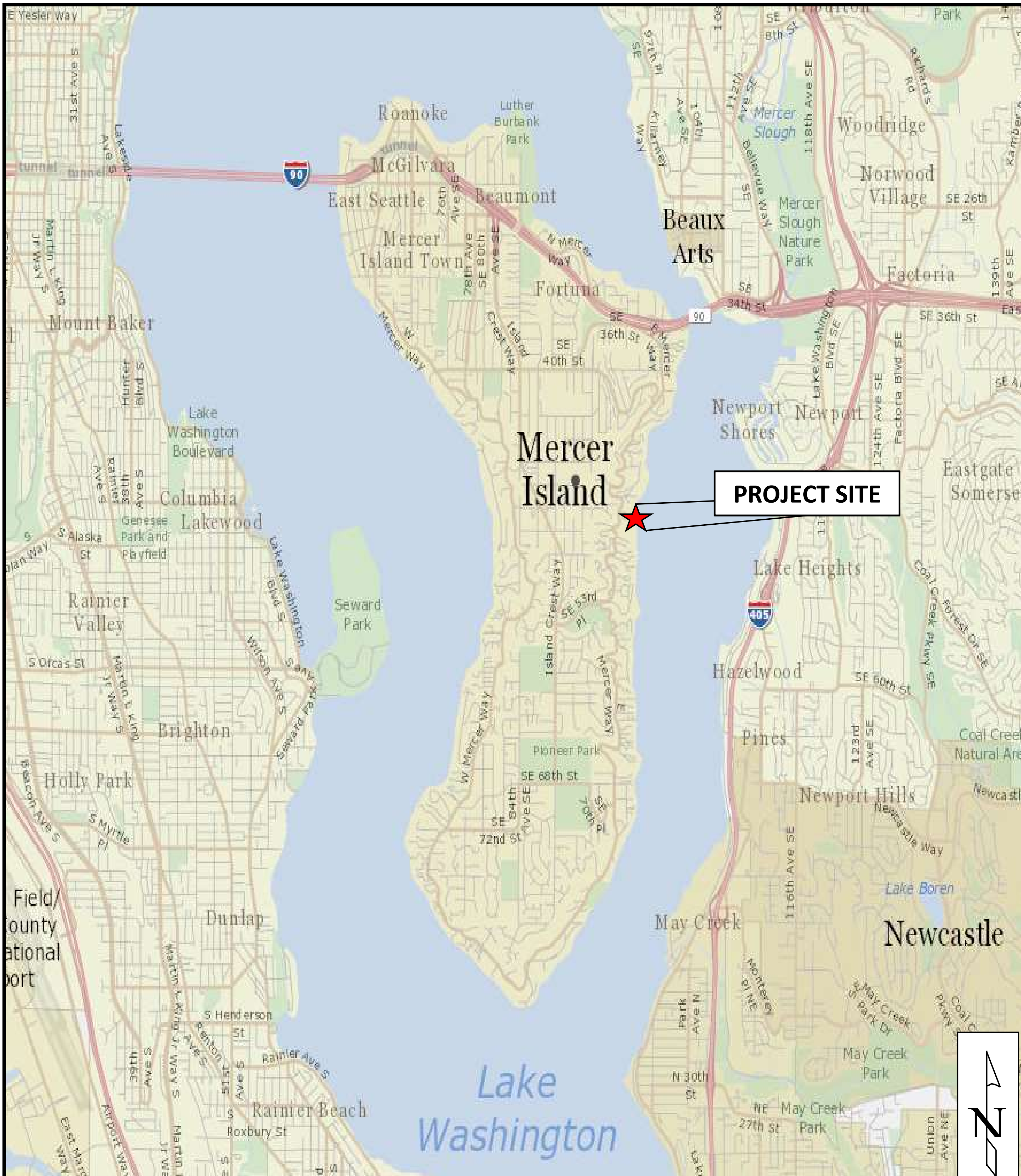
Dated: 10/31/2022

Andrew Hoff, G.I.T.
Staff Engineering Geologist

William Chang, P.E.
Principal Engineer

Attachments:

- Plate 1 – *Vicinity Map*
- Plate 2 – *Site Plan*
- Plate 3 – *Geologic Hazard Map*
- Plate 4 – *Segmental Block Wall Drainage*
- Plate 5 – *Rockery Section Detail*
- Appendix A – *USCS Soil Classification & Boring Logs*
- Appendix B – *ARC Standard Rockery Construction Guidelines*



Source: King County iMap, 2022

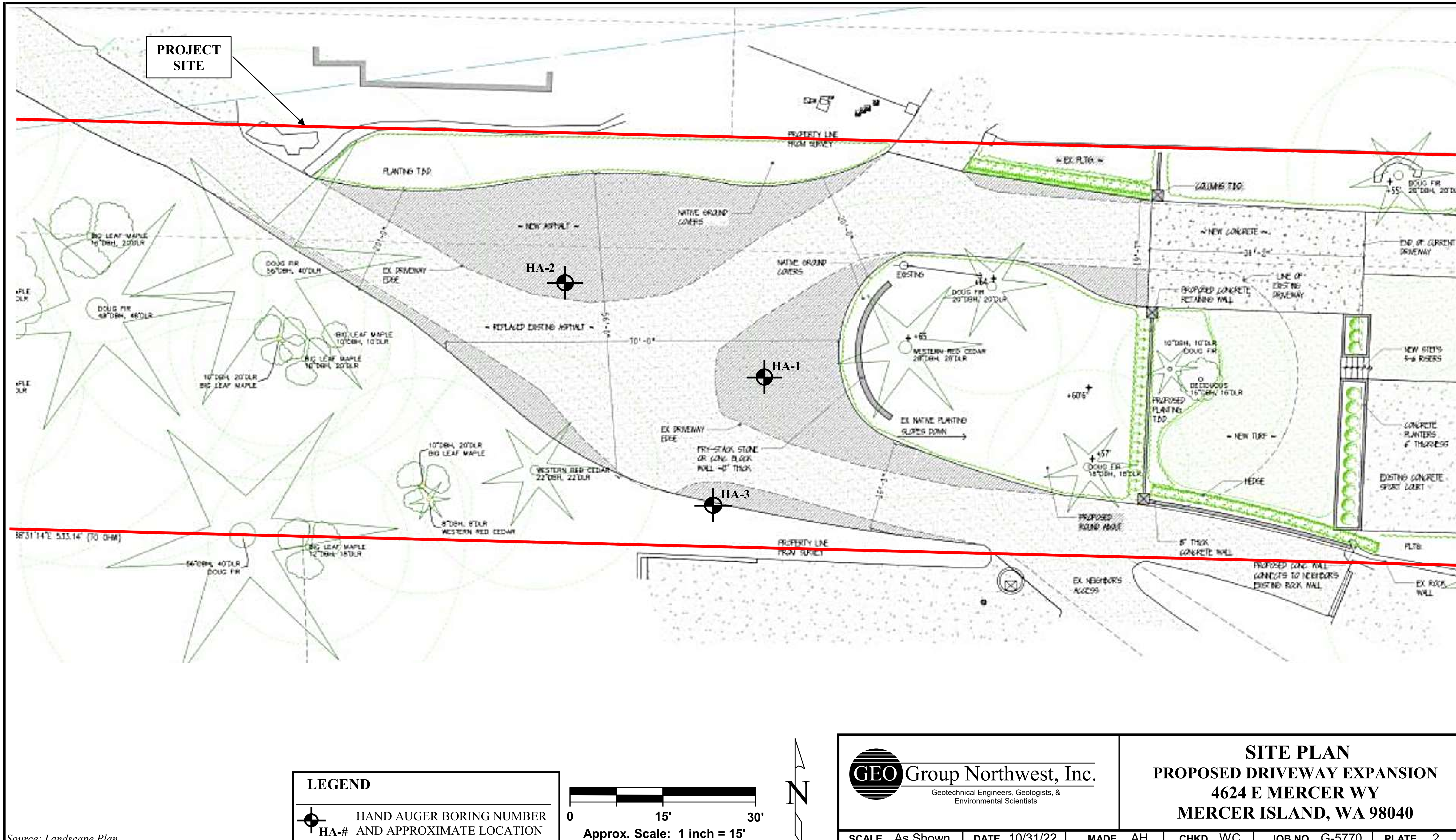
GEO Group Northwest, Inc.

Geotechnical Engineers, Geologists, & Environmental Scientists

VICINITY MAP

PROPOSED DRIVEWAY EXPANSION
4624 E MERCER WY
MERCER ISLAND, WA 98040

SCALE	NONE	DATE	10/31/2022	MADE	AH	CHKD	WC	JOB NO.	G-5770	PLATE	1

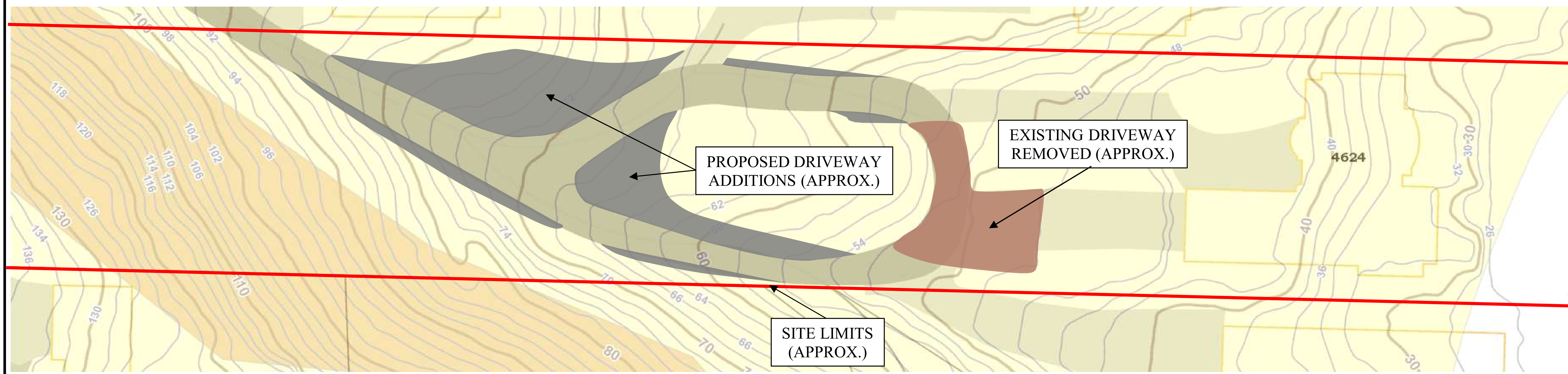


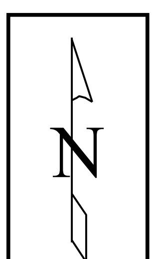
Source: Landscape Plan

GEO Group Northwest, Inc.
Geotechnical Engineers, Geologists, & Environmental Scientists

SITE PLAN
PROPOSED DRIVEWAY EXPANSION
4624 E MERCER WY
MERCER ISLAND, WA 98040

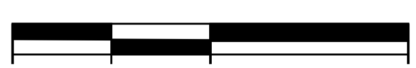
SCALE	DATE	MADE	CHKD	JOB NO.	PLATE
As Shown	10/31/22	AH	WC	G-5770	2





NOTE:
ENTIRE SITE IS MAPPED AS A SEISMIC HAZARD AREA AND POTENTIAL LANDSLIDE HAZARD AREA BY MERCER ISLAND.

Source: City of Mercer Island GIS, 2022



Approx. Scale: 1 inch = 30'

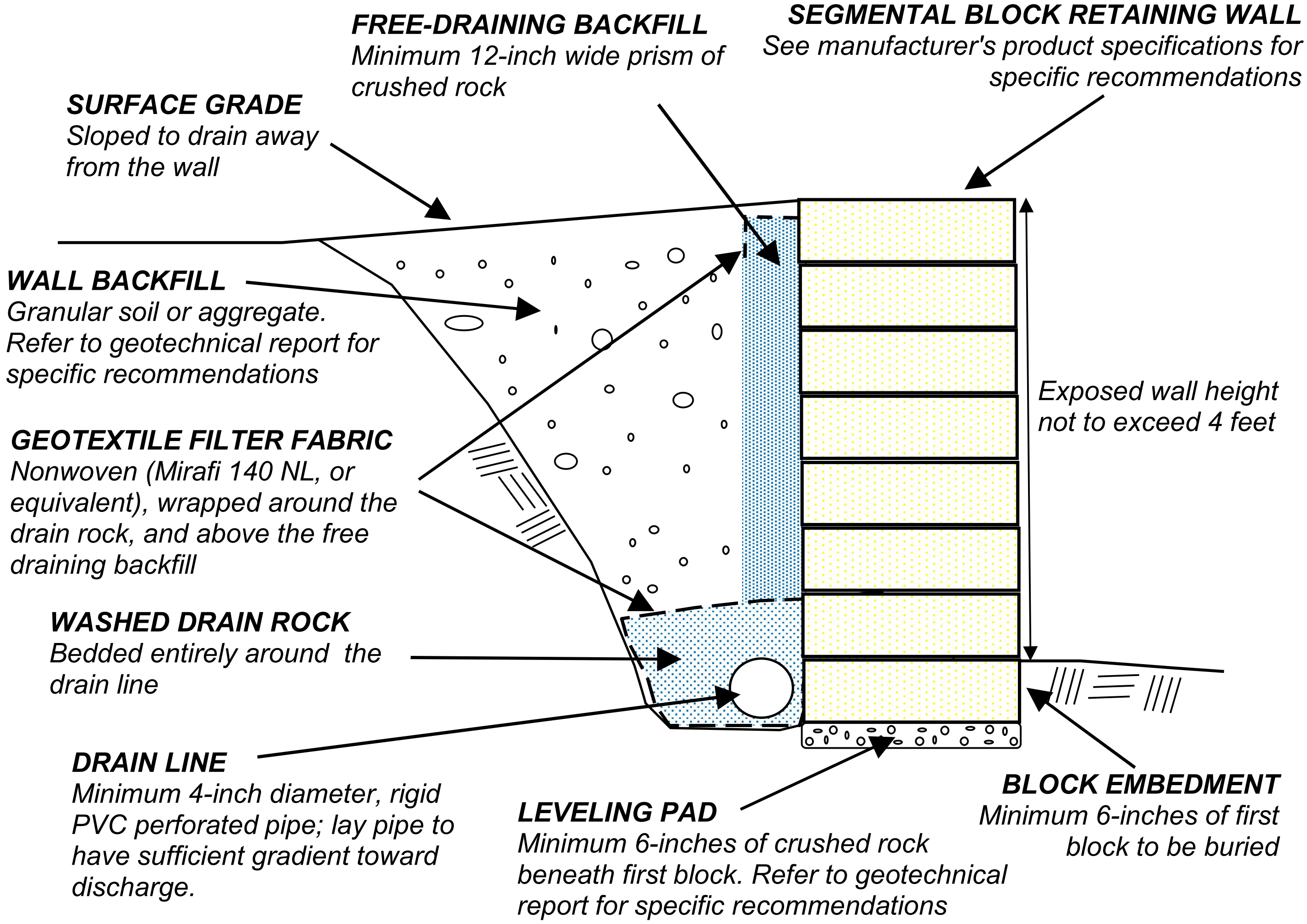
LEGEND
- STEEP SLOPE HAZARD AREA
- EROSION HAZARD AREA

GEO Group Northwest, Inc.
Geotechnical Engineers, Geologists, & Environmental Scientists

GEOLOGIC HAZARD MAP
PROPOSED DRIVEWAY MODIFICATIONS
4624 E MERCER WAY
MERCER ISLAND, WA 98040

SCALE	DATE	MADE	CHKD	JOB NO.	PLATE
As Shown	10/31/22	AH	WC	G-5770	3

SEGMENTAL BLOCK WALL DRAINAGE



NOTES:

NOT TO SCALE

1.) Do not replace rigid PVC pipe with flexible corrugated plastic pipe.

2.) Perforated PVC pipe should be tight jointed and laid with perforations oriented downward. The pipe should be gently sloped to provide flow toward the tightline or discharge location.

3.) Do not connect other drain lines into the footing drain system.

4.) Backfill should meet structural fill specifications if it will support driveways, sidewalks, patios, or other structures. Refer to the geotechnical engineering report for structural fill recommendations.

5.) Surface grade above the backfill can be covered with a layer of relatively low-permeablity soil to reduce infiltration of surface water into the backfill and drainage system

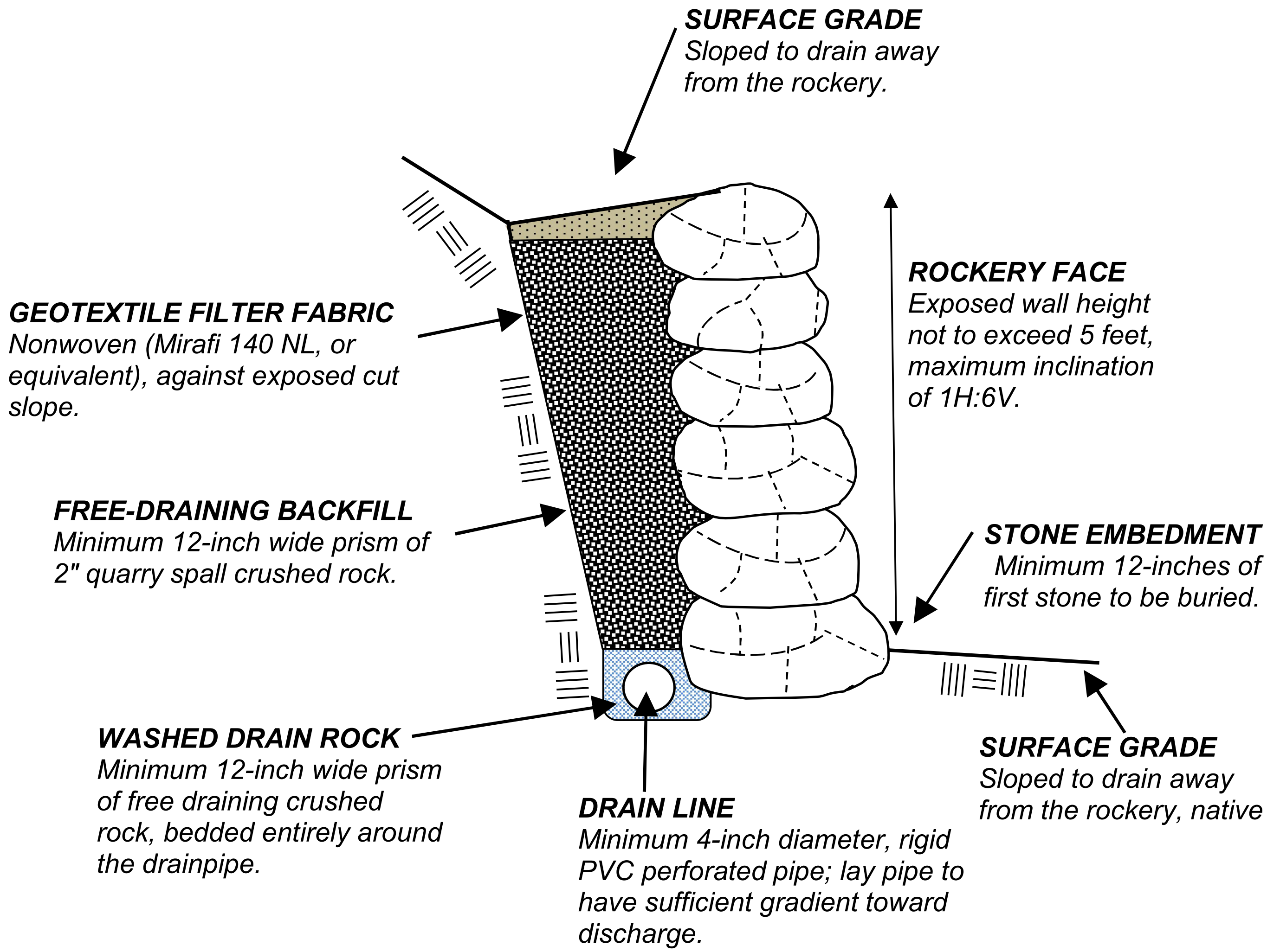
GEO Group Northwest, Inc.
Geotechnical Engineers, Geologists, & Environmental Scientists

SEGMENTAL BLOCK WALL DRAINAGE

PROPOSED DRIVEWAY MODIFICATIONS
4624 E MERCER WAY
MERCER ISLAND, WA 98040

SCALE NONE	**DATE** 10/31/2022	**MADE** AH	**CHKD** WC	**JOB NO.** G-5770	**PLATE** 4

ROCKERY SECTION DETAIL



NOT TO SCALE

NOTES:

1.) Do not replace rigid PVC pipe with flexible corrugated plastic pipe.

2.) Perforated PVC pipe should be tight jointed and laid with perforations oriented downward. The pipe should be gently sloped to provide flow toward the approved discharge location.

3.) Do not connect other drain lines into the rockery drain system.

4.) Surface grade above the backfill can be covered with a layer of relatively low-permeablity soil to reduce infiltration of surface water into the rockery backfill and drainage system.

GEO Group Northwest, Inc.
Geotechnical Engineers, Geologists, & Environmental Scientists

ROCKERY SECTION DETAIL

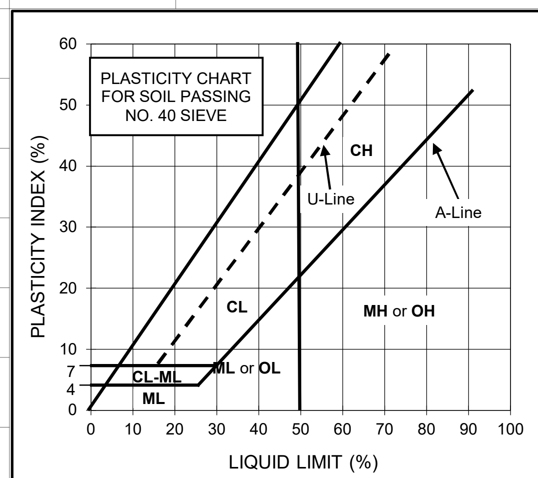
PROPOSED DRIVEWAY MODIFICATIONS
4624 E MERCER WAY
MERCER ISLAND, WA 98040

SCALE NONE	**DATE** 10/31/2022	**MADE** AH	**CHKD** WC	**JOB NO.** G-5770	**PLATE** 5

SOIL CLASSIFICATION & PENETRATION TEST DATA EXPLANATION

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)

MAJOR DIVISION			GROUP SYMBOL	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA	
COARSE-GRAINED SOILS More Than Half by Weight Larger Than No. 200 Sieve	**GRAVELS** (More Than Half Coarse Fraction is Larger Than No. 4 Sieve)	**CLEAN GRAVELS** (little or no fines)	GW	WELL GRADED GRAVELS, GRAVEL-SAND MIXTURE, LITTLE OR NO FINES	CONTENT OF FINES BELOW 5%	Cu = (D60 / D10) greater than 4 Cc = $(D30)^2$ / (D10 * D60) between 1 and 3
			GP	POORLY GRADED GRAVELS, AND GRAVEL-SAND MIXTURES LITTLE OR NO FINES		CLEAN GRAVELS NOT MEETING ABOVE REQUIREMENTS
		DIRTY GRAVELS (with some fines)	GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12%	GM: ATTERBERG LIMITS BELOW "A" LINE. or P.I. LESS THAN 4
			GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES		GC: ATTERBERG LIMITS ABOVE "A" LINE. or P.I. MORE THAN 7
	SANDS (More Than Half Coarse Fraction is Smaller Than No. 4 Sieve)	**CLEAN SANDS** (little or no fines)	SW	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	CONTENT OF FINES BELOW 5%	Cu = (D60 / D10) greater than 6 Cc = $(D30)^2$ / (D10 * D60) between 1 and 3
			SP	POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES		CLEAN SANDS NOT MEETING ABOVE REQUIREMENTS
		DIRTY SANDS (with some fines)	SM	SILTY SANDS, SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12%	ATTERBERG LIMITS BELOW "A" LINE with P.I. LESS THAN 4
			SC	CLAYEY SANDS, SAND-CLAY MIXTURES		ATTERBERG LIMITS ABOVE "A" LINE with P.I. MORE THAN 7
FINE-GRAINED SOILS Less Than Half by Weight Larger Than No. 200 Sieve	**SILTS** (Below A-Line on Plasticity Chart, Negligible Organics)	Liquid Limit < 50%	ML	INORGANIC SILTS, ROCK FLOUR, SANDY SILTS OF SLIGHT PLASTICITY		
		Liquid Limit > 50%	MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY OR SILTY SOIL		
	CLAYS (Above A-Line on Plasticity Chart, Negligible Organics)	Liquid Limit < 50%	CL	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY, OR SILTY CLAYS, CLEAN CLAYS		
		Liquid Limit > 50%	CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS		
	ORGANIC SILTS & CLAYS (Below A-Line on Plasticity Chart)	Liquid Limit < 50%	OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY		
		Liquid Limit > 50%	OH	ORGANIC CLAYS OF HIGH PLASTICITY		
HIGHLY ORGANIC SOILS			Pt	PEAT AND OTHER HIGHLY ORGANIC SOILS		



SOIL PARTICLE SIZE

FRACTION	U.S. STANDARD SIEVE			
	Passing		Retained	
	Sieve	Size (mm)	Sieve	Size (mm)
SILT / CLAY	#200	0.075		
SAND				
FINE	#40	0.425	#200	0.075
MEDIUM	#10	2.00	#40	0.425
COARSE	#4	4.75	#10	2.00
GRAVEL				
FINE	0.75"	19	#4	4.75
COARSE	3"	76	0.75"	19
COBBLES	76 mm to 203 mm			
BOULDERS	> 203 mm			
ROCK FRAGMENTS	> 76 mm			
ROCK	>0.76 cubic meter in volume			

GENERAL GUIDANCE FOR ENGINEERING PROPERTIES OF SOILS, BASED ON STANDARD PENETRATION TEST (SPT) DATA

SANDY SOILS				SILTY & CLAYEY SOILS		
Blow Counts N	Relative Density, %	Friction Angle ϕ, degrees	Description	Blow Counts N	Unconfined Strength q_u, tsf	Description
0 - 4	0 -15		Very Loose	< 2	< 0.25	Very soft
4 - 10	15 - 35	26 - 30	Loose	2 - 4	0.25 - 0.50	Soft
10 - 30	35 - 65	28 - 35	Medium Dense	4 - 8	0.50 - 1.00	Medium Stiff
30 - 50	65 - 85	35 - 42	Dense	8 - 15	1.00 - 2.00	Stiff
> 50	85 - 100	38 - 46	Very Dense	15 - 30	2.00 - 4.00	Very Stiff
				> 30	> 4.00	Hard

GEO Group Northwest, Inc.
Geotechnical Engineers, Geologists, & Environmental Scientists
13705 Bel-Red Rd Bellevue, WA 98005
Phone (425) 649-8757 Fax (425) 649-8758

PLATE A1

BORING LOG HA-1

Completed By: AH   Date Drilled: 9/28/2022   Surface Elev. Approx. 67 ft

Depth ft.	Elevation	USCS Code	Description	Sample Loc.	Sample No.	Probing Rod Penet. (in.)	Water Content %	Other Tests/ Comments
0		SM	- Surficial layer of mulch underlain by light brown to grayish brown SILTY SAND, sand is fine to medium grained, loose, dry; abundant small diameter roots.			6"		
1		ML	- Light gray SILT WITH SAND, sand is fine grained, medium stiff to stiff, dry; trace subrounded gravel is fine to coarse.			2.5"		
				I	S1		7.3	
2						1"		
		ML	- As above, color changes to olive gray.					
3			Total depth = 3.0', Dense material encountered. No groundwater seepage encountered.			<1"		
4								
5								

LEGEND: I Sample Location (Approximate)

GEO Group Northwest, Inc.
Geotechnical Engineers, Geologists, & Environmental Scientists

BORING LOG
PROPOSED DRIVEWAY EXPANSION
4624 E MERCER WY
MERCER ISLAND, WA 98040

JOB NO. G-5770 **DATE** 10/31/2022 **PLATE** A2

BORING LOG HA-2

Completed By: AH Date Drilled: 9/28/2022 Surface Elev. Approx. 75 ft

Depth ft.	Elevation	USCS Code	Description	Sample Loc.	Sample No.	Probing Rod Penet. (in.)	Water Content %	Other Tests/ Comments
		SM	- Thin moss groundcover underlain by brown to reddish brown SILTY SAND, sand is fine to coarse grained, very loose, dry to damp; abundant small diameter roots and organic debris, trace subrounded gravel is fine.			12.5"		
1		SM	- same as above, occasional organic debris, trace mottling.	I	S1	4"	10.5	
2						3.5"		
		SM	- Dark brown to brown SILTY SAND, sand is fine to coarse grained, loose, damp; abundant organic debris.					
		ML	- Light brown to light gray SILT WITH SAND, sand is fine grained, stiff, dry; trace mottling.					
3		ML	- same as above, color mostly light gray, trace subrounded gravel is fine to coarse.	I	S2	1"	6.7	
						<1"		
			Total Depth = 3.5', Dense material encountered. No groundwater seepage encountered.					
4								
5								

LEGEND: I Sample Location (Approximate)

GEO Group Northwest, Inc.
Geotechnical Engineers, Geologists, & Environmental Scientists

BORING LOG

PROPOSED DRIVEWAY EXPANSION
4624 E MERCER WY
MERCER ISLAND, WA 98040

JOB NO. G-5770 **DATE** 10/31/2022 **PLATE** A3

BORING LOG HA-3

Completed By: AH Date Drilled: 9/28/2022 Surface Elev. Approx. 65 ft

Depth ft.	Elevation	USCS Code	Description	Sample Loc.	Sample No.	Probing Rod Penet. (in.)	Water Content %	Other Tests/ Comments
		SM	- Surficial layer of dark brown mulch underlain by grayish brown SILTY SAND, sand is fine to medium grained, loose, dry; abundant organic debris, trace subrounded and angular gravel is fine to coarse.			5"		
		SM	- brownish gray SILTY SAND WITH GRAVEL, sand is fine to medium grained, subrounded and angular gravel is fine to coarse, loose, dry to damp; some cobbles and rock fragments, occasional small diameter roots and organic debris					
1								
		SM	- same as above, color changes to dark gray, damp.	I	S1	1"	10.4	
2						0-2"		
			Total depth = 2.0', Equipment refusal. No groundwater seepage encountered.					
3								
4								
5								

LEGEND: I Sample Location (Approximate)

GEO Group Northwest, Inc.
Geotechnical Engineers, Geologists, & Environmental Scientists

BORING LOG

PROPOSED DRIVEWAY EXPANSION
4624 E MERCER WY
MERCER ISLAND, WA 98040

JOB NO. G-5770 **DATE** 10/31/2022 **PLATE** A4

ARC ROCKERY CONSTRUCTION GUIDELINES

Section 1
Introduction

1.01.1 Historical Background

These rock wall construction guidelines have been developed in an effort to provide a more stringent degree of control on materials and construction methodology in the Pacific Northwest, and elsewhere. They have been assembled from numerous other data presently in use in the area, from expertise provided by local geotechnical engineers, and from the wide experience of the members of the Associated Rockery Contractors (ARC).

1.101.2 Goal

The primary goals of this document are to develop appropriate methods of construction for rock walls, including those of less than over four feet in height, and to provide a means of verifying the quality of materials used in construction and the workmanship employed in construction. These guidelines have also been developed in a manner that makes them, to the best of ARC's knowledge, more stringent than the others construction methods or requirements presently in use by local municipalities.

Section 2
Materials

2.01.1 Rock Quality

All rock shall be sound, angular ledge rock that is resistant to weathering. The longest dimension of any individual rock should not exceed three times its shortest dimension. Acceptability of rock will be determined by laboratory tests as hereinafter specified, geologic examination and historical usage records.

All rock delivered to and incorporated in the project shall meet the following **Minimum** specifications:

a.	Absorption ASTM C-127 AASHTO T-85	*Not more than 2.0% for igneous and metamorphic rock types and 3.0% for sedimentary rock types.*
b.	Accelerated Expansion *(15 days) CRD-C-148 *1, *2*	*Not more than 15% breakdown.*
c.	*Soundness (MsSO4 at 5 cycles)* ASTM C-88 or CRD-C-137	*Not greater than 5% loss.*

d.	Unconfined Compressive Strength *ASTM D-2938*	*Intact strength of 6,000 psi,* or greater
e.	Bulk Specific Gravity (155pcf) *ASTM C-127* *AASHTO T-85*	*Greater than 2.48*

*1. The test sample will be prepared and tested in accordance with Corps of Engineers Testing procedure CRD-C-148, "Method of Testing Stone for Expansive Breakdown on Soaking in Ethylene Glycol."

*2. Accelerated expansion tests should also include analysis of the fractures and veins found in the rock.

2.01.2 Frequency of Testing

Quarry sources shall begin testing program when either becominga supplier or when a new area of the source pit is opened. The tests described in Section 2.01.1 shall be performed for every four thousand (4000) tons, for the first twelve thousand (12,000) tons of wall rock supplied to establish that specific rock source. The tests shall then be performed once a year, every forty thousand (40,000) tons (whichever occurs first), or at an apparent change in material. If problems with a specific area in a pit, or with a particular material, are encountered the initial testing cycle shall be restarted.

2.01.3 Rock Density

Recognizing that numerous sources of rock exist, and that the nature of rock will vary not only between sources but also within each source, the density ofthe rock shall be equal to, or greater than, one hundred fifty-five (155) pcf. Typically, rocks used for rock wall construction shall be sized approximately as follows:

Rock Size	Rock Weight	Average Dimension
One Man	50-200 pounds	12 to 18 inches
Two Man	200-700 pounds	18 to 28 inches
Three Man	700-2000 pounds	28 to 36 inches
Four Man	2000-4000 pounds	36 to 48 inches
Five Man	4000-6000 pounds	48 to 54 inches
Six Man	6000-8000 pounds	54 to 60 inches

ARC ROCKERY CONSTRUCTION GUIDELINES

In rock walls of greater than eight feet in free-standing height it should not be possible to move the large sized rocks (four to six-man size) with a pry bar. If these rocks can be moved, the rock wall should not be considered capable of restraining any significant lateral load. However, it is both practical and even desirable that smaller rocks, particularly those used for "chinking" purposes, can be moved with a pry bar to achieve the "best fit".

2.01.4 Submittals

The rock source shall present current geologic and test data for the minimum guidelines described in Section 2.01.1 on request by either the rock wall contractor, the owner, or the applicable public agency.

Section 3
Rock Wall Construction

3.01.1 General

Rock wall construction is a craft and depends largely on the skill and experience of the builder. A rock wall is a protective system which helps to retard the weathering and erosion process acting on an exposed cut or fill soil face. While by its nature (the mass, size and shape of the rocks) it will provide some undetermined degree of "mass" or "gravity" retention, it is not typically a designed or engineered system in the sense a reinforced concrete retaining wall would be considered designed or engineered. The degree of retention achieved is dependent on the size of rock used; that is, the "mass" or weight, and the height of the rock wall being constructed. The larger the rock, the more competent the rock wall. To develop an appropriate degree of competency, all rock walls in excess of four feet in height should be built on a "mass" basis, i.e. by the ton, NOT on a square foot of exposed face basis.

To provide a competent and adequate rock wall structure, all rock walls constructed in front of either cuts or fills eight feet and over in height should be bid and constructed in accordance with these guidelines and the geotechnical engineer's supplemental geotechnical recommendations. Both the ARC guidelines and the supplemental geotechnical recommendations should be provided to prospective bidders **before** bidding and the start of construction.

3.01.2 Geotechnical Engineer

The geotechnical engineer retained to provide necessary supplemental rock wall construction guidelines shall be a practicing geotechnical/civil engineer licensed as a professional civil engineer in the State of Washington. He or she should have at least four years of professional employment as a geotechnical engineer in responsible charge, including experience with fill construction and stability and rock wall construction. The geotechnical engineer should be hired either by the rock wall contractor or the owner.

It is **CRITICAL** that the geotechnical engineer visit the site of a proposed rockery before providing any geotechnical recommendations whatsoever. This visit provides the opportunity for the geotechnical engineer to evaluate the proposed wall location and alignment, and to determine if there are any potential site related concerns that might detrimentally impact the rockery's "design" or construction. Failure to conduct this site visit could result in damage to the constructed wall or even to a wall failure.

3.01.3 Responsibility

The ultimate responsibility for rock wall construction should remain with the rock wall builder. However, rock walls protecting moderate to thick fills, with steep sloping surfaces above or below them, with multiple steps or stages, with foundation or other surcharge loads affecting them, protecting sandy or gravelly soils subject to raveling, with seepage or wet conditions, or that are greater than eight feet in free-standing height, all represent special "design" conditions and require consultation and/or advice from a suitably qualified geotechnical engineer.

3.01.4 Workmanship

All workmanship is guaranteed by the rock wall contractor and all materials are guaranteed by the supplying quarry for a period of six years from the date of completion of erection, providing no modification or changes to the conditions existing at the time of completion are made.

3.01.5 Changes to Finished Product

Such changes include, but are not necessarily limited to, temporary excavation of ditches or trenches for any utility within a distance of less than five feet from the back of the top of the rock wall; excavation made either within a distance equal to at least two thirds of the free-standing wall height in front of the toe of a rock wall, or that will penetrate an imaginary line extended at a 1H:1V (Horizontal:Vertical) slope from the front edge of the rock wall toe (see figure D); removal of any material from the subgrade in front of the wall, excavation of material from any location behind the rock wall within a distance at least equal to the rock wall's height, the addition of any surcharge or other loads within a similar distance of the top of the wall, or surface or subsurface water forced, directed, or otherwise caused to flow behind the rock wall in any quantity.

ARC ROCKERY CONSTRUCTION GUIDELINES

3.01.6 Slopes

Slopes above rock walls should be kept as flat as possible, but should not exceed 2H:1V unless the rock wall is "engineered" specifically to provide some restraint to the surcharge load imposed by the slope. Any slope existing above a completed rock wall should be immediately covered with vegetation by the owner to help reduce the potential for surface water flow induced erosion. It should consist of a deep rooted, rapid growth vegetative mat, and will typically be placed by hydroseeding and covered with a mulch. It is often useful to overlay the seed and mulch with either pegged in-place jute matting, or some other form of approved geotextile or erosion control blanket, to help maintain the seed in-place until the root mat has an opportunity to germinate and take hold,

3.01.7 Monitoring

All rock walls constructed against cuts or fills of greater than four feet in height shall be periodically monitored during construction by the geotechnical engineer to verify that the nature and quality of the materials being used are appropriate, that the construction procedures are appropriate, and that the rock wall is being constructed in a generally professional manner and in accordance with this ARC guideline and any supplemental geotechnical recommendations. Past experience indicates that a **minimum** of two visits of limited duration is typically acceptable for monitoring purposes of single-stage walls of less than fifty (50) feet in length. For walls of greater than fifty (50) feet but less than one hundred (100) feet in length three monitoring visits are considered the **minimum** acceptable. For walls of greater than one hundred (100) feet in length an appropriate monitoring program shall be developed by the geotechnical engineer. For a multi-stage rock wall the **minimum** acceptable number of monitoring visits shall be considered at two visits for each stage of the wall.

The monitoring agent, typically the geotechnical engineer of record, shall maintain a written record of the nature and condition of the segment of the rock wall being monitored during that visit. An example of a Rockery Examination Record suitable for this form of documentation is attached to this ARC Guideline for informational purposes.

Where there is a slope above or below the rockery wall it is important that the monitoring agent make a visual assessment of the slopes' stability, and record the results. Additionally, the inclination of the slope either in degrees or as a H:V slope, shall be approximately determined and recorded.

When the monitoring agent is checking a rocks soundness as it is struck with a hammer (see attached Rockery Examination Record) one of several "sounds" will be generated. A "clink" or "ringing ping" typically results from a fresh and competent rock with little or no defects. A duller "thud" or "clonk" sound is more indicative of a poor quality rock, often with many seams or defects. The duller "thudding" sound is often exhibited by a rock that has a high tendency to rapidly deteriorate back into a highly weathered and "soft" rock or even to a "soil." Where such rocks are encountered the contractor should be requested to move the rock to the upper row or to a lower segment of the wall where it can more easily be reached and removed when it degrades without causing any significant disruption to the completed wall.

On completion of the rock wall, the geotechnical engineer should submit to the client, the rock wall contractor, and to the appropriate municipality, copies of his rock wall examination reports along with a final report summarizing rock wall construction.

3.01.8 Fill Compaction

Where rock walls are constructed in front of a fill, it is imperative that the owner ensure the fill be placed and compacted in a manner that will provide a competent fill mass. To achieve this goal, all fills should consist of relatively clean, organic and debris free, granular material with a maximum size of four inches. Ideally, but particularly if placement and compaction is to take place during the wet season, they should contain no more than five percent fines (silt and clay sized particles) passing the number 200 mesh sieve).

All fills should be placed in thin lifts not exceeding ten (10) inches in loose thickness. Each lift should be compacted to at least 95 percent of the maximum dry density, as determined by Modified Proctor, before any additional fill is placed and compacted. In-place density tests should be performed by an independent testing agency at random locations within each lift of the fill using either a nuclear density testing gauge or a more traditional sand cone device to verify that this degree of compaction is being achieved. Failure to achieve this degree of compaction could result in the imposition of a greater lateral load on the rock wall that could, over time, cause lateral movement or even "failure" of the rock wall. This situation is to be avoided!

3.01.9 Fill Construction Reinforcement

There are two methods of constructing a fill. The first, which typically applies to rock walls of less than eight feet in free-standing height, is to overbuild and then cut back the fill. The second, which applies to all rock walls of greater than eight feet in height, is to construct the fill using a geogrid or geotextile reinforcement.

Overbuilding the fill allows for satisfactory compaction of the fill mass out beyond the location of the fill face to be protected. Overbuilding also allows the earthwork contractor to use larger and more effective compaction equipment in his compactive efforts, thereby typically achieving a more competent fill mass. Cutting back into the well compacted fill also typically results in construction ofa competent near vertical fill face against which to build the rock wall. This option is pictorially depicted on Plate B, attached.

ARC ROCKERY CONSTRUCTION GUIDELINES

3.01.13 Rock Selection

The contractor should have sufficient space available so that he can select from among a number of stockpiled rocks for each space in the rock wall to be filled. Rockswhich have shapes which do not match the spaces offered by the previous course of rock should be placed elsewhere to obtain a better fit. Rock should be of a generally cubical, tabular or rectangular shape and selected in accordance with Section 2.01.3 of this Guideline. Any rocks of basically rounded or tetrahedral form should be rejected or used for filling large void spaces.

It is also important to select rocks that do not exhibit any significant cracks, seams or foliation joints so that, once in-place, the individual rocks do not break, split or crumble and thereby create a weak zone within the constructed wall. It is acceptable to install individual rocks with cracks, seams, or foliation joints in a wall providing that theycan be firmly and adequately confined by the surrounding rocks. It is critical that the cracks, seams or foliation joints do NOT allow for portions of the rock to spall off and fall out of the wall. Similarly, considerable care should be exercised by the rock wall contractor to avoid installing any rock with a weakened or "scabbing" face that might spall off and fall out of the wall, or off the wall face.

3.01.14 Rock Placement

The first course of rock should be placed on firm unyielding soil, or onto the previously installed layer of crushed rock. There should be full contact between the rock and soil or crushed rock surface, which may require shaping of the ground surface or slamming or dropping the rocks into place so that the soil or angular crushed rock covered subgrade better conforms to the rock face bearing on it. The bottom of the first course of rock should be a **minimum** of twelve (12) inches below the lowest adjacent site grade, or not less than two feet for a waterfront bulkhead wall per Section 3.01.10 of this Guideline.

As the rock wall is constructed, the rocks should be placed so that there are no continuous joint planes in either the vertical or lateral direction. Wherever possible, each rock should bear on a least two rocks below it. Rocks should be placed so that there is some bearing between flat rock faces rather than in or on spaces between the underlying rocks. The upper plane of each rock between courses (the top surface of rock), should slope back towards the protected soil face and away from the face of the rock wall.

Because stacked rocks exhibit a tendency to "topple" outwards it is **crucial** that individual rocks NOT be stacked like shoe boxes in any wall regardless of the total height. Whilst an occasional rock will, simply because of its shape or size, be stacked atop another, stacking must not become a practice. If rocks are stacked like shoe

ARC ROCKERY CONSTRUCTION GUIDELINES

For higher rock walls the use of a geogrid or geotextile fabric to help reinforce the fill results in construction of a more stable fill face against which to construct the rock wall. This form of construction leads to a longer lasting more stable rock wall and helps reduce the risk of significant long term maintenance.

This latter form of construction requires a design by the geotechnical engineer for each specific case. The vertical spacing of the reinforcement, the specific type of reinforcement, the distance it must extend back into the fill, the amount of lapping and the construction sequence must be determined on a case by case basis. This option is pictorially depicted on Plate C, attached.

3.01.10 Rock Wall Keyway

The first step in rock wall construction, after general excavation, is to construct a keyway in which to install or "set" the basal row of rock forming the rock wall. The keyway shall comprise a shallow trench of not less than twelve (12) inches in depth, extending for the full length of the rock wall. If the rock wall is a waterfront bulkhead wall the **Minimum** keyway depth shall be two feet, measured from the natural beach elevation in front of the wall that existed before wall construction began. The keyway subgradeshould be slightly inclined back towards the face being protected. It is typically dug as wide as the rock wall (including the width of the drain rock layer). If thecondition of the cut face is of concern, the keyway should be constructed in sections of manageable length, that is, of a length that can be constructed in one shift or one day's work, or if a waterfront wall between high tides.

The competency of the keyway subgrade to support the rock wall shall be verified by the geotechnical engineers' probing with a small diameter steel rod. The rod shall have a diameter of between three-eighths and one-half inch, and shall be pushed into the subgrade in a smooth unaided manner under the body weight of the prober only. Penetration of up to six inches, with some difficulty, shall indicate a "competent" keyway subgrade unless other factors in the geotechnical engineer's opinion shall be considered to indicate otherwise.

Penetration in excess of six inches, with ease, shall indicate a "soft" subgrade and one that could require treatment. Shallow soft areas of the subgrade can be "firmed up" by tamping a layer of coarse quarry spalls into the subgrade.

Where a rock wall is being "analyzed" or "engineered" as a wall capable of at least partially restraining a lateral load it is often appropriate to install a layer of coarse, angular crushed rock over the prepared keyway subgrade to enhance the frictional resistance between the subgrade and basal rock and, thus, the walls ability to resist sliding. This crushed rock layer should be not less than six inches in thickness, after being firmly tamped into the subgrade, and should typically comprise "fines free" two to four inch sized crushed rock "quarry spalls" or crushed recycled concrete.

ARC ROCKERY CONSTRUCTION GUIDELINES

3.01.11 Keyway Drainage

Upon completion of keyway excavation, a four-inch minimum diameter perforated or slotted, smooth-walled rigid plastic drain pipe, or equivalent approved in writing by a geotechnical engineer, should be installed at the rear of the keyway, behind the basal rock. It should be bedded on and surrounded by a free-draining crushed rock. It is **critical** to exercise due care when setting rocks to prevent the pipe from being inadvertently crushed by pieces of the rock wall rock. This drain pipe should be installed with sufficient gradient to initiate flow either to one end or the other, or to a low point, and the outfall should be connected by unperforated tightline to a positive and permanent discharge.

Positive and permanent drainage should be considered to mean an existing, or to be installed, storm drain system, a detention or retention pond, drain swale, or other stable native site feature or previously installed collection system.

Where a rock wall is being installed as a waterfront bulkhead wall subject to tidal and current activity the above-described drain pipe becomes redundant and may be omitted. With hydraulic/tidal fluctuations the water penetrating through the rock wall will drain back out through the void spaces far more rapidly than can be achieved by the basal drain.

In arid regions, such as Eastern Washington and Nevada, where there is little risk of seepage occurring the basal drain pipe may be omitted. However, the minimum thickness of drain rock should be installed to help protect the soil face behind the constructed wall, and to assist in "blocking" or "chinking" the voids between the individual rockery rocks.

3.01.12 Rock Wall Thickness

The individual rock wall thickness should be equal to the thickness of the recommended size of rock plus the thickness of the drain rock layer. This thickness, which will be determined on a case by case basis, will be dependant on the specific rock sizes recommended for each individual rock wall. For example, if four-man rock is used the rock wall thickness will be approximately five feet (rock width plus twelve [12] inches of drain rock).

If the rock wall is to act, even in part, as a "retaining" structure it is **critical** that the size and mass of the in-place rock is adequate to resist the applied load. In some instances it may be necessary to install more than one row of rock. In this case it is **imperative** that the owner and rock wall contractor seek the advice of a professional geotechnical engineer before proceeding with construction.

boxes the rock wall contractor shall be instructed to "deconstruct" the affected portion of the wall and to rebuild it in strict accordance with these ARC Guidelines.

It is also **critical** that no rock be set into any wall with a top surface sloping downwards out of the wall face. This will create a potential plane of weakness, if not of failure, within the wall and should be avoided at all costs. If any rock is seen to be placed within a wall with this outwards sloping surface the rock wall contractor must be directed to remove it and replace it before proceeding with wall construction. No completed rock wall shall be accepted by the geotechnical engineer if any rock within the structure exhibits this outwards sloping geometry.

It is also important to place as much mass of rock in-place as possible to create a stable rock wall. In addition to the selection of appropriately sized rocks, it is also important, wherever possible, to install the rocks with the longest dimension set back towards the soil face being protected. This is of particular importance when construction a rock bulkhead wall that is likely to be subject to tidal and/or hydraulic action.

Smaller rocks (one or two-man size) are often used to create an aesthetically pleasing "top edge" to a rock wall. This is an acceptable practice provided none of the events described in Section 3.01.5 of this Guideline occur, and that people are prevented form climbing or walking on the finished wall. ***This is the owner's responsibility.***

Where a rock wall is constructed as a waterfront bulkhead it is **critical** that the ends of the wall either abut a neighboring bulkhead wall, or that a "return" back into the protected site be constructed. Where the wall abuts its neighbor the placement of the end rocks becomes a critical element of the walls construction since these end walls must make as close contact with the neighboring wall as is possible to avoid developing any significant void spaces. The wall contractor must make every reasonable effort to install rocks that can be set essentially "flush" against the neighboring wall.

Where a "return" is constructed the contractor must excavate an extension of the keyway approximately at a right angle (90 degrees) to the wall alignment back into the site. Where there is the potential for tidal activity above the toe of the wall it is important that this return extend for a distance sufficient to install a minimum of three rocks of equal size to those used in the construction of the wall face. For example, if five-man size rocks (average dimension of about fifty [50] inches) are used in the wall the return should be approximately thirteen (13) to fourteen (14) feet long. Wherever possible, any space between the return rocks and the excavated soil face should be carefully and thoroughly backfilled with two to four inch sized coarse, angular, crushed rock "quarry spalls" or recycled concrete.

ARC ROCKERY CONSTRUCTION GUIDELINES

3.01.15 Face Inclination

The face of the rock wall should be inclined at gradient of about 1H:6V back towards the face being protected. The inclination of the wall face shouldnot be constructed flatter than 1H:4V.

3.01.16 Voids

Because of the nature of the product used to construct a rock wall, it is virtually impossible to avoid creating void spaces between individual rocks. However, it should be recognized that voids do not necessarily constitute a problem in rock wall construction. As the size of rock used to build a rock wall increases, i.e. to six-man size, the void spaces between individual rocks should be expected to be larger due simply to the rock dimensions and shape.

Where voids of greater than six inches in dimension exist in the face of a rock wall they should be visually examined to determine if contact between the rocks exists within the thickness of the rock wall. If contact does exist, no further action is required. However, if there is no rock contact within the rock wall thickness the void should be "chinked"with a smaller piece of rock.

Because the loss of drain rock or of the soil being protected by the rock wall must be avoided, "chinking" of these larger void spaces is a critical element in rock wall construction. To create a stable wall, and particularly if the wall is to be a waterfront bulkhead wall subject to tidal and hydraulic impacts, all chinking shall be carried out from the rear face of the wall. In this manner the chinking rocks can be firmly set into the voids and braced against the inboard sides of the wall rocks thereby enhancing their ability to resist being "flushed" or "picked" out of the wall. Whilst recognizing this form of chinking can slow down the speed with which a contractor can erect a rock wall, this methodology is considered to be of critical importance to the long term stability and structural integrity of a constructed rock wall and its attendant drainage system.

3.01.17 Drain Rock Layer

In order to provide some degree of drainage control behind the rock wall, and as a means of helping to prevent the potential loss of soil through the face of the rock wall, a rock drainage "filter" layer shall be installed between the rear face of the rock wall and the soil face being protected. This drain rock layer should be a minimum of twelve (12) inches in thickness. For rock walls of greater than eight feet in free-standing height should be at least eighteen (18) inches thick. It should be composed of two to four inch sized crushed rock quarry spalls, crushed recycled concrete, or other material approved in writing by the geotechnical engineer.

3.01.18 Surface Drainage

It is the owner's responsibility to intercept surface drainage from above the rock wall and direct it away from the rock wall to a positive and permanent discharge well below and beyond the top or toe of the rock wall. Use of other drainage control measures should be determined on a case-by-case basis by the geotechnical engineer prior to the contractor bidding on the project.