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February 19, 2016
Project No. KE150714A

Mr. Donovan Tracy
15044 Beach Drive NE
Lake Forest Park, Washington 98155

Subject: Subsurface Exploration and Geotechnical Engineering Report
Tracy Bulkhead
15044 Beach Drive NE
Lake Forest Park, Washington

Dear Mr. Tracy:

Associated Earth Sciences, Inc. (AESI) completed subsurface exploration activities in the vicinity of the shoreline bulkhead at your residence located at 15044 Beach Drive NE in Lake Forest Park, Washington (Figure 1). The purpose of this exploratory work was to provide information concerning the subsurface soil conditions behind the bulkhead along Lake Washington. This information was then used to develop geotechnical engineering recommendations for replacement of the bulkhead. Our findings and recommendations are outlined in the following sections of this report.

SITE AND PROJECT DESCRIPTION

The bulkhead addressed by this study is approximately 50 feet long and lies between Lake Washington and the adjacent rear yard area for the residence, with an existing pier extending past the northern portion of the bulkhead over the lake. We visited the subject site on February 3, 2016, to observe the conditions of the bulkhead. Judging from the type of construction, this bulkhead appears to be at least several decades old. The existing rock bulkhead structure displays signs of distress, with rocks having toppled into the lake. Based on our review of project plans prepared by Waterfront Construction, Inc., dated December 10, 2015, we understand that the proposed project includes repairs to or replacement of the existing rock bulkhead.

SUBSURFACE EXPLORATION

Our field study included drilling one exploration boring near the failing bulkhead location. The exploration boring location is shown on the attached Figure 2. The various types of sediments, as well as the depths where characteristics of the sediments changed, are indicated on the attached exploration log. The depths indicated on the log where conditions changed may represent gradational variations between sediment types in the field. If changes occurred between sample intervals in our boring, they were interpreted.

The conclusions and recommendations presented in this report are based on the exploration boring completed for this study, and our observations of the structure and the surrounding terrain. The location and depth of the exploration were completed within site and budgetary constraints. Because of the nature of exploratory work below ground, extrapolation of subsurface conditions beyond the field exploration is necessary.

Exploration Borings

The exploration boring was completed by advancing a hollow-stem auger with a subcontracted hand-portable drill rig. During the drilling process, samples were obtained at 2.5-foot-depth intervals. The boring was continuously observed and logged by an engineering geologist from our firm. The attached exploration log is based on the field log, drilling action, and inspection of the secured samples.

Disturbed but representative samples were obtained by using the Standard Penetration Test (SPT) procedure in accordance with *American Society for Testing and Materials* (ASTM):D 1586. This test and sampling method consists of driving a standard 2-inch, outside-diameter, split-barrel sampler a distance of 18 inches into the soil with a 140-pound hammer free-falling a distance of 30 inches. The number of blows for each 6-inch interval is recorded, and the number of blows required to drive the sampler the final 12 inches is known as the Standard Penetration Resistance ("N") or blow count. If a total of 50 blows are recorded within one 6-inch interval, the blow count is recorded as 50 blows for the corresponding number of inches of penetration. The resistance, or N-value, provides a measure of the relative density of granular soils or the relative consistency of cohesive soils; these values are plotted on the attached boring log.

The samples obtained from the split-barrel sampler were classified in the field and representative portions placed in watertight containers. The samples were then transported to our laboratory for further visual classification, as necessary.

SUBSURFACE CONDITIONS

Subsurface conditions were inferred from the field exploration accomplished for this study. As shown on the boring log, the exploration generally encountered loose sand over medium dense

sand and stiff silt, with varying amounts of gravel and woody debris. The upper roughly 10 feet soil within exploration boring EB-1 was interpreted to be fill material. The fill consisted of sand or silt with gravel, organics and metal fragments in places, and appeared to be wall backfill or fill associated with the past grading of the area immediately behind the existing bulkhead.

Sediments encountered below the fill generally consisted of medium dense sand and stiff silt, with varying amounts of gravel and woody debris, interpreted as recent lake sediments. The coarse-grained deposit underlying the lake sediments, at 17 feet below the ground surface, was interpreted to originally represent deposits placed prior to the Fraser Glaciation and subsequently compacted by the weight of the overlying glacial ice.

Review of the regional geologic map titled *The Geologic Map of Seattle - A Progress Report, 2005* (K.G. Troost, D.B. Booth, A.P. Wisher, and S.A. Shimel, 2005, U.S. Geological Survey [USGS] Open File Report 2005-1252, scale 1:24,000) indicates that the area of the subject site is underlain by recent lake sediments (Ql) overlying pre-Fraser-age deposits (Qpf). Our interpretation of the sediments encountered at the subject site is in general agreement with the regional geologic map.

Ground water was encountered within exploration boring EB-1 at a depth of 8 feet below the ground surface. We expect shallow ground water seepage across much of the upper portion of the site to be limited to interflow. Interflow occurs when surface water percolates down through the surficial weathered or higher-permeability sediments and becomes perched atop underlying, lower-permeability sediments. Fluctuations in the level of the ground water may occur due to variations in the level of Lake Washington, rainfall, site use, and the time of the year.

BULKHEAD CONDITIONS AND RECOMMENDED REMEDIATION

From the exploration data, it appears that the bulkhead was originally founded on the loose sandy fill that was encountered in exploration boring EB-1 below the bottom elevation of the bulkhead. The fill soils behind the wall are generally suitable for support of a landscaped area, but are susceptible to erosion and soil loss by "piping" from behind the bulkhead if exposed to wave water. In our opinion, the bulkhead failure is caused by a combination of scour of soils in front of the toe of the wall, erosion of soil from beneath the wall footing, and piping of soil from behind the wall. Partial loss of soils beneath the wall and lateral pressure of soil and water behind the wall have caused portions of the bulkhead to topple into the lake. This failure mechanism is discussed in more detail below.

Erosion/Scour at the Toe and Below the Footing

Seasonal variability in lake or beach levels can result in the footing being exposed to wave action during the winter storm season. Wave action removes the sediment at the base of the

bulkhead, exposing the footing to wave action that erodes soil particles from beneath and behind the wall. As waves strike the bulkhead, water surges beneath the footing and, as the waves recede, sediments behind and beneath the wall are transported out into the lake. This piping of sediments results in the removal of soil from beneath the bulkhead footing, causing both settlement and lateral movement of the bulkhead, shifting the positions of individual rocks. This shifting can lead to the toppling of rocks from the bulkhead into the lake, as displayed at the subject site. If not mitigated, soil loss would eventually cause the bulkhead to collapse.

Recommendations for Remediation

There are several options for remediation of the failing bulkhead ranging from "doing nothing" to complete replacement. It is our opinion that the "do nothing" alternative is not recommended because the remaining portion of the bulkhead is undergoing a progressive failure that will lead to additional collapse. Collapse of the bulkhead can occur with little additional warning and result in significant property and environmental damage. A partial repair/replacement of the bulkhead, at the collapsed portion, would not address the risk of collapse of the remaining structure. Therefore, it is our opinion that the remediation option presented below, which includes repairs to or the replacement of the existing distressed bulkhead with a new bulkhead, appears to be the most viable at this time.

Bulkhead Construction Considerations

The following notes present construction considerations for the proposed rock bulkhead. In addition, the contractor should confirm that the bulkhead configuration conforms to current City of Lake Forest Park specifications. As stated above, we understand that the proposed project includes repairs to or replacement of the existing rock bulkhead. We recommend the following measures to mitigate potential soil loss from below and behind the proposed rock bulkhead.

Rock Bulkhead

The base of the rock bulkhead should be embedded at least 2 feet below the existing lake bottom elevation. We recommend that loose or organic-laden material encountered below this elevation be excavated, where practicable, and replaced with rock spalls prior to bulkhead construction. The bulkhead rocks should be hard, sound, and durable rocks with suitable size to bring the bulkhead up to a height that will reduce the occurrence of overtopping by storm waves. The added rocks should be set concurrent with a crushed rock backfill zone located behind the rock bulkhead. Construction of a rock bulkhead in accordance with these recommendations should provide suitable protection of the shoreline from erosion. However, rock bulkheads should be considered a long-term maintenance item.

The following notes present rock bulkhead construction considerations:

A) We recommend the rocks used in the bulkhead construction be placed at a 1H:3V (Horizontal:Vertical) batter. The rocks should consist of graduated sizes from "4-man" to "2-man", from bottom to top:

Approximate Weight (lbs)	Average Dimension
500/4,000 lbs, graded top/bottom	28/48 inches, graded top/bottom

B) Each individual rock should be as nearly rectangular as possible. No stone should be used that does not extend completely through the bulkhead. The rock material should be hard, sound, durable, and free of weathered portions, seams, cracks, excessive porosity, or other defects. The rock density should be at least 160 pounds per cubic foot (pcf).

C) Rock selection and placement should be such that there will be a minimum of voids. The rocks should be placed in a manner such that the longitudinal axis of the rock will be perpendicular to the bulkhead face. Each rock should be placed so as to lock into two rocks in the underlying rock course.

D) The bulkhead should be backfilled with 2- to 6-inch crushed rock [Washington State Department of Transportation (WSDOT) Standard Specification 9-13.7(2)] enveloped in a layer of filter fabric, such as Mirafi Filterweave 403, or equivalent. The crushed rock backfill should have a minimum thickness of 4 feet between the bulkhead and the retained soil material and extend to the bottom of the rock bulkhead. The crushed rock backfill should be placed in lifts to an elevation of approximately 6 inches below the top of each course of rocks as they are placed until the uppermost course is placed. Any crushed rock backfill material falling onto the bearing surface of a rock course should be removed before the setting of the next course. To mitigate the risk of soil loss originating from the area behind the landward end of the existing pier, we recommend that this crushed rock backfill zone, along with the enveloping filter fabric, be extended to include the area of the pier.

   The crushed rock backfill may be capped with a soil layer provided a geofabric is used to provide separation of the two materials. We recommend that the soil cap be limited to 12 inches thick.

E) Any disturbed landscape area above the bulkhead should be planted in accordance with an approved shoreline revegetation plan.

F) The new structure should be positioned to close any gaps between it and adjacent bulkheads, but should be designed as a freestanding structure without reliance on supplementary support from adjacent walls.

G) AESI should observe the construction of the rock bulkhead as it progresses to verify that construction is completed in accordance with these recommendations.

Wall Drainage

Another factor affecting the failure of the bulkhead is drainage. Significant hydrostatic pressures can result when there is inadequate drainage behind the bulkhead. In addition, drainage material should be resistant to erosion and piping beneath the wall footing. In our opinion, the rock backfill and filter fabric recommended in note "D", above, should provide a suitable drainage zone for the bulkhead. Also, the spaces between the facing rocks should provide a suitable route for wave water overtopping the wall to flow back to the lake without the need for a piped collection and discharge system for the bulkhead.

CLOSURE

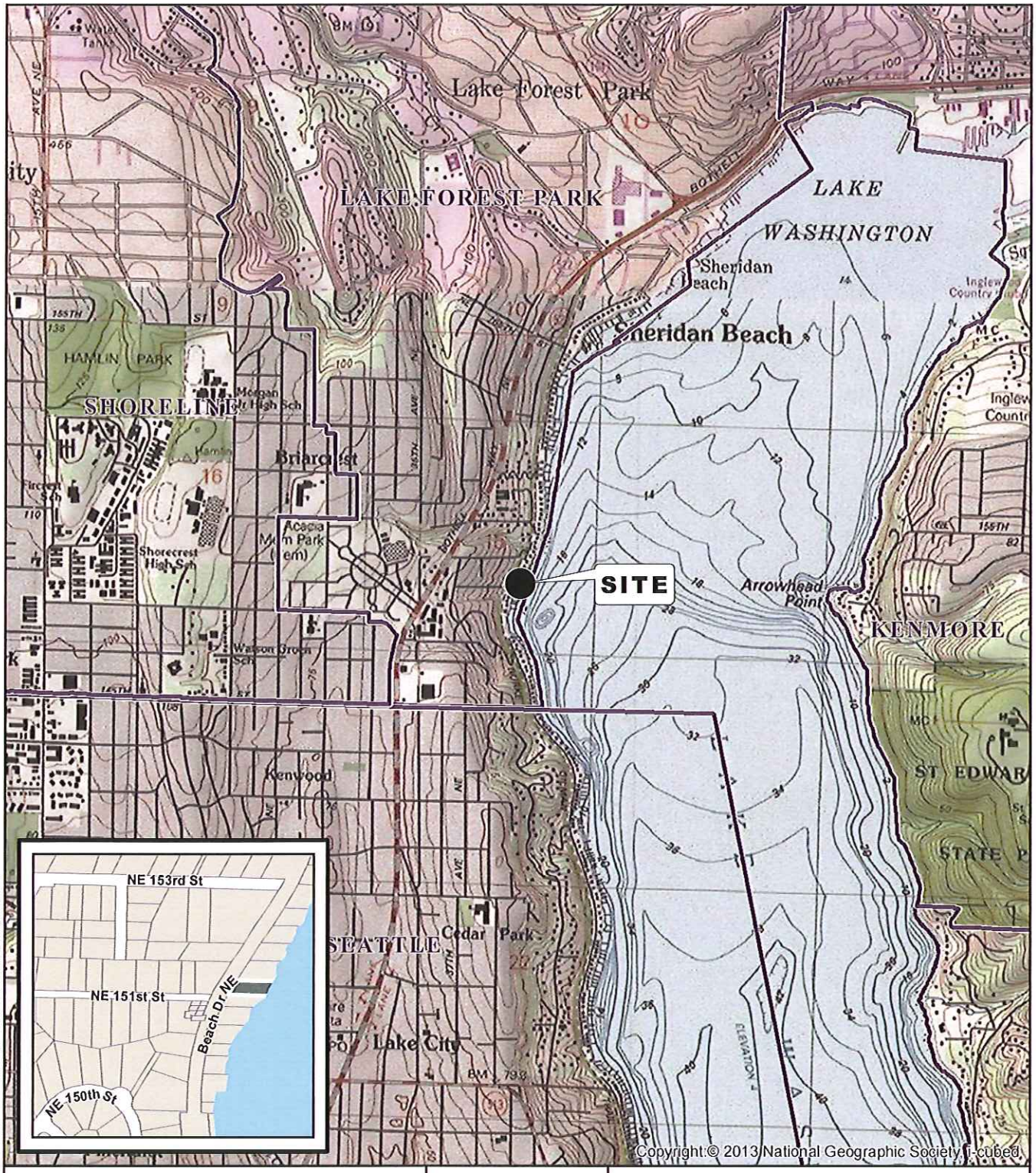
With suitable implementation of the remediation elements discussed herein, it is our opinion that the risk of ground loss from the property can be greatly reduced. AESI can provide additional recommendations as the design progresses. We trust that this report will meet your current project needs. If you should have any questions or if we can be of additional help to you, please do not hesitate to call.

Sincerely,
ASSOCIATED EARTH SCIENCES, INC.
Kirkland, Washington

Jeffrey P. Laub, L.G., L.E.G.
Senior Project Engineering Geologist

Bruce L. Blyton, P.E.
Senior Principal Engineer

Attachments: Figure 1: Vicinity Map
Figure 2: Site and Exploration Plan
Exploration Log



DATA SOURCES / REFERENCES:
USGS: 24K SERIES TOPOGRPAHIC MAPS
KING CO: STREETS, PARCELS

LOCATIONS AND DISTANCES SHOWN ARE APPROXIMATE

N

0 1000 2000

FEET

NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION

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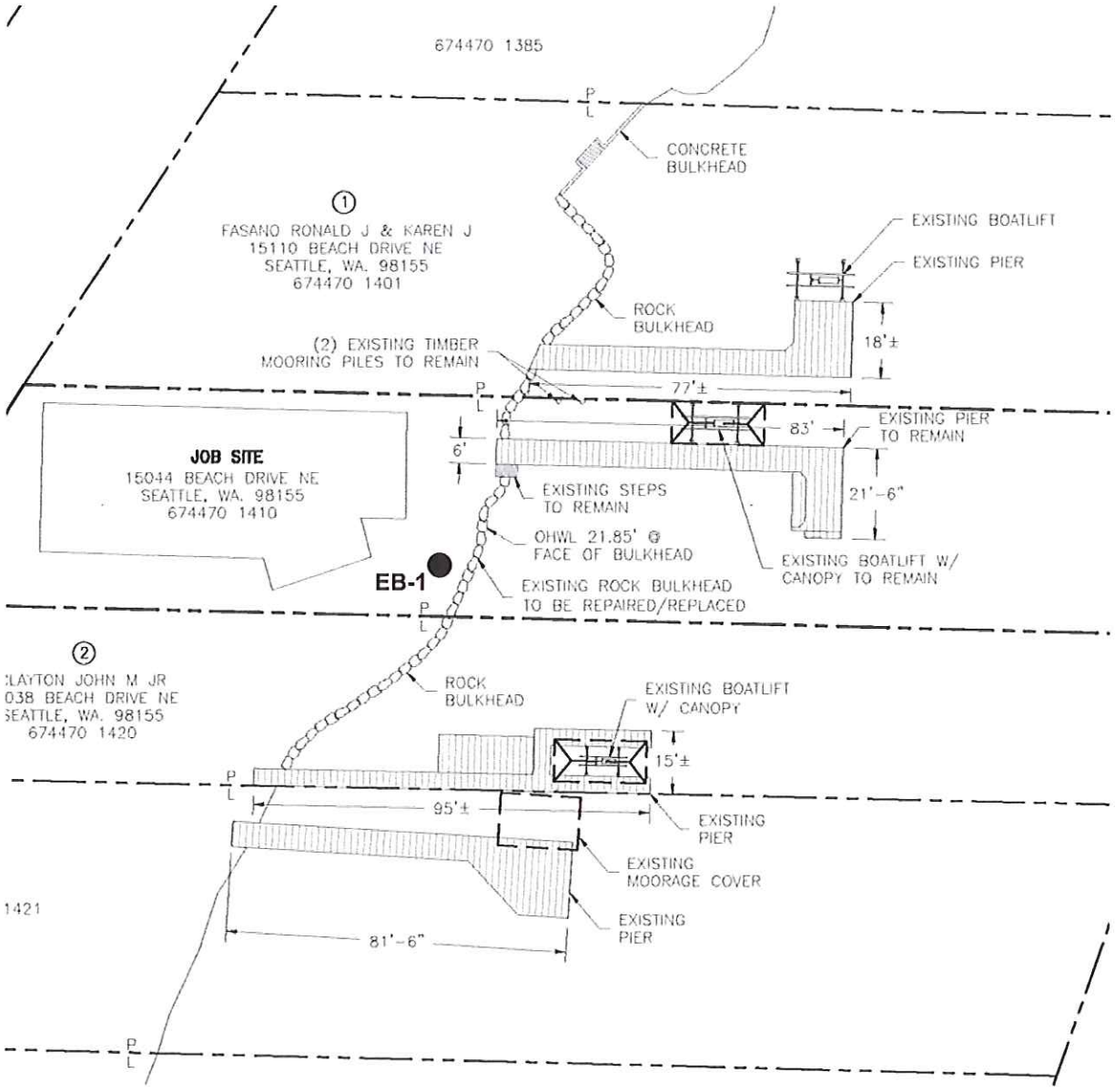
VICINITY MAP

TRACY BULKHEAD
LAKE FOREST PARK, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KE150714A	2/16	1

Document Path: H:\GIS_Projects\aTemplates\aVM_Template\150xxx Fig1 ProjectVicinity_KingN.Tmxd



LEGEND:

● **EB** EXPLORATION BORING

NOTE: LOCATION AND DISTANCES SHOWN ARE APPROXIMATE.
BASE MAP REFERENCE: WATERFRONT CONSTRUCTION, SHEET 2 OF 5, 12-10-15

N

0 20 40

FEET

NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

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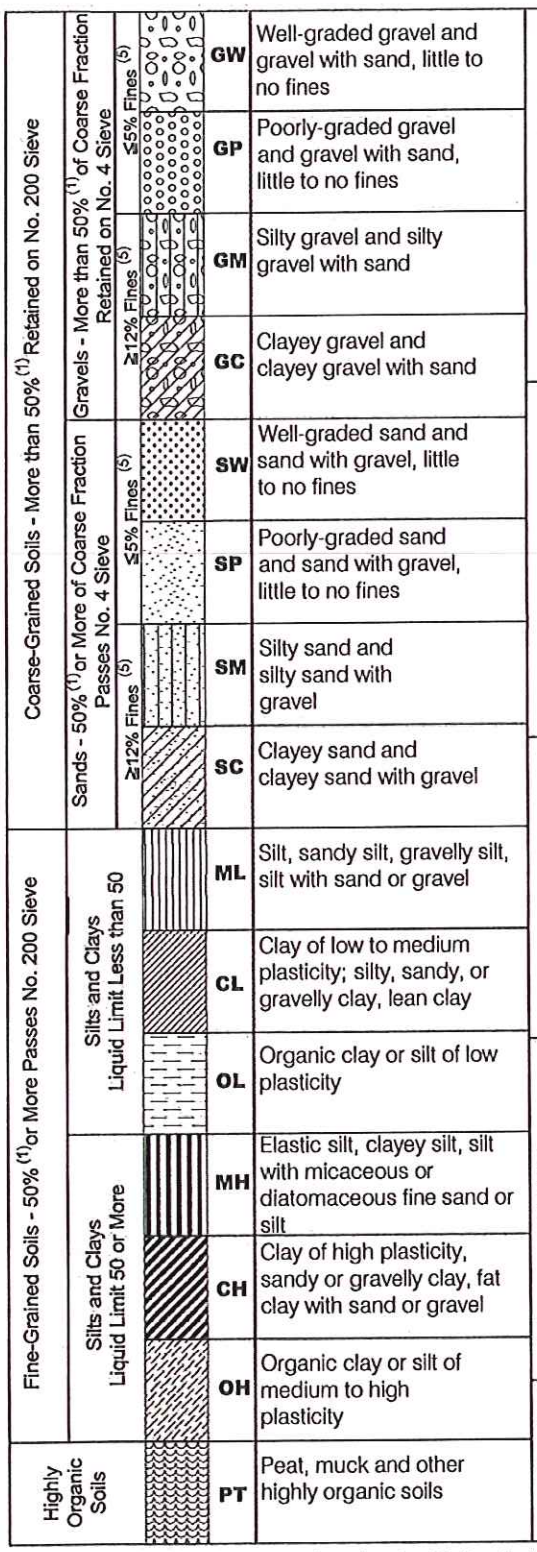
SITE AND EXPLORATION PLAN

TRACY BULKHEAD
LAKE FOREST PARK, WASHINGTON

PROJ NO.	DATE:	FIGURE:
KE150714A	2/16	2

150714 Tracy Bulkhead \ 150714 F2 Site and Exploration Plan.cdr



Terms Describing Relative Density and Consistency

	Density	SPT[2] blows/foot
Coarse-Grained Soils	Very Loose	0 to 4
	Loose	4 to 10
	Medium Dense	10 to 30
	Dense	30 to 50
	Very Dense	>50
	Consistency	**SPT[2] blows/foot**
Fine-Grained Soils	Very Soft	0 to 2
	Soft	2 to 4
	Medium Stiff	4 to 8
	Stiff	8 to 15
	Very Stiff	15 to 30
	Hard	>30

Test Symbols

G = Grain Size
M = Moisture Content
A = Atterberg Limits
C = Chemical
DD = Dry Density
K = Permeability

Component Definitions

Descriptive Term	Size Range and Sieve Number
Boulders	Larger than 12"
Cobbles	3" to 12"
Gravel	3" to No. 4 (4.75 mm)
Coarse Gravel	3" to 3/4"
Fine Gravel	3/4" to No. 4 (4.75 mm)
Sand	No. 4 (4.75 mm) to No. 200 (0.075 mm)
Coarse Sand	No. 4 (4.75 mm) to No. 10 (2.00 mm)
Medium Sand	No. 10 (2.00 mm) to No. 40 (0.425 mm)
Fine Sand	No. 40 (0.425 mm) to No. 200 (0.075 mm)
Silt and Clay	Smaller than No. 200 (0.075 mm)

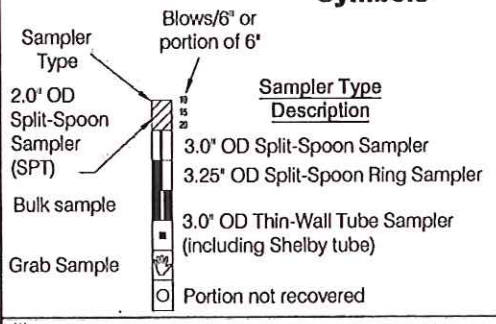
[3] Estimated Percentage

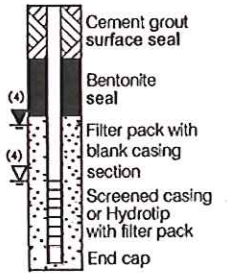
Component	Percentage by Weight
Trace	<5
Some	5 to <12
Modifier (silty, sandy, gravelly)	12 to <30
Very *modifier* (silty, sandy, gravelly)	30 to <50

Moisture Content

Dry - Absence of moisture, dusty, dry to the touch
Slightly Moist - Perceptible moisture
Moist - Damp but no visible water
Very Moist - Water visible but not free draining
Wet - Visible free water, usually from below water table

Symbols





(1) Percentage by dry weight
(2) (SPT) Standard Penetration Test (ASTM D-1586)
(3) In General Accordance with Standard Practice for Description and Identification of Soils (ASTM D-2488)
(4) Depth of ground water
ATD = At time of drilling
Static water level (date)
(5) Combined USCS symbols used for fines between 5% and 12%

Classifications of soils in this report are based on visual field and/or laboratory observations, which include density/consistency, moisture condition, grain size, and plasticity estimates and should not be construed to imply field or laboratory testing unless presented herein. Visual-manual and/or laboratory classification methods of ASTM D-2487 and D-2488 were used as an identification guide for the Unified Soil Classification System.

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EXPLORATION LOG KEY

FIGURE A1

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Exploration Log

Project Number	Exploration Number	Sheet
KE150714A	EB-1	1 of 1

Project Name	Tracy Bulkhead	Ground Surface Elevation (ft)	
Location	Lake Forest Park, WA	Datum	N/A
Driller/Equipment	CN Drilling / Acker	Date Start/Finish	2/3/16,2/3/16
Hammer Weight/Drop	140# / 30"	Hole Diameter (in)	6 inches

Depth (ft)	ST	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot (10 20 30 40)	Other Tests
				Topsoil					
		S-1		**Fill** Moist, brownish gray, fine SAND (SP).			1 2 2	▲4	
		S-2		As above; organics and woody debris at sampler tip.			2 1 1	▲2	
5		S-3		Moist, bluish gray, silty SAND, some gravel, some silt beds, some organics and metal fragments (SM).			1 1 2	▲3	
		S-4		Moist to wet, brown and gray, SILT with sand pockets, organics and woody debris (ML).		▼	1 2 10	▲12	
10				**Lake Sediments**					
		S-5		Wet, brownish gray, fine to medium SAND, some gravel, some silt beds, some woody debris (SP).			1 2 11	▲13	
		S-6		Wet, gray, fine to coarse SAND, with silty zones, some gravel, trace woody debris (SM).			4 5 6	▲11	
15		S-7		No recovery.			4 6 7	▲13	
				Pre-Fraser Undifferentiated					
		S-8		Driller report 2 foot heave at 17 feet. Wet, gray, sandy GRAVEL (GP).			4 11 17	▲28	
20				Gravelly drilling action.					
		S-9		Wet, brownish gray, silty SAND, some gravel (SM).			24 12 14	▲26	
				Bottom of exploration boring at 21.5 feet					
25									

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture

▽ Water Level ()

▼ Water Level at time of drilling (ATD)

Logged by: JPL

Approved by: JNS

AESIBOR 150714.GPJ February 16, 2016