GARRY E. HORVITZ
STATE OF WASHINGTON
19478
REGISTERED
PROFESSIONAL ENGINEER
3/3/17

MEMORANDUM

DATE: March 3, 2017

TO: Joe Brogan, Foster Pepper

FROM: Garry E. Horvitz, PE. LEG, Hart Crowser, Inc.

RE: **Geotechnical Engineering Conclusions and Recommendations**
Runstad Property, Blakely Island, Washington
17921-00

This technical memorandum was prepared by Garry E. Horvitz, PE, LEG, a professional engineer and engineering geologist with more than 40 years of experience in the field of geotechnical engineering. In accordance with SJCC 18.35.130(G)(3)(f)(vii) the qualifications of Garry Horvitz meet the San Juan County definition of a "qualified professional." This technical memorandum provides the information, and results of the analysis that is required to comply with geotechnical analyses required under the updated, March 31, 2014 San Juan County SJCC 18.35.130(G) Ordinance 01-2015.

This memo serves to present our conclusions and recommendations with respect to analyses undertaken to demonstrate the necessity of construction of bank stabilization along beachfront property at the Runstad Property on Blakely Island (the "Project"). Our work was conducted in accordance with the standard of care of our profession, based on commonly accepted engineering principles. No other warranty, express or implied, is made.

This work was completed to satisfy the requirements of the appropriate geotechnical sections of Chapter 18.35.130 of the San Juan County Code. This memo also responds to comments in the Friends of the San Juans' ("Friends") letter report dated April 6, 2016, which addressed analyses that Friends believed deficient in our memo dated December 17, 2015. Our December 17 memo responded to information requests sent by San Juan County on September 18, 2015.

Our site review and analyses demonstrate that the "structures" (defined as the uphill residence, roadway, utilities, and other appurtenances) will likely suffer damage from shoreline erosion without the Project's bank stabilization to prevent further erosion of the bank.

Background

Attachment 2 of the Friends' April 6, 2016 letter report includes a review of our December 17, 2015 memo. The review was conducted by Western Geotechnical Consultants, Inc. and suggested the steep bank at the site may be more stable than we presented. Western Geotechnical Consultants, Inc. and Friends suggested we perform a proper subsurface investigation to substantiate our slope stability analysis. On January 10, 2017, a field geologist from Hart Crowser and a drill crew from Geologic Drilling visited the property on Blakely Island. The crew conducted 2 soil borings and one test pit at the site. The locations of our explorations can be seen on the Site and Exploration Plan following this memo (Figure 1) and logs of the explorations can be found in Appendix A. Atterberg Limits were conducted on a select sample from our explorations shown in Figure B-2. Grain size plots on Figure B-3 were from existing samples collected along the general location of the bulkhead during a site visit in December 2013. Additional grain size analyses were conducted on specific samples retrieved from the recent borings. Those test results are presented as Figure B-4.

We had visited the site previously to observe the conditions along the shoreline. Repairs to the beach area had been made shortly after a severe storm event in 2011. The predominant cause of the erosion was likely wave run up at high tide. Repairs at the time consisted of placement of riprap and other rock to stabilize the toe of the failed slope just above the beach.

Based on our observations of soil conditions and review of publicly available geologic mapping sources, the site soils along this edge of Blakely Island consist of a base deposit of glacial till soils. The site slopes steeply from the beach upward toward the interior of the Island. We observed weathered and reworked till soils exposed in areas and it is likely that much of this material is slope debris which has washed down from higher elevations over the years and which has also weathered and loosened in place. Although till is a glacially overridden material and dense in its in situ condition, it weathers quickly and loosens to a very weak and highly erodible material. There are numerous signs of instability along the slope between the gravel road and the water's edge. This is evidenced by oversteepened scarps as well as leaning trees and "pistol-butted" trees which are signs of long term instability.

Portions of the area that were washed away left an oversteepened condition which has warranted stabilization. The stability of these soils is largely a function of the strength of the soils and the angle of the slope. Although the major cause of the oversteepening is the storm event of early 2011, the resultant steep slopes have been reduced in their stability (stability decreases as slope angle increases for any given set of geologic conditions), which warrants the remedial measures which have been undertaken.

Slope Stability Analyses

The San Juan County Code (SJCC 18.35.130(G)(3)(e)(i)) requires conclusive evidence that the structure is in danger and will suffer damage from shoreline erosion caused by tidal action, currents, or waves. In our professional opinion, this is indeed the case.

We have performed slope stability analyses to evaluate the relative factors of safety against instability for the case of the existing slope angles at the site. To do this we have used topographic survey information prepared by San Juan Surveying for Jon Runstad dated November 23, 2015. We prepared cross sections at four locations within the area of the Project. The location of the most reasonable cross section for analysis is shown on the attached Figure 1. The analyses of the critical cross section are presented in Figures 2 through 4 following the text.

Slope stability analyses were performed using the software Slide Version 7.021 (Rocscience 2016) and the Morgenstern-Price method for slope stability analysis for rotational, circular (Figure 2) and non-circular (Figures 3 and 4) slip surfaces. In our previous analysis, strength parameters for the site soils were developed based on empirical correlation to grain size based on our experience and professional judgment. In this updated analysis, we developed strength parameters based on empirical correlation to SPT blow counts from the explorations and Atterberg Limits obtained from tests performed in our lab. Table 1 below provides a list of soil units used in our analysis and their respective Mohr-Coulomb strength parameters.

Table 1 – Stability Analysis Strength Parameters

Soil Unit	Unit Weight	Friction Angle
Fill/Colluvium	120	34[a]
Clay	110	26
Dense Sand	130	35
Till	135	38

a. The friction angle of surficial soils has been increased from 32 to 34 degrees from our previous analysis to our current analysis. Previous values were based on assumed conditions and current values are based on actual conditions.

The factors of safety[1] for the most critical surfaces in the global and local scenarios are presented on Figures 2 through 4. Our updated analyses confirm our previous work and indicate a factor of safety between 0.9 and 1.0 for the current slope condition and account for tidal lag. This indicates that the overall slope is just barely stable. We also analyzed the stability of the lower portion of the slope. The results of that analysis are shown in Figure 4. The Factor of Safety for that case is 0.62. A Factor of Safety

[1] Factors of Safety presented by Slide are only valid to one decimal place. Any further reporting is performed for ease of comparison.

less than 1.0 is indicative of a failure. The implication of this low factor of safety is that the lower slope is essentially in a failed condition and the slope is currently being retained by the buttressing action of the existing bank stabilization of the Project. Without the presence of the stabilizing and buttressing effect of the Project's bank stabilization, the slope will continue to fail in a "calving" mechanism which will cause the slope to regress as "slivers" of the face of the slope and continue to fail, if the Project was not present. This would cause an ongoing oversteepening of the slope which would lead to a progressively greater amount of instability and reduce the overall slope Factor of Safety to something significantly below 1.0. As a result, larger and larger sections of this slope would tend to fail over shorter and shorter periods of time. Although it is impossible to state unequivocally that the slope failures would reach the edge of the road and utilities within three years it is highly likely that this will be the case due to the increased rate of erosional slope failures.

Alternative Slope Stabilization Measures

The SJCC requires an assessment of alternative methodologies for bank stabilization to provide slope protection.

We concur with the conclusion reached by Coast and Harbor Engineering's technical memorandum (Runstad Property – Shoreline Erosion Protection, November 26, 2012, page 4) which states, "Wave parameters at the project site for the design storm event are very energetic and only a structural solution can protect against shoreline erosion. From the possible structural solutions, such as sheet-pile wall, revetment, breakwater, or other, a rock bulkhead appears to be the most reasonable method for stabilization of existing uplands at the Runstad property."

There are potential methodologies that could be employed ***away*** from the existing shoreline that would be protective of the upland structures. For example, the roadway and utilities could be protected from further erosion at the downhill side of the roadway. This could be done by installing a sheetpile wall in what is now the upland, paralleling the road just on the downslope side of the road such that when the unprotected shoreline eroded back to the sheet pile wall the bank regression would be stopped. However, because we do not know what the ongoing erosional forces would be (that might start eroding a deeper hole in front of the sheet pile wall) it would be necessary to assume that the eventual exposed height of the wall might eventually need to be substantial which would result in the need for a very robust wall with a reinforced concrete cap beam to tie the sheets together. The cost of such a heavy duty structural steel and concrete system would likely be greater than an order of magnitude more expensive than placing what is the existing slope stabilization on the oversteepened slope.

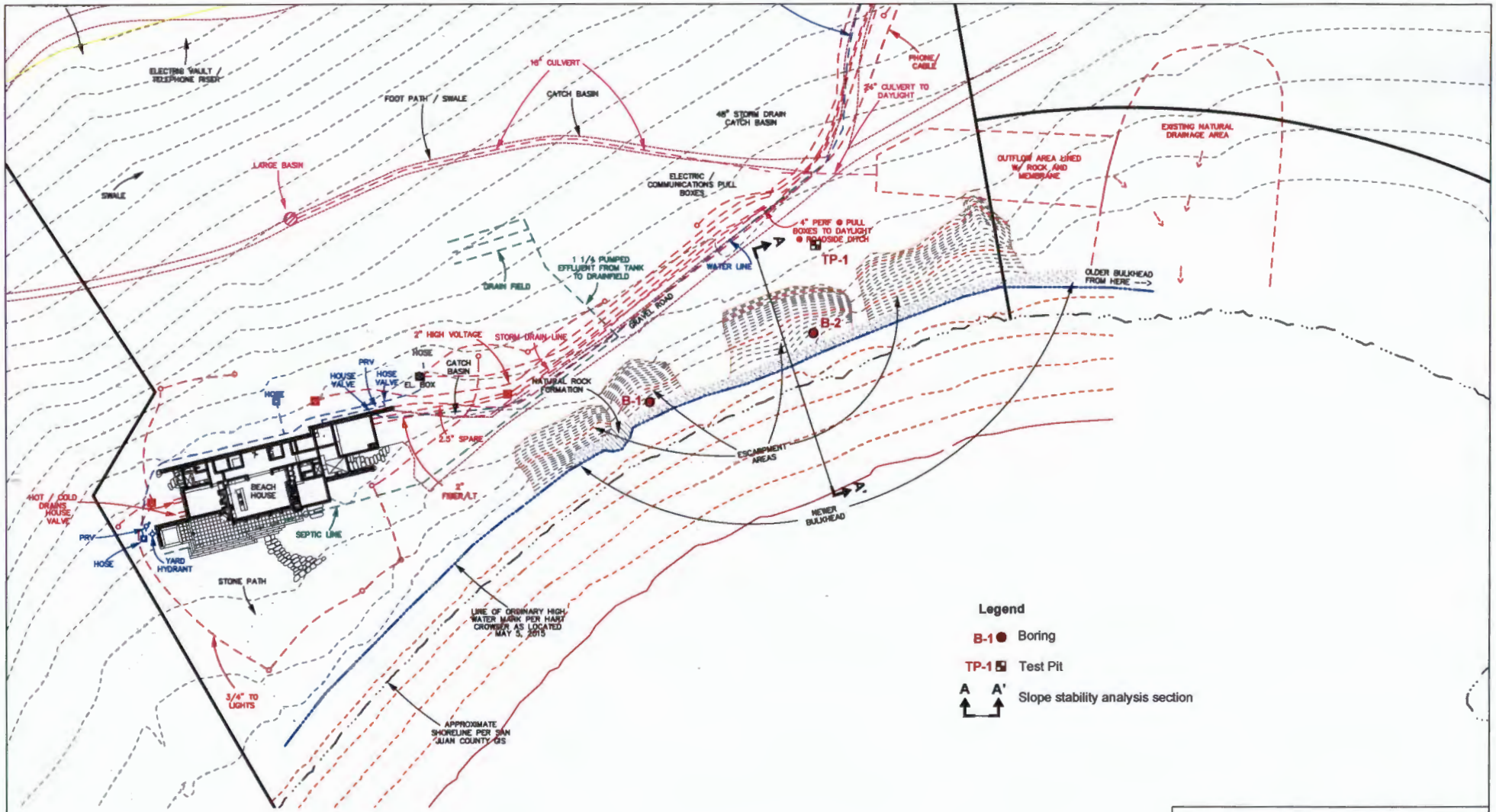
Therefore, it is our professional opinion that the use of riprap to form bank stabilization at the location of the existing oversteepened scarp along the shoreline is both necessary and is the most reasonable and, by far, the most cost effective solution to reduce the rate of slope regression and offer a greater amount of long term protection from the associated roadway and utilities uphill of the shoreline.

Other Potential Impacts

SJCC 18.35.130(G)(3)(f)(vii)(K) requires an "Evaluation of potential effectiveness of corrective measures for on-site drainage issues as an alternative to installing hard or soft structural shoreline stabilization measures." The topography suggests and site observations would indicate that there is potential erosion resulting from the flow of storm water over the slope. Although this may have been a contributing factor to erosion of the slope, it is minor in comparison to the contribution of wave and current erosion. The onsite drainage issues have been repaired and the potential of additional corrective measures as an alternative would not address the fundamental instability of the slope observed at the property; therefore, no additional assessment of enhancing on site drainage is necessary.

Attachments:
Figure 1 – Site and Exploration Plan
Figure 2 – Global Failure Circular Failure Surface
Figure 3 – Global Failure Non-Circular Failure Surface
Figure 4 – Local Failure Non-Circular Failure Surface
Appendix A – Field Explorations
Appendix B – Laboratory Testing Program

L:\NOTEBOOKS\1792100_Runstad Residence Beach Repair\Deliverables\Memos\Revised Geotech Memo\SEADOCS-#51587437-v1- RUNSTAD-Bulkhead Updated Geotechnical Memo (2-21-2016 Draft) (wFP comments).DOCX



Runstad Residence Shoreline Repairs
Blakely Island, Washington

Site and Exploration Plan

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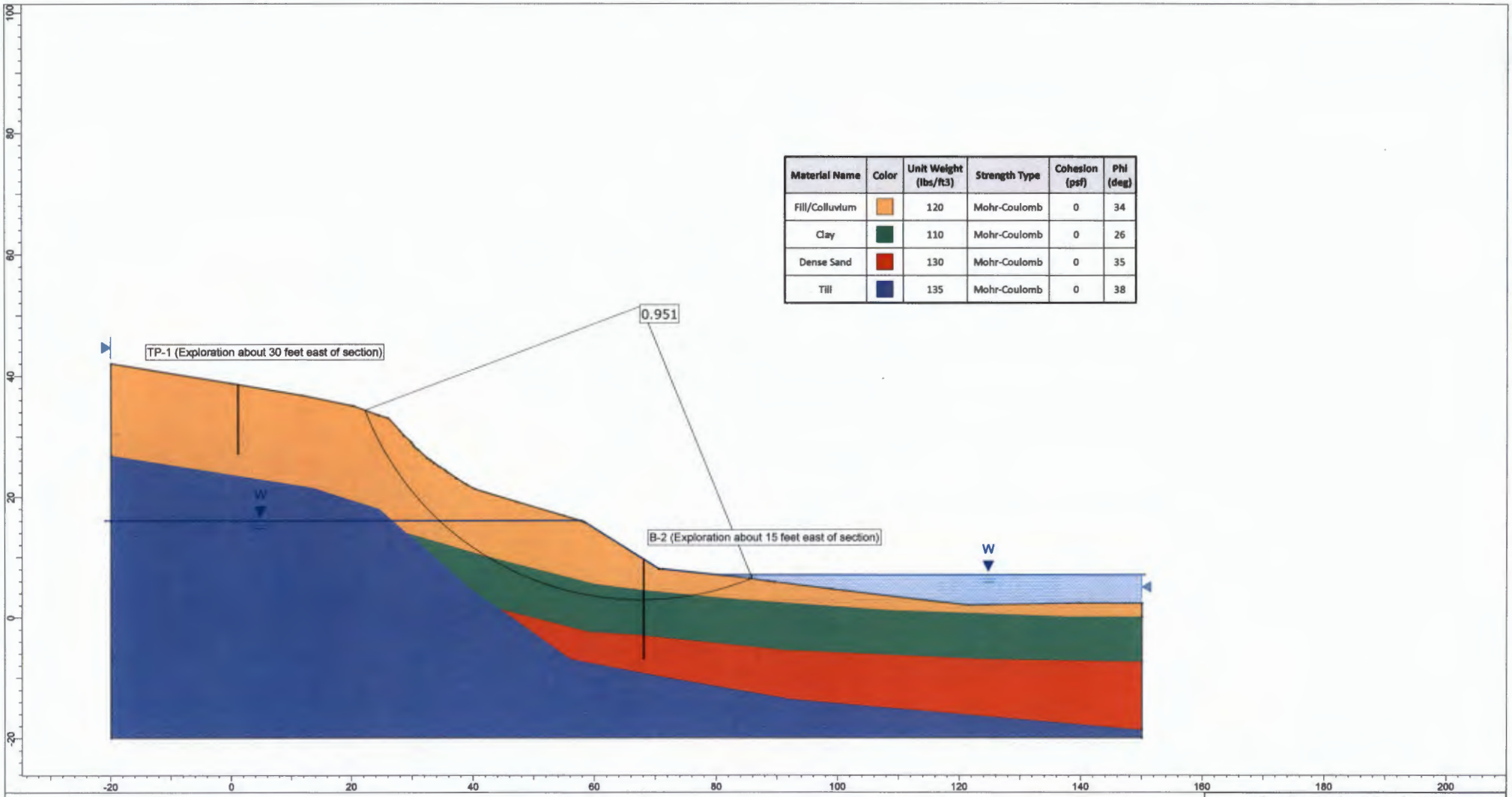
Figure 1

EAL 01/17/17 17921/00-002.dwg

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Fill/Colluvium		120	Mohr-Coulomb	0	34
Clay		110	Mohr-Coulomb	0	26
Dense Sand		130	Mohr-Coulomb	0	35
Till		135	Mohr-Coulomb	0	38



Runstad Residence Beach Repair
Blakely Island, Washington

Global Failure
Circular Failure Surface

17921-00 Scale 1:180 1/17

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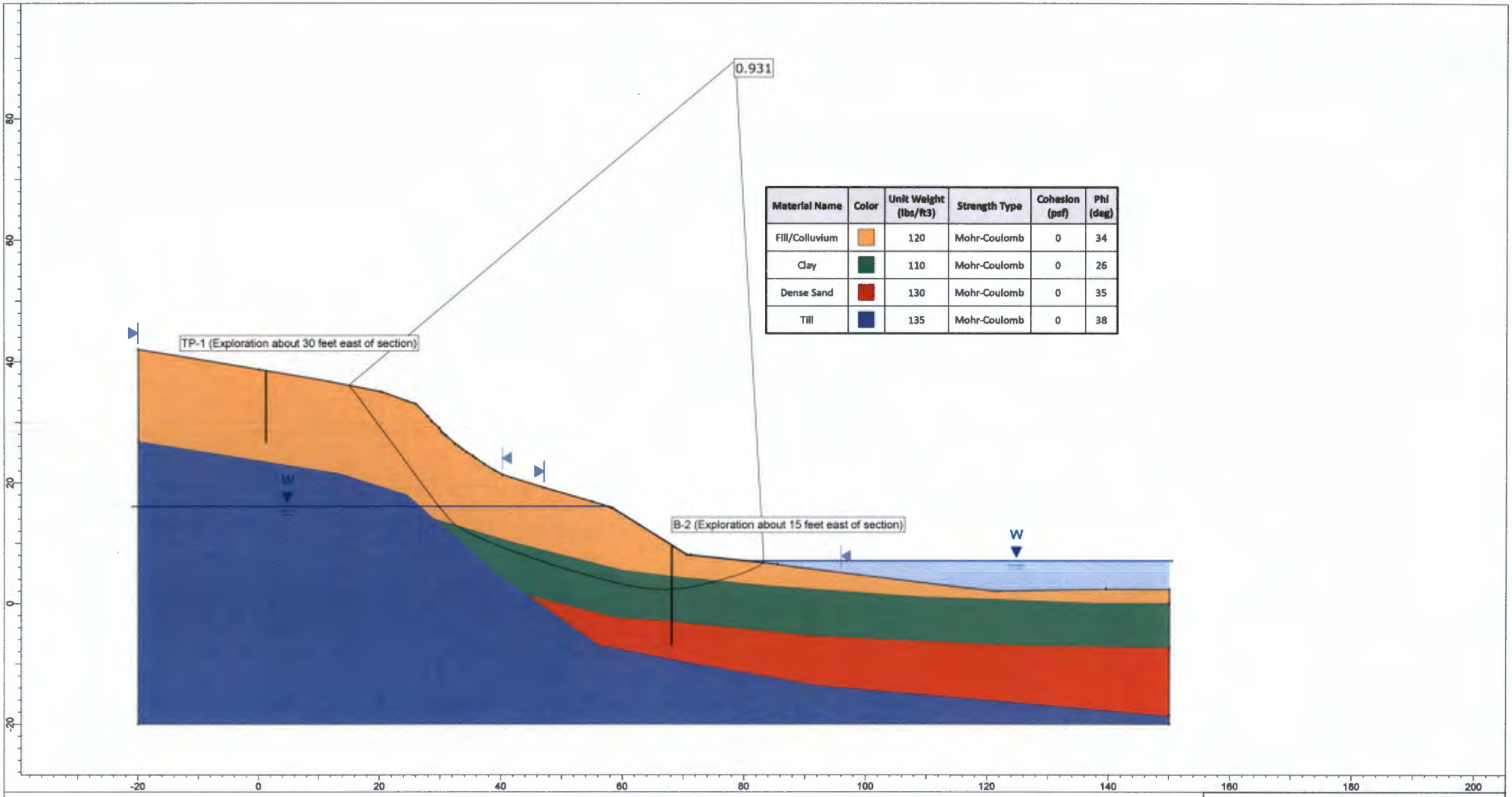
Figure
2



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Fill/Colluvium		120	Mohr-Coulomb	0	34
Clay		110	Mohr-Coulomb	0	26
Dense Sand		130	Mohr-Coulomb	0	35
Till		135	Mohr-Coulomb	0	38

Runstad Residence Beach Repair
Blakely Island, Washington

Global Failure
Non-Circular Failure Surface

17921-00 Scale 1:180 1/17

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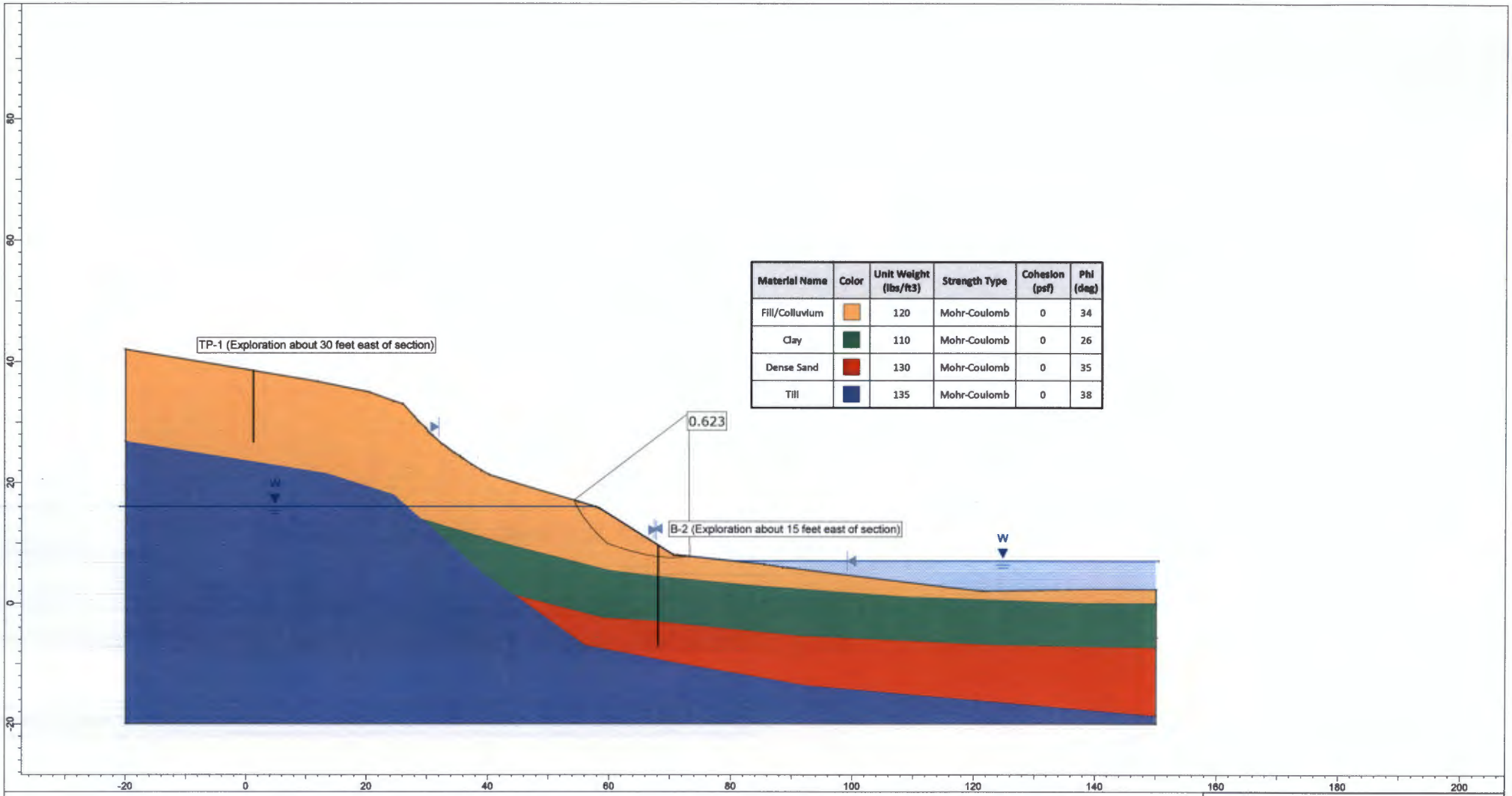
Figure
3



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Fill/Colluvium		120	Mohr-Coulomb	0	34
Clay		110	Mohr-Coulomb	0	26
Dense Sand		130	Mohr-Coulomb	0	35
Till		135	Mohr-Coulomb	0	38

Runstad Residence Beach Repair
Blakely Island, Washington

Local Failure
Non-Circular Failure Surface

17921-00 Scale 1:180 1/17

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Figure
4

APPENDIX A
Field Explorations

Key to Exploration Logs

Sample Description

Classification of soils in this report is based on visual field and laboratory observations which include density/consistency, moisture condition, grain size, and plasticity estimates and should not be construed to imply field nor laboratory testing unless presented herein. Visual-manual classification methods of ASTM D 2488 were used as an identification guide.

Soil descriptions consist of the following:
Density/consistency, moisture, color, minor constituents, MAJOR CONSTITUENT, additional remarks.

Density/Consistency

Soil density/consistency in borings is related primarily to the Standard Penetration Resistance. Soil density/consistency in test pits and probes is estimated based on visual observation and is presented parenthetically on the logs.

SAND or GRAVEL Density	Standard Penetration Resistance (N) in Blows/Foot	SILT or CLAY Consistency	Standard Penetration Resistance (N) in Blows/Foot	Approximate Shear Strength in TSF
Very loose	0 to 4	Very soft	0 to 2	<0.125
Loose	4 to 10	Soft	2 to 4	0.125 to 0.25
Medium dense	10 to 30	Medium stiff	4 to 8	0.25 to 0.5
Dense	30 to 50	Stiff	8 to 15	0.5 to 1.0
Very dense	>50	Very stiff	15 to 30	1.0 to 2.0
		Hard	>30	>2.0

Sampling Test Symbols

- 1.5" I.D. Split Spoon
- Grab (Jar)
- 3.0" I.D. Split Spoon
- Shelby Tube (Pushed)
- Bag
- Cuttings
- Core Run

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	SAND AND SANDY SOILS	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
				SP	POORLY-GRADED SANDS, GRAVELLY SAND, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION PASSING ON NO. 4 SIEVE	SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

Moisture

Dry	Little perceptible moisture
Damp	Some perceptible moisture, likely below optimum
Moist	Likely near optimum moisture content
Wet	Much perceptible moisture, likely above optimum

Minor Constituents

Minor Constituents	Estimated Percentage
Trace	<5
Slightly (clayey, silty, etc.)	5 - 12
Clayey, silty, sandy, gravelly	12 - 30
Very (clayey, silty, etc.)	30 - 50

Laboratory Test Symbols

GS	Grain Size Classification
CN	Consolidation
UU	Unconsolidated Undrained Triaxial
CU	Consolidated Undrained Triaxial
CD	Consolidated Drained Triaxial
QU	Unconfined Compression
DS	Direct Shear
K	Permeability
PP	Pocket Penetrometer Approximate Compressive Strength in TSF
TV	Torvane Approximate Shear Strength in TSF
CBR	California Bearing Ratio
MD	Moisture Density Relationship
AL	Atterberg Limits

Water Content in Percent
Liquid Limit
Natural
Plastic Limit

PID	Photoionization Detector Reading
CA	Chemical Analysis
DT	In Situ Density in PCF
OT	Tests by Others

Groundwater Indicators

- Groundwater Level on Date or (ATD) At Time of Drilling
- Groundwater Seepage (Test Pits)

Sample Key

Sample Type
Sample Recovery
S-1
12
23
50/3"
Sample Number
Blows per 6 inches

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Figure A-1

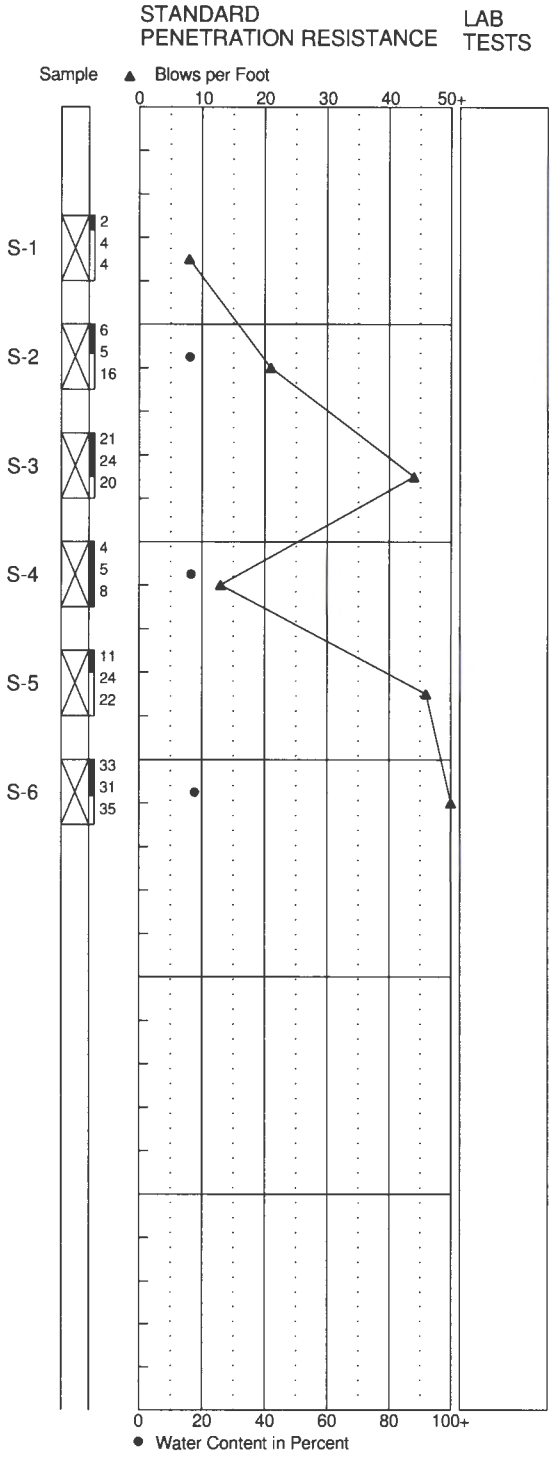
KEY SHEET 1792100-BL.GPJ HC_CORP.GDT 1/13/17

Boring Log B-1

Location: 48.53877, -122.79855
Approximate Ground Surface Elevation: 15 Feet
Horizontal Datum: WGS84
Vertical Datum: NAVD88

Drill Equipment: Acker Soil Mechanic
Hammer Type: SPT w/140 lb. hammer on cathead
Hole Diameter: 4 inches
Logged By: C. McCabe Reviewed By: J. Thomas

USCS Class	Soil Descriptions	Depth in Feet
GP SP	Loose, dry, brown, trace to slightly silty, gravelly SAND with organics. (TOPSOIL/FILL)	0
SP-SC	Medium dense, moist, gray-brown to gray, clayey, fine to medium SAND.	5
	Gravelly from 7.5 to 10 feet.	10
SP	Dense, wet, gray, gravelly SAND.	ATD, 15
	Bottom of Boring at 16.5 Feet. Started 01/10/17. Completed 01/10/17.	20, 25, 30



NEW BORING LOG 1792100-BL.GPJ HC_CORP.GDT 1/18/17

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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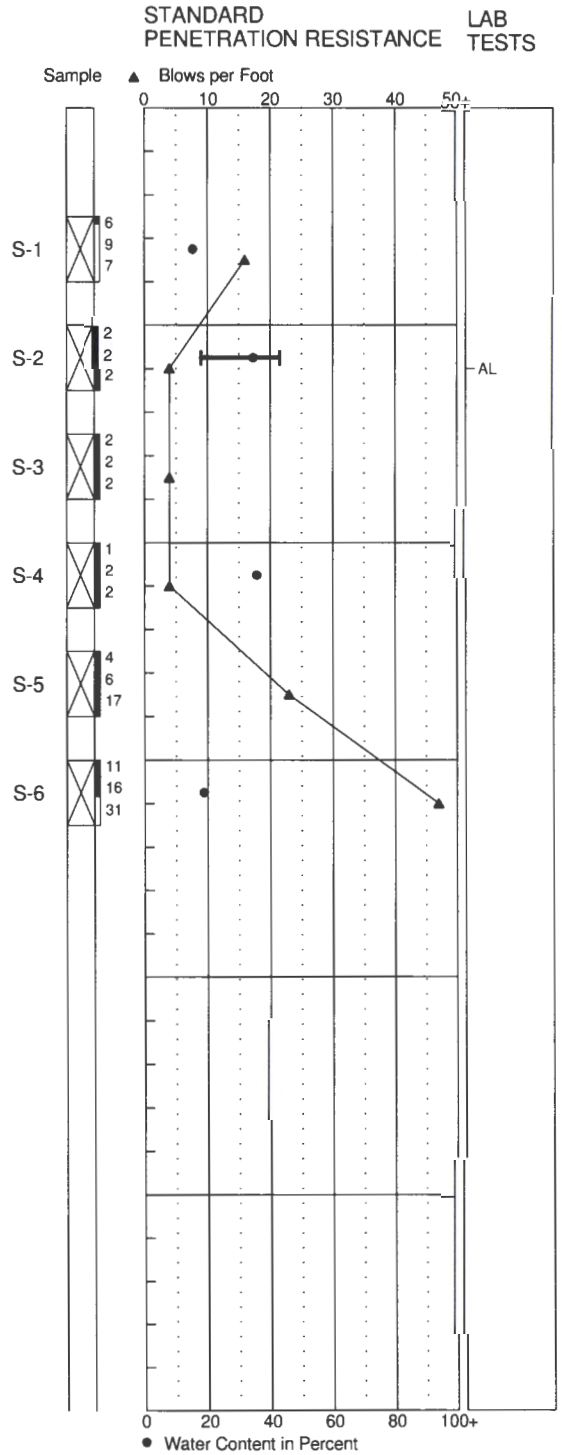
Figure A-2

Boring Log B-2

Location: 48.53888, -122.79819
Approximate Ground Surface Elevation: 10 Feet
Horizontal Datum: WGS84
Vertical Datum: NAVD88

Drill Equipment: Acker Soil Mechanic
Hammer Type: SPT w/140 lb. hammer on cathead
Hole Diameter: 4 inches
Logged By: C. McCabe Reviewed By: J. Thomas

USCS Class	Graphic Log	Soil Descriptions	Depth in Feet
SP		Medium dense, dry, brown, gravelly SAND with organics. (TOPSOIL/FILL)	0
CL		Soft, moist to wet, gray, slightly sandy to sandy CLAY.	5
SP-SM		Medium dense to dense, wet, gray, slightly silty to silty SAND.	10 ▽ ATD
		Bottom of Boring at 16.5 Feet. Started 01/10/17. Completed 01/10/17.	15
			20
			25
			30



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2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
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4. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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Figure A-3

NEW BORING LOG 1792100-BL.GPJ HC_CORP.GDT 1/18/17

Test Pit Log TP-1

Location: 48.53901, -122.79819
Approximate Ground Surface Elevation: 35 Feet
Logged By: C. McCabe Reviewed By: J. Thomas

Horizontal Datum: WGS84
Vertical Datum: NAVD88

USCS Class	Graphic Log	Soil Descriptions	Depth in Feet	Sample	Water Content in Percent	PID	LAB TESTS
SP-SM		(Medium dense to dense), damp to moist, brown, silty, gravelly SAND with frequent cobbles and boulders.	0				
		Less cobbles below 4 feet.	5				
			ATD				
SP		(Medium dense to dense), wet, gray, gravelly SAND.	10				
		Bottom of Test Pit at 12.0 Feet. Started 01/10/17. Completed 01/10/17.	15				

NEW TEST PIT LOG 1792100-TP.GPJ HC_CORP.GDT 1/13/17

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. USCS designations are based on visual manual classification (ASTM D 2488) unless otherwise supported by laboratory testing (ASTM D 2487).
4. Groundwater conditions, if indicated, are at time of excavation. Conditions may vary with time.

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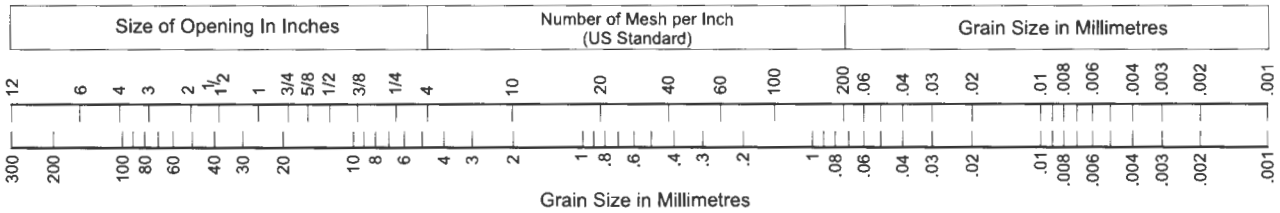
Figure A-4

APPENDIX B
Laboratory Testing Program

Unified Soil Classification (USC) System
Soil Grain Size



Coarse-Grained Soils

G W	G P	G M	G C	S W	S P	S M	S C
Clean GRAVEL <5% fines	*	GRAVEL with >12% fines		Clean SAND <5% fines	*	SAND with >12% fines	
GRAVEL >50% coarse fraction larger than No. 4				SAND >50% coarse fraction smaller than No. 4			
Coarse-Grained Soils >50% larger than No. 200 sieve							

G W and S W $\left(\frac{D_{60}}{D_{10}}\right)$ >4 for G W, >6 for S W & $1 \leq \left(\frac{(D_{30})^2}{D_{10} \times D_{60}}\right) \leq 3$

G P and S P Clean GRAVEL or SAND not meeting requirements for G W and S W

G M and S M Atterberg limits below A line with PI <4

G C and S C Atterberg limits above A Line with PI >7

* Coarse-grained soils with percentage of fines between 5 and 12 are considered borderline cases requiring use of dual symbols.

D_{10}, D_{30}, and D_{60} are the particles diameter of which 10, 30, and 60 percent, respectively, of the soil weight are finer.

Fine-Grained Soils

M L	C L	O L	M H	C H	O H	Pt
SILT	CLAY	Organic	SILT	CLAY	Organic	Highly Organic Soils
Soils with Liquid Limit <50%			Soils with Liquid Limit >50%			
Fine-Grained Soils >50% smaller than No. 200 sieve						

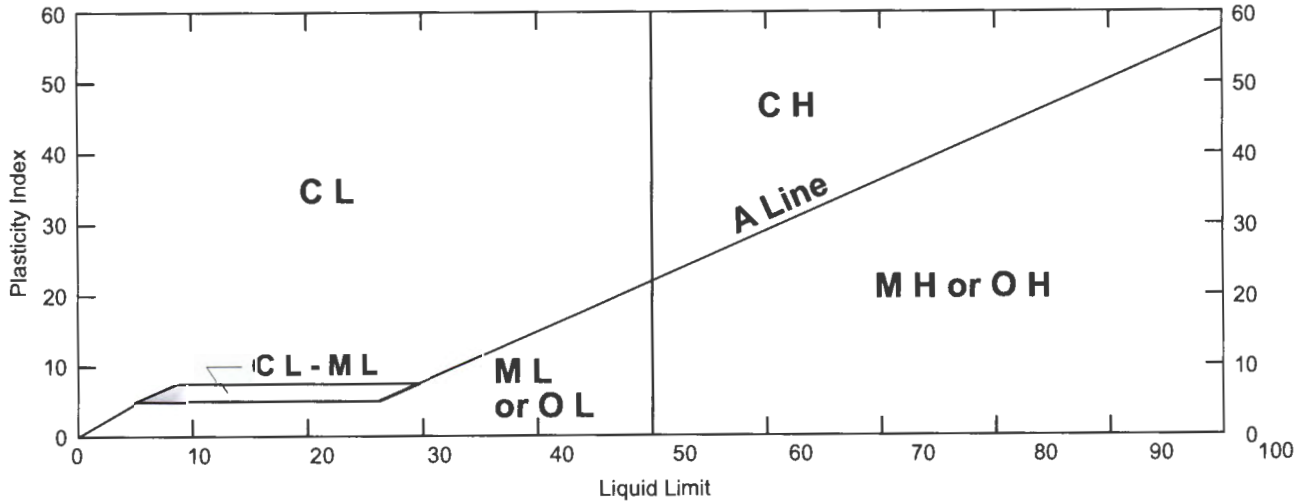


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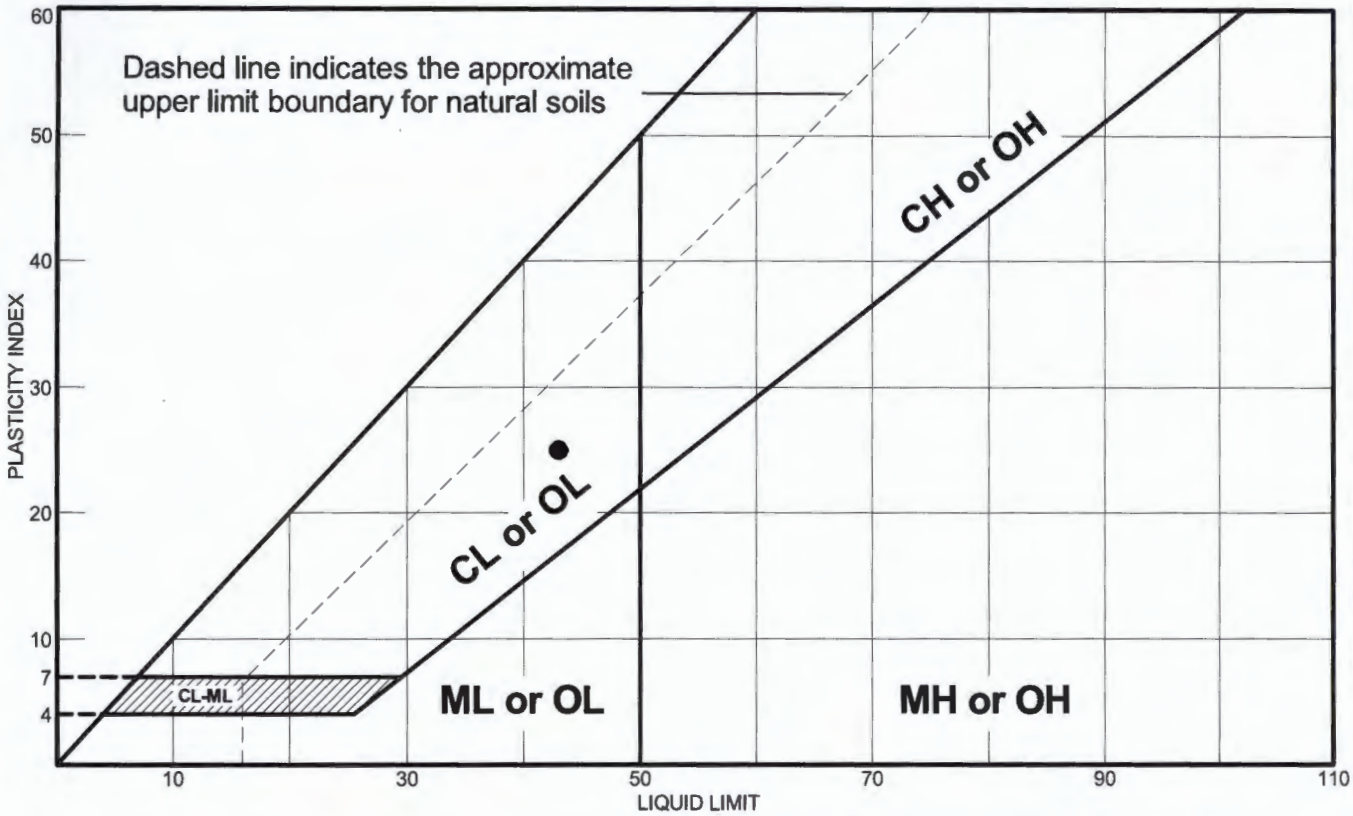
Figure B-1

SRF Grain Size (B-1).cdr 3/06

Liquid and Plastic Limits Test Report



Location + Description	LL	PL	PI	-200	USCS
● Source: B-2 Sample No.: S-2 Depth: 5 lean CLAY	43	18	25		CL

Remarks:

●

Project: Runstad Residence Beach Repair

Client:

Location:

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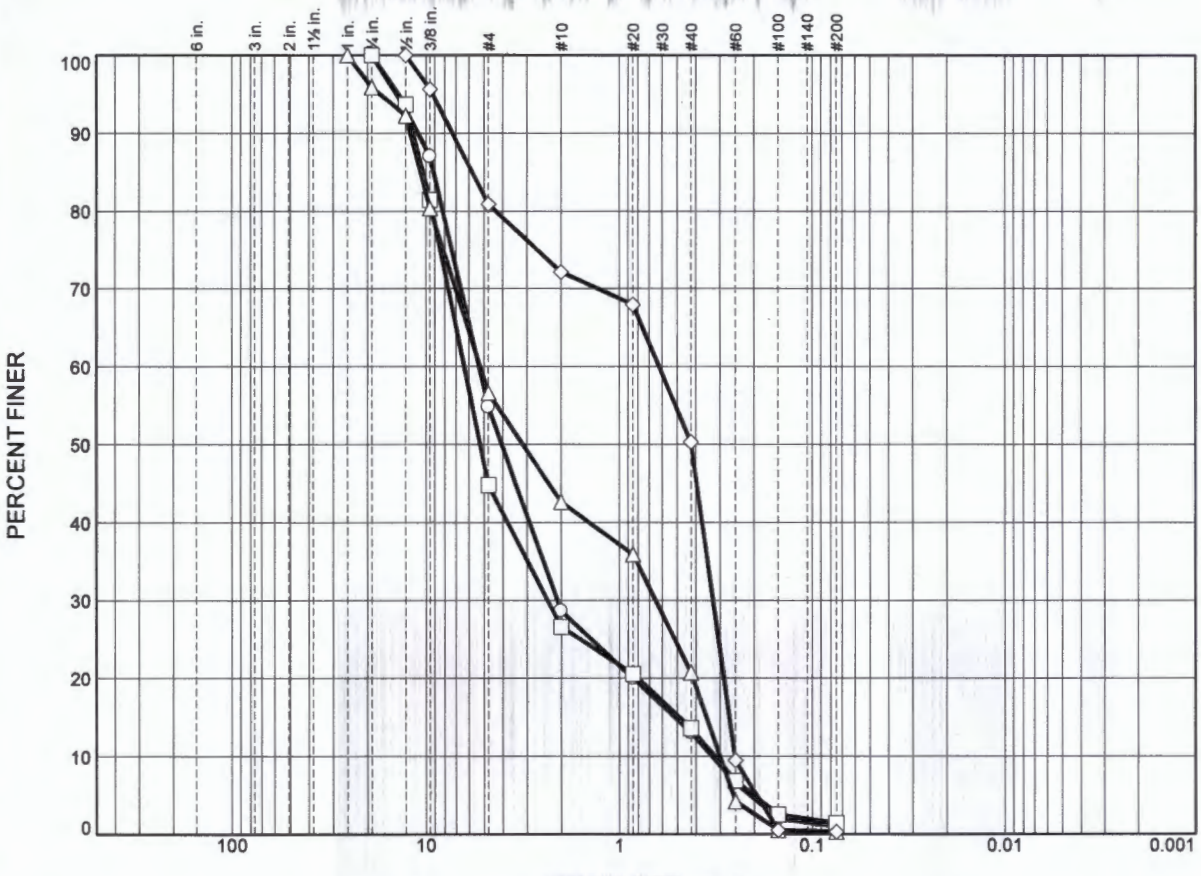
Figure B- 2

Particle Size Distribution Report



	% +3"	% Gravel	% Sand	% Silt	% Clay
○	0.0	45.2	53.8	1.0	
□	0.0	55.2	43.4	1.4	
△	0.0	43.4	56.3	0.3	
◇	0.0	19.1	80.6	0.3	

SOIL DATA

SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	Material Description	USCS
○	Whaleback	#1		very gravelly SAND, trace silt	SW
□	Whaleback	#2		very sandy GRAVEL, trace silt	GW
△	Whaleback	#3		very gravelly SAND	SP
◇	Whaleback	#4		gravelly SAND	SP

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Client:

Project: Runstad Residence Beach Repair

Project No.: 17921-00

Figure B-3