

Technical Memorandum

To: Project File and **Appendix F** to Sediment Remedial Investigation Report
From: Sara L. Leow, PE
Subject: Geotechnical Investigation and Results Summary
Date: February 2013
Project: U.S. Steel Spirit Lake Sediment Investigation

Overview

A geotechnical investigation was performed in conjunction with the remedial investigation for the U.S. Steel (USS) Spirit Lake Sediment Investigation project during the summer and fall of 2011. The geotechnical investigation served to document general geotechnical soil characteristics across the site by means of field and laboratory testing. This memo presents a summary of the geotechnical field and laboratory testing data collected during the investigation. This memo is to accompany the associated *Sediment Remedial Investigation Report* (RI Report). Please refer to the RI report for complete project description, background information, site figures, and environmental data.

Field Testing

The geotechnical field investigation consisted of soil borings, standard penetration tests (SPT), cone penetration test (CPT) soundings, pore-pressure dissipation (PPD) testing, flat plate dilatometer (DMT) testing, and vane shear testing (VST). The locations of the Fall 2011 geotechnical borings are presented on Figure F-1. Boring logs, CPT logs, pore-water dissipation plots, DMT data, and lab testing data are included in this memo as attachments F-1 through F-4. Each of the field tests is described below, and results of field data are shown in the attached Table F-1 or in attached report sheets, as applicable.

Soil Borings

Soil borings were completed at several locations within the Unnamed Creek (UC) and Wire Mill areas. Soil borings were initially denoted with a solely numerical label, and subsequently renamed to include a UC or WM to designate of the area where the test boring was performed. The old boring number is provided in parentheses next to the new denotation in this document.

Soil borings were performed at six locations at the site, including three in the Unnamed Creek area: UC-94 (304), UC-96 (305), and UC-97 (309); as well as three in the Wire Mill area: WM-100 (311), WM-101 (314), and WM-102 (315) (Figure F-1). Each test boring was performed in general accordance with ASTM D1586 from a balloon-tired drill rig mounted on a barge, and were extended to a depth of 20

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to 36.5 feet below the riverbed. The borings were advanced using hollow stem auger. Continuous sampling was performed with a standard split spoon for two test borings, UC-94 (304) and WM-100, and with a modified California sampler for the remaining four test borings. Shelby (thinwall) tube samples were collected at select intervals per ASTM D1597, with the majority collected in offset borings.

USCS soil classifications are shown on the geotechnical test boring logs, provided as attachments. In general, the subsurface conditions consist of organic silt or peat underlain by layers of lean clay, sandy clay, silt, sandy silt, sand, and silty sand. In some cases, multiple layers of peat were encountered, separated by layers of clay, silt, and/or sand. Due to the complex depositional environment at the site, soils with the same USCS symbols may have different geotechnical properties. Soil types and properties should be further assessed at specific locations and depths for design as part of future project phase(es).

Standard Penetration Tests

Blow counts were recorded per each 6-inch drive of a standard split spoon over a two-foot interval for SPT performed at two soil borings, UC-94 (304) and WM-100 (311) (see Figure F-1). The SPT N-value is calculated as the sum of the blow counts for the second and third 6-inch drives. The uncorrected SPT N-values are shown on the boring logs. N-values ranged from less than 1 to 16, with the majority between less than 1 and 7.

It should be noted that although blow counts were recorded while sampling with the modified California sampler, those blow counts were not considered viable for future geotechnical design since a correlation cannot reliably be made between SPT N-values and blow counts recorded while driving a modified California sampler.

Cone Penetration Test Soundings

CPT soundings were performed at twelve locations from equipment mounted to a barge in general accordance with ASTM D5778, each to a depth of 50 feet below the riverbed. The associated test boring is designated in parentheses after the CPT number. Seven CPT soundings, CPT-301 (UC-94), CPT-303 (UC-93), CPT-304 (UC-92), CPT-305 (UC-96), CPT-306 (UC-95), CPT-307 (UC-98), and CPT-309 (UC-97) were performed in the Unnamed Creek area, and five CPT soundings, CPT-310 (WM-99), CPT-311 (WM-100), CPT-314 (WM-101), CPT-315 (WM-102), and CPT-316 (WM-103) were performed in the Wire Mill area (Figure F-1).

CPT logs are attached. Similar to the conditions encountered in the soil borings, the CPT soundings indicate subsurface conditions consisting of layers of clay, silt, and sand. Based on the CPT results, the undrained shear strengths of cohesive soils (clays) range from approximately 150 to greater than 2,000 pounds per square foot (psf). For non-cohesive soils (sand and silt), the angle of internal friction ranges from approximately 28 degrees to greater than 40 degrees based on the CPT results. Attached Figures F-2 and F-3 graphically depict the undrained shear strength and angle of internal friction ranges.

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Pore Pressure Dissipation Tests

PPD was also performed at select intervals during CPT testing per ASTM D5778. PPD test data is available from CPT-303 (UC-93), CPT-304 (UC-92), CPT-314 (WM-101), and CPT-316 (WM-103) at approximate depths of 4.6, 4.6, 31.8, and 4.8 feet below the riverbed, respectively (Figure F-1). Soil coefficients of permeability from the PPD tests range from 5×10^{-8} to 2×10^{-5} centimeters per second (cm/s). The time duration to reach 50% dissipation (t_{50}) mainly varied between 0.33 and 0.67 minutes, although a t_{50} of 3.92 minutes was calculated for the dissipation test performed at CPT-303 (UC-93). PPD plots are attached to this memo.

Flat Plate Dilatometer Testing

DMT testing was performed to document soil characteristics to, in conjunction with consolidation lab testing, aid in settlement assessment during future project phases. DMT was performed in general accordance with ASTM D6635 at locations offset from four CPT soundings, CPT-301 (UC-94), CPT-306 (UC-95), CPT-305 (UC-96), and CPT-311 (WM-100) (Figure F-1). DMT testing was performed at select intervals to termination depths of approximately 15 to 37 feet below the sediment surface. DMT data is attached.

In-Situ Vane Shear Testing

Vane shear testing was performed to document shear strength of soft soils at various depths in general accordance with ASTM D2573. Vane shear testing of near-riverbed surface soils was initially attempted through the ice in March 2011; however, the strength of the surficial sediments did not provide the resistance necessary to record readings with the field equipment available at the time. A more sensitive vane shear tool was obtained, and vane shear testing was performed at depths below the riverbed of 5 feet and shallower in June 2011. The results of shallow vane shear testing near the riverbed performed in June 2011 indicate peak undrained shear strengths between approximately 37 and 1,600 psf; a summary of the results is provided in Table F-1. The strength values attained from this testing period are considered preliminary. Factors such as performing the test from a moving platform affixed to a small boat and approximations of test depths relative to variable water surface elevations may have affected the data. The recorded shear strength for some intervals may also be arbitrarily high due to the presence of debris in some near-surface soil layers. Additional vane shear testing should be performed to further document strengths for near-riverbed surface soils for design.

Additional vane shear testing was performed at depths below the riverbed generally greater than 5 feet in November 2011. A summary of the results from the vane shear testing is presented in Table F-1. Results of vane shear tests performed at greater depths in November 2011 indicate that peak undrained shear strengths range between 32 and 990 psf, while remolded shear strengths range between 32 and 301 psf.

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Laboratory Testing

Laboratory testing was performed on select samples to further document soil properties. The laboratory testing performed and associated methods are listed below, followed by a description of each test and summary of test results. Test results are also presented in the attached Table F-1, as well as in attached laboratory test reports.

- Moisture Content tests per ASTM D2216, “Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass”.
- Unit Weight tests per ASTM D7263, “Standard Test Methods for Laboratory Determination of Density (Unit Weight) of Soil Specimens”.
- Grain Size and Hydrometer Analyses per ASTM D422, “Standard Test Method for Particle-Size Analysis of Soils”.
- Atterberg Limits per ASTM D4318, “Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils”.
- Permeability testing per ASTM D5080, “Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using Flexible Wall Permeameter”.
- Consolidation testing per ASTM D2435, “Standard Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading”.
- Triaxial Compressive Strength per ASTM D2850, “Standard Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils”.
- Organic Content tests per ASTM D2974, “Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and other Organic Soils”.

In addition to the samples discussed below, laboratory testing consisting of moisture content, unit weight, Atterberg Limits, organic content, and consolidated undrained (CU) triaxial testing were performed on a Shelby tube sample collected between the depths of 17.5 to 20 feet below riverbed at test boring UC-96 (305). Further review of this information indicated significantly different laboratory test results than anticipated based on similar materials encountered at the site. As such, it is recommended that the lab test data from the 17.5 to 20 foot Shelby tube sample from test boring UC-96 (305) should not be used for analyses.

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Moisture Content Tests

Moisture content tests were performed on eight Shelby (thinwall) tube samples collected from borings UC-94 (304), UC-96 (305), WM-100 (311), and WM-101 (314) (Figure F-1). Results of tests on these samples indicate a moisture content range of approximately 24 to 97 percent, with the higher moisture contents generally associated with soils containing organics (peat, organic silt, or organic clay).

Unit Weight Tests

Unit weight tests were also performed on eight Shelby tube samples collected from borings UC-94 (304), UC-96 (305), WM-100 (311), and WM-101 (314) (Figure F-1). The dry unit weights of these samples range from 48 to 104 pounds per cubic foot (pcf), and the moist unit weights vary from 95 to 128 pcf. The lower densities are generally associated with materials containing organics.

Grain Size Analyses

Grain size analysis tests, including both sieve and hydrometer tests, were performed on several near-surface (shallower than approximately 5 feet) soil samples collected via vibracore methods at UC-11, UC-23, UC-29, WM-3, WM-10, WM-18, WM-21, WM-30, and WM-32. Vibracore samples were collected mainly for the intention of environmental analyses. Gradation tests were also performed on three Shelby tube samples from test borings UC-96 (305), WM-100 (311), and WM-101 (314) (Figure F-1). Test results indicate that near-surface soil samples contain gravel, sand, silt, and clay ranges of 0 to 3.8 percent, 0.8 to 97.4 percent, 1.6 to 89.1 percent, and 1 to 28.5 percent, respectively. Gradation results for the Shelby tube samples indicate soils containing gravel, sand, silt, and clay ranges of zero percent, 0.1 to 13.5 percent, 72.5 to 91.3, and 6.1 to 14 percent, respectively.

Atterberg Limits Tests

Atterberg Limits tests were performed on several near-surface vibracore soil samples from locations UC-11, UC-23, UC-29, WM-3, WM-10, WM-18, WM-21, WM-30, and WM-32 (Figure F-1). Atterberg limits tests were also performed on the eight Shelby tube samples collected from borings UC-94 (304), UC-96 (305), WM-100 (311), and WM-101 (314) (Figure F-1). Test results indicate the liquid limit ranges from 23 to 123 percent, the plastic limit ranges from 19 to 52 percent, and the plasticity index ranges from 1 to 73 percent. Atterberg limits results of the tested samples indicate near-surface soils (shallower than approximately 5 feet) consist of fat clay (CH), high plasticity silt/high plasticity organic silt (MH/OH), low plasticity silt/low plasticity organic silt (ML/OL), and low plasticity clay/low plasticity organic clay (CL/OL). Atterberg limits tests on deeper soils indicate silt (ML), lean clay (CL), and silty clay (CL-ML) soils.

Permeability Tests

Permeability tests were performed on three Shelby tube samples collected from UC-96 (305), WM-100 (311), and WM-101 (314) (Figure F-1). The tests indicate coefficients of permeability between approximately 3.0×10^{-7} to 2.0×10^{-6} cm/s.

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Consolidation Tests

Consolidation testing was performed on two Shelby tube samples collected from test borings UC-94 (304) and UC-96 (305) (Figure F-1). The testing indicates coefficients of consolidation between 0.13 to 0.73, and coefficients of recompression from 0.01 to 0.03. This data will be used in conjunction with DMT testing data to aid in settlement evaluation for future project phases.

Consolidated Undrained (CU) Triaxial Tests

CU triaxial tests were performed on two Shelby tube samples collected from test borings UC-94 (304) and WM-100 (311) (Figure F-1) to document strength characteristics. Test results indicate drained angles of internal friction between approximately 34 and 36 with an associated drained cohesion value of 0 psf.

Closing

This memo has presented a summary of the geotechnical investigation performed as part of the USS Spirit Lake Sediment Investigation. Soil characteristics discussed in this memo will be further evaluated and employed as applicable to designs for environmental remediation efforts developed during future project phases.

Attachments:

Table F-1 Geotechnical Field and Laboratory Data Summary

Figure F-1 Fall 2011 Geotechnical Boring Locations
Figure F-2 Graph, Undrained Shear Strength from CPT vs. Depth
Figure F-3 Graph, Friction Angle vs. Depth

Attachment F-1 Boring Logs

Attachment F-2 CPT Logs

Attachment F-3 Pore Pressure Dissipation Plots

Attachment F-4 DMT Data

Attachment F-5 Laboratory Testing Data

Tables

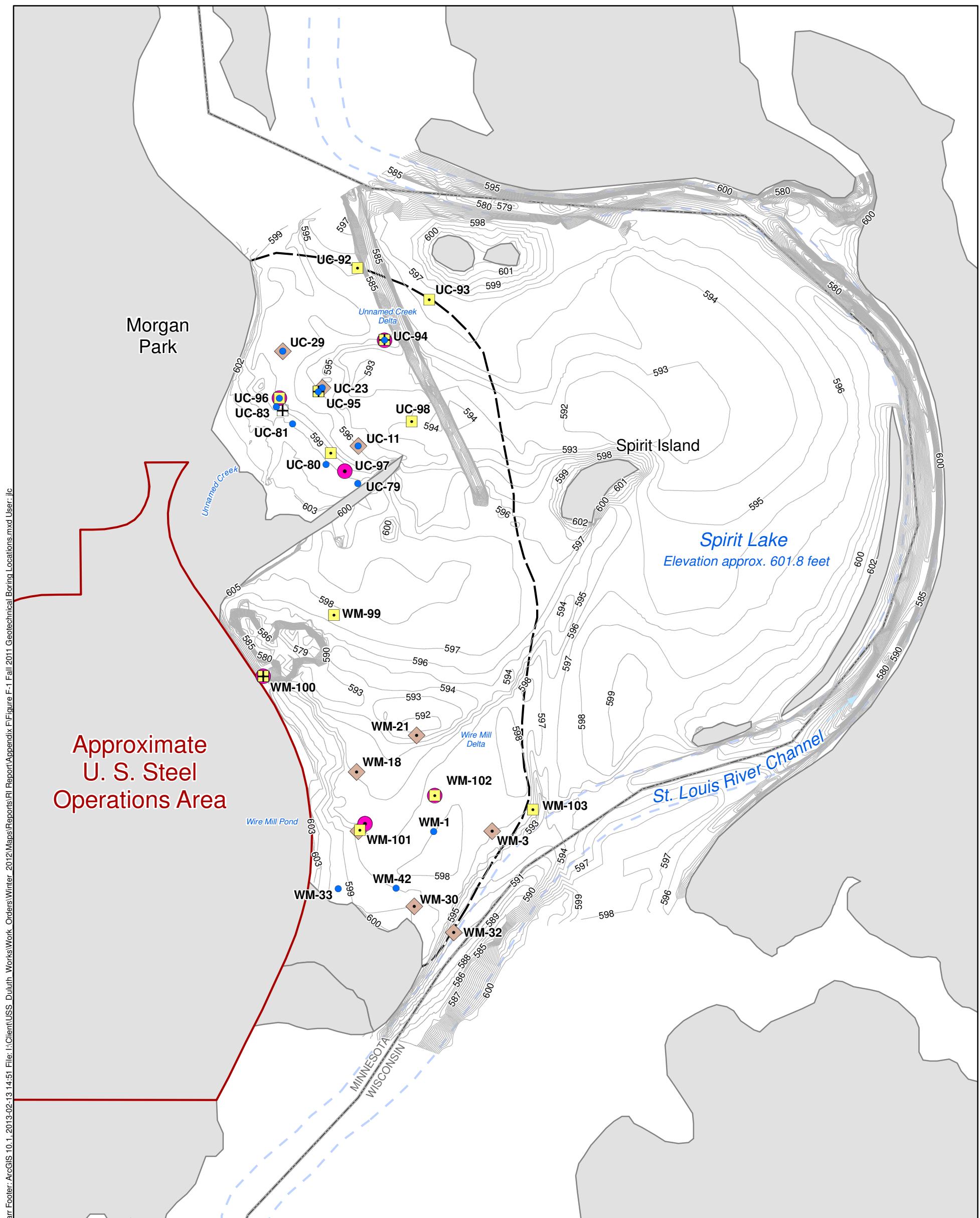
Table F-1: Geotechnical Field and Lab Data Summary

Sample Location ID	Sample Type	Depth (ft)			USCS Soil Classification	Soil Classification Notes	SPT Data				Moisture Content (%)	Dry Density (pcf)	Moist Density (pcf)	Atterberg Limits			Grain Size Analysis				Consolidation			CU Triax		Organic Content (%)	Permeability (cm/s)	VST		PPD						
							Incremental Blow Counts		N-Value	Atterberg Limits				Grain Size Analysis				Consolidation			CU Triax			Peak Strength, s_u (psf)	Remolded Strength, s_{ur} (psf)		t_{50} (min)	k, high end (cm/s)	k, low end (cm/s)							
		Top	Bottom	Average			1	2	3	4				LL (%)	PL (%)	PI (%)	% Gravel	% Sand	% Silt	% Clay	σ'_v (tsf)	C_c	C_r	e_0	c' (psf)	ϕ' (deg)										
UC-11	in-situ	0.0	0.3	0.2	CH/OH																									37*						
UC-11	in-situ	1.6	2.0	1.8	ML/OH																										74*					
UC-11	VC	0.0	1.0	0.5	CH/OH																															
UC-11	VC	1.0	2.0	1.5	MH/OH																															
UC-11	VC	2.0	3.0	2.5	MH/OH																															
UC-11	in-situ	3.3	3.6	3.5	ML/OH																												260*			
UC-11	in-situ	4.9	5.3	5.1	PT																												298*			
UC-23	in-situ	0.0	0.3	0.2	CH/OH																											74*				
UC-23	VC	0.0	0.5	0.3	CH/OH																															
UC-23	VC	1.5	2.0	1.8	MH/OH																															
UC-23	in-situ	1.6	2.0	1.8	ML/OH																											74*				
UC-23	VC	2.5	3.0	2.8	MH/OH																															
UC-23	in-situ	3.3	3.6	3.5	MH/OH																											298*				
UC-23	VC	3.8	4.3	4.0	SM	with Peat																									74*					
UC-29	in-situ	0.0	0.3	0.2	CH/OH																															
UC-29	VC	0.0	0.5	0.3	CH/OH																															
UC-29	VC	1.0	1.5	1.3	MH/OH																															
UC-29	in-situ	1.6	2.0	1.8	ML/OH																											74*				
UC-29	VC	2.5	3.0	2.8	MH/OH																															
UC-29	in-situ	3.3	3.6	3.5	MH/OH																										298*					
UC-29	VC	3.8	4.3	4.0	SM	with Peat																									74*					
UC-29	in-situ	0.0	0.3	0.2	CH/OH																															
UC-29	VC	0.0	0.5	0.3	CH/OH																															
UC-29	VC	1.0	1.5	1.3	MH/OH																															
UC-29	in-situ	1.6	2.0	1.8	ML/OH																										74*					
UC-29	VC	2.5	3.0	2.8	MH/OH																															
UC-29	in-situ	3.3	3.6	3.5	MH/OH																										298*					
UC-79	in-situ	0.0	0.3	0.2	SM/OL																															
UC-80	in-situ	0.0	0.3	0.2	ML	weakly cemented, with crystals																												1053*		
UC-81	in-situ	0.0	0.3	0.2	SM																													707*		
UC-83	in-situ	0.0	0.3	0.2	SM																													372*		
UC-83	in-situ	1.6	2.0	1.8	SM																													595*		
UC-93 (303)	in-situ				ML																													3.92	2.5E-06	5.0E-08
UC-94 (304)	SS	0.0	2.0	1.0	OL	Mainly organic silt underlain by PT, SC, and SP				WH	WH	1	2	1																						
UC-94 (304)	SS	2.0	4.0	3.0	CL					WH	WH	WH																								

Table F-1: Geotechnical Field and Lab Data Summary (cont.)

Sample Location ID	Sample Type	Depth (ft)			USCS Soil Classification	Soil Classification Notes	SPT Data				Moisture Content (%)	Dry Density (pcf)	Moist Density (pcf)	Atterberg Limits			Grain Size Analysis				Consolidation			CU Triax		Organic Content (%)	Permeability (cm/s)	VST		PPD						
		Top	Bottom	Average			Incremental Blow Counts	1	2	3	4			LL (%)	PL (%)	PI (%)	% Gravel	% Sand	% Silt	% Clay	σ'_p (tsf)	C_c	C_r	e_0	c' (psf)	ϕ (deg)	Peak Strength, s_u (psf)	Remolded Strength, s_{ur} (psf)	t_{50} (min)	k, high end (cm/s)	k, low end (cm/s)					
		WM-42	in-situ	3.3	3.6	3.5	ML	trace to with organics																					1153*							
WM-43	in-situ	0.0	0.3	0.2	ML/OL																								149*							
WM-43	in-situ	1.6	2.0	1.8	ML/OL																								186*							
WM-43	in-situ	3.3	3.6	3.5	PT	Silty																							930*							
WM-45	in-situ	0.0	0.3	0.2	SM	trace organics																							744*							
WM-45	in-situ	1.6	2.0	1.8	SP																								1451*							
WM-45	in-situ	3.3	3.6	3.5	SP	lenses of Sand																							1600*							
WM-63	in-situ	0.0	0.3	0.2	ML/OL	trace to with organics, trace metallic particles and shells																							186*							
WM-63	in-situ	1.6	2.0	1.8	SM																								149*							
WM-63	in-situ	3.3	3.6	3.5	SM																								1023*							
WM-71	in-situ	0.0	0.3	0.2	SP	with metallic particles																							149*							
WM-71	in-situ	1.6	2.0	1.8	SP	with metallic particles																							1042*							
WM-73	in-situ	0.0	0.3	0.2	ML/OL																								298*							
WM-73	in-situ	1.6	2.0	1.8	ML	with Peat																							930*							
WM-73	in-situ	3.3	3.6	3.5	ML	with Peat																							1153*							
WM-100 (311)	SS	0.0	2.0	1.0	OL/SP	Organic ML to 1.4, then SP				WH	WH	1	WH	1																						
WM-100 (311)	SS	2.0	4.0	3.0	SP/CL-ML	SP to 3, then CL-ML				WH	WH	WH	WH	<1																						
WM-100 (311)	TW	3.0	5.5	4.3	CL	with Sand, trace Peat				WH	WH	120.6	28.5	19.8	8.7	0	13.5	72.5	14												3.0E-07					
WM-100 (311)	SS	4.0	6.0	5.0	CL	with Sand, trace Peat				WH	WH	WH	WH	<1																						
WM-100 (311)	in-situ					6.0																							280	32						
WM-100 (311)	SS	6.0	8.0	7.0	CL-ML	with Sand, trace Peat				WH	WH	WH	WH	<1																						
WM-100 (311)	SS	8.0	10.0	9.0	CL-ML	with Sand and Peat				WH	WH	WH	WH	<1																						
WM-100 (311)	in-situ					10.5																									678	N/A**				
WM-100 (311)	SS	10.0	12.0	11.0	ML	Sandy, 'milled' wood fill 10.4-10.6				WH	WH	3	3	3																						
WM-100 (311)	in-situ					11.5																									990	301				
WM-100 (311)	SS	12.0	14.0	13.0	ML	Trace gravel				WH	4	4	8	8																						
WM-100 (311)	TW	12.0	14.5	13.3	ML	Sandy									23.7	100	123.7													0	34.8					
WM-100 (311)	SS	14.0	16.0	15.0	SM	Trace gravel 15.6-15.8				3	8	8	7	16																						
WM-100 (311)	in-situ					16.0																											688	237		
WM-100 (311)	SS	16.0	18.0	17.0	SM/CL	SM to 17.2, then CL				5	6	1	5	7																						
WM-100 (311)	SS	18.0	20.0	19.0	SP					3	3	3	5	6																						
WM-100 (311)	SS	20.0	22.0	21.0																																

Figures



- Core Penetration Test (CPT) Sounding Location
- ✚ Plate Plate Dilatometer Test (DMT) Location
- Hollow Stem Auger (HSA) Soil Boring Location
- Vane Shear Locations
- ◆ Vibracore Sample Collection Locations
- Bathymetry Contour (1-Foot)
- Approximate Outer Study Area Limit
- Approximate Location of St. Louis River Channel, Based on Orthophoto Interpretation
- Approximate U. S. Steel Operations Area (URS, 2008)

Figure F-1

**FALL 2011
GEOTECHNICAL BORING LOCATIONS**
Spirit Lake Sediment Site -
Former U. S. Steel Duluth Works
Saint Louis River
Duluth, Minnesota



0 1,000 2,000
Feet

Undrained Shear Strength, s_u [psf]

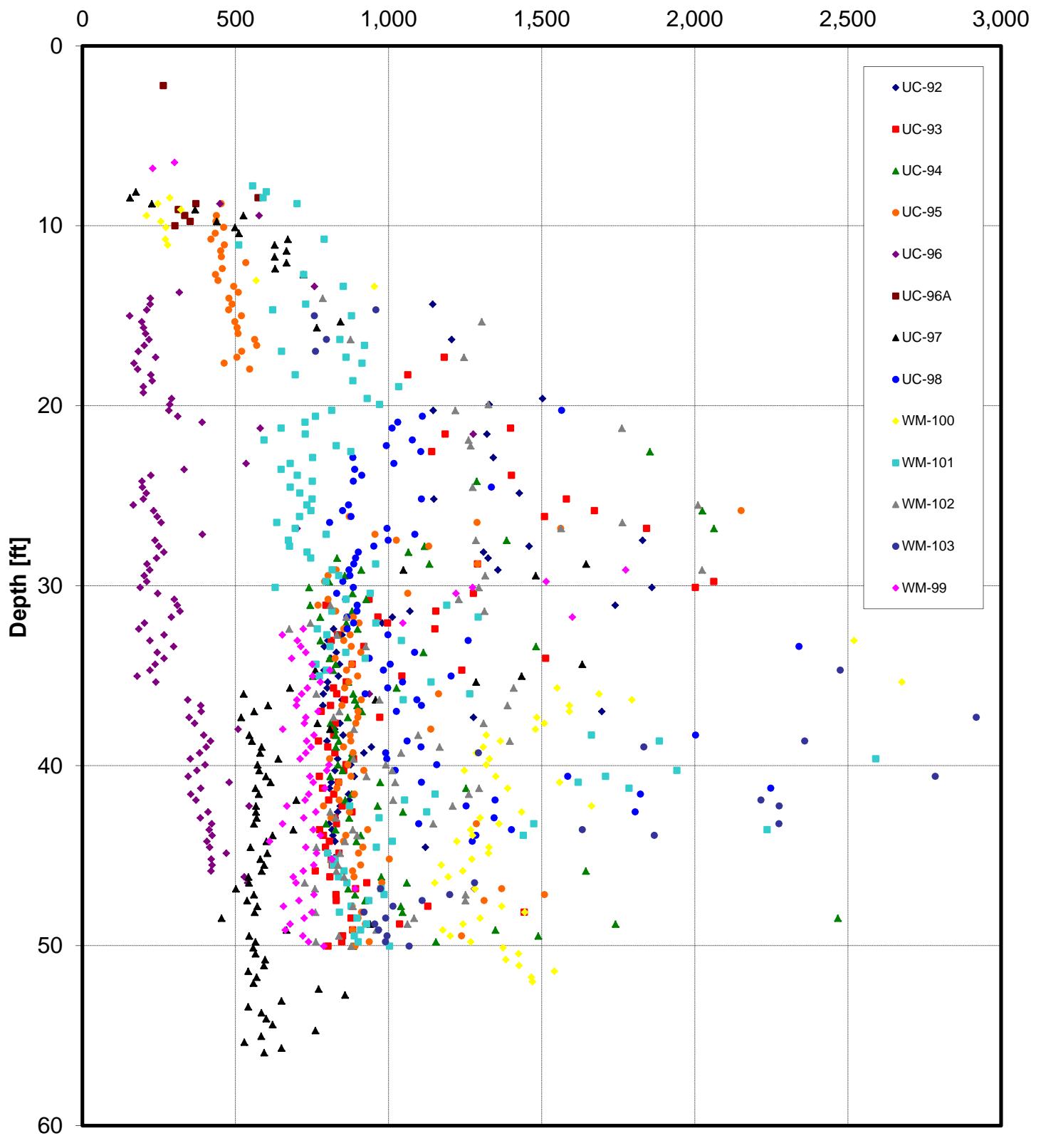
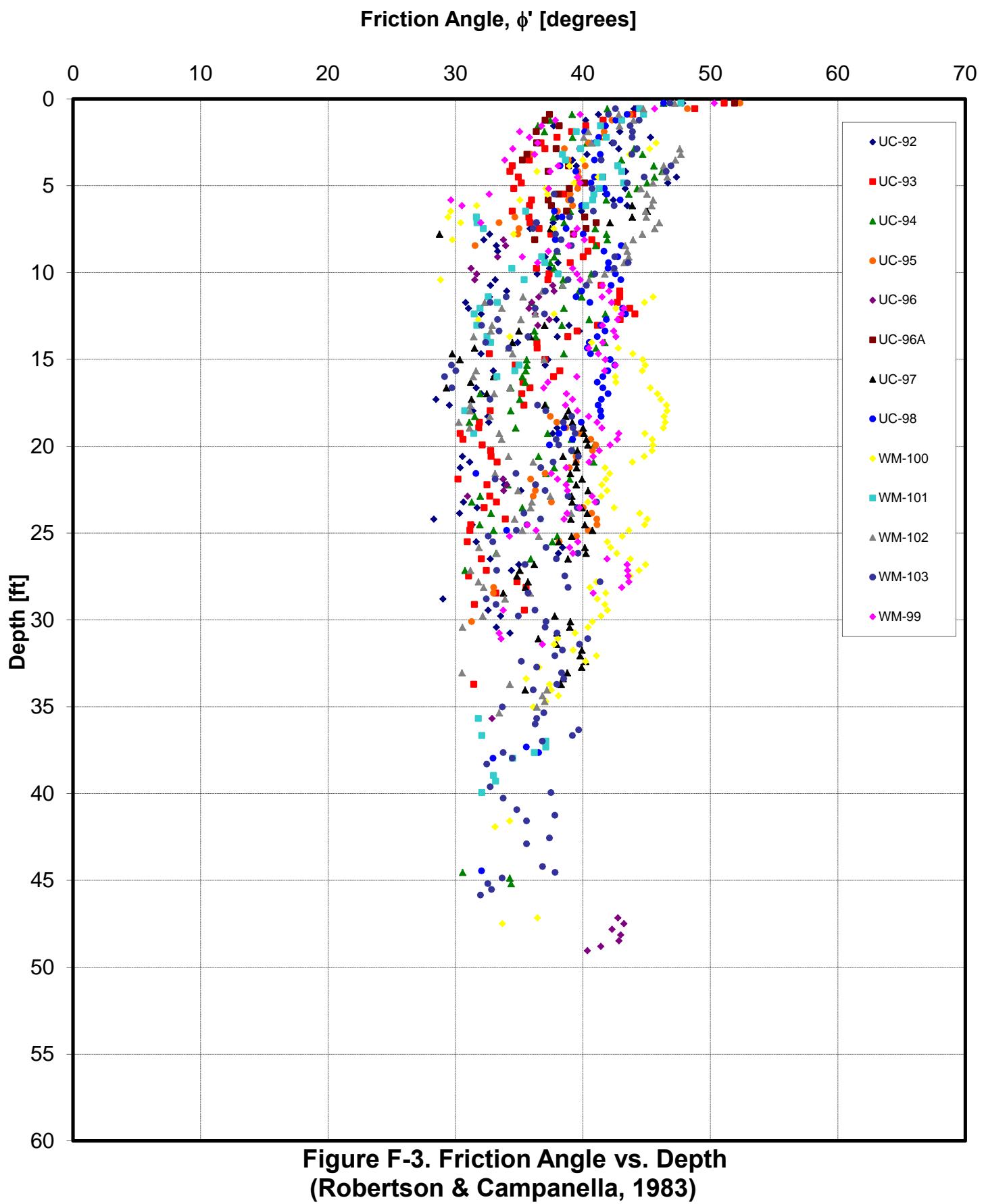


Figure F-2. Undrained Shear Strength from CPT vs. Depth ($N_{kt}=16$)



Attachments

Attachment F-1

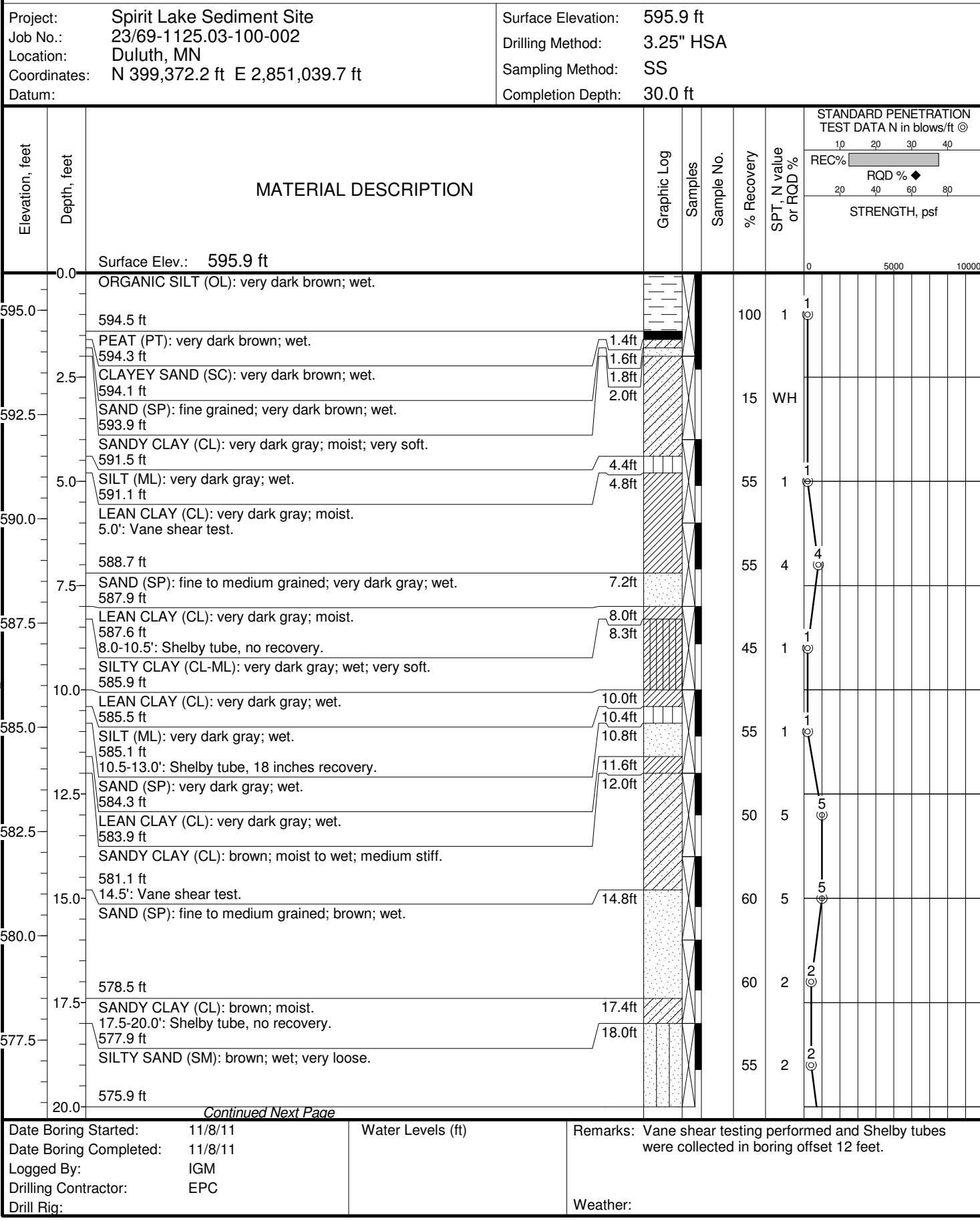
Soil Boring Logs



Barr Engineering Company
332 W. Superior St. Suite 600
Duluth, MN 55802
Telephone: 218-727-5218

LOG OF BORING UC-94 (304)

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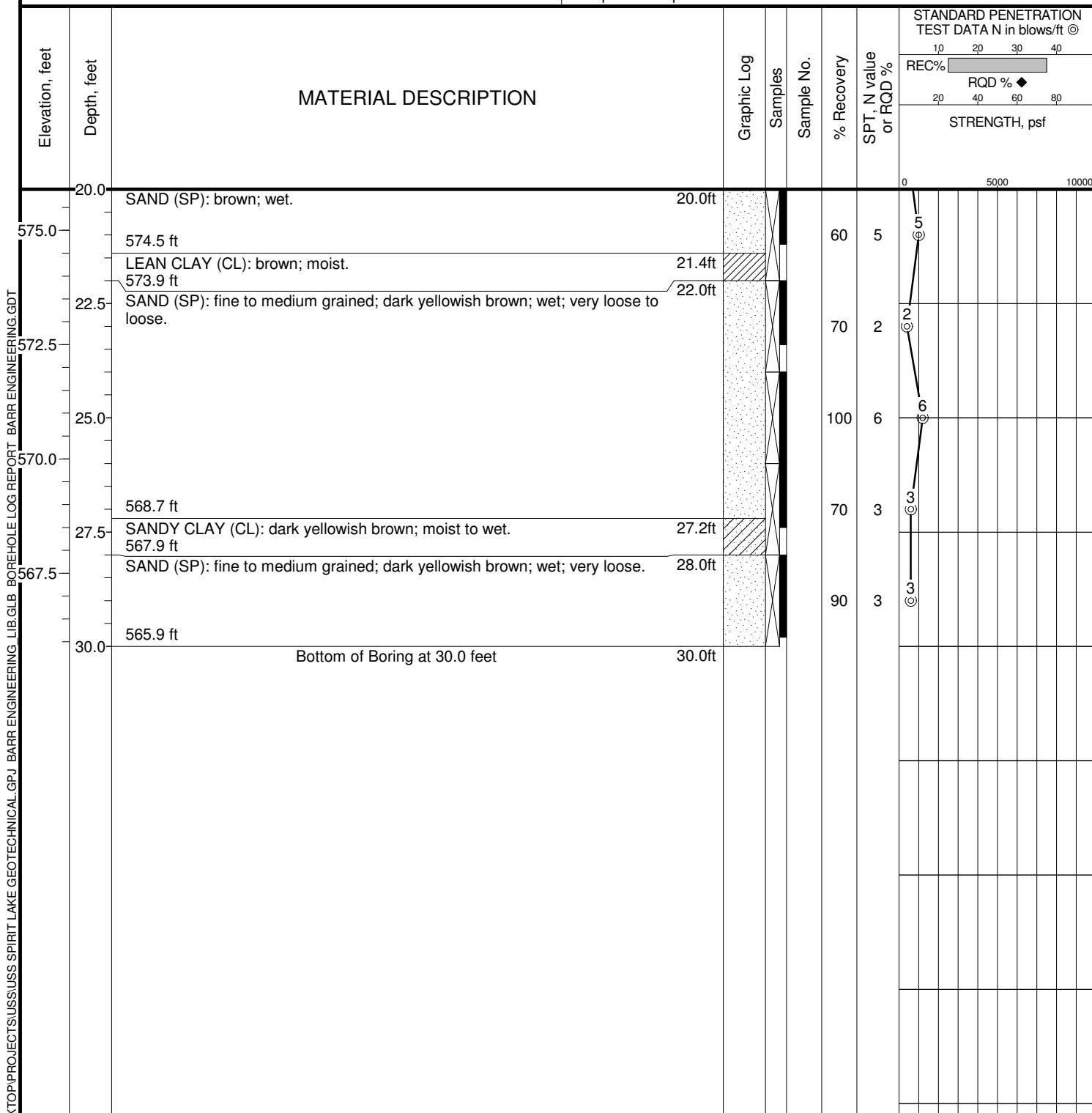
Barr Engineering Company
332 W. Superior St. Suite 600
Duluth, MN 55802
Telephone: 218-727-5218

LOG OF BORING UC-94 (304)

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Project: Spirit Lake Sediment Site
Job No.: 23/69-1125.03-100-002
Location: Duluth, MN
Coordinates: N 399,372.2 ft E 2,851,039.7 ft
Datum:

Surface Elevation: 595.9 ft
Drilling Method: 3.25" HSA
Sampling Method: SS
Completion Depth: 30.0 ft



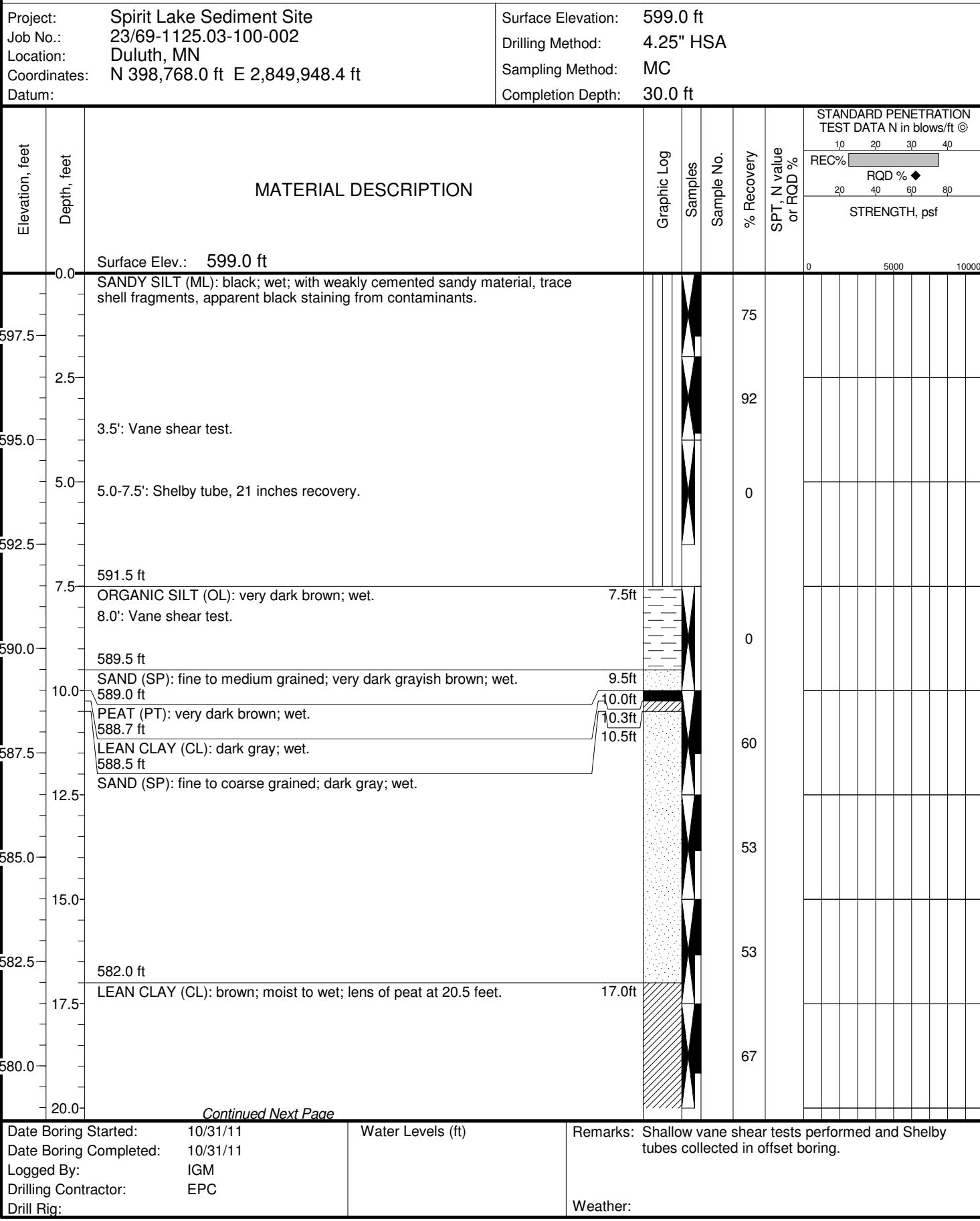
Date Boring Started:	11/8/11	Water Levels (ft)	Remarks: Vane shear testing performed and Shelby tubes were collected in boring offset 12 feet.
Date Boring Completed:	11/8/11		
Logged By:	IGM		
Drilling Contractor:	EPC		
Drill Rig:			Weather:



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LOG OF BORING UC-96 (305)

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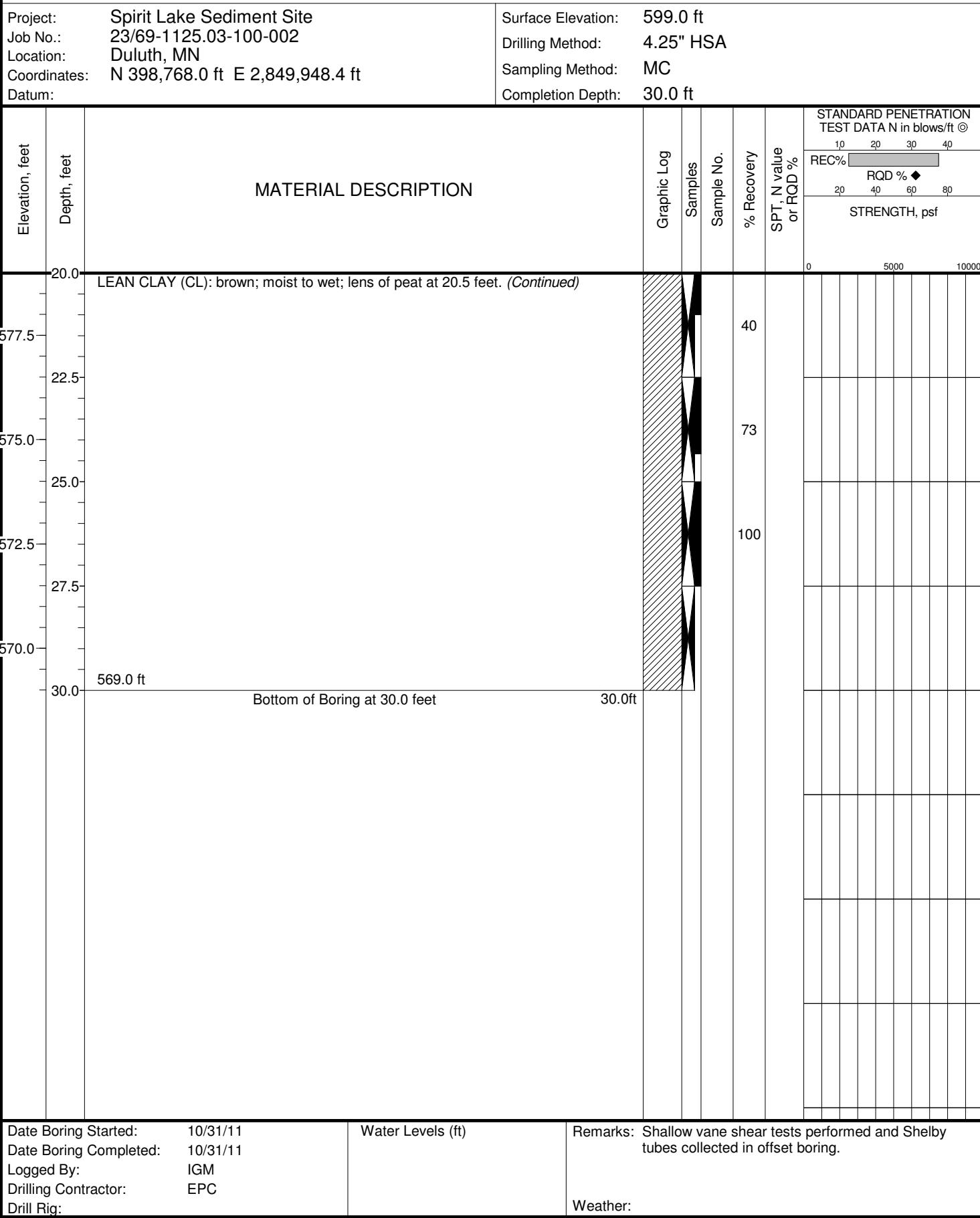




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LOG OF BORING UC-96 (305)

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Duluth, MN 55802
Telephone: 218-727-5218

LOG OF BORING UC-96 (305) A

Sheet 1 of 2

Project: Job No.: Location: Coordinates: Datum:		Spirit Lake Sediment Site 23/69-1125.03-100-002 Duluth, MN	Surface Elevation: Drilling Method: 3.25" HSA Sampling Method: MC Completion Depth: 25.0 ft						
Elevation, feet	Depth, feet	MATERIAL DESCRIPTION		Graphic Log	Samples	Sample No.	% Recovery	SPT, N value or RQD %	STRENGTH, psf
0.0	Surface Elev.:	No samples collected - see UC-96 (305).							
2.5									
5.0	SILTY SAND (SM): black; wet; trace shell fragments and peat.	5.0ft					53		
7.5	ORGANIC SILT (OL): black; wet; trace clay.	7.5ft					80		
10.0	SAND (SP): fine to medium grained; dark grayish brown; wet. SILTY CLAY (CL-ML): dark brown.	9.5ft 10.0ft					90		
12.5	SAND (SP): fine to coarse grained; dark grayish brown.	11.0ft					40		
15.0									
17.5	LEAN CLAY (CL): brown.	17.5ft					45		
20.0									
Continued Next Page									
Date Boring Started:	11/1/11	Water Levels (ft)	Remarks: Boring offset 5 feet from UC-96 (305).						
Date Boring Completed:	11/1/11								
Logged By:	JD (EPC)								
Drilling Contractor:	EPC								
Drill Rig:			Weather:						



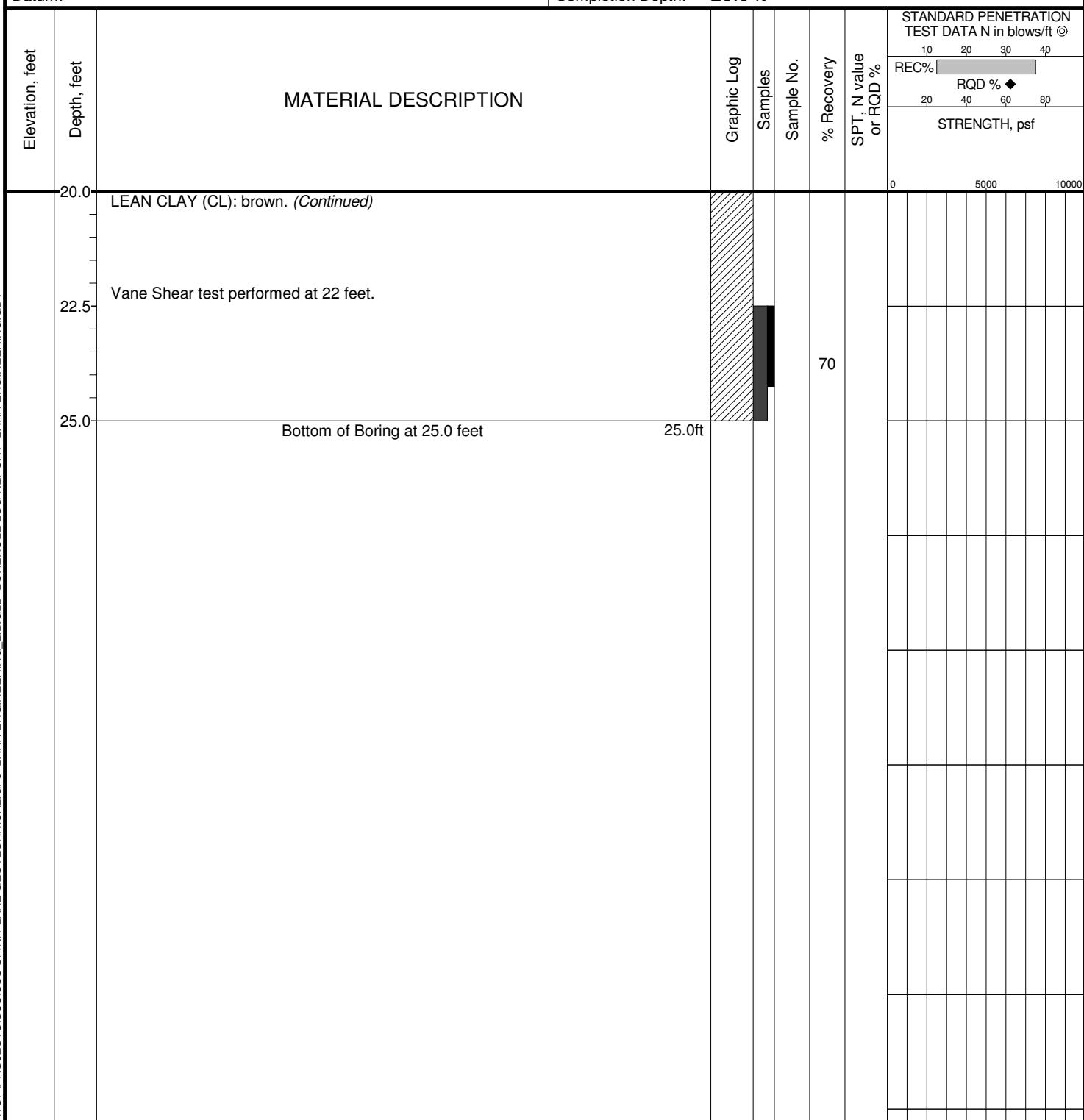
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LOG OF BORING UC-96 (305) A

Sheet 2 of 2

Project: Spirit Lake Sediment Site
Job No.: 23/69-1125.03-100-002
Location: Duluth, MN
Coordinates:
Datum:

Surface Elevation:
Drilling Method: 3.25" HSA
Sampling Method: MC
Completion Depth: 25.0 ft



Date Boring Started:	11/1/11	Water Levels (ft)	Remarks: Boring offset 5 feet from UC-96 (305).
Date Boring Completed:	11/1/11		
Logged By:	JD (EPC)		
Drilling Contractor:	EPC		
Drill Rig:			Weather:



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LOG OF BORING UC-97 (309)

Sheet 1 of 2

Project: Job No.: Location: Coordinates: Datum:		Surface Elevation: 599.7 ft Drilling Method: 3.25" HSA Sampling Method: MC Completion Depth: 20.0 ft	
Elevation, feet	Depth, feet	Graphic Log	Samples
MATERIAL DESCRIPTION			
0.0	Surface Elev.: 599.7 ft		
0.0	SAND (SP): fine grained; black; wet. 599.2 ft		
0.5ft	SANDY SILT (ML): bluish black; moist; weakly cemented, laminations of white crystal pieces.		
2.5			
5.0	594.7 ft SILT (ML): very dark brown and black; moist; laminated, weakly cemented. 5.0ft		
6.5	Trace greenish, weakly cemented sandy material between approximately 6.5 and 7 feet.		
7.0ft	592.7 ft PEAT (PT): very dark brown; moist; fibrous.		
7.5	7.5ft SILT (ML): very dark brown; wet.		
10.0ft	589.7 ft PEAT (PT): very dark brown; moist to wet; fibrous.		
12.5			
13.5ft	586.2 ft SANDY SILT (ML): fine grained; dark grayish brown; moist to wet. Apparent milled wood pieces between approximately 13.5 and 13.75 feet.		
15.0			
Continued Next Page			
Date Boring Started:	11/1/11	Water Levels (ft)	Remarks:
Date Boring Completed:	11/1/11		
Logged By:	IGM		
Drilling Contractor:	EPC		
Drill Rig:		Weather:	



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LOG OF BORING UC-97 (309)

Sheet 2 of 2

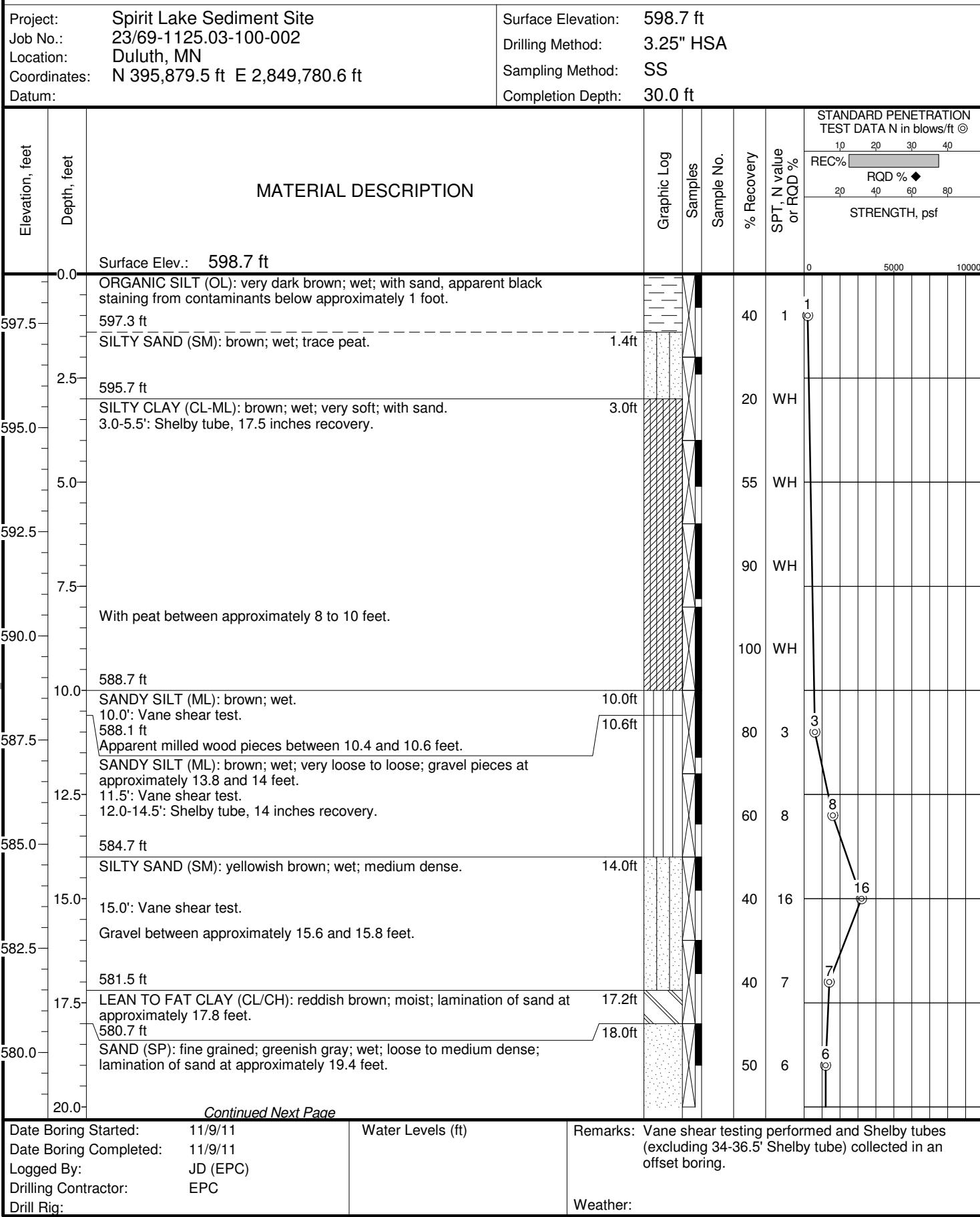
Project:	Spirit Lake Sediment Site	Surface Elevation:	599.7 ft
Job No.:	23/69-1125.03-100-002	Drilling Method:	3.25" HSA
Location:	Duluth, MN	Sampling Method:	MC
Coordinates:	N 398,009.7 ft E 2,850,626.7 ft	Completion Depth:	20.0 ft
Datum:			
Elevation, feet	Depth, feet	MATERIAL DESCRIPTION	
			Graphic Log Samples Sample No.
			% Recovery SPT, N value or RQD %
			STRENGTH, psf
			0 5000 10000
15.0		SANDY SILT (ML): fine grained; dark grayish brown; moist to wet. <i>(Continued)</i> 583.7 ft	
16.0ft		SAND (SP): fine to medium grained; brown; wet.	
17.5			
582.5			
18.5ft			
18.7ft			
19.0ft			
581.2 ft		SILTY SAND (SM): fine grained; brown; wet.	
581.0 ft			
580.7 ft		LEAN CLAY (CL): brown; wet.	
580.0			
20.0		SAND (SP): fine grained; brown; wet.	
579.7 ft			
		Bottom of Boring at 20.0 feet	
Date Boring Started:	11/1/11	Water Levels (ft)	Remarks:
Date Boring Completed:	11/1/11		
Logged By:	IGM		
Drilling Contractor:	EPC		
Drill Rig:			Weather:



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LOG OF BORING WM-100 (311)

Sheet 1 of 2

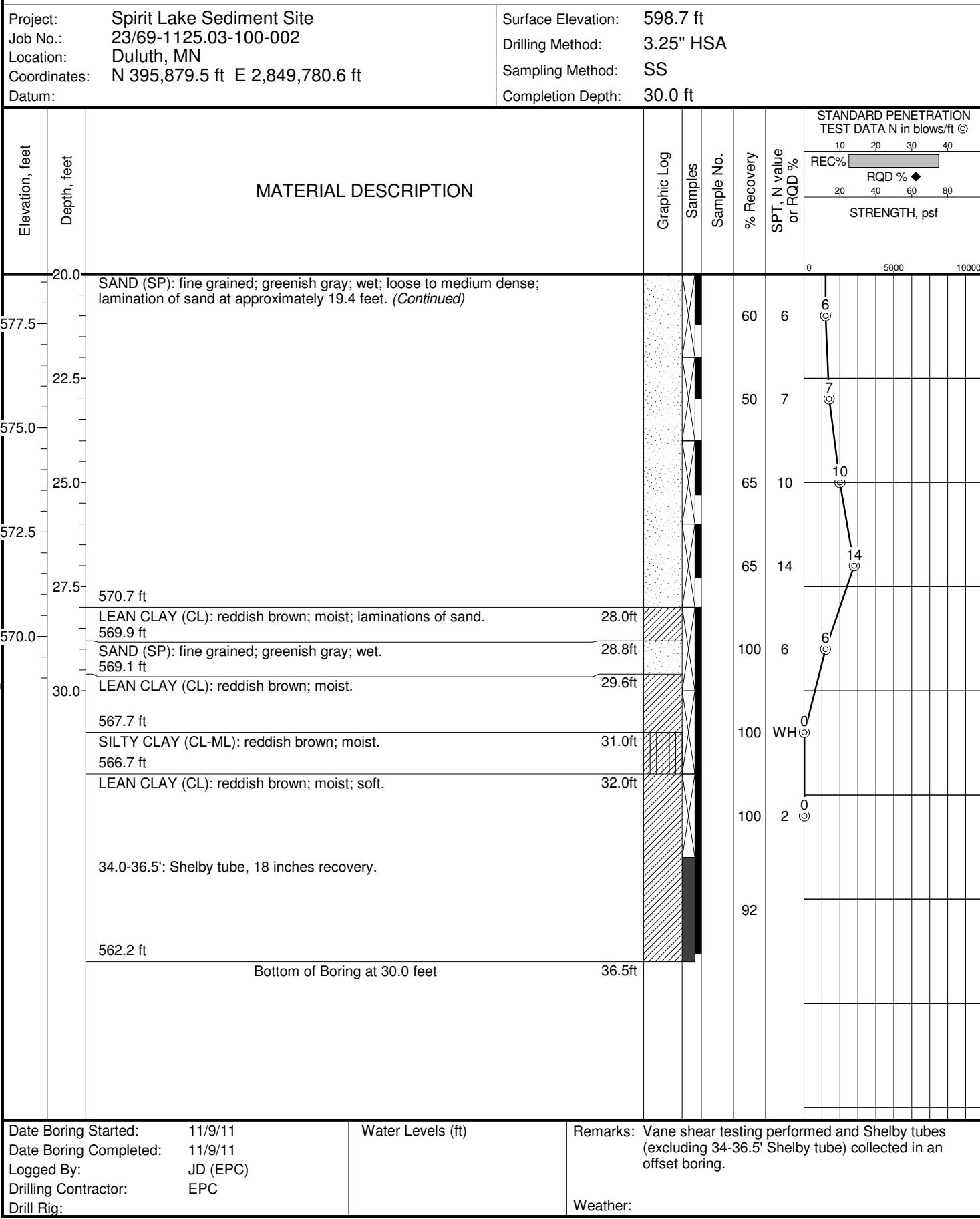




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LOG OF BORING WM-100 (311)

Sheet 2 of 2





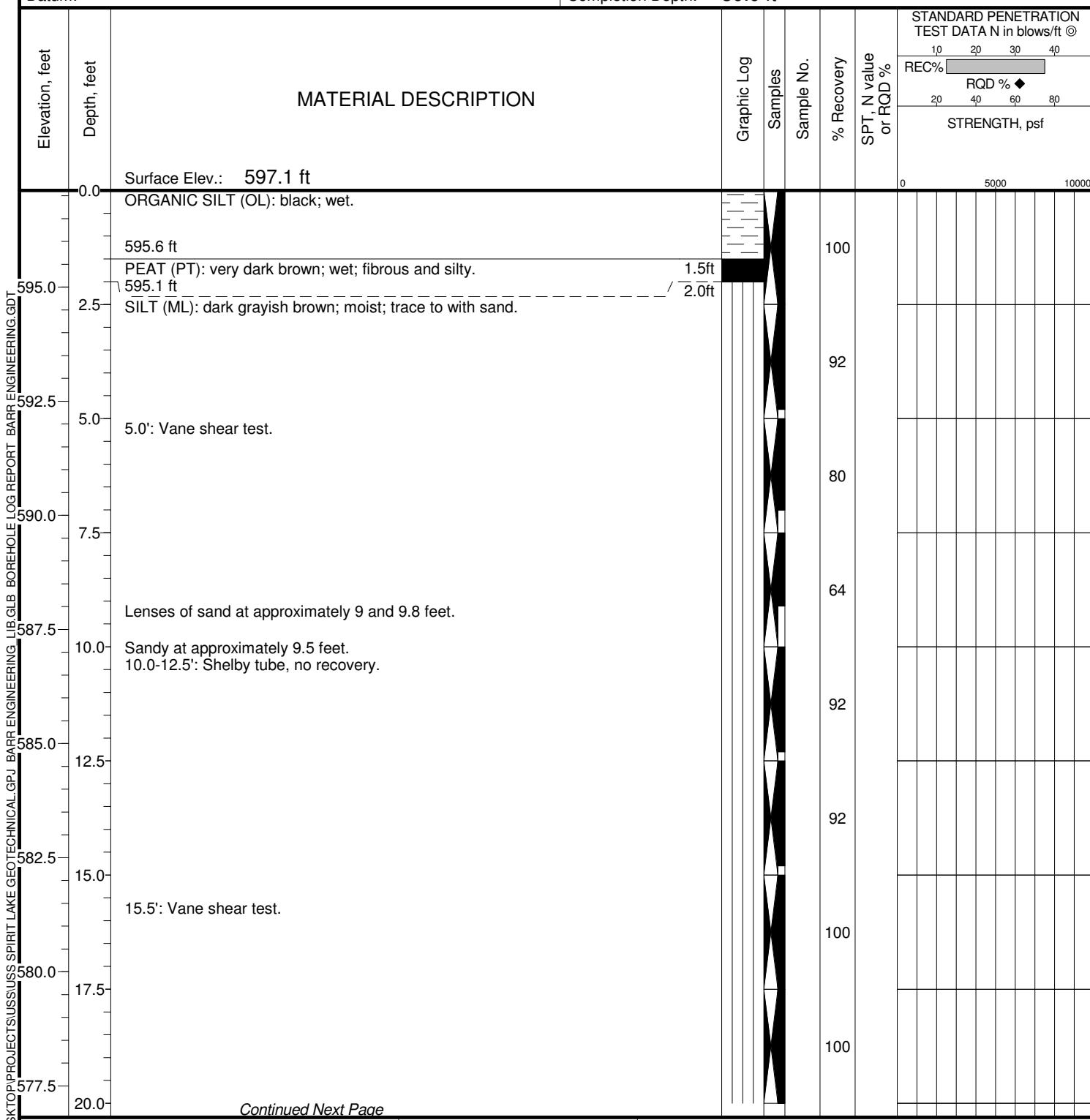
Barr Engineering Company
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LOG OF BORING WM-101 (314)

Sheet 1 of 2

Project: Spirit Lake Sediment Site
Job No.: 23/69-1125.03-100-002
Location: Duluth, MN
Coordinates: N 394,347.2 ft E 2,850,836.6 ft
Datum:

Surface Elevation: 597.1 ft
Drilling Method: 3.25" HSA
Sampling Method: MC
Completion Depth: 30.0 ft



Continued Next Page

Date Boring Started:	11/10/11	Water Levels (ft)	Remarks: Vane shear testing performed and Shelby tubes (excluding 27.5-30.0' shelby tube) were collected in an offset boring.
Date Boring Completed:	11/10/11		
Logged By:	JD (EPC)		
Drilling Contractor:	EPC		
Drill Rig:		Weather:	



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LOG OF BORING WM-101 (314)

Sheet 2 of 2

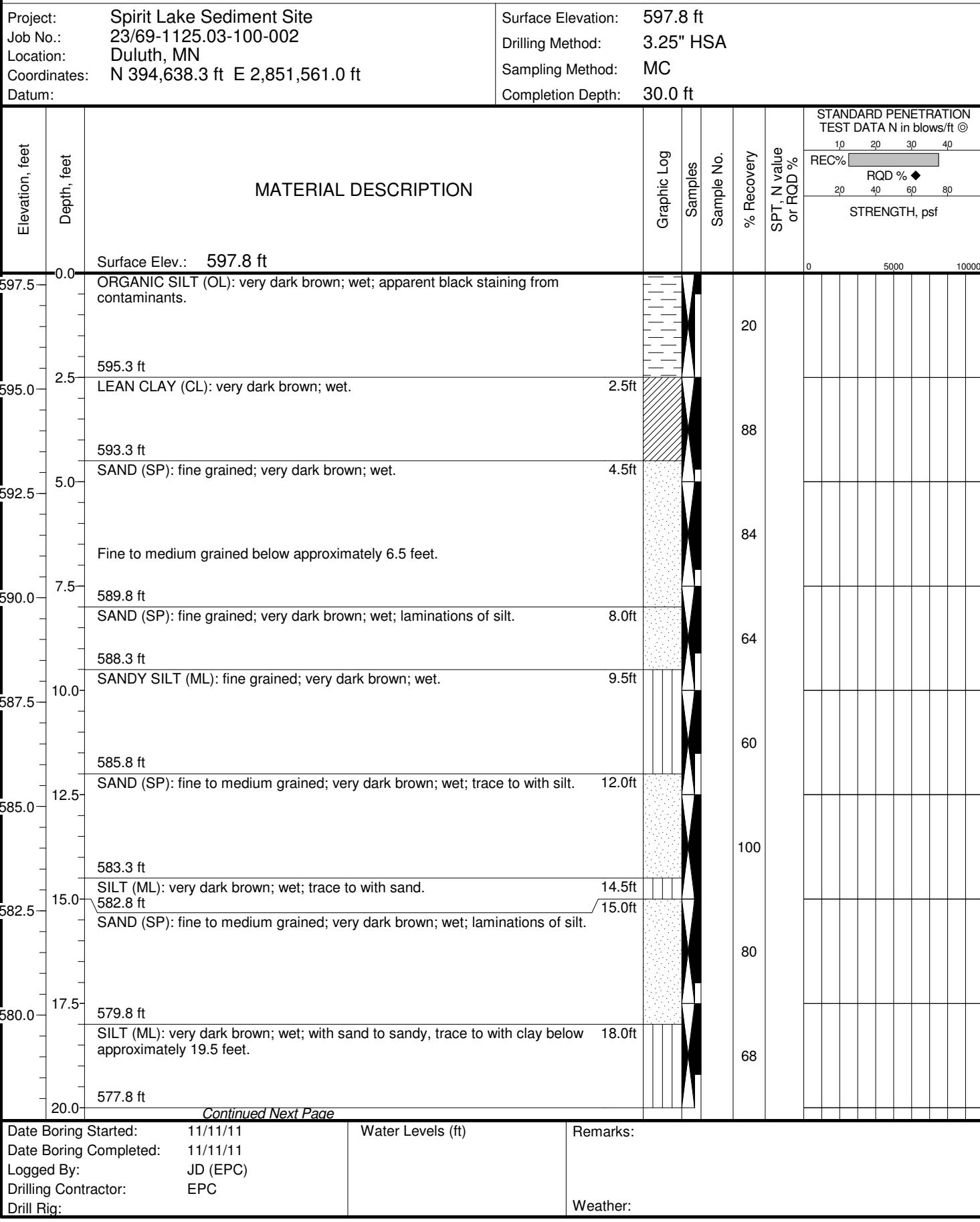
Project:	Spirit Lake Sediment Site	Surface Elevation:	597.1 ft
Job No.:	23/69-1125.03-100-002	Drilling Method:	3.25" HSA
Location:	Duluth, MN	Sampling Method:	MC
Coordinates:	N 394,347.2 ft E 2,850,836.6 ft	Completion Depth:	30.0 ft
Datum:			
Elevation, feet	Depth, feet	MATERIAL DESCRIPTION	
Graphic Log	Samples	Sample No.	% Recovery
SPT, N value or RQD %	STRENGTH, psf		
20.0	SILT (ML): dark grayish brown; moist; trace to with sand. <i>(Continued)</i>		100
22.5	Trace to with clay between approximately 22 and 25 feet.		100
25.0			100
27.5	27.5-30.0': Shelby tube, 18 inches recovery.		
30.0	Bottom of Boring at 30.0 feet	30.0ft	
STANDARD PENETRATION TEST DATA N in blows/ft @			
10	20	30	40
REC%			
20	40	60	80
RQD %			
0	5000	10000	
LIBGLB BOREHOLE LOG REPORT BARR ENGINEERING GDT			
Date Boring Started:	11/10/11	Water Levels (ft)	Remarks: Vane shear testing performed and Shelby tubes (excluding 27.5-30.0' shelby tube) were collected in an offset boring.
Date Boring Completed:	11/10/11		
Logged By:	JD (EPC)		
Drilling Contractor:	EPC		
Drill Rig:		Weather:	



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LOG OF BORING WM-102 (315)

Sheet 1 of 2





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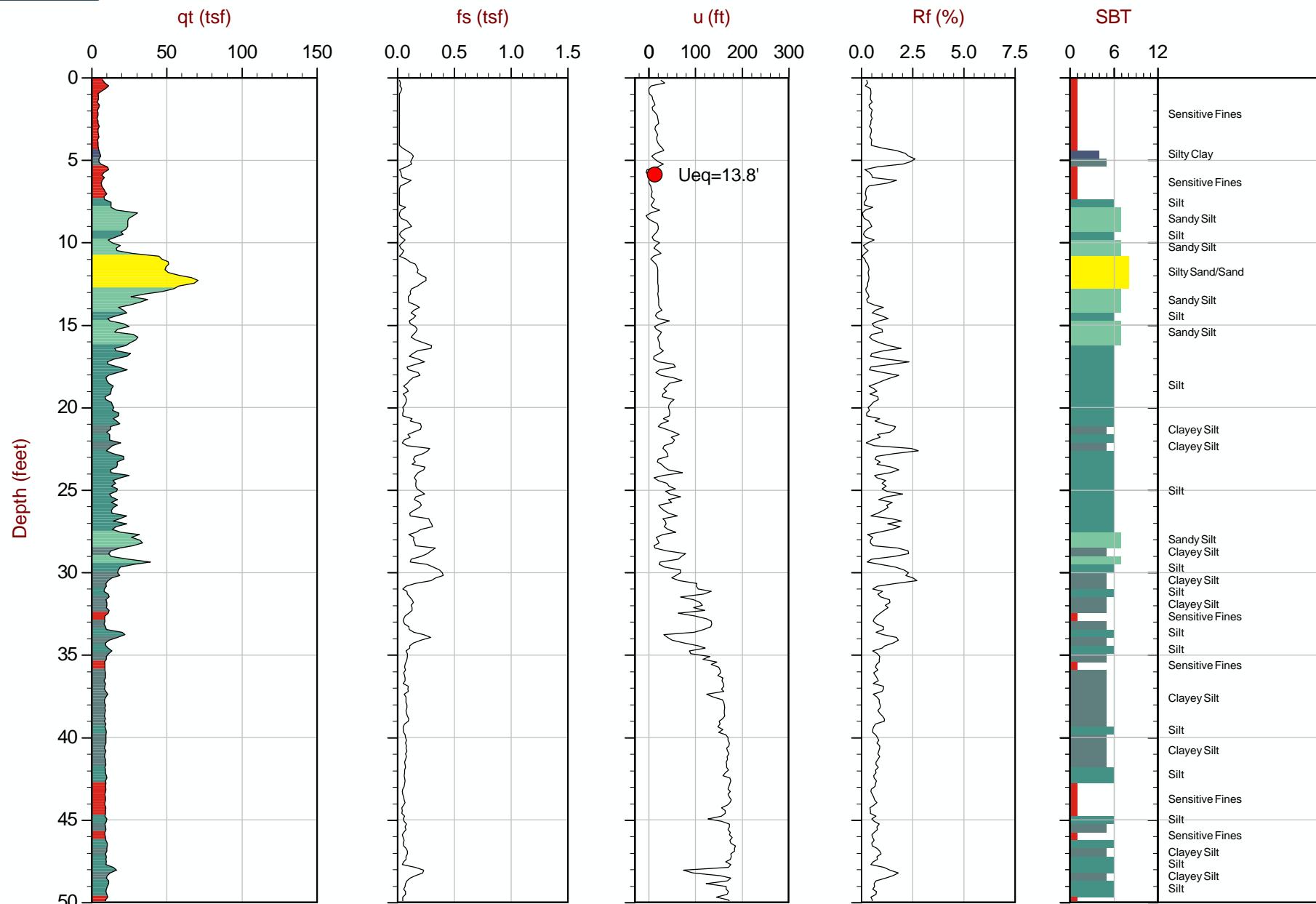
LOG OF BORING WM-102 (315)

Sheet 2 of 2

Project: Job No.: Location: Coordinates: Datum:		Surface Elevation: 597.8 ft Drilling Method: 3.25" HSA Sampling Method: MC Completion Depth: 30.0 ft	
Elevation, feet	Depth, feet	Graphic Log	Samples
		MATERIAL DESCRIPTION	Sample No.
577.5	20.0	SILT (ML): very dark brown; wet; with sand to sandy.	20.0ft
575.0	22.5		
573.3 ft	25.0	SAND (SP): fine grained; very dark brown; wet.	24.5ft
572.3 ft	25.5ft	SILTY SAND (SM): fine to medium grained; very dark brown; wet; lenses of wood chips.	
570.3 ft	27.5	SAND (SP): fine to medium grained; very dark brown; wet.	27.5ft
567.8 ft	30.0	Bottom of Boring at 30.0 feet	30.0ft
		STANDARD PENETRATION TEST DATA N in blows/ft @ REC% RQD % 20 40 60 80	
		STRENGTH, psf 0 5000 10000	
C:\USERS\SLIDESKTOP\PROJECTS\SPIRIT LAKE GEOTECHNICAL GPU BARR ENGINEERING LIB\GLB BOREHOLE LOG REPORT BARR ENGINEERING GDT		% Recovery SPT, N value or RQD %	
Date Boring Started: 11/11/11 Date Boring Completed: 11/11/11 Logged By: JD (EPC) Drilling Contractor: EPC Drill Rig:		Water Levels (ft) Remarks: Weather:	

Attachment F-2

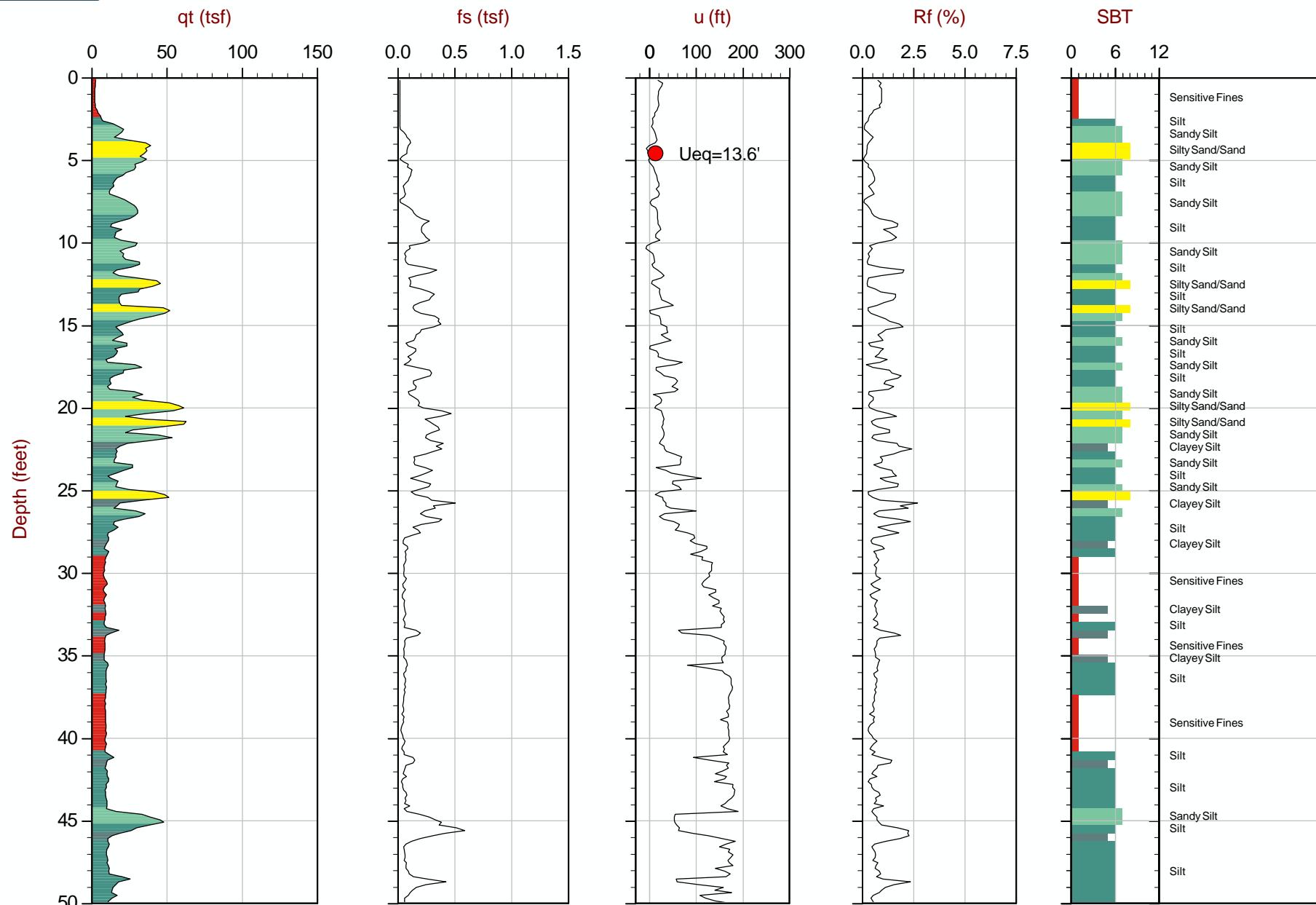
Cone Penetration Test (CPT) Logs

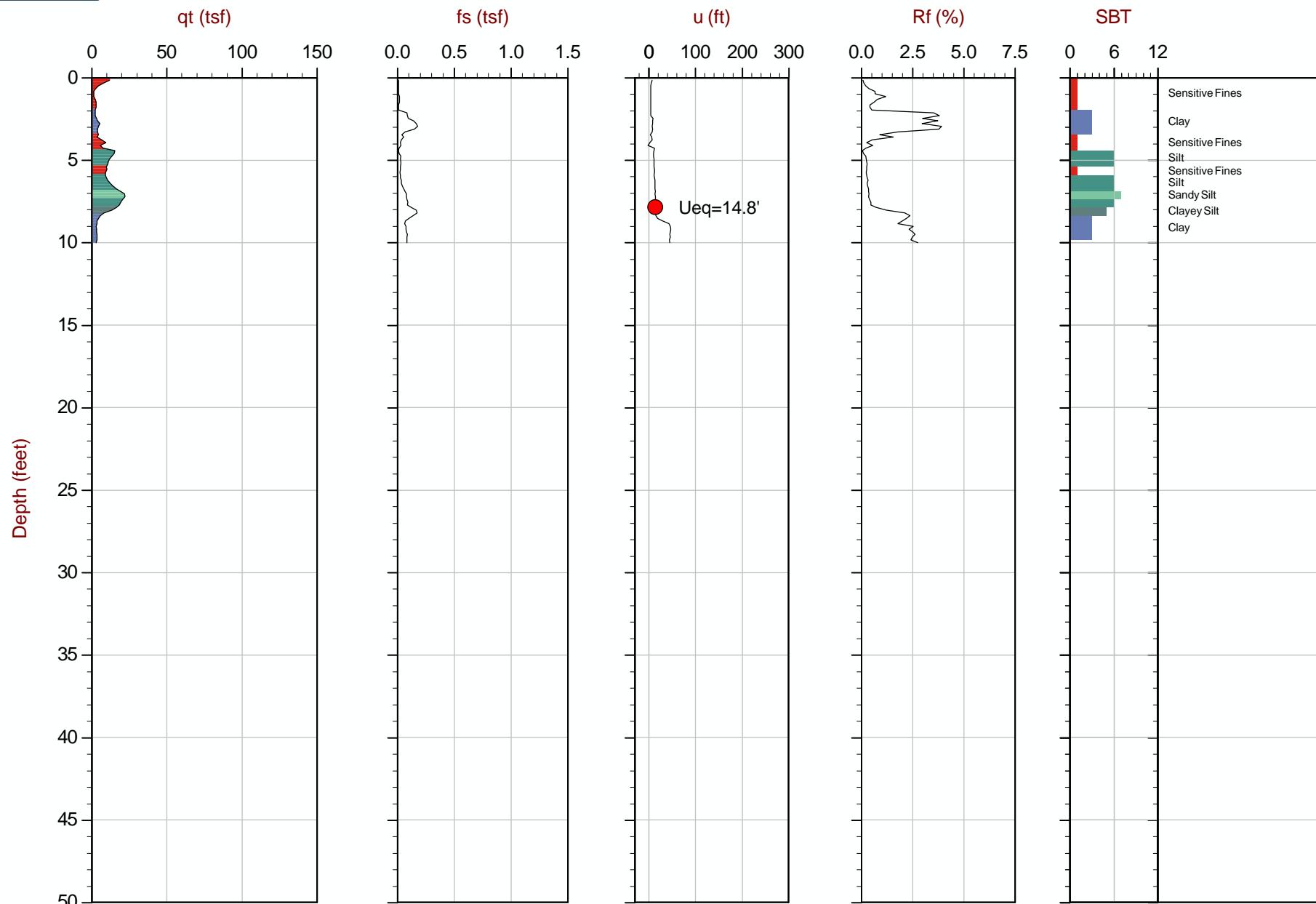


Max Depth: 15.250 m / 50.03 ft
 Depth Inc: 0.050 m / 0.164 ft
 Avg Int: 0.150 m

File: 11-411CP303.COR
 Unit Wt: SBT Chart Soil Zones

SBT: Lunne, Robertson and Powell, 1997
 Coords: Lat: 46.69300 Long: -92.196210
 ● Equilibrium Pore Pressure from Dissipation

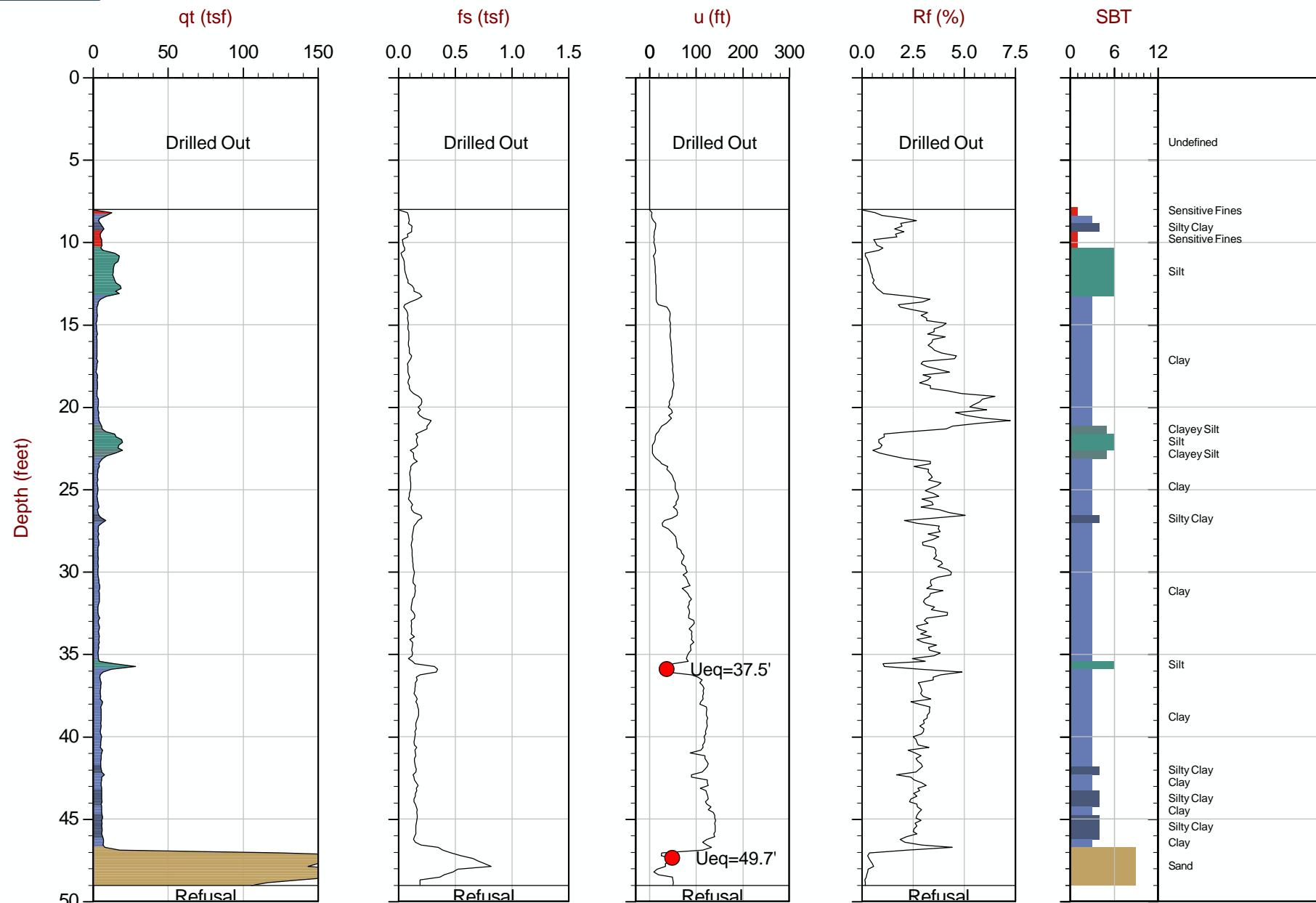




Max Depth: 3.050 m / 10.01 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.150 m

File: 11-411CP305A.COR
Unit Wt: SBT Chart Soil Zones

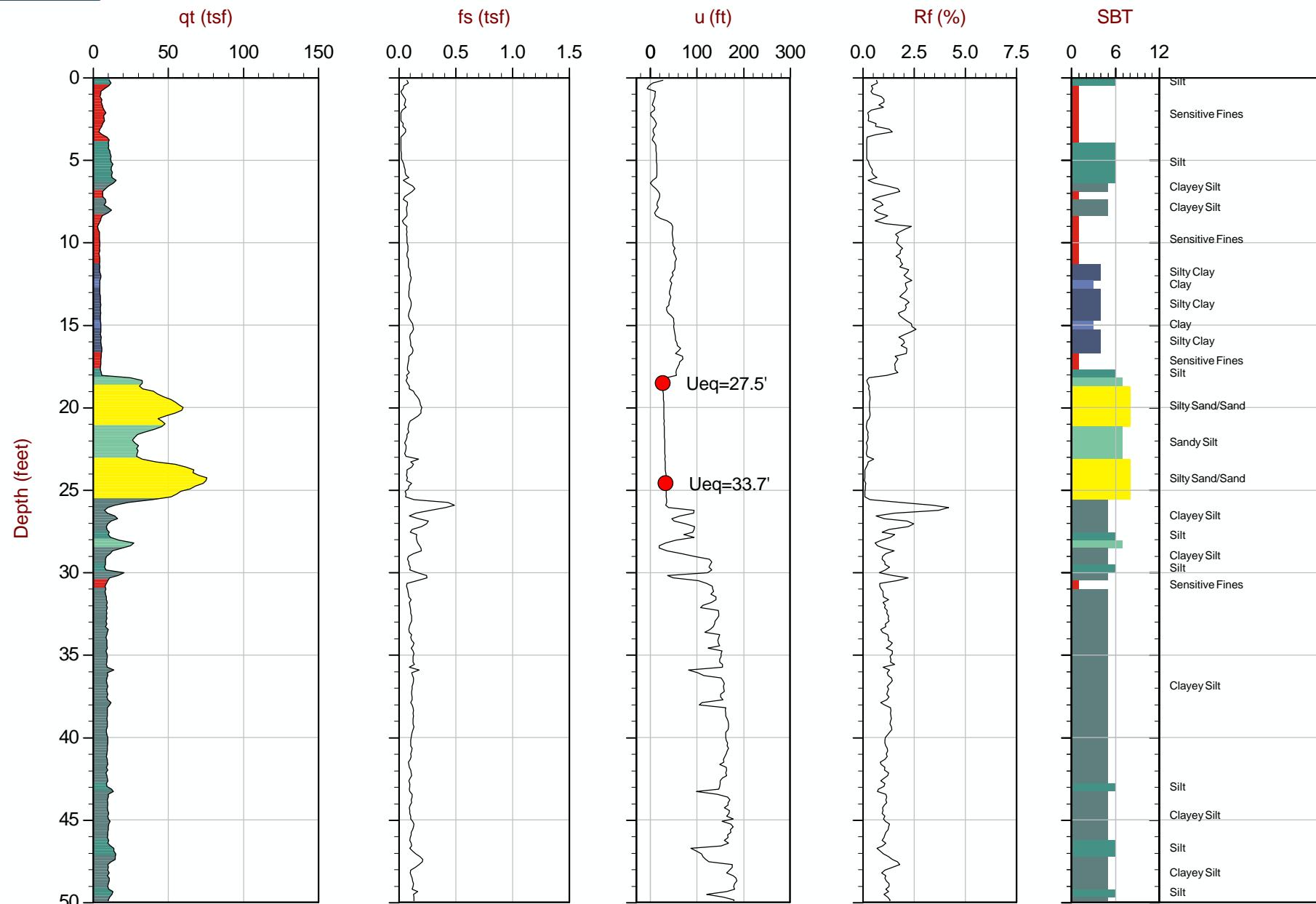
SBT: Lunne, Robertson and Powell, 1997
Coords: Lat: 46.690250 Long: -92.202430
● Equilibrium Pore Pressure from Dissipation

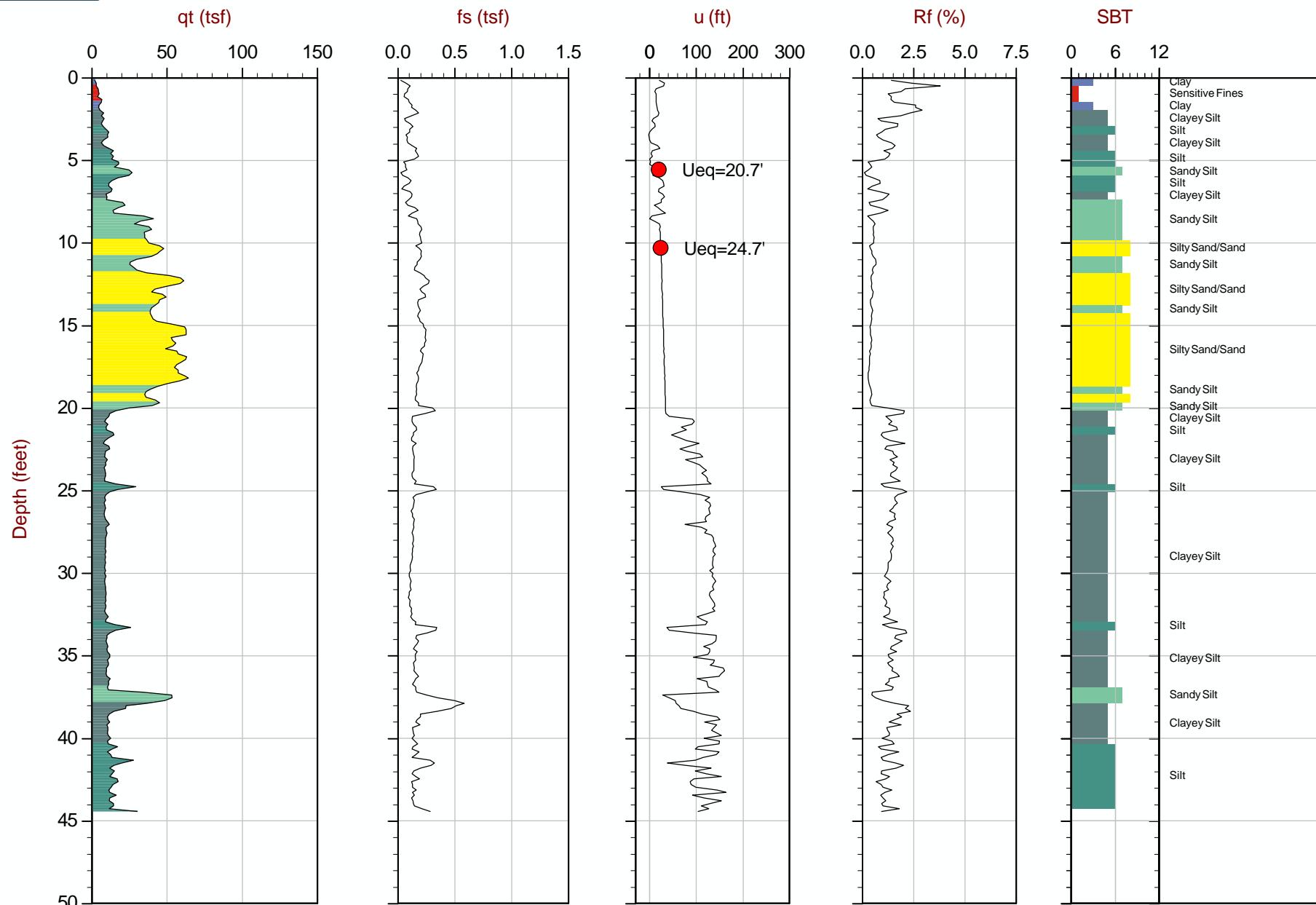


Max Depth: 14.950 m / 49.05 ft
 Depth Inc: 0.050 m / 0.164 ft
 Avg Int: 0.150 m

File: 11-411CP305.COR
 Unit Wt: SBT Chart Soil Zones

SBT: Lunne, Robertson and Powell, 1997
 Coords: Lat: 46.690270 Long: -92.202480
 ● Equilibrium Pore Pressure from Dissipation

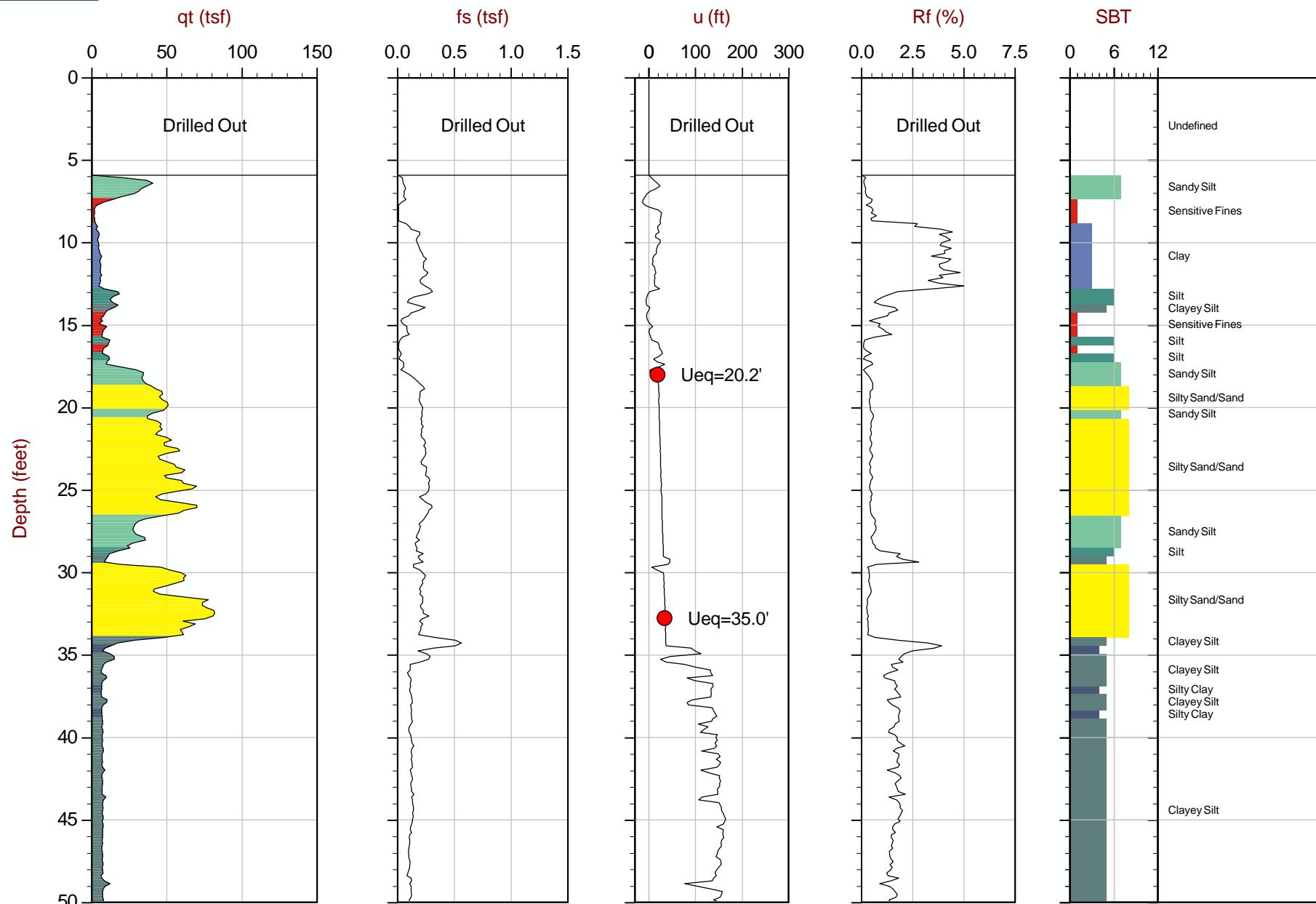




Max Depth: 13.550 m / 44.45 ft
 Depth Inc: 0.050 m / 0.164 ft
 Avg Int: 0.150 m

File: 11-411CP307.COR
 Unit Wt: SBT Chart Soil Zones

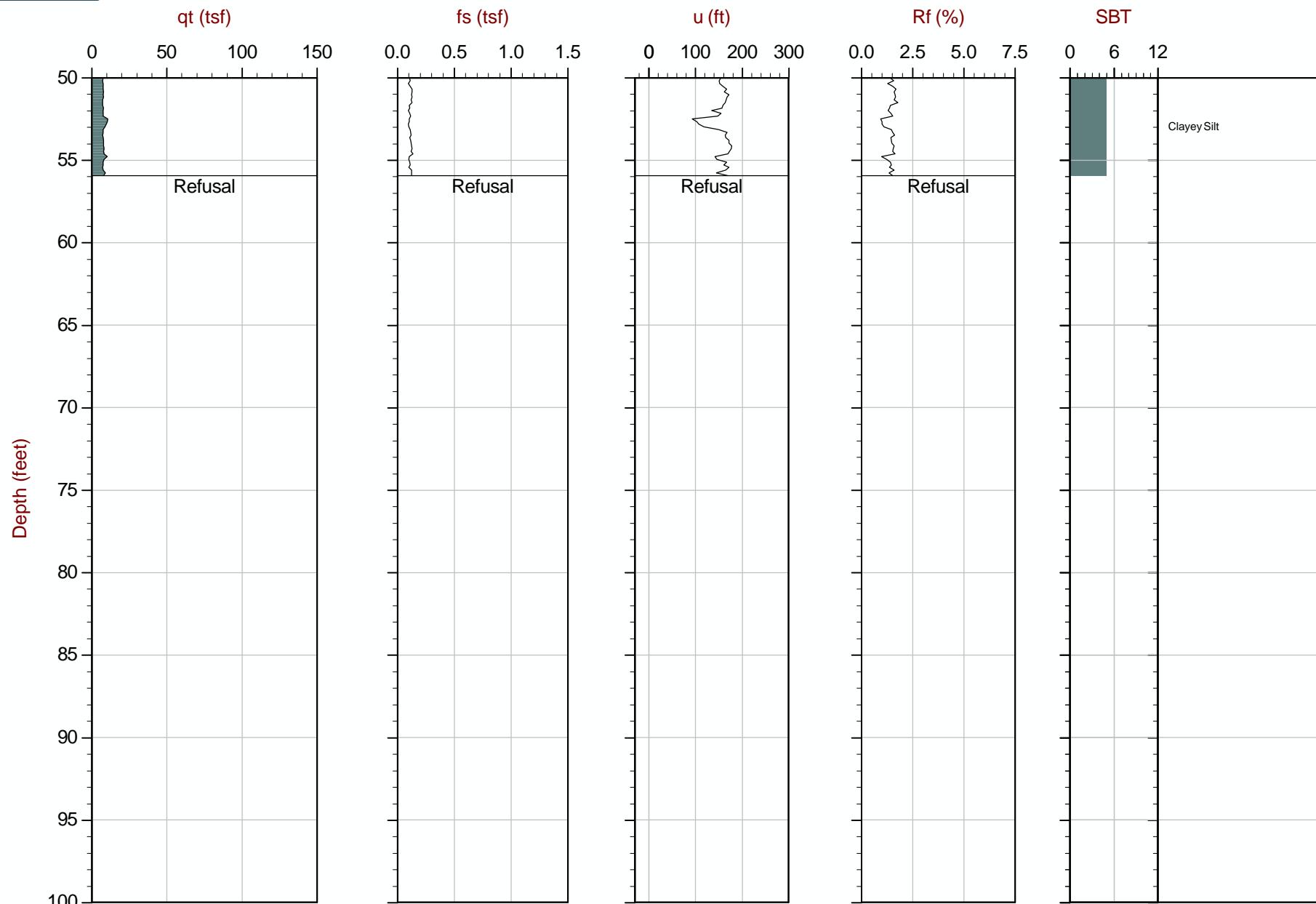
SBT: Lunne, Robertson and Powell, 1997
 Coords: Lat: 46.689500 Long: -92.197000
 ● Equilibrium Pore Pressure from Dissipation



Max Depth: 17.050 m / 55.94 ft
 Depth Inc: 0.050 m / 0.164 ft
 Avg Int: 0.150 m

File: 11-411CP309.COR
 Unit Wt: SBT Chart Soil Zones

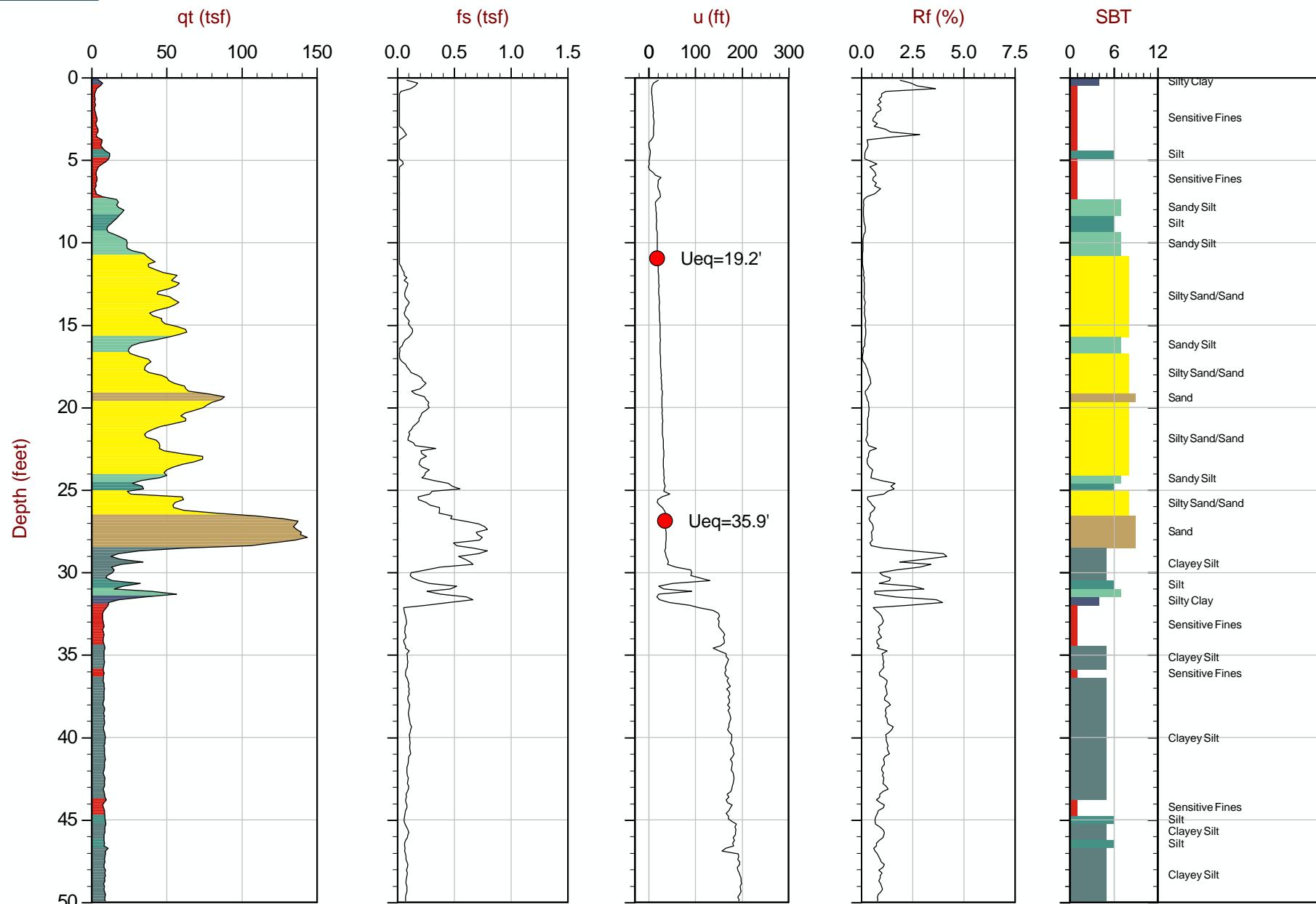
SBT: Lunne, Robertson and Powell, 1997
 Coords: Lat: 46.688640 Long: -92.200330
 ● Equilibrium Pore Pressure from Dissipation



Max Depth: 17.050 m / 55.94 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.150 m

File: 11-411CP309.COR
Unit Wt: SBT Chart Soil Zones

SBT: Lunne, Robertson and Powell, 1997
Coords: Lat: 46.688640 Long: -92.200330
● Equilibrium Pore Pressure from Dissipation



Max Depth: 15.250 m / 50.03 ft
 Depth Inc: 0.050 m / 0.164 ft
 Avg Int: 0.150 m

File: 11-411CP310.COR
 Unit Wt: SBT Chart Soil Zones

SBT: Lunne, Robertson and Powell, 1997
 Coords: Lat: 46.683980 Long: -92.200200
 ● Equilibrium Pore Pressure from Dissipation



EPC Engineering

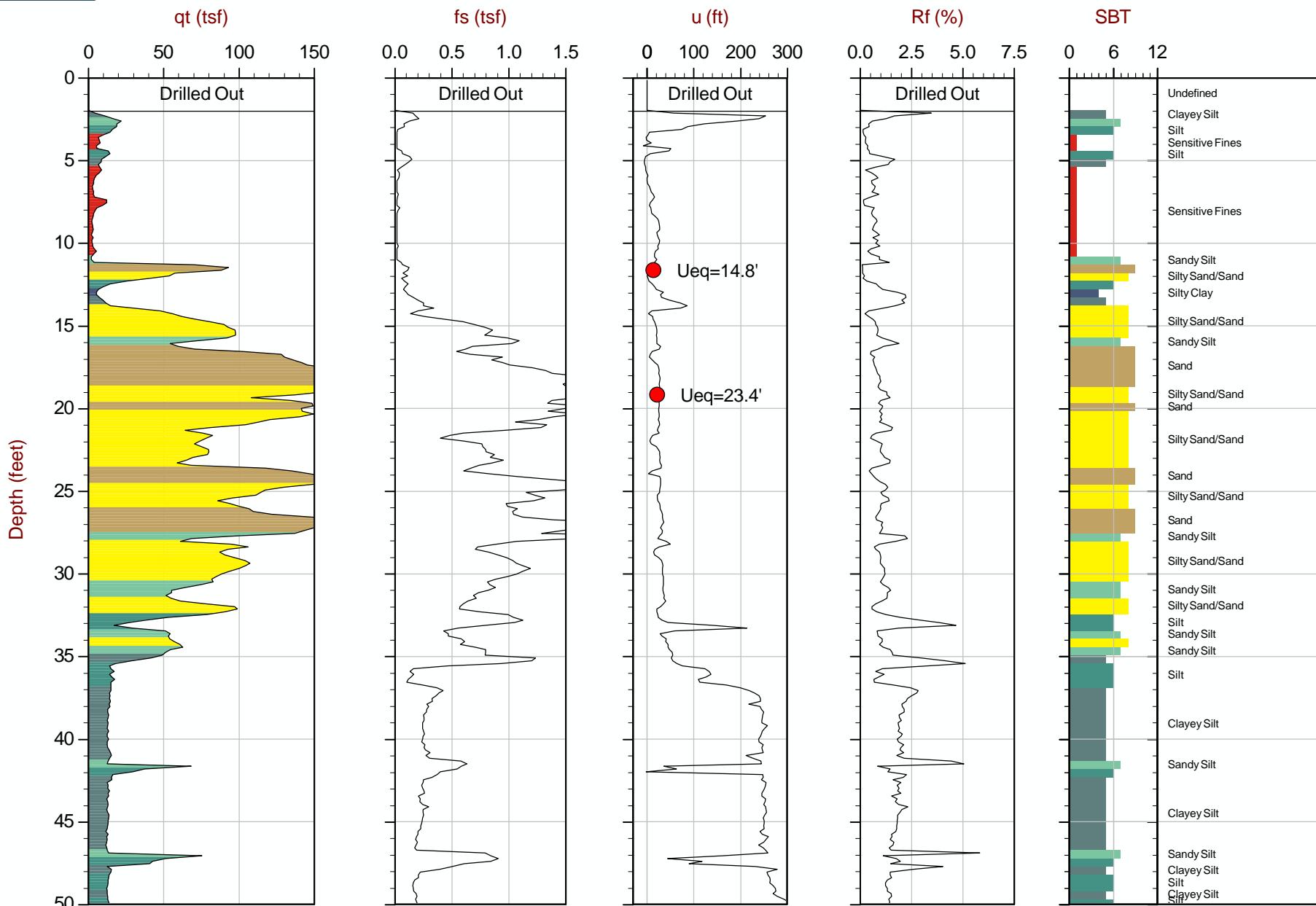
Job No: 11-41

Date: 10:27:11 14:41

Site: SPIRIT LAKE SEDIMENT STUDY

Sounding: CPT-311

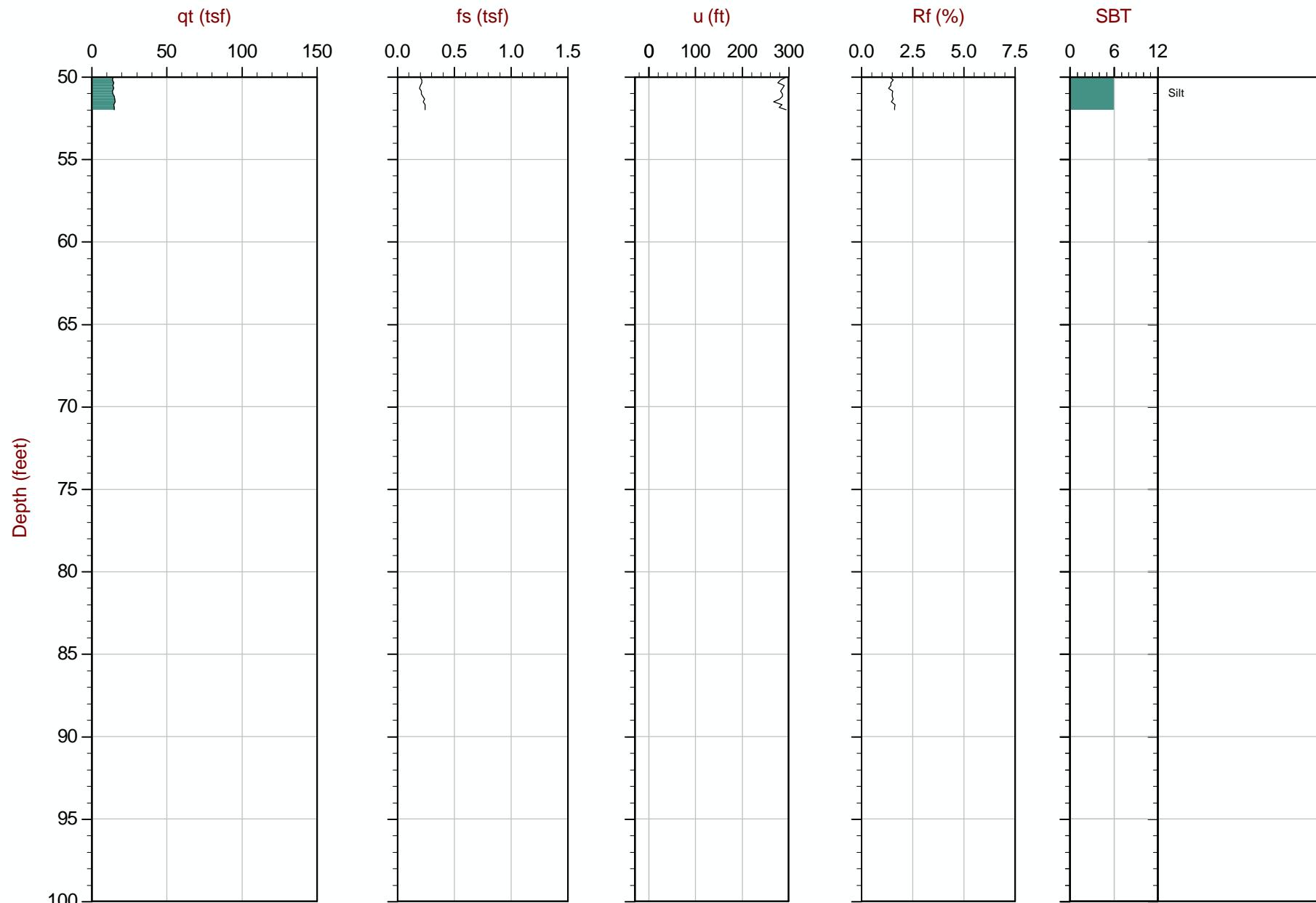
Cone: 155:T1500F15U500



Max Depth: 15.850 m / 52.00 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.150 m

File: 11-411CP311.COR
Unit Wt: SBT Chart Soil Zones

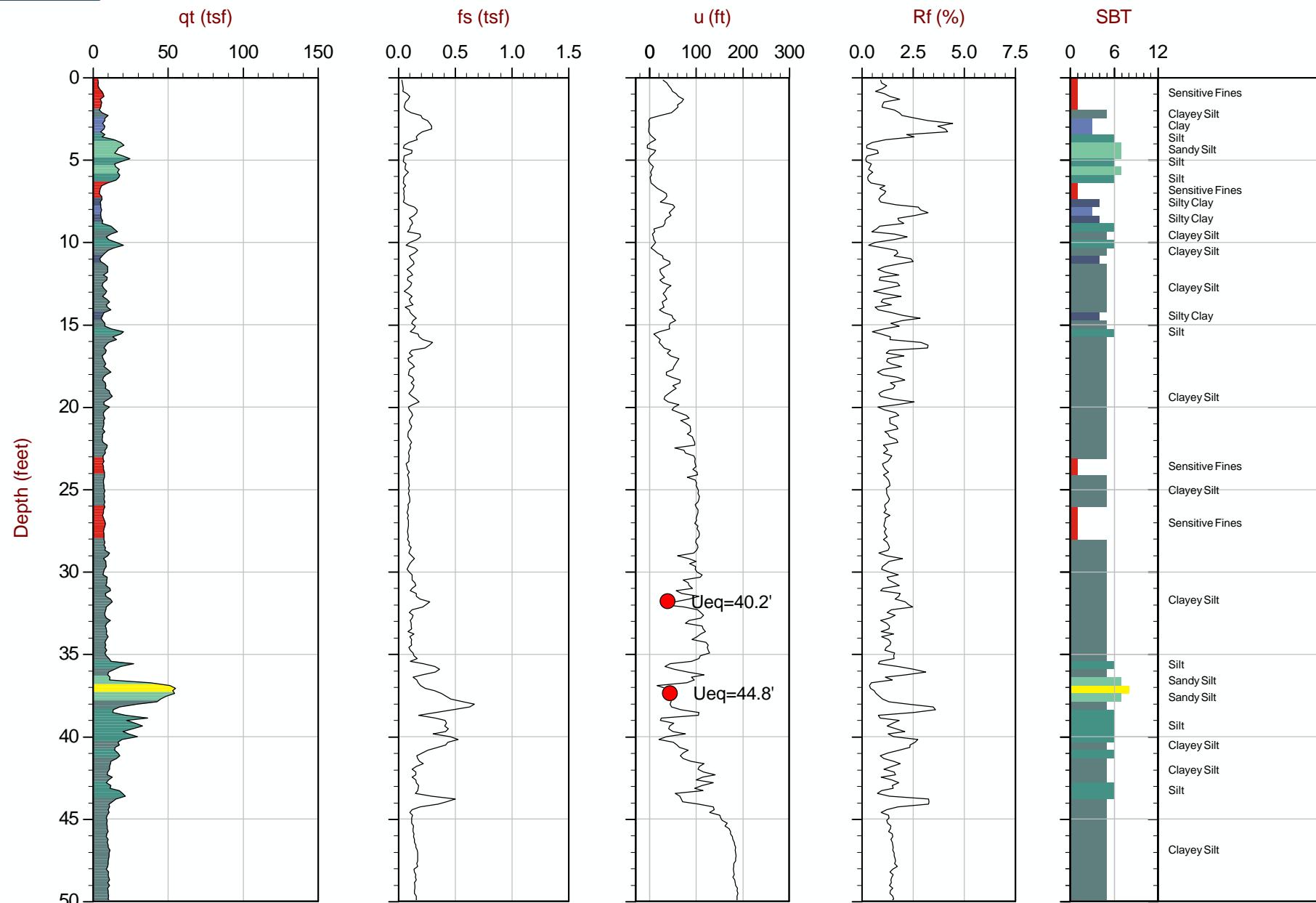
SBT: Lunne, Robertson and Powell, 1997
Coords: Lat: 46.682300 Long: -92.203270
● Equilibrium Pore Pressure from Dissipation



Max Depth: 15.850 m / 52.00 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.150 m

File: 11-411CP311.COR
Unit Wt: SBT Chart Soil Zones

SBT: Lunne, Robertson and Powell, 1997
Coords: Lat: 46.682300 Long: -92.203270
● Equilibrium Pore Pressure from Dissipation



Max Depth: 15.250 m / 50.03 ft
 Depth Inc: 0.050 m / 0.164 ft
 Avg Int: 0.150 m

File: 11-411CP314.COR
 Unit Wt: SBT Chart Soil Zones

SBT: Lunne, Robertson and Powell, 1997
 Coords: Lat: 46.677880 Long: -92.199360
 ● Equilibrium Pore Pressure from Dissipation



EPC Engineering

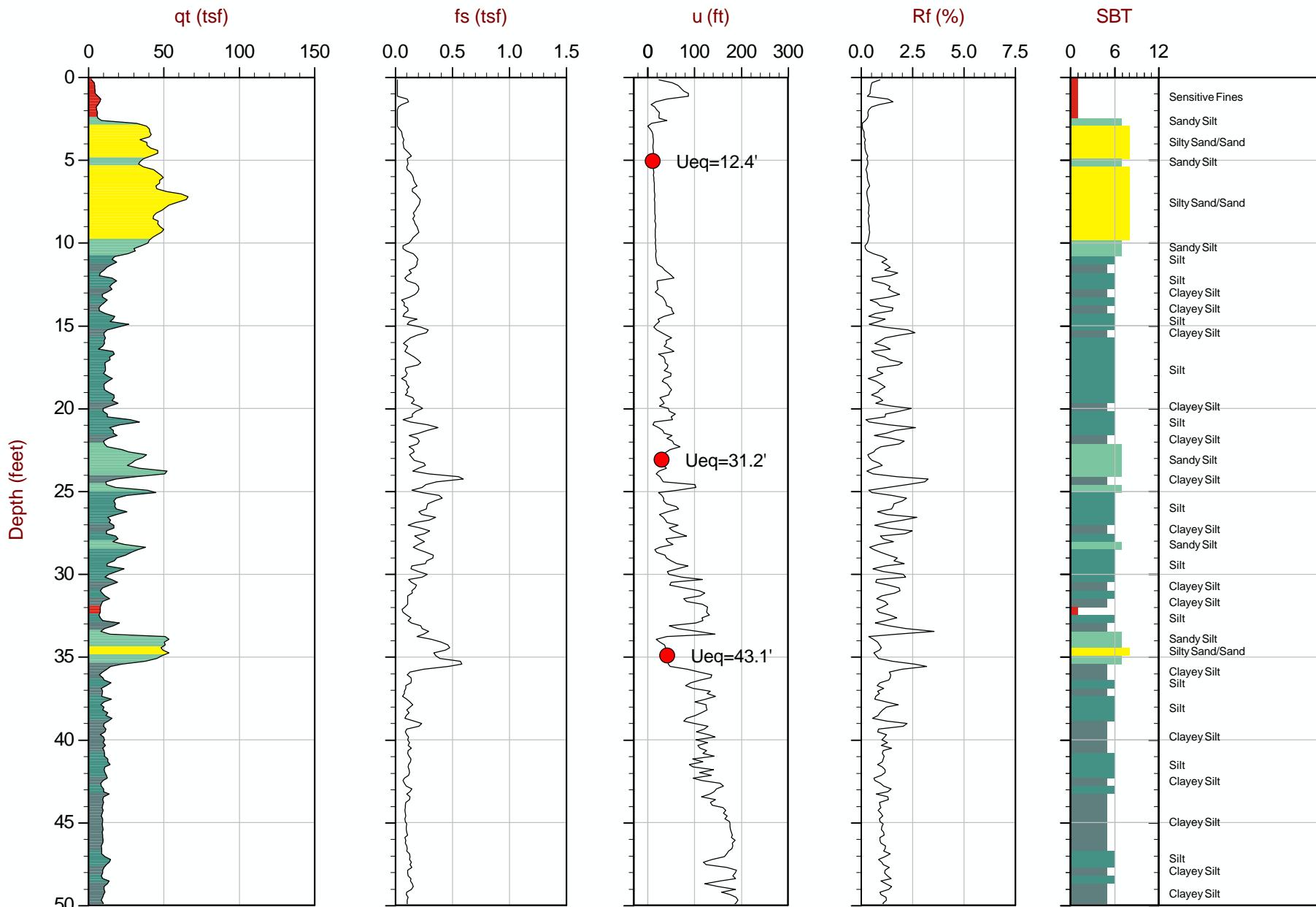
Job No: 11-4

Date: 10:28:11 11:06

Site: SPIRIT LAKE SEDIMENT STUDY

Sounding: CPT-315

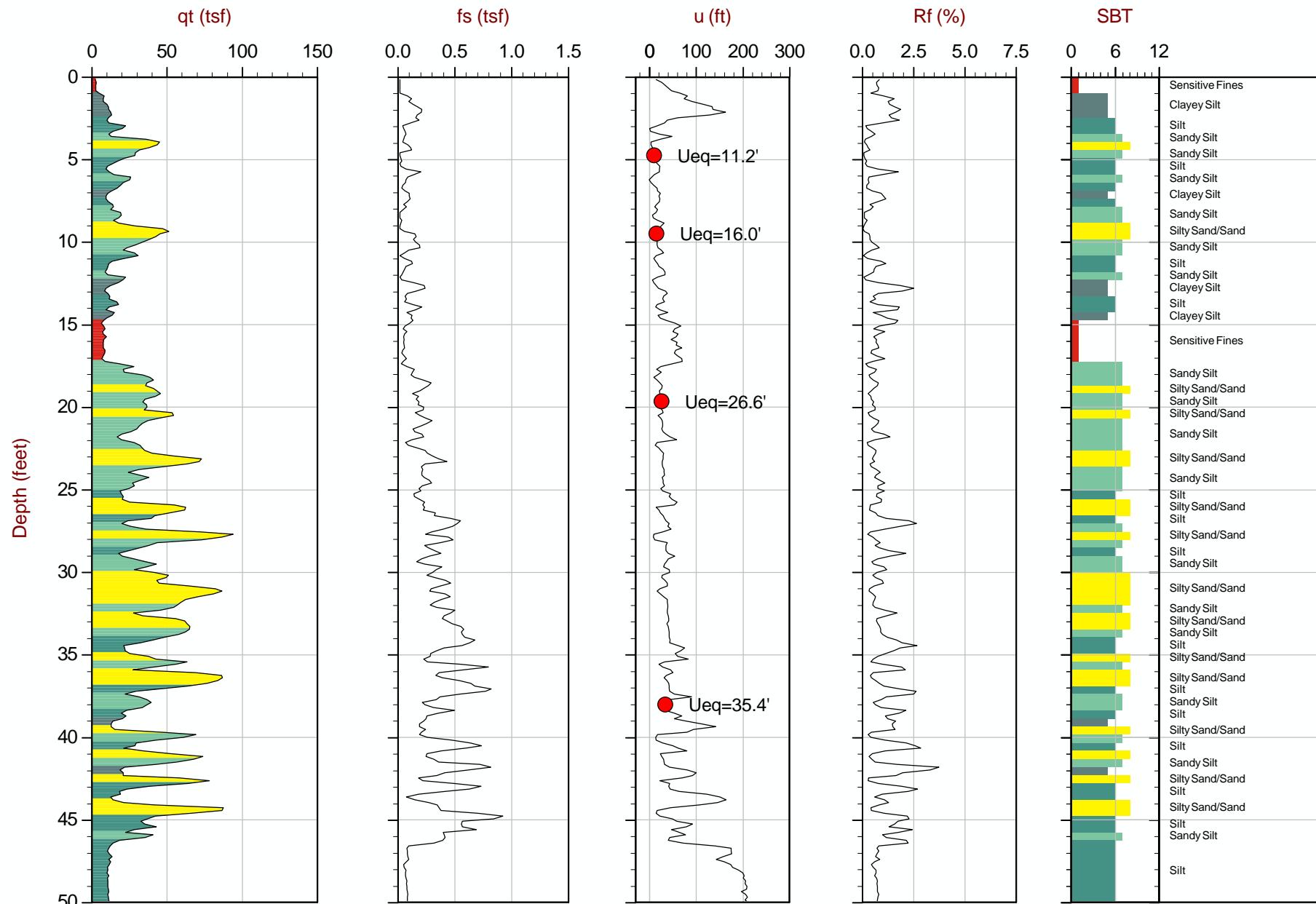
Cone: 155:T1500F15U500



Max Depth: 15.250 m / 50.03 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.150 m

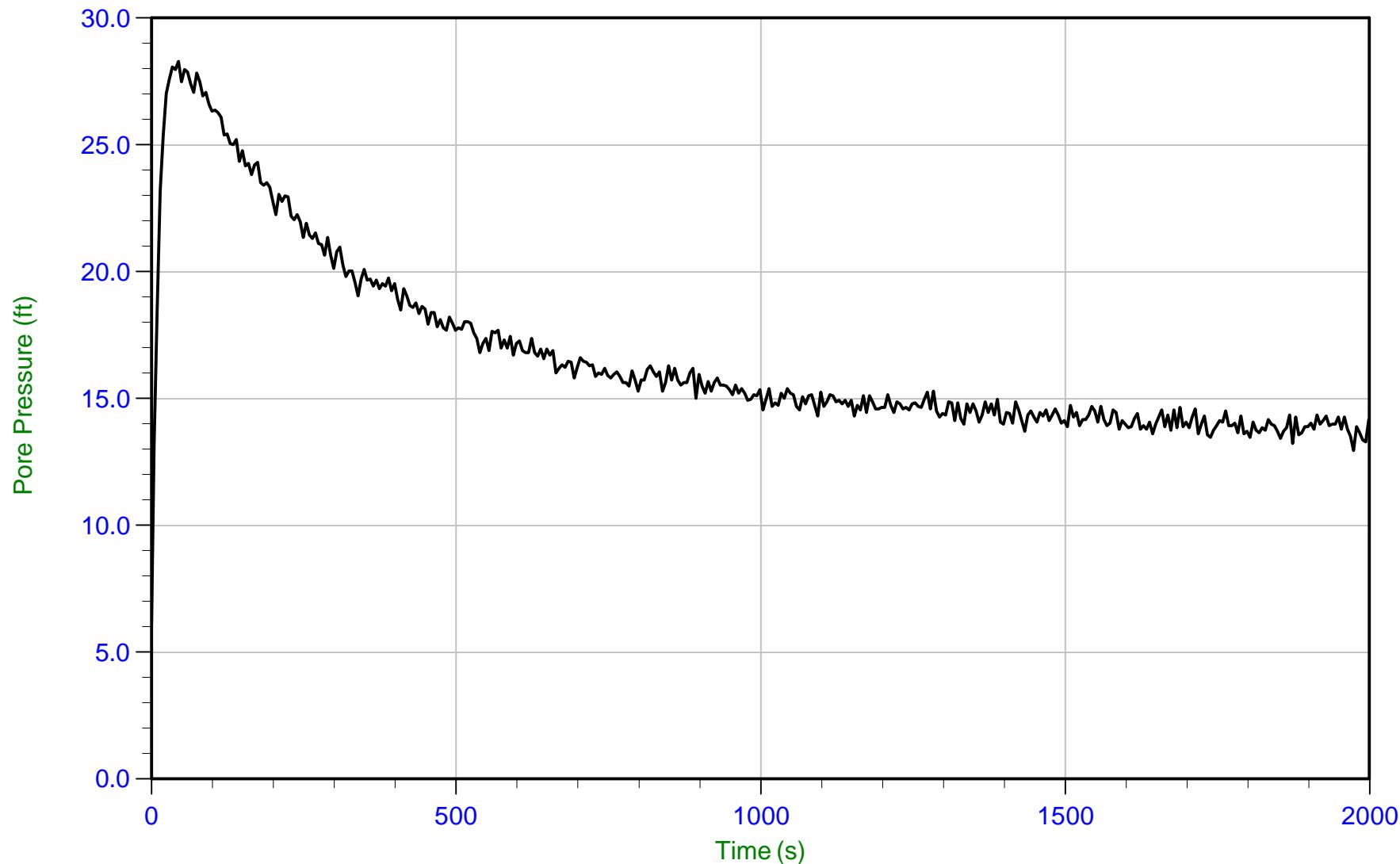
File: 11-411CP315.COR
Unit Wt: SBT Chart Soil Zones

SBT: Lunne, Robertson and Powell, 1997
Coords: Lat: 46.678830 Long: -92.196260
● Equilibrium Pore Pressure from Dissipation



Attachment F-3

Pore Pressure Dissipation (PPD) Plots



Trace Summary:

Filename: 11-411CP303.PPD

Depth: 1.800 m / 5.905 ft

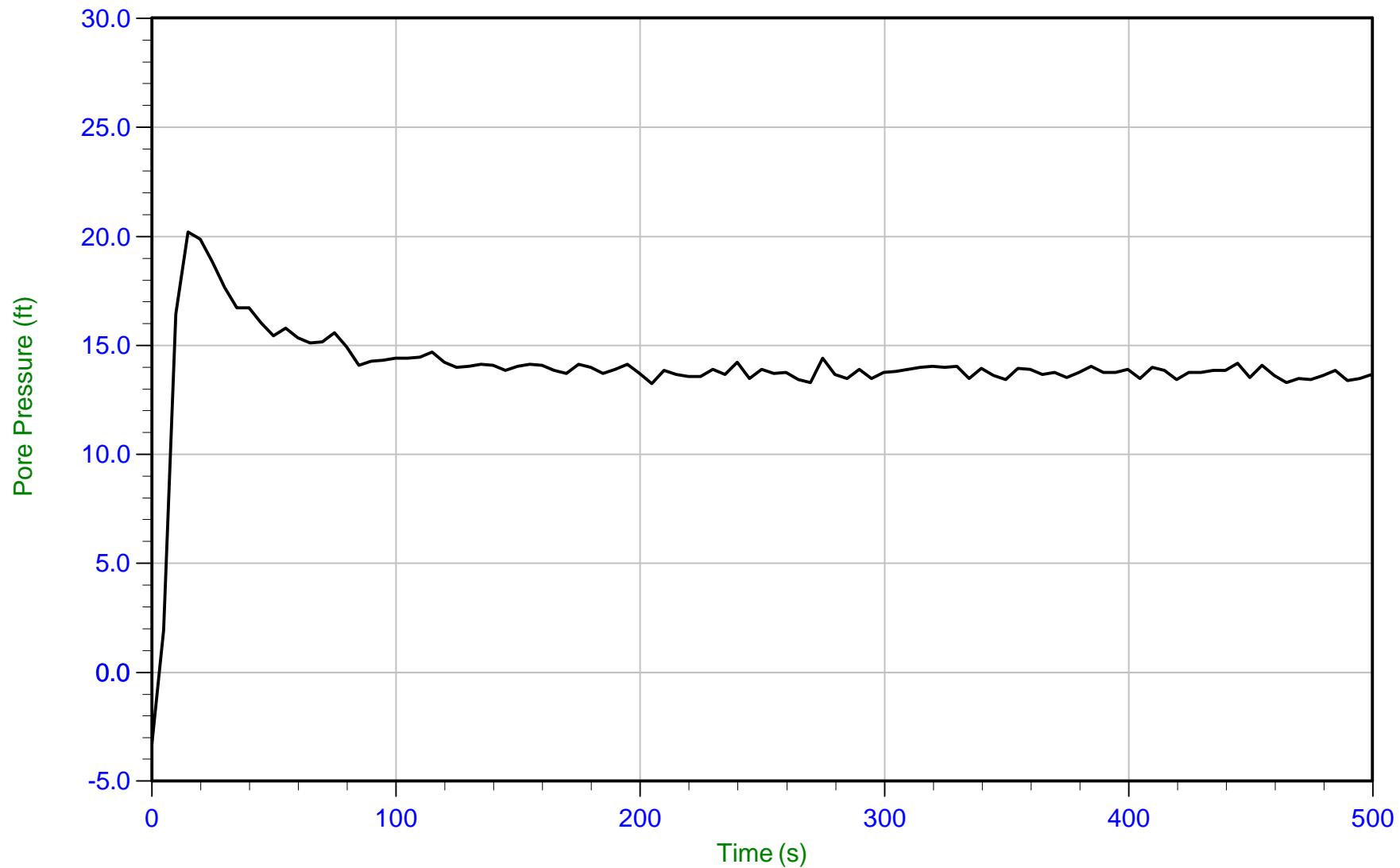
Duration: 2000.0 s

U Min: 6.1 ft

U Max: 28.3 ft

WT: -2.393 m / -7.851 ft

Ueq: 13.8 ft

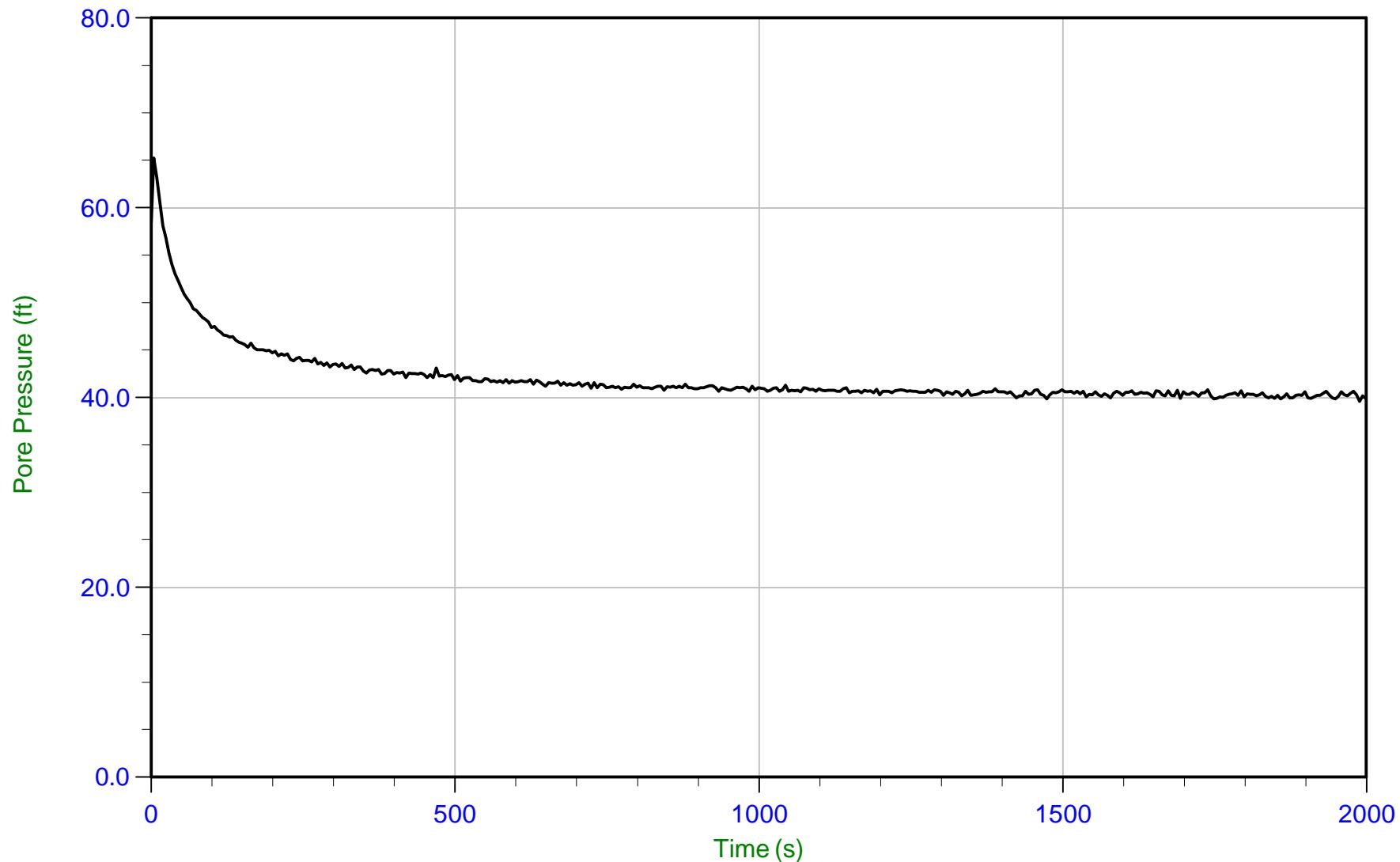


Trace Summary:

Filename: 11-411CP304.PPD
Depth: 1.400 m / 4.593 ft
Duration: 500.0 s

U Min: -3.3 ft
U Max: 20.2 ft

WT: -2.742 m / -8.996 ft
Ueq: 13.6 ft



Trace Summary:

Filename: 11-411CP314.PPD

U Min: 39.6 ft

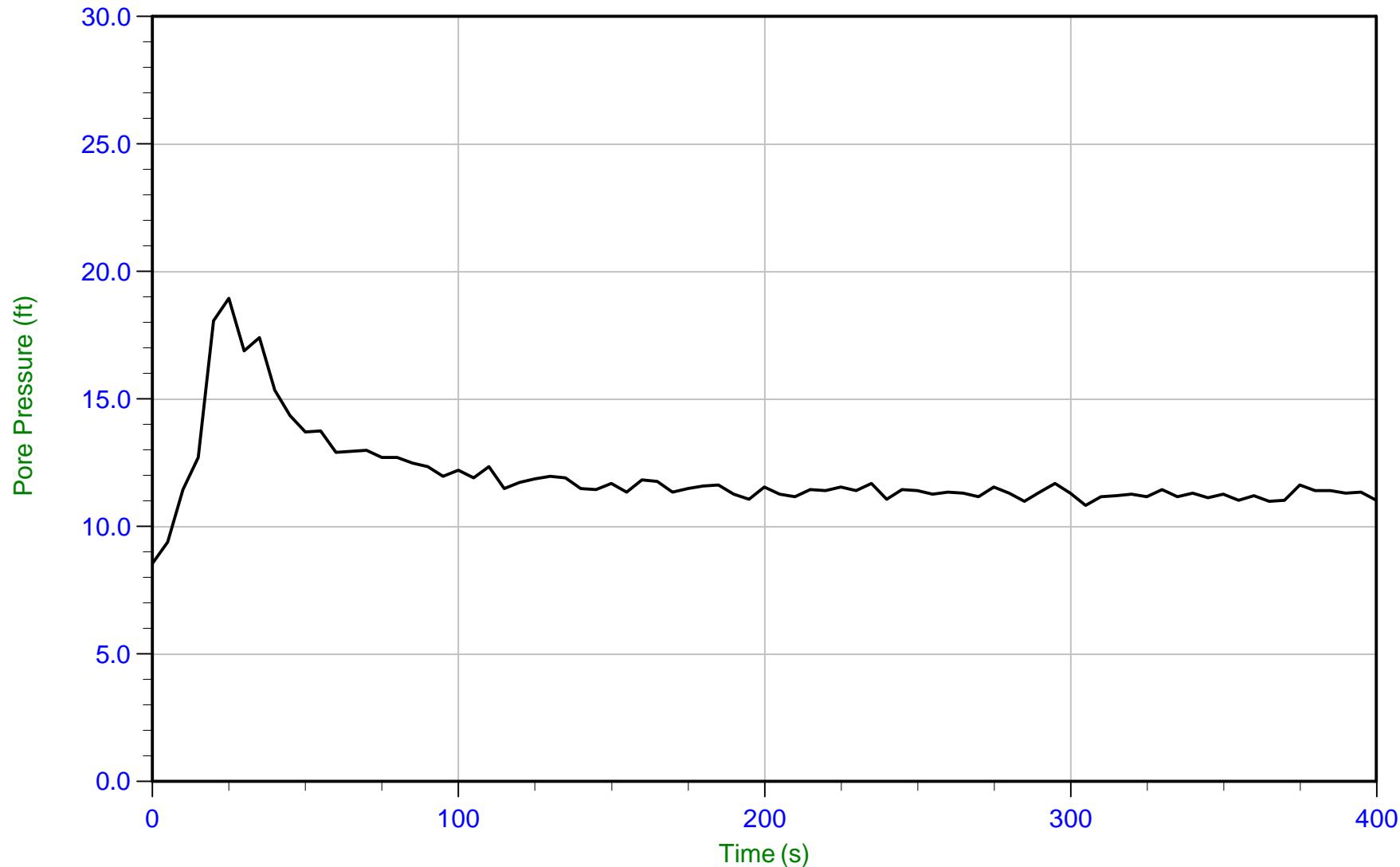
WT: -2.555 m / -8.382 ft

Depth: 9.700 m / 31.824 ft

U Max: 65.3 ft

Ueq: 40.2 ft

Duration: 2000.0 s



Trace Summary:

Filename: 11-411CP316.PPD

U Min: 8.5 ft

WT: -1.961 m / -6.434 ft

Depth: 1.450 m / 4.757 ft

U Max: 19.0 ft

Ueq: 11.2 ft

Duration: 400.0 s

Attachment F-4

Flat Plate Dilatometer (DMT) Data



Barr Engineering Company
DMT Spreadsheet- Data Summary
St Louis River Duluth Works Sediment
23/69-1125
Sounding No: UC-94
October 29, 2011

Water Depth (ft): -4.66

UTM, Zone 16N - NAD 83 (m)

Northing: 0.0

Easting: 0.0

¹ Depth Below Existing Ground Surface

² Mayne, 1995

³ Marchetti, 1980

⁴ Marchetti, 1997

⁵ Campanella and Robertson, 1991

⁶ Marchetti, 1980

⁷ Schmertman, 1981

Depth ¹ (ft)	A (bar)	B (bar)	po	p1 (psf)	u _o (psf)	s _{vo} (psf)	s _{vo'} (psf)	I _d	K _D (bar)	E _D	K _o	OCR ²	OCR ³	ϕ ⁴ (deg)	ϕ ⁵ (deg)	E _D (ksf)	s _u ⁶ (psf)	s _u ⁷ (psf)	M (ksf)
3.0	0.55	1.15	0.69	0.9	478	591	113	0.46	8.5	7	1.7	4.3	9.6			2.3	15	152	96 36
4.0	0.85	1.35	1.00	1.1	540	691	150	0.14	10.2	4	1.9	5.2	12.7			2.5	8	254	154 19
5.0	0.8	1.7	0.93	1.45	603	791	188	0.82	7.1	18	1.5	3.6	7.2			2.1	38	200	133 82
6.0	0.95	1.6	1.09	1.35	665	891	226	0.34	7.1	9	1.5	3.6	7.2			2.2	19	243	161 41
7.0	0.95	1.75	1.08	1.5	728	991	263	0.57	5.8	15	1.3	3.0	5.3			1.9	30	219	153 59
12.0	1.25	3.35	1.32	3.1	1040	1491	451	2.18	3.8	62	0.9			35.7	39.0	1.6	129		207
17.0	2.55	8.55	2.42	8.3	1352	1991	639	3.32	5.8	204	1.3			37.9	40.1	2.0	426		863
22.0	2.1	4.35	2.16	4.1	1664	2491	827	1.43	3.4	67	0.9			35.2	38.7	1.5	141		206
27.0	2.1	3.7	2.19	3.45	1976	2991	1015	1.01	2.6	44	0.7	1.3	1.5			1.1	91	304	260 104
32.0	2.9	4.05	3.01	3.8	2288	3491	1203	0.41	3.3	27	0.9	1.7	2.2			1.4	57	500	400 78
37.0	3	5.25	3.06	5	2600	3991	1391	1.07	2.7	67	0.7	1.4	1.6			1.2	141	450	379 170



Barr Engineering Company
DMT Spreadsheet- Data Summary
St Louis River Duluth Works Sediment
23/69-1125
Sounding No: UC-95
October 29, 2011

Water Depth (ft): -5.58

UTM, Zone 16N - NAD 83 (m)

Northing: 0.0

Easting: 0.0

¹ Depth Below Existing Ground Surface

² Mayne, 1995

³ Marchetti, 1980

⁴ Marchetti, 1997

⁵ Campanella and Robertson, 1991

⁶ Marchetti, 1980

⁷ Schmertman, 1981

Depth ¹ (ft)	A (bar)	B (bar)	po	p1 (psf)	u _o (psf)	s _{vo} (psf)	s _{vo'} (psf)	I _d	K _D	E _D (bar)	K _o	OCR ²	OCR ³	ϕ ⁴ (deg)	ϕ ⁵ (deg)	E _D (ksf)	s _u ⁶ (psf)	s _u ⁷ (psf)	M (ksf)	
6.6	0.3	1.3	0.45	1.05	762	1011	249	7.42	0.7	21	0.1			25.5	#NUM!	0.9	44		37	
7.8	0.3	1.35	0.44	1.10	834	1126	293	14.73	0.3	23	-0.1			20.2	#NUM!	0.9	48		40	
8.9	0.65	1.95	0.78	1.70	905	1241	336	2.64	2.2	32	0.6			32.7	37.2	1.1	67		76	
9.9	0.85	3.15	0.93	2.90	967	1340	373	4.20	2.6	68	0.7			33.7	37.9	1.3	143		191	
14.5	1.3	1.95	1.46	1.70	1253	1799	545	0.27	3.3	8	0.8	1.7	2.2			1.4	17	225	180	23
19.6	1.65	2.25	1.82	2.00	1571	2307	737	0.17	3.0	6	0.8	1.5	1.9			1.3	13	271	222	17
24.5	2.25	6.55	2.23	6.30	1878	2800	922	3.05	3.0	141	0.8			34.5	38.3	1.5	295		430	
29.6	1.05	2	1.20	1.75	2195	3308	1113	3.73	0.3	19	-0.1			19.2	#NUM!	0.9	40		34	
34.5	3.45	4.45	3.60	4.20	2502	3800	1298	0.25	3.9	21	1.0	2.0	2.8			1.5	44	649	501	67
37.3	3.9	4.95	4.04	4.70	2676	4079	1403	0.24	4.1	23	1.0	2.1	3.1			1.6	48	760	577	76



Barr Engineering Company
DMT Spreadsheet- Data Summary
St Louis River Duluth Works Sediment
23/69-1125
Sounding No: UC-96
October 29, 2011

Water Depth (ft): -1.75

UTM, Zone 16N - NAD 83 (m)

Northing: 0.0

Easting: 0.0

¹ Depth Below Existing Ground Surface

² Mayne, 1995

³ Marchetti, 1980

⁴ Marchetti, 1997

⁵ Campanella and Robertson, 1991

⁶ Marchetti, 1980

⁷ Schmertman, 1981

Depth ¹ (ft)	A (bar)	B (bar)	po	p1 (psf)	u _o (psf)	s _{vo} (psf)	s _{vo'} (psf)	I _d	K _D (bar)	E _D	K _o	OCR ²	OCR ³	ϕ ⁴ (deg)	ϕ ⁵ (deg)	E _D	s _u ⁶ (ksf)	s _u ⁷ (psf)	M (ksf)
1.1	0.7	2.55	0.78	2.30	181	224	43	2.20	33.4	53	3.7			45.4	43.9	3.6	110		402
2.1	0.3	0.9	0.44	0.65	242	322	80	0.65	8.4	7	1.7	4.3	9.4			2.3	15	107	68
3.3	0.3	0.75	0.45	0.50	314	437	123	0.18	5.0	2	1.2	2.6	4.2			1.8	4	86	62
4.4	0.3	0.8	0.45	0.55	386	552	167	0.40	3.3	4	0.8	1.7	2.1			1.4	8	68	54
5.4	0.35	0.85	0.50	0.60	447	651	204	0.37	2.9	4	0.8	1.5	1.8			1.2	8	71	59
6.6	0.45	0.95	0.60	0.70	519	765	247	0.30	2.9	4	0.8	1.5	1.8			1.2	8	88	72
7.7	0.5	1	0.65	0.75	590	880	290	0.29	2.6	4	0.7	1.3	1.5			1.1	8	89	76
8.7	0.55	1.15	0.69	0.90	652	979	327	0.56	2.4	7	0.7	1.2	1.3			1.0	15	91	79
9.8	0.65	1.2	0.79	0.95	723	1094	370	0.35	2.5	5	0.7	1.3	1.4			1.1	11	109	93
11.0	0.75	2.05	0.86	1.80	795	1208	413	1.99	2.4	33	0.6			33.2	37.6	1.2	68		80
12.0	1.15	3.75	1.19	3.50	856	1307	450	2.96	3.6	80	0.9			35.5	38.9	1.6	167		270
13.1	1.4	4.7	1.41	4.45	928	1422	493	3.17	4.1	106	1.0			36.1	39.2	1.7	221		379
14.3	1.75	5.1	1.75	4.85	1000	1536	537	2.43	5.0	107	1.2			37.1	39.7	1.9	224		419
15.3	1.95	5.55	1.94	5.30	1061	1635	574	2.35	5.2	117	1.2			37.4	39.8	1.9	244		464



Barr Engineering Company
DMT Spreadsheet- Data Summary
St Louis River Duluth Works Sediment
23/69-1125
Sounding No: WM-100
October 29, 2011

Water Depth (ft): -4.75

UTM, Zone 16N - NAD 83 (m)

Northing: 0.0

Easting: 0.0

¹ Depth Below Existing Ground Surface

² Mayne, 1995

³ Marchetti, 1980

⁴ Marchetti, 1997

⁵ Campanella and Robertson, 1991

⁶ Marchetti, 1980

⁷ Schmertman, 1981

Depth ¹ (ft)	A (bar)	B (bar)	po	p1 (psf)	u _o (psf)	s _{vo} (psf)	s _{vo'} (psf)	I _d	K _D	E _D (bar)	K _o	OCR ²	OCR ³	ϕ ⁴ (deg)	ϕ ⁵ (deg)	E _D (ksf)	s _u ⁶ (psf)	s _u ⁷ (psf)	M (ksf)
3.0	0.45	1	0.59	0.75	484	596	113	0.44	6.7	5	1.4	3.4	6.6			2.1	11	112	75 24
4.0	0.65	1.3	0.79	1.05	546	696	150	0.50	7.3	9	1.5	3.7	7.5			2.2	19	167	110 41
5.0	0.8	1.3	0.95	1.05	608	796	188	0.16	7.3	4	1.5	3.7	7.5			2.2	8	207	137 17
10.0	1	1.5	1.15	1.25	920	1296	376	0.15	3.9	4	1.0	2.0	2.8			1.5	8	191	147 12
15.0	1.45	3.2	1.53	2.95	1232	1796	564	1.50	3.5	49	0.9			35.3	38.8	1.5	103		152
20.0	1.7	3.55	1.78	3.30	1544	2296	752	1.47	2.9	53	0.8			34.3	38.2	1.3	110		143
25.0	3.1	6.65	3.09	6.40	1856	2796	940	1.50	4.9	115	1.1			37.1	39.7	1.8	240		434
30.0	5.75	7.85	5.82	7.60	2168	3296	1128	0.37	8.8	62	1.7	4.5	10.2			2.4	129	1591	998 307
35.0	5.65	7.85	5.71	7.60	2480	3796	1316	0.42	7.2	66	1.5	3.7	7.3			2.2	137	1430	945 296

Attachment F-5

Laboratory Testing Data

Grain Size Distribution ASTM D422

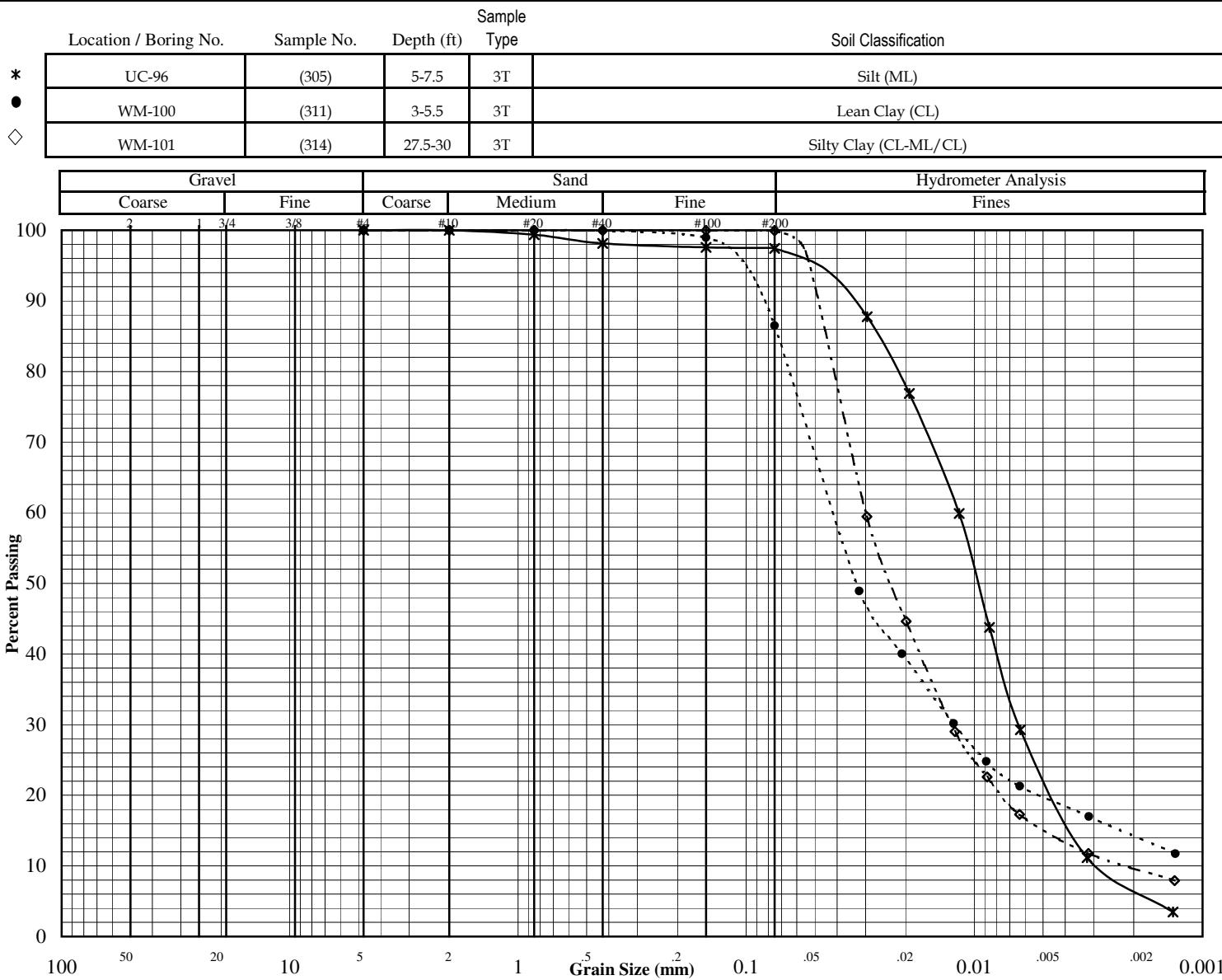
Job No. : 8192-A

Project: Spirit Lake Sediment Site - Former US Steel Duluth Works

Test Date: 1/25/12

Reported To: Barr Engineering Company

Report Date: 1/31/12



	Other Tests		
	*	●	◇
Liquid Limit	46.8	28.5	28.1
Plastic Limit	34.5	19.8	21.4
Plasticity Index	12.3	8.7	6.7
Water Content			
Dry Density (pcf)			
Specific Gravity	2.71*	2.71*	2.71*
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

	Percent Passing		
	*	●	◇
Mass (g)	92.9	118.5	144.9
2"			
1.5"			
1"			
3/4"			
3/8"			
#4	100.0	100.0	100.0
#10	100.0	100.0	100.0
#20	99.4	100.0	100.0
#40	98.1	100.0	100.0
#100	97.6	99.0	100.0
#200	97.4	86.5	99.9

	*	●	◇
D ₆₀			
D ₃₀			
D ₁₀			
C _U			
C _C			

Remarks:

Hydraulic Conductivity Test Data

Project: Spirit Lake Sediment Site - Former US Steel Duluth Works Date: 2/7/2012

Reported To: Barr Engineering Company Job No.: 8192-A

Boring No.:	UC-96	WM-100	WM-101				
Sample No.:	305	311	314				
Depth (ft)	5-7.5	3-5.5	27.5-30				
Location:							
Sample Type:	3T	3T	3T				
	Organic Clay (OH)	Lean Clay (CL)	Silty Clay (CL-ML/CL)				
Soil Type:							
Atterberg Limits							
LL	78.6	28.5	28.1				
PL	41.8	19.8	21.4				
PI	36.8	8.7	6.7				
Permeability Test	Undisturbed	Undisturbed	Undisturbed				
Before Test Conditions:							
Saturation %:							
Porosity:							
Ht. (in):	1.45	2.76	2.74				
Dia. (in):	2.88	2.85	2.91				
Dry Density (pcf):	48.3	94.0	88.6				
Water Content:	96.7%	28.3%	31.2%				
Test Type:	Falling	Falling	Falling				
Max Head (ft):	5.0	5.0	5.0				
Confining press. (Effective-psi):	2.0	2.0	2.0				
Trial No.:	7-11	9-13	8-12				
Water Temp °C:	21.0	21.0	21.0				
% Compaction							
% Saturation (After Test)							

Coefficient of Permeability

K @ 20 °C (cm/sec)	2.0 x 10 ⁻⁶	3.0 x 10 ⁻⁷	1.1 x 10 ⁻⁶				
K @ 20 °C (ft/min)	4.0 x 10 ⁻⁶	5.8 x 10 ⁻⁷	2.1 x 10 ⁻⁶				

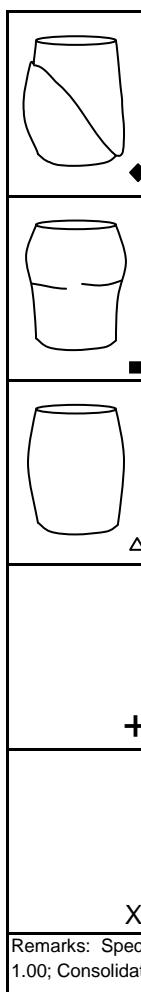
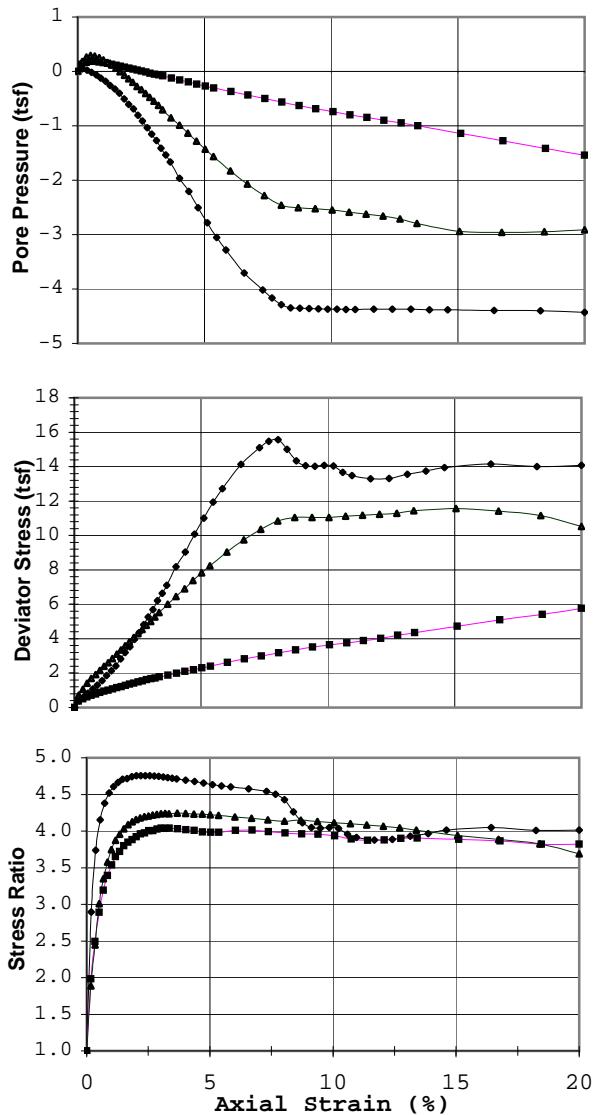
Notes:

TRIAXIAL TEST ASTM: D 4767

Job No. 8192-A

Date: 2/16/12

Project: Spirit Lake Sediment Site - Former US Steel Duluth Works
 Boring #: 304 Sample #: 3T Depth (ft): 10.5-13 (Mid)
 Soil Type: Specimen A: Silty Sand (SM) Specimens B and C: Sandy Silt to Silt w/sand (ML)



Failure Criterion:

Max. Stress Ratio

Angle of internal friction, $\phi' = 38.9^\circ$

Apparent Cohesion, $c' = 0.00$ (tsf)

Test Date: 1/26/12

Liquid Limit:

Test Type: CU w/pp

Plastic Limit:

Strain Rate (in/min): 0.001369

Plasticity Index:

Strain Rate (%/min): 0.050

Spec. Gravity (Assumed): 2.69

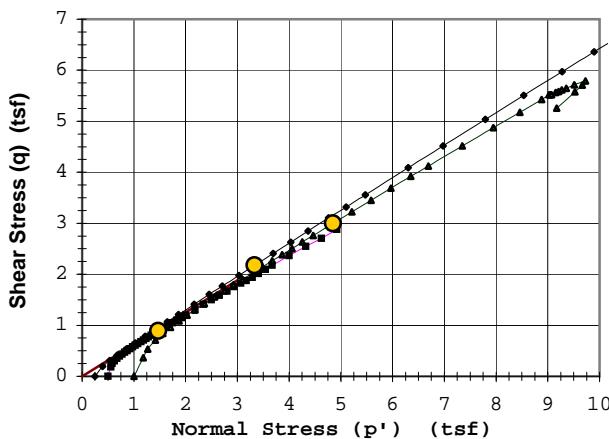
Before Consolidation

A	B	C	D	E
1.45	1.45	1.45		
2.74	2.99	2.99		
24.6	25.8	21.9		
97.3	96.3	104.1		
0.73	0.74	0.61		

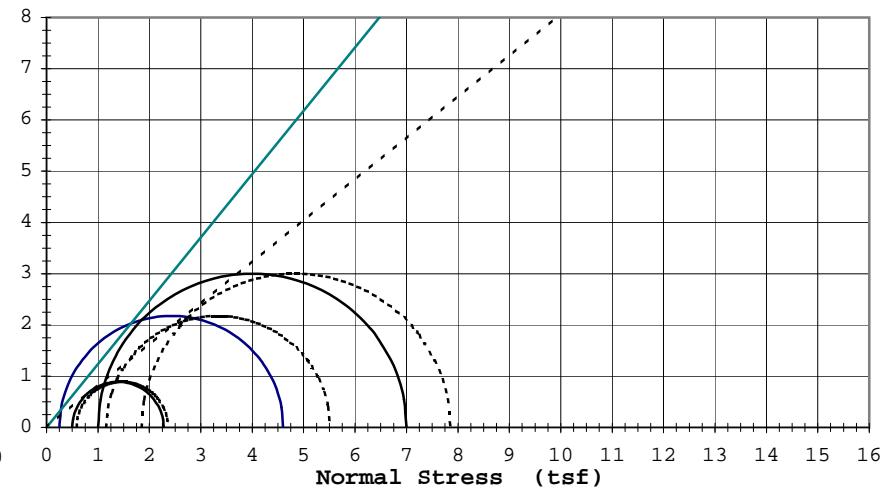
"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"

Remarks: Specimen trimmed to given dimensions; Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared.

Specimens varied significantly in sand content from a Silty Sand (SM) for the 0.25 tsf specimen A to the Silt w/sand (ML) for specimens B and C.



Rupture Envelope at Failure
 $\phi' = 32.1^\circ$
 $a = 0.0$ (tsf)



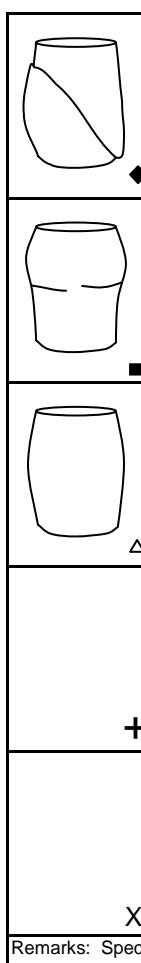
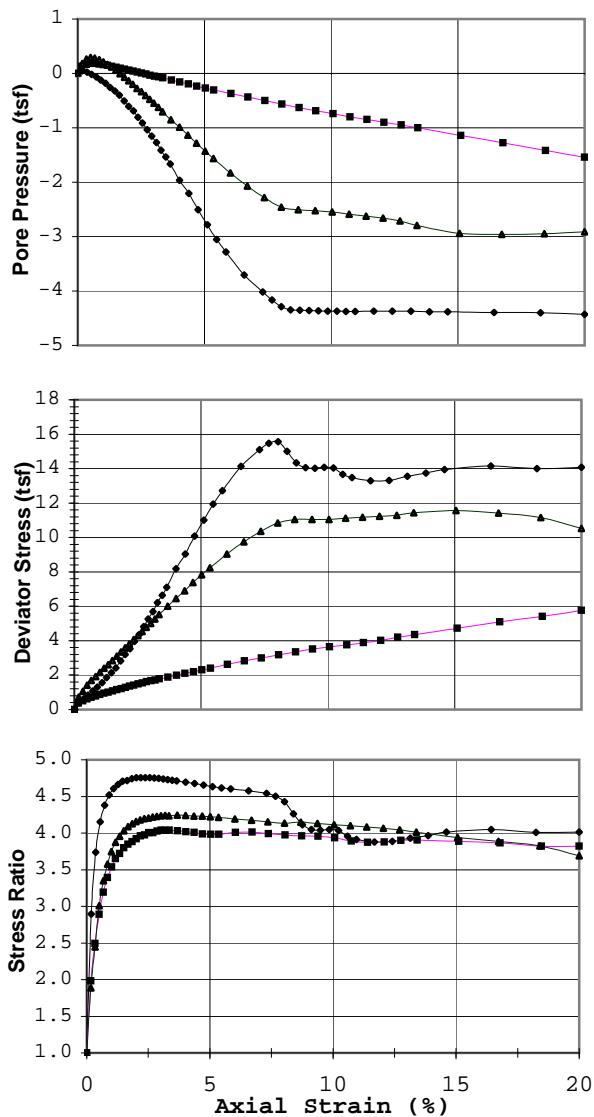
----- Effective $\phi' = 38.9^\circ$ $c' = 0.00$ (tsf)
 _____ Total $\phi' = 51.0^\circ$ $c = 0.00$ (tsf)

TRIAXIAL TEST ASTM: D 4767

Job No. 8192-A

Date: 2/16/12

Project: Spirit Lake Sediment Site - Former US Steel Duluth Works
 Boring #: 304 Sample #: 3T Depth (ft): 10.5-13 (Mid)
 Soil Type: Specimen A: Silty Sand (SM) Specimens B and C: Sandy Silt to Silt w/sand (ML)

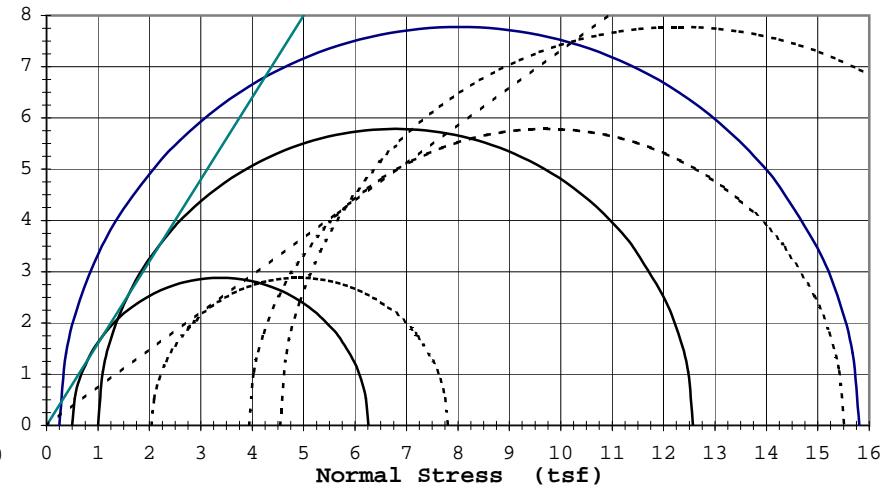
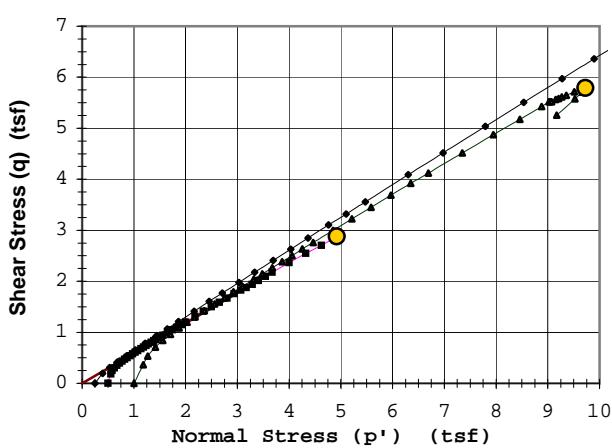


Failure Criterion:		Max. Deviator Stress		
Angle of internal friction, $\phi' = 36.2^\circ$				
Apparent Cohesion, $c' = 0.00 \text{ (tsf)}$				
Test Date: 1/26/12		Liquid Limit:		
Test Type: CU w/pp		Plastic Limit:		
Strain Rate (in/min): 0.001369		Plasticity Index:		
Strain Rate (%/min): 0.050		Spec. Gravity (Assumed): 2.69		
Before Consolidation				
Diameter (in)		A 1.45	B 1.45	C 1.45
Height (in)		2.74	2.99	2.99
Water Content (%)		24.6	25.8	21.9
Dry Density (pcf)		97.3	96.3	104.1
Void Ratio		0.73	0.74	0.61
After Consolidation				
Diameter (in)		1.45	1.44	1.44
Height (in)		2.74	2.98	2.99
Water Content (%)		26.9	27.0	22.2
Dry Density (pcf)		97.4	97.3	105.2
Void Ratio		0.72	0.73	0.60
Back Pressure (tsf)		5.8	5.8	5.8
Minor Principal Stress (tsf)		0.25	0.50	1.00
Max. Deviator Stress (tsf)		15.56	5.76	11.57
Ultimate Deviator Stress (tsf)		14.08	5.76	10.52
Deviator Stress at Failure (tsf)		15.56	5.76	11.57
Max. Pore Pressure Buildup (tsf)		0.05	0.18	0.29
Pore Pressure Parameter "B"		1.0	1.0	1.0
Pct. Axial Strain at Failure		8.0	20.0	15.1

"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"

Remarks: Specimen trimmed to given dimensions; Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared.

Specimens varied significantly in sand content from a Silty Sand (SM) for the 0.25 tsf specimen A to the Silt w/sand (ML) for specimens B and C.

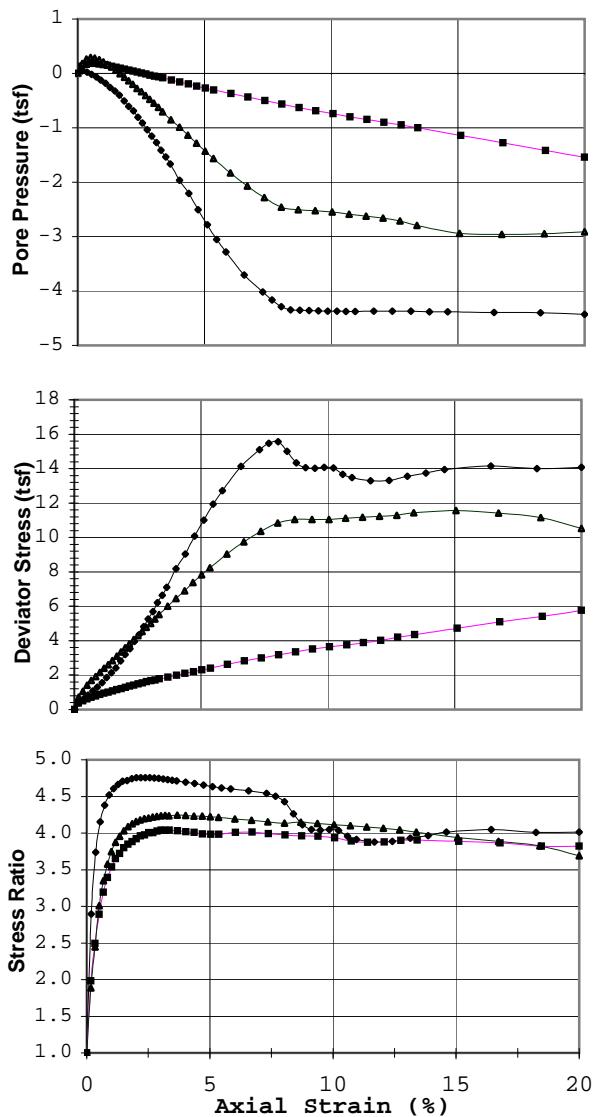


TRIAXIAL TEST ASTM: D 4767

Job No. 8192-A

Date: 2/16/12

Project: Spirit Lake Sediment Site - Former US Steel Duluth Works
 Boring #: 304 Sample #: 3T Depth (ft): 10.5-13 (Mid)
 Soil Type: Specimen A: Silty Sand (SM) Specimens B and C: Sandy Silt to Silt w/sand (ML)

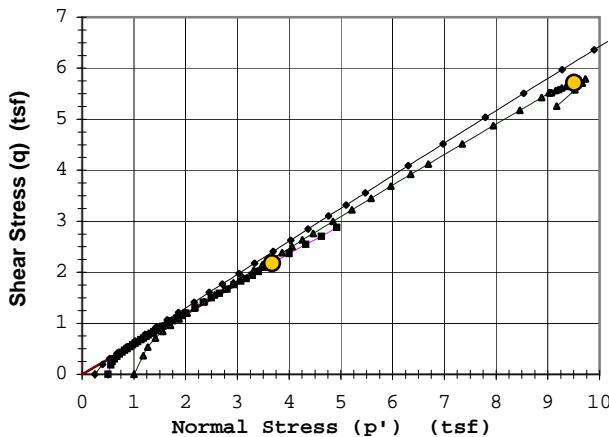


 	Failure Criterion: Given Strain of: 15%				
	Angle of internal friction, ϕ' =	36.2 °			
	Apparent Cohesion, c' =	0.00 (tsf)			
	Test Date:	1/26/12	Liquid Limit:		
	Test Type:	CU w/pp	Plastic Limit:		
	Strain Rate (in/min):	0.001369	Plasticity Index:		
	Strain Rate (%/min):	0.050	Spec. Gravity (Assumed):		
			2.69		
	<i>Before Consolidation</i>				
	Diameter (in)	A	B	C	D
	Height (in)	1.45	1.45	1.45	
	Water Content (%)	2.74	2.99	2.99	
	Dry Density (pcf)	24.6	25.8	21.9	
	Void Ratio	97.3	96.3	104.1	
		0.73	0.74	0.61	
	<i>After Consolidation</i>				
	Diameter (in)	1.45	1.44	1.44	
	Height (in)	2.74	2.98	2.99	
	Water Content (%)	26.9	27.0	22.2	
	Dry Density (pcf)	97.4	97.3	105.2	
	Void Ratio	0.72	0.73	0.60	
	Back Pressure (tsf)	5.8	5.8	5.8	
	Minor Principal Stress (tsf)	0.25	0.50	1.00	
	Max. Deviator Stress (tsf)	15.56	5.76	11.57	
	Ultimate Deviator Stress (tsf)	14.08	5.76	10.52	
	Deviator Stress at Failure (tsf)	13.95	4.35	11.43	
	Max. Pore Pressure Buildup (tsf)	0.05	0.18	0.29	
	Pore Pressure Parameter "B"	1.0	1.0	1.0	
	Pct. Axial Strain at Failure	15.0	15.0	15.0	

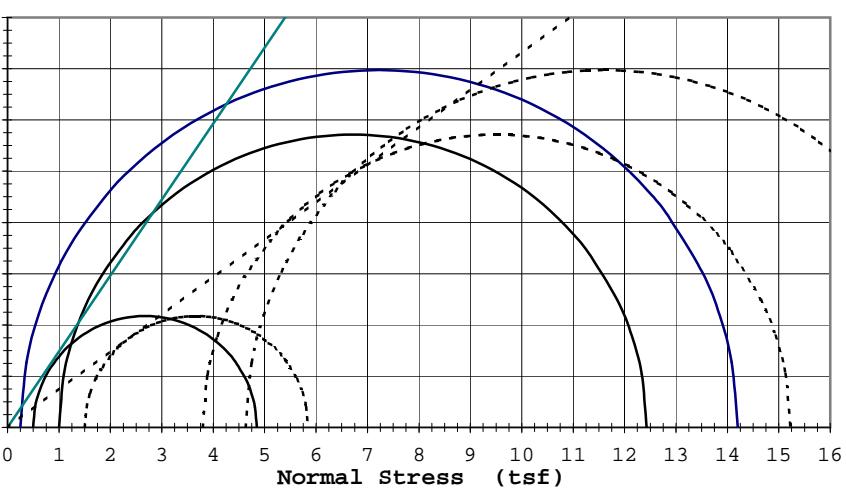
"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"

Remarks: Specimen trimmed to given dimensions; Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared.

Specimens varied significantly in sand content from a Silty Sand (SM) for the 0.25 tsf specimen A to the Silt w/sand (ML) for specimens B and C.



Rupture Envelope at Failure
 $= 30.6^\circ$ $a = 0.0$ (tsf)



Boring:

304

Sample:

Triaxial Data

Job: **8192-A**
Date: **2/16/12**

TRIAXIAL TEST ASTM: D 4767

Job No. 8192-A

Date: 2/16/12

Project:

Spirit Lake Sediment Site - Former US Steel Duluth Works

Boring #:

UC-96

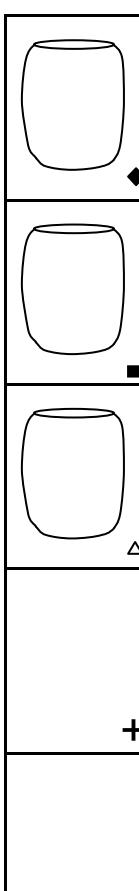
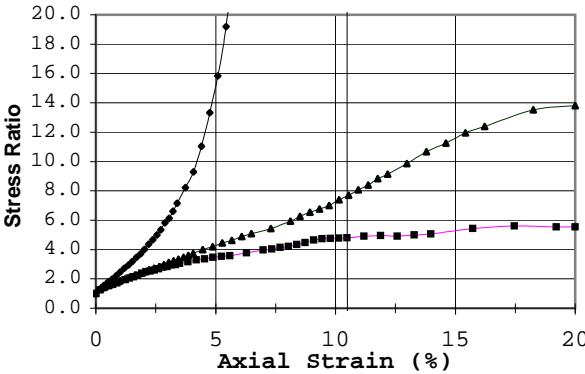
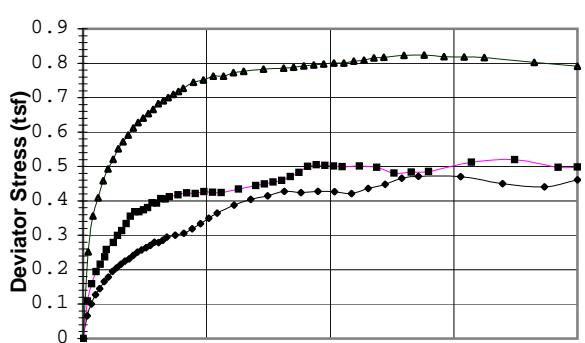
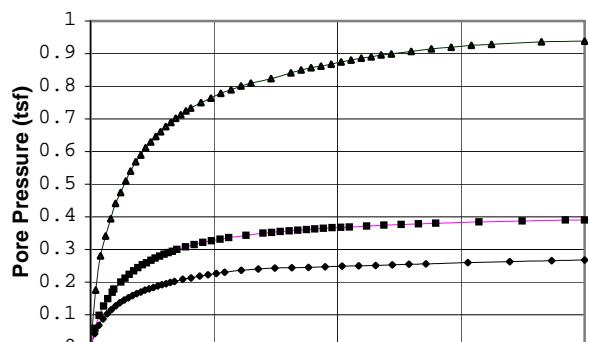
Sample #: 305

Type: 3T

Depth (ft): 17.5-20

Soil Type:

Organic Clay (OH) **



Failure Criterion:

Max. Stress Ratio

Angle of internal friction, $\phi' = 16.8^\circ$

Apparent Cohesion, $c' = 0.16 \text{ (tsf)}$

Test Date: 1/27/12

Liquid Limit:

Test Type: CU w/pp

Plastic Limit:

Strain Rate (in/min): 0.00147

Plasticity Index:

Strain Rate (%/min): 0.050

Spec. Gravity (Assumed): 2.69

Before Consolidation

A

1.45

2.99

133.9

35.1

3.79

B

1.45

2.99

115.8

39.2

3.28

C

1.45

2.74

122.9

37.7

3.46

D

1.45

2.74

122.9

37.7

3.46

E

1.45

2.74

122.9

37.7

3.46

After Consolidation

A

1.43

2.95

134.1

36.4

3.61

5.8

0.25

0.47

0.46

0.43

0.27

1.0

10.2

B

1.40

2.86

105.9

43.6

2.85

5.8

0.50

0.52

0.50

0.52

0.94

1.0

17.5

C

1.40

2.47

102.8

44.6

2.77

5.8

1.00

0.82

0.79

0.79

0.94

1.0

20.0

D

1.40

2.47

102.8

44.6

2.77

5.8

1.00

0.82

0.79

0.79

0.94

1.0

E

1.40

2.47

102.8

44.6

2.77

5.8

1.00

0.82

0.79

0.79

0.94

1.0

F

1.40

2.47

102.8

44.6

2.77

5.8

1.00

0.82

0.79

0.79

0.94

1.0

G

1.40

2.47

102.8

44.6

2.77

5.8

1.00

0.82

0.79

0.79

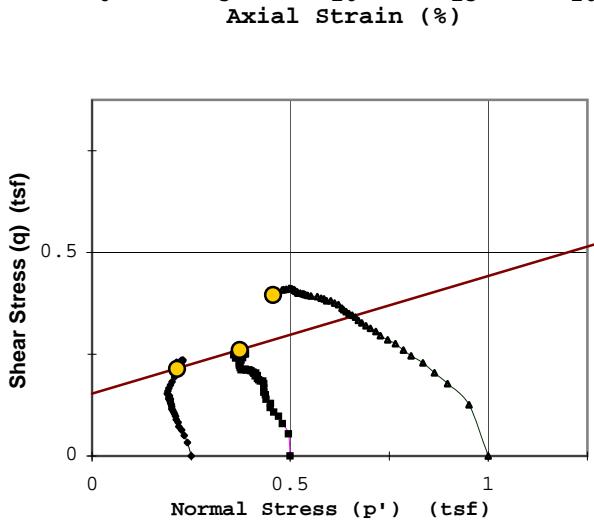
0.94

1.0

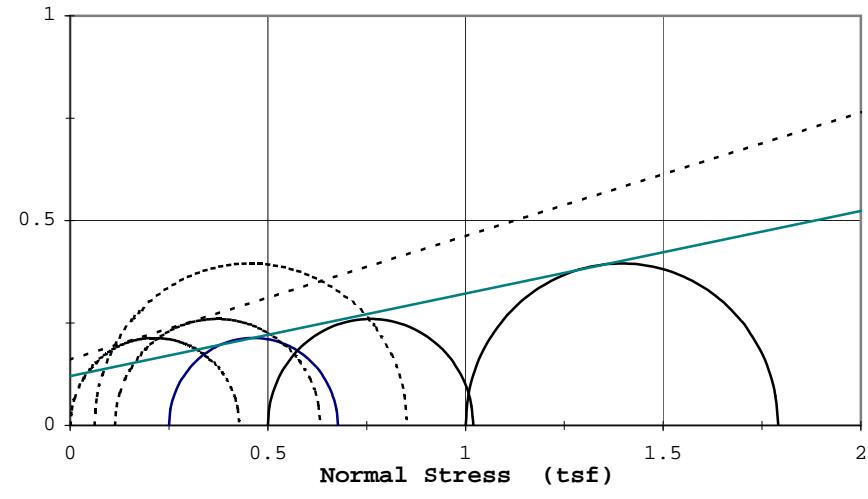
"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"

Remarks: Radial drainage strips applied to trimmed specimen; Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared.

**Material was unusual, with atterberg limits that varied greatly depending upon preparation method.



Rupture Envelope at Failure
= 16.1 ° a = 0.2 (tsf)



Effective φ' = 16.8 ° c' = 0.16 (tsf)
Total φ' = 11.4 ° c = 0.12 (tsf)

TRIAXIAL TEST ASTM: D 4767

Job No. 8192-A

Date: 2/16/12

Project:

Spirit Lake Sediment Site - Former US Steel Duluth Works

Boring #:

UC-96

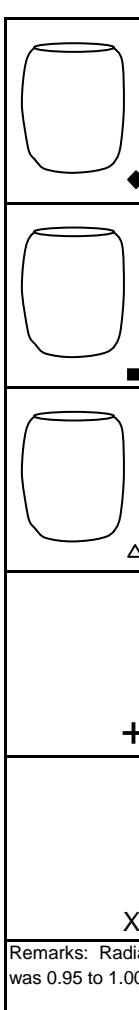
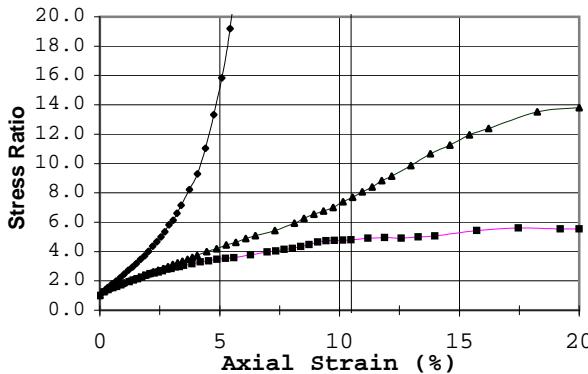
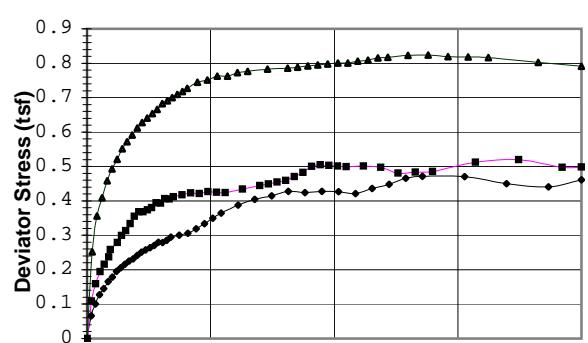
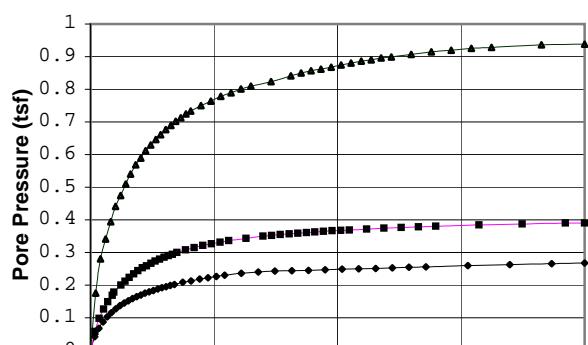
Sample #: 305

Type: 3T

Depth (ft): 17.5-20

Soil Type:

Organic Clay (OH) **



Failure Criterion:

Max. Deviator Stress

Angle of internal friction, $\phi' = 11.5^\circ$

Apparent Cohesion, $c' = 0.19$ (tsf)

Test Date: 1/27/12

Liquid Limit:

Test Type: CU w/pp

Plastic Limit:

Strain Rate (in/min): 0.00147

Plasticity Index:

Strain Rate (%/min): 0.050

Spec. Gravity (Assumed): 2.69

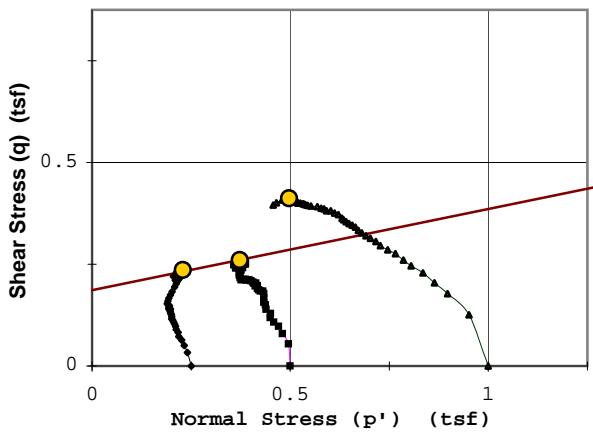
Before Consolidation

	A	B	C	D	E
Diameter (in)	1.45	1.45	1.45		
Height (in)	2.99	2.99	2.74		
Water Content (%)	133.9	115.8	122.9		
Dry Density (pcf)	35.1	39.2	37.7		
Void Ratio	3.79	3.28	3.46		

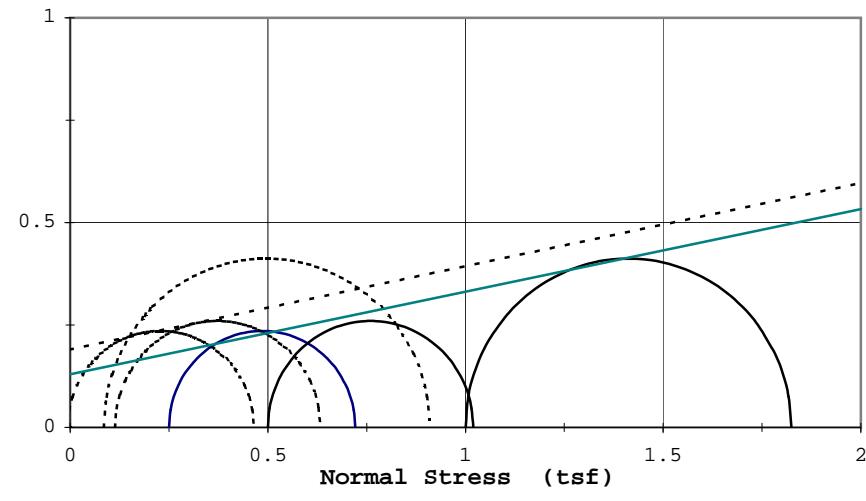
"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"

Remarks: Radial drainage strips applied to trimmed specimen; Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared.

**Material was unusual, with Atterberg limits that varied greatly depending upon preparation method.



Rupture Envelope at Failure
 $\phi' = 11.3^\circ$ $a = 0.2$ (tsf)



----- Effective $\phi' = 11.5^\circ$ $c' = 0.19$ (tsf)
 _____ Total $\phi' = 11.4^\circ$ $c' = 0.13$ (tsf)

TRIAXIAL TEST ASTM: D 4767

Job No. 8192-A

Date: 2/16/12

Project:

Spirit Lake Sediment Site - Former US Steel Duluth Works

Boring #:

UC-96

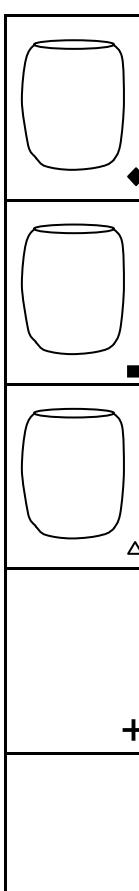
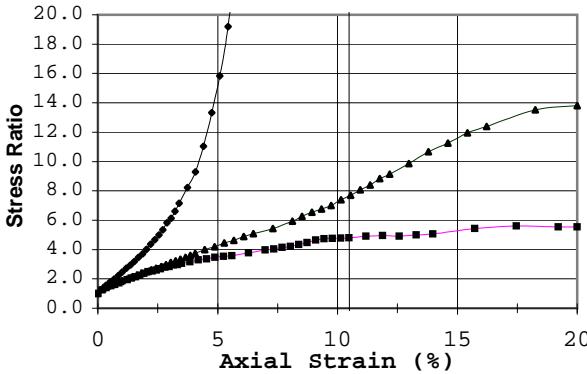
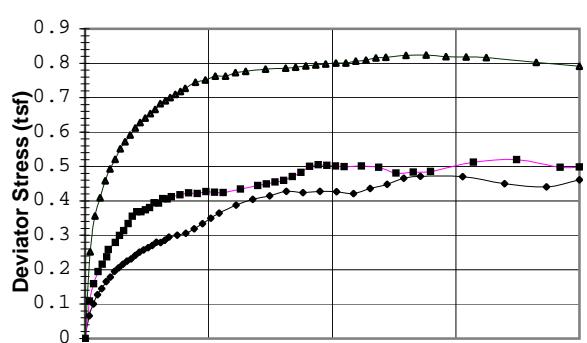
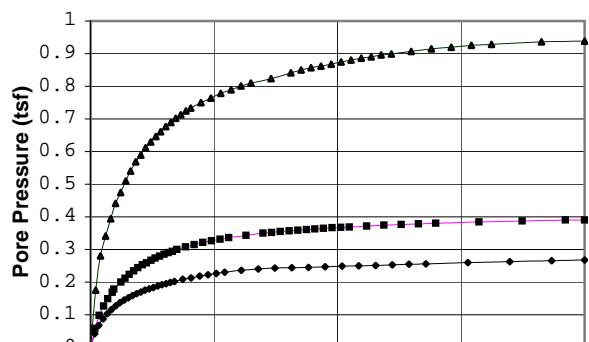
Sample #: 305

Type: 3T

Depth (ft): 17.5-20

Soil Type:

Organic Clay (OH) **



Failure Criterion: Given Strain of: 15%

Angle of internal friction, $\phi' = 16.5^\circ$

Apparent Cohesion, $c' = 0.16$ (tsf)

Test Date: 1/27/12 Liquid Limit:
Test Type: CU w/pp Plastic Limit:
Strain Rate (in/min): 0.00147 Plasticity Index:
Strain Rate (%/min): 0.050 Spec. Gravity (Assumed): 2.69

Before Consolidation

	A	B	C	D	E
Diameter (in)	1.45	1.45	1.45		
Height (in)	2.99	2.99	2.74		
Water Content (%)	133.9	115.8	122.9		
Dry Density (pcf)	35.1	39.2	37.7		
Void Ratio	3.79	3.28	3.46		

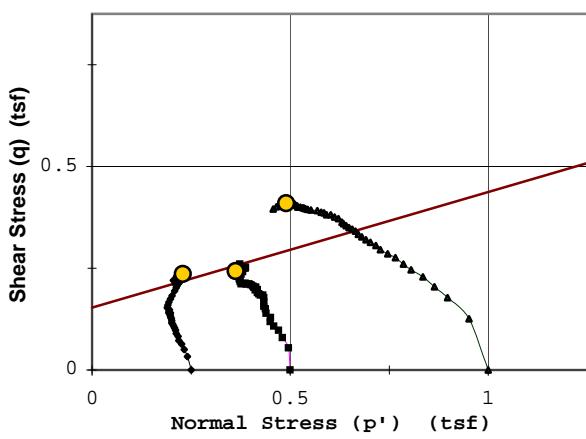
After Consolidation

	A	B	C	D	E
Diameter (in)	1.43	1.40	1.40		
Height (in)	2.95	2.86	2.47		
Water Content (%)	134.1	105.9	102.8		
Dry Density (pcf)	36.4	43.6	44.6		
Void Ratio	3.61	2.85	2.77		
Back Pressure (tsf)	5.8	5.8	5.8		
Minor Principal Stress (tsf)	0.25	0.50	1.00		
Max. Deviator Stress (tsf)	0.47	0.52	0.82		
Ultimate Deviator Stress (tsf)	0.46	0.50	0.79		
Deviator Stress at Failure (tsf)	0.47	0.49	0.82		
Max. Pore Pressure Buildup (tsf)	0.27	0.39	0.94		
Pore Pressure Parameter "B"	1.0	1.0	1.0		
Pct. Axial Strain at Failure	15.0	15.0	15.0		

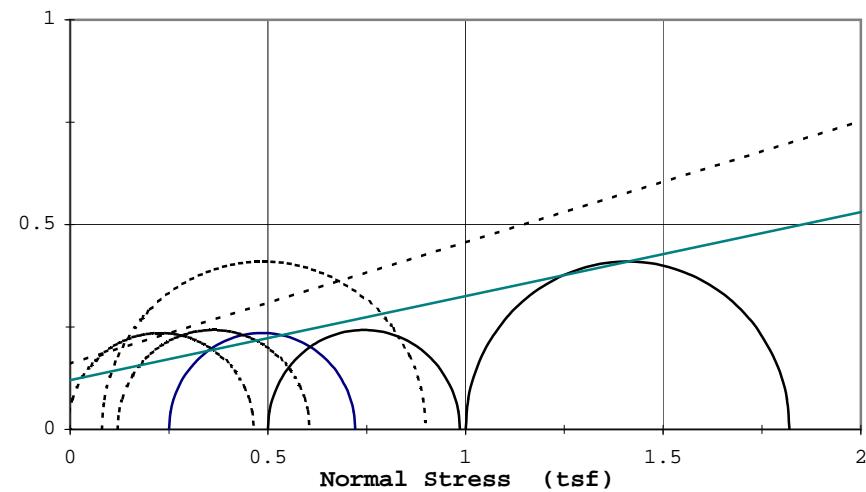
"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"

Remarks: Radial drainage strips applied to trimmed specimen; Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared.

**Material was unusual, with Atterberg limits that varied greatly depending upon preparation method.



Rupture Envelope at Failure
 $\phi' = 15.9^\circ$ $a = 0.2$ (tsf)



----- Effective $\phi' = 16.5^\circ$	$c' = 0.16$ (tsf)
_____ Total $\phi' = 11.6^\circ$	$c' = 0.12$ (tsf)

Boring:

UC-96

Sample:

Triaxial Data

305

Depth: 17.5-20

Job: 8192-A

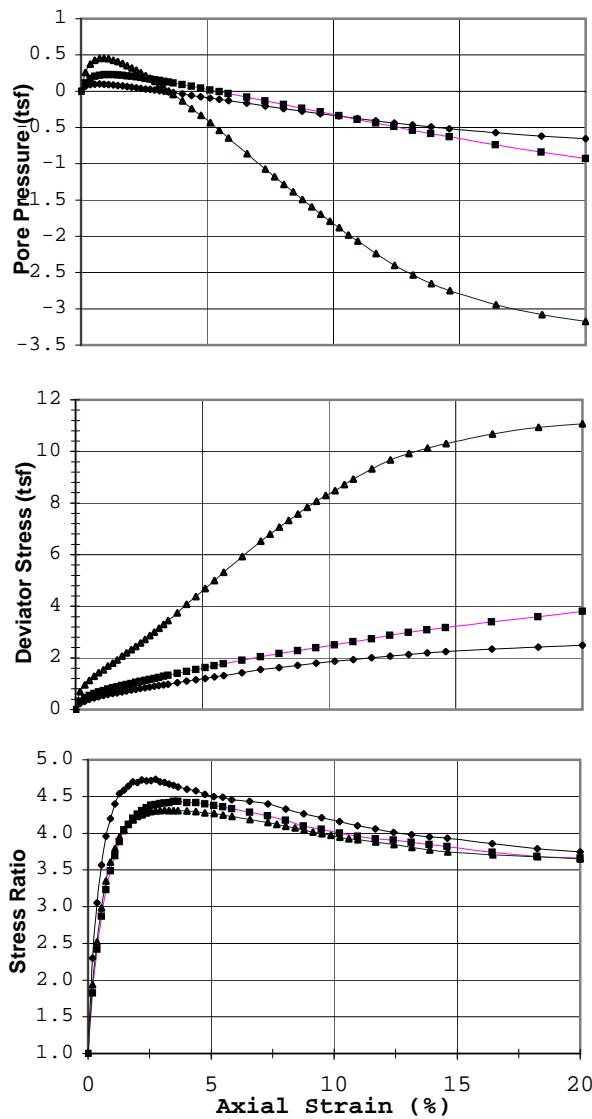
Date: 2/16/12

TRIAXIAL TEST ASTM: D 4767

Job No. 8192-A

Date: 2/16/12

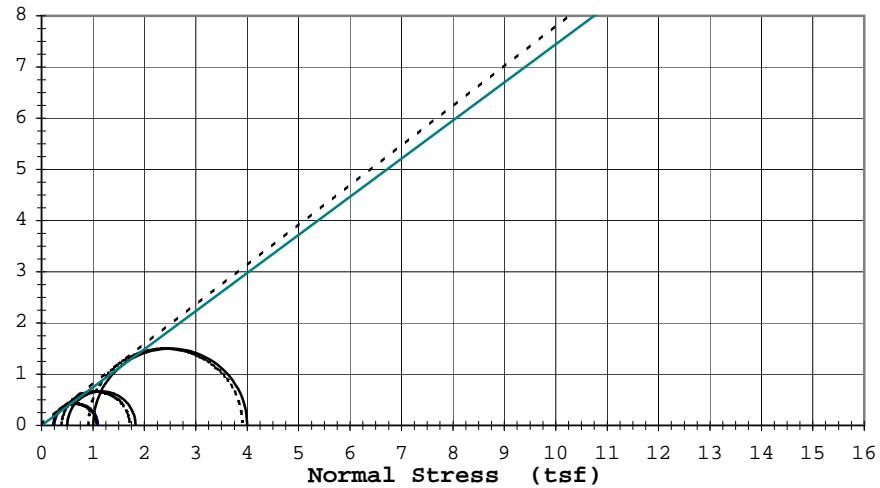
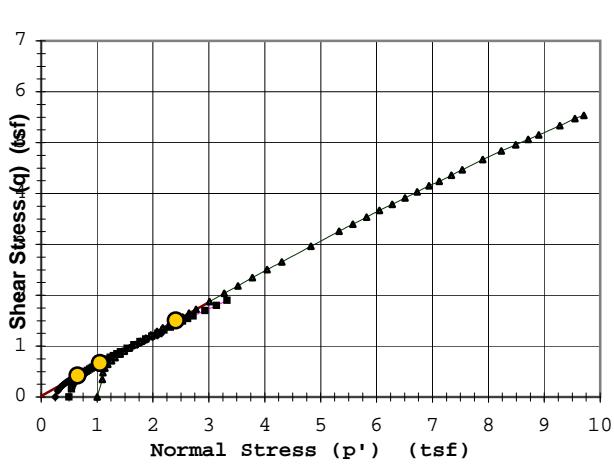
Project: Spirit Lake Sediment Site - Former US Steel Duluth Works
 Boring #: 311 Sample #: 3T Type: 3T Depth (ft): 12-14.5
 Soil Type: Sandy Silt (ML)



Failure Criterion:		Max. Stress Ratio				
		Angle of internal friction, $\phi' = 37.9^\circ$				
		Apparent Cohesion, $c' = 0.03$ (tsf)				
Test Date:	1/26/12	A	B	C	D	E
Test Type:	CU w/pp	1.45	1.45	1.45		
Strain Rate (in/min):	0.00137	2.74	2.74	2.74		
Strain Rate (%/min):	0.050	22.2	23.2	25.6		
<i>Before Consolidation</i>		Plasticity Index:				
Water Content (%)		Spec. Gravity (Assumed):				
Dry Density (pcf)	102.4	100.2	97.4			
Void Ratio	0.64	0.68	0.72			
<i>After Consolidation</i>		Liquid Limit:				
Water Content (%)		Plastic Limit:				
Dry Density (pcf)	103.0	101.3	99.0			
Void Ratio	0.63	0.66	0.70			
Back Pressure (tsf)	5.8	5.8	5.8			
Minor Principal Stress (tsf)	0.25	0.50	1.00			
Max. Deviator Stress (tsf)	2.49	3.80	11.07			
Ultimate Deviator Stress (tsf)	2.49	3.80	11.07			
Deviator Stress at Failure (tsf)	0.85	1.33	3.00			
Max. Pore Pressure Buildup (tsf)	0.10	0.23	0.45			
Pore Pressure Parameter "B"	1.0	1.0	1.0			
Pct. Axial Strain at Failure	2.7	3.6	3.1			

"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"

Remarks: Radial drainage strips applied to trimmed specimen; Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared.

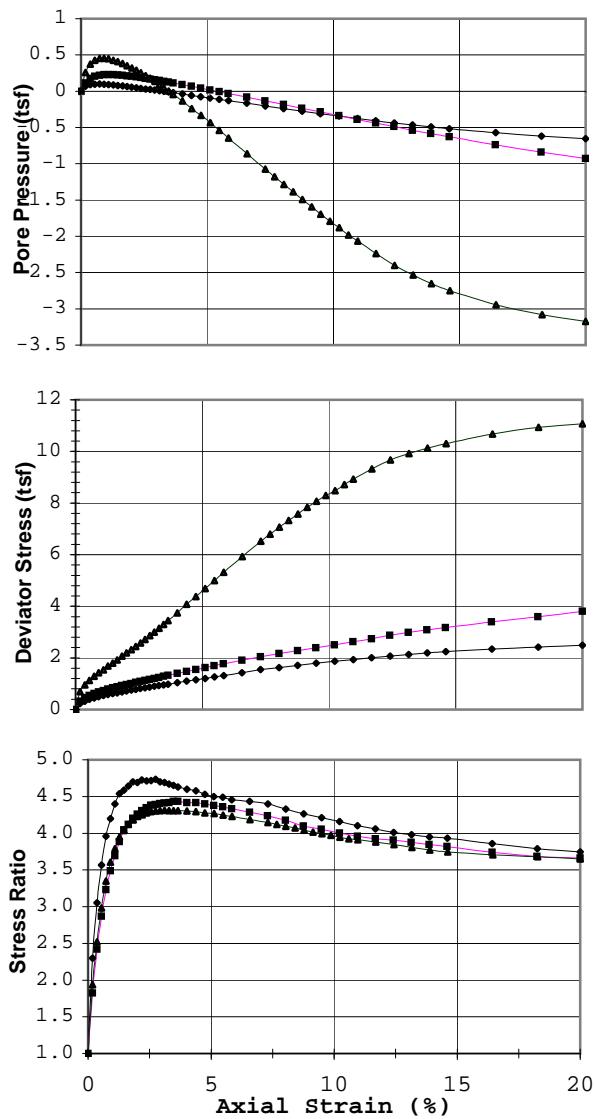


TRIAXIAL TEST ASTM: D 4767

Job No. 8192-A

Date: 2/16/12

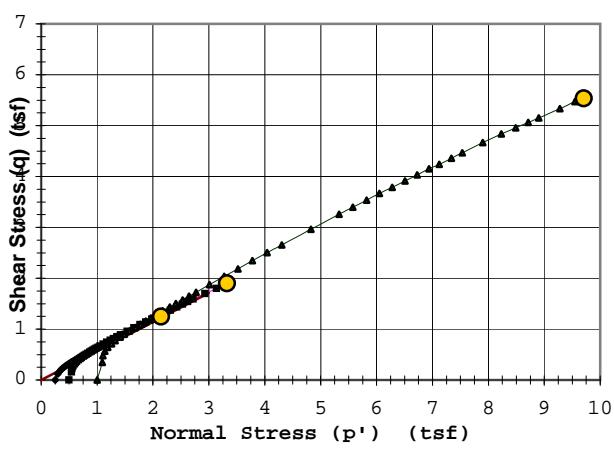
Project: Spirit Lake Sediment Site - Former US Steel Duluth Works
 Boring #: 311 Sample #: Type: 3T Depth (ft): 12-14.5
 Soil Type: Sandy Silt (ML)



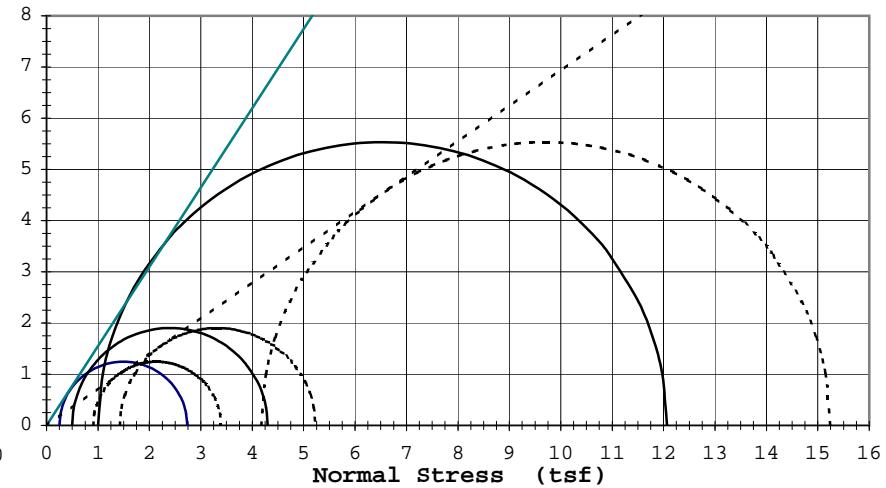
Failure Criterion:		Max. Deviator Stress				
		Angle of internal friction, $\phi' = 34.8^\circ$				
		Apparent Cohesion, $c' = 0.00$ (tsf)				
		Test Date: 1/26/12				
		Test Type: CU w/pp				
		Strain Rate (in/min): 0.00137				
		Strain Rate (%/min): 0.050				
<i>Before Consolidation</i>		Plasticity Index:				
		Spec. Gravity (Assumed): 2.69				
		A	B	C	D	E
		1.45	1.45	1.45		
		2.74	2.74	2.74		
		22.2	23.2	25.6		
		102.4	100.2	97.4		
		0.64	0.68	0.72		
<i>After Consolidation</i>		Diameter (in)				
		Height (in)				
		Water Content (%)				
		Dry Density (pcf)				
		Void Ratio				
		1.45	1.44	1.44		
		2.74	2.74	2.74		
		23.4	24.4	25.9		
		103.0	101.3	99.0		
		0.63	0.66	0.70		
		Back Pressure (tsf)	5.8	5.8	5.8	
		Minor Principal Stress (tsf)	0.25	0.50	1.00	
		Max. Deviator Stress (tsf)	2.49	3.80	11.07	
		Ultimate Deviator Stress (tsf)	2.49	3.80	11.07	
		Deviator Stress at Failure (tsf)	2.49	3.80	11.07	
		Max. Pore Pressure Buildup (tsf)	0.10	0.23	0.45	
		Pore Pressure Parameter "B"	1.0	1.0	1.0	
		Pct. Axial Strain at Failure	20.0	20.0	20.0	

"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"

Remarks: Radial drainage strips applied to trimmed specimen; Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared.



Rupture Envelope at Failure
 $\phi' = 29.7^\circ$ $a = 0.0$ (tsf)



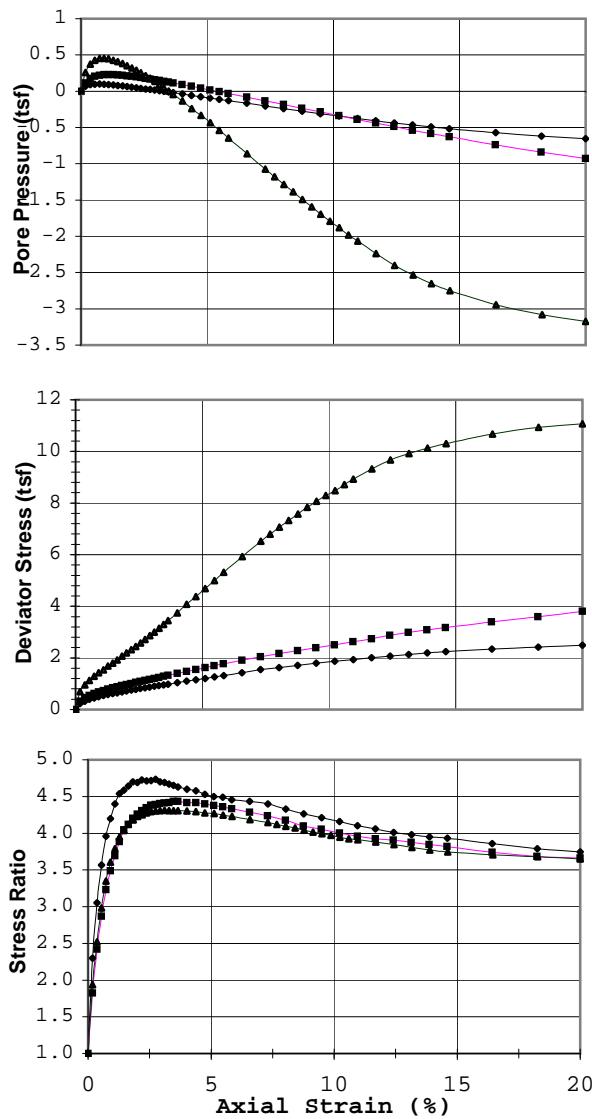
----- Effective $\phi' = 34.8^\circ$ $c' = 0.00$ (tsf)
 _____ Total $\phi' = 57.1^\circ$ $c = 0.00$ (tsf)

TRIAXIAL TEST ASTM: D 4767

Job No. 8192-A

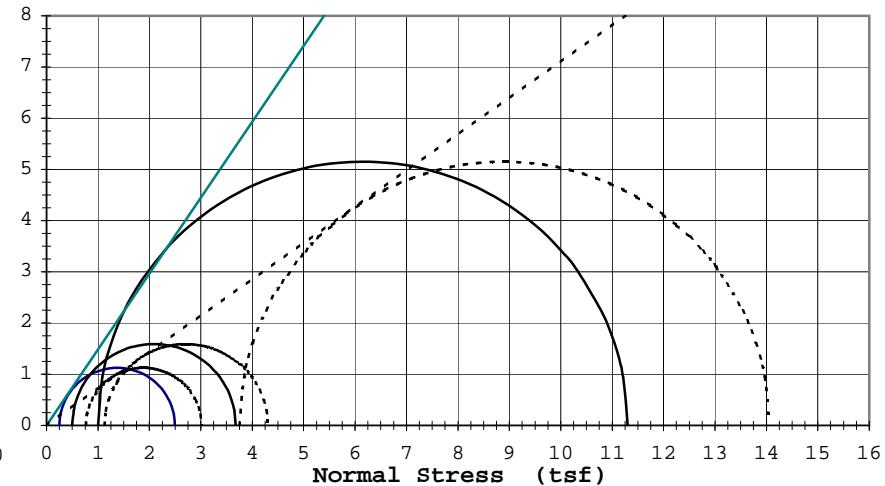
Date: 2/16/12

Project: Spirit Lake Sediment Site - Former US Steel Duluth Works
 Boring #: 311 Sample #: 3T Type: 3T Depth (ft): 12-14.5
 Soil Type: Sandy Silt (ML)



Failure Criterion:		Given Strain of: 15%				
		Angle of internal friction, $\phi' = 35.4^\circ$				
		Apparent Cohesion, $c' = 0.00$ (tsf)				
		Test Date: 1/26/12				
		Test Type: CU w/pp				
		Strain Rate (in/min): 0.00137				
		Strain Rate (%/min): 0.050				
<i>Before Consolidation</i>		Plastic Limit:				
		Liquid Limit:				
		Plasticity Index:				
		Spec. Gravity (Assumed): 2.69				
		A	B	C	D	E
		1.45	1.45	1.45		
		2.74	2.74	2.74		
		22.2	23.2	25.6		
		102.4	100.2	97.4		
		0.64	0.68	0.72		
<i>After Consolidation</i>						
		Diameter (in)				
		Height (in)				
		Water Content (%)				
		Dry Density (pcf)				
		Void Ratio				
		1.45	1.44	1.44		
		2.74	2.74	2.74		
		23.4	24.4	25.9		
		103.0	101.3	99.0		
		0.63	0.66	0.70		
		Back Pressure (tsf)	5.8	5.8	5.8	
		Minor Principal Stress (tsf)	0.25	0.50	1.00	
		Max. Deviator Stress (tsf)	2.49	3.80	11.07	
		Ultimate Deviator Stress (tsf)	2.49	3.80	11.07	
		Deviator Stress at Failure (tsf)	2.25	3.18	10.30	
		Max. Pore Pressure Buildup (tsf)	0.10	0.23	0.45	
		Pore Pressure Parameter "B"	1.0	1.0	1.0	
		Pct. Axial Strain at Failure	15.0	15.0	15.0	
"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"						

Remarks: Radial drainage strips applied to trimmed specimen; Saturated, backpressured until "B" response was 0.95 to 1.00; Consolidated; All Drainage valves closed and immediately sheared.



Rupture Envelope at Failure
 $\phi' = 30.1^\circ$ $a = 0.0$ (tsf)

Effective $\phi' = 35.4^\circ$ $c' = 0.00$ (tsf)
 Total $\phi' = 56.0^\circ$ $c' = 0.00$ (tsf)

Boring:

311

Sample:

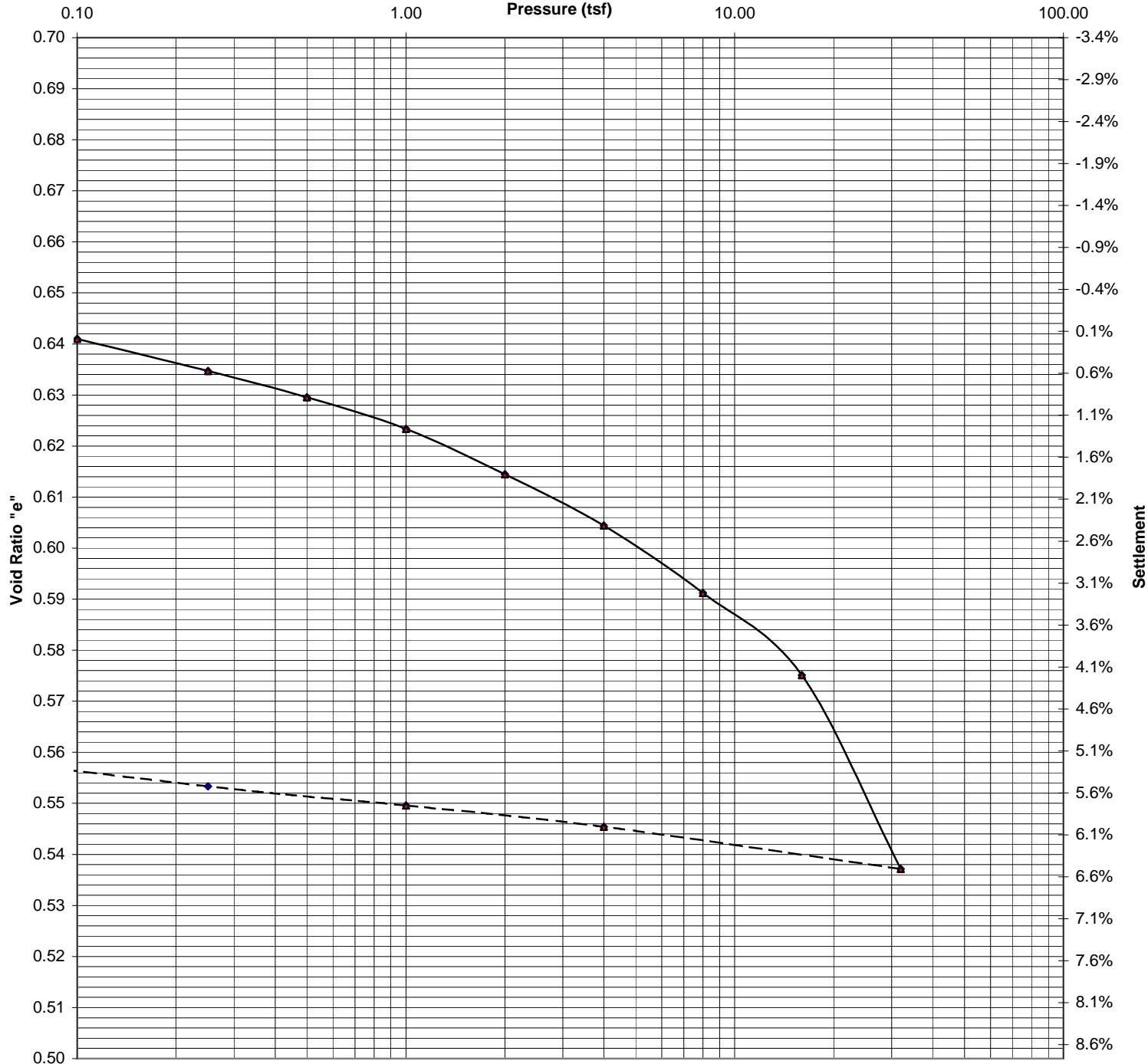
Triaxial Data

Job: 8192-A
Date: 2/16/12

Depth: 12-14.5

Sample 1			Sample 2			Sample 3			Sample 4			Sample 5		
Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)	Strain (%)	Deviator Stress (tsf)	Pore Pressure (tsf)
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.18	0.23	0.07	0.18	0.32	0.11	0.18	0.70	0.26						
0.37	0.33	0.09	0.36	0.46	0.18	0.37	0.96	0.37						
0.55	0.39	0.10	0.55	0.55	0.21	0.55	1.13	0.43						
0.73	0.45	0.10	0.73	0.63	0.22	0.73	1.29	0.45						
0.91	0.50	0.10	0.91	0.68	0.23	0.91	1.42	0.45						
1.10	0.54	0.09	1.09	0.73	0.23	1.10	1.54	0.45						
1.28	0.58	0.09	1.28	0.79	0.23	1.28	1.68	0.43						
1.46	0.61	0.08	1.46	0.84	0.22	1.46	1.79	0.41						
1.64	0.65	0.07	1.64	0.88	0.22	1.64	1.93	0.38						
1.83	0.69	0.06	1.82	0.93	0.21	1.83	2.07	0.35						
2.01	0.72	0.06	2.01	0.96	0.20	2.01	2.19	0.32						
2.19	0.75	0.05	2.19	1.01	0.20	2.19	2.31	0.29						
2.37	0.78	0.04	2.37	1.05	0.19	2.38	2.44	0.26						
2.56	0.81	0.03	2.55	1.09	0.18	2.56	2.58	0.22						
2.74	0.85	0.02	2.74	1.13	0.17	2.74	2.71	0.18						
2.92	0.87	0.02	2.92	1.17	0.16	2.92	2.87	0.13						
3.10	0.90	0.01	3.10	1.20	0.15	3.11	3.00	0.09						
3.29	0.93	0.00	3.28	1.25	0.14	3.29	3.15	0.05						
3.47	0.95	-0.01	3.47	1.29	0.12	3.47	3.30	0.00						
3.65	0.98	-0.02	3.65	1.33	0.11	3.66	3.45	-0.04						
4.02	1.04	-0.04	4.01	1.40	0.09	4.02	3.75	-0.13						
4.38	1.10	-0.06	4.38	1.48	0.07	4.39	4.08	-0.24						
4.75	1.15	-0.08	4.74	1.56	0.04	4.75	4.37	-0.33						
5.11	1.21	-0.09	5.11	1.63	0.02	5.12	4.69	-0.43						
5.48	1.26	-0.11	5.47	1.70	-0.01	5.48	5.00	-0.54						
5.84	1.31	-0.13	5.84	1.77	-0.03	5.85	5.31	-0.65						
6.57	1.43	-0.17	6.57	1.91	-0.08	6.58	5.93	-0.86						
7.30	1.54	-0.20	7.30	2.05	-0.13	7.31	6.52	-1.07						
8.03	1.63	-0.24	8.03	2.17	-0.18	7.68	6.80	-1.18						
8.76	1.71	-0.27	8.76	2.28	-0.23	8.04	7.07	-1.28						
9.49	1.80	-0.31	9.49	2.40	-0.28	8.41	7.33	-1.39						
10.22	1.87	-0.34	10.22	2.51	-0.34	8.77	7.58	-1.49						
10.95	1.94	-0.38	10.95	2.63	-0.39	9.14	7.83	-1.60						
11.68	2.01	-0.41	11.68	2.75	-0.44	9.50	8.07	-1.69						
12.41	2.07	-0.44	12.41	2.87	-0.49	9.87	8.30	-1.79						
13.14	2.13	-0.47	13.13	2.98	-0.54	10.23	8.48	-1.88						
13.87	2.19	-0.49	13.86	3.08	-0.58	10.60	8.72	-1.98						
14.60	2.25	-0.52	14.59	3.18	-0.63	10.97	8.93	-2.07						
16.43	2.35	-0.57	16.42	3.39	-0.74	11.70	9.33	-2.24						
18.26	2.42	-0.62	18.24	3.60	-0.84	12.43	9.67	-2.40						
20.00	2.49	-0.66	20.00	3.80	-0.93	13.16	9.92	-2.53						
						13.89	10.12	-2.65						
						14.62	10.30	-2.75						
						16.45	10.67	-2.94						
						18.28	10.94	-3.08						
						20.00	11.07	-3.17						

Void Ratio and % Settlement vs. Log of Pressure



Project: Spirit Lake Sediment Site - Former US Steel Duluth Works

Date: 2/17/12

Sample #: 304

Boring #: UC-94

Depth ft: 10.5-13

Job #: 8192-A

Soil Type: Sandy Silt (ML/SM)

Initial W/C (%): 23.5

Dry Density (pcf): 103.7

LL: 23.4

PL: 20.4

PI: 3.0

Gs: 2.73 (Assumed)

Organic Content (%):

Initial Height (in.): 0.746

Diameter (in.): 2.506

$e_0 = 0.644$

Preconsolidation Pressure (Pc):

9 tsf

Compression Index (Cc):

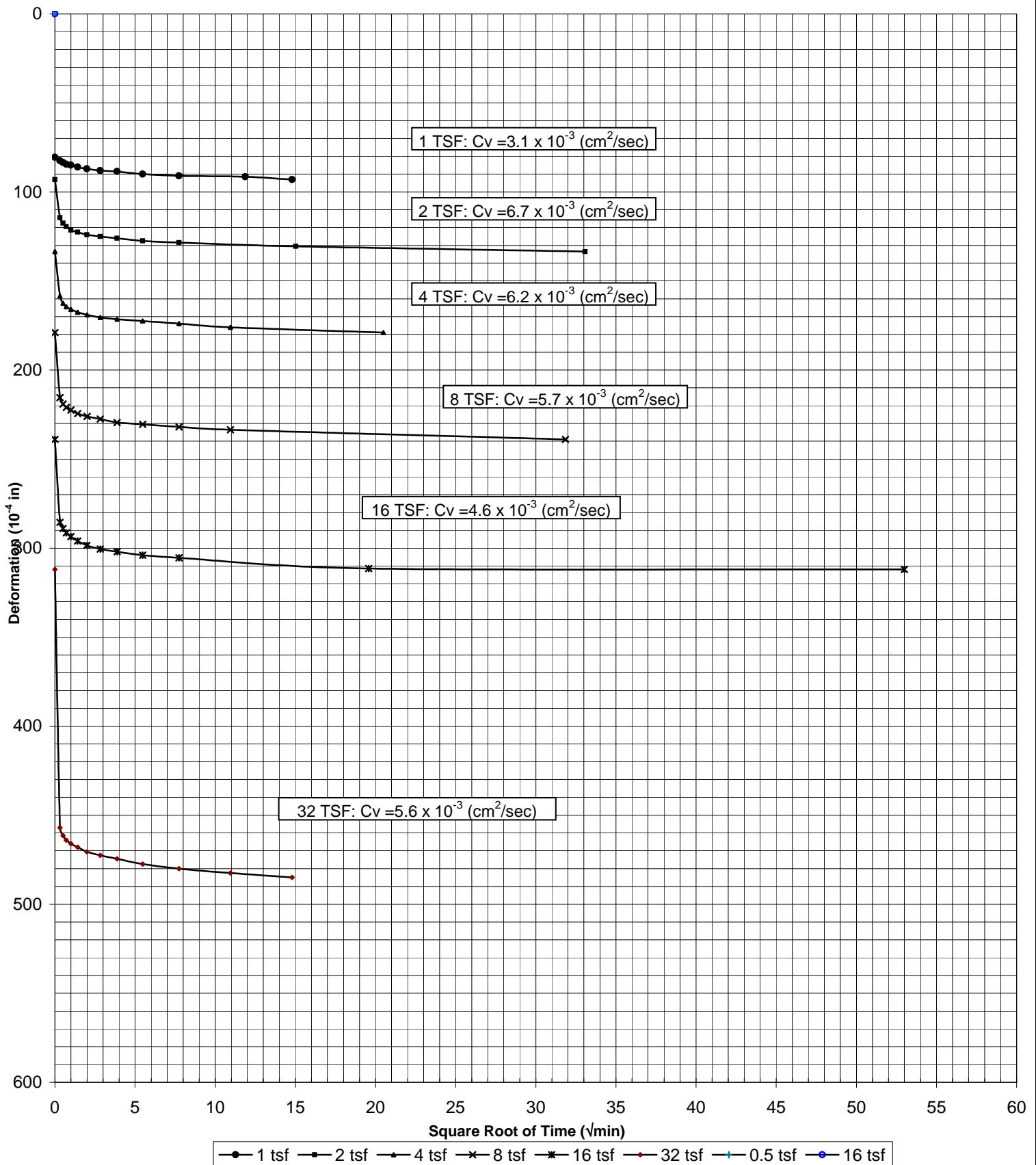
0.13

Recompression Index (Cr):

≥ 0.01

Remarks:

Square Root of Time Curves



Project: Spirit Lake Sediment Site - Former US Steel Duluth Works

Date: 2/17/12

Sample #: 304

Boring #: UC-94

Depth ft: 10.5-13

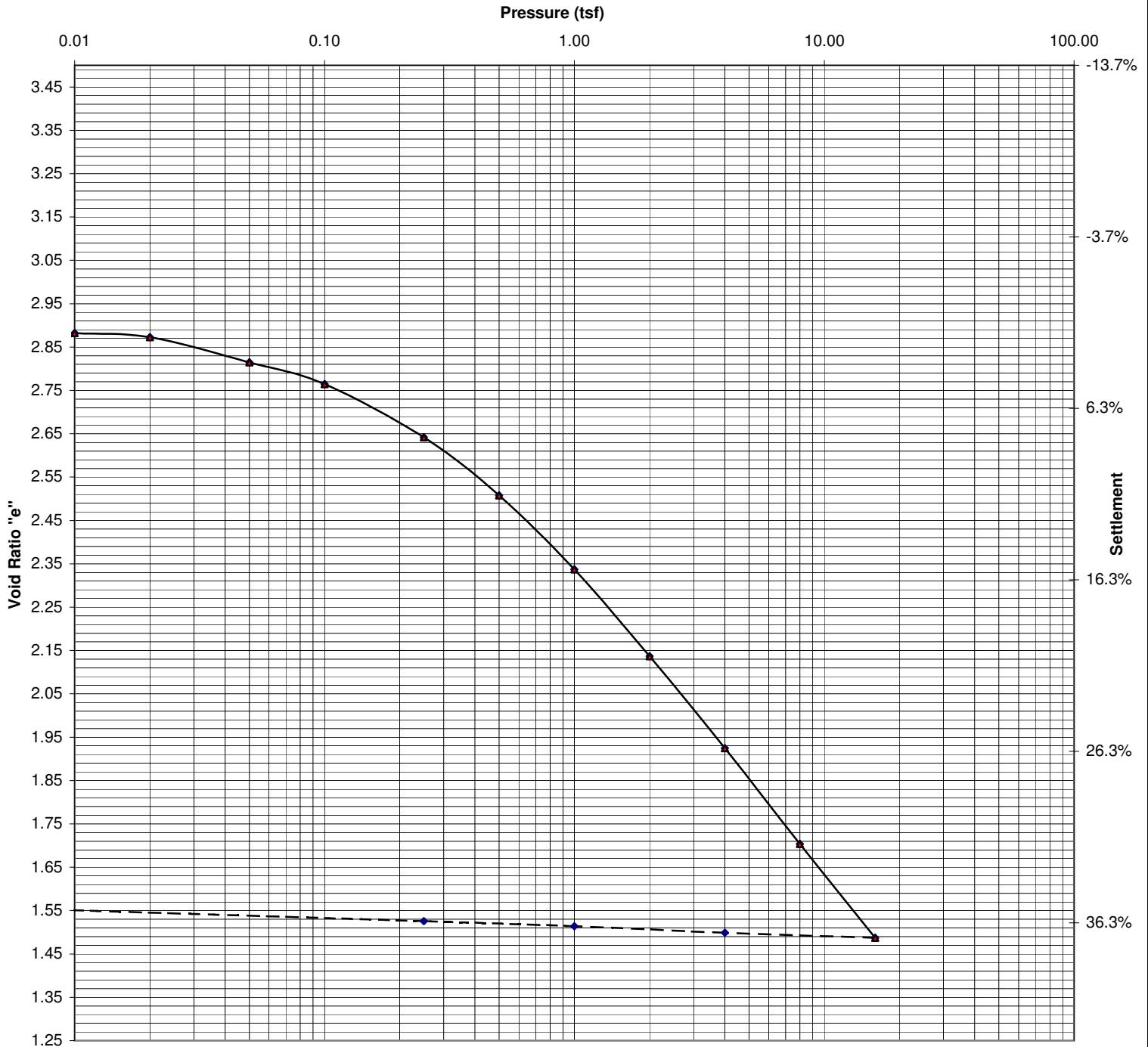
Job #: 8192-A

2401 W 66th Street

E OIL
ENGINEERING
TESTING, INC.

Richfield, Minnesota 55423-2031

Void Ratio and % Settlement vs. Log of Pressure



Project: Spirit Lake Sediment Site - Former US Steel Duluth Works

Date: 1/24/12

Sample #: 305

Boring #: UC-96

Depth ft: 5-7.5

Job #: 8192-A

Soil Type: Organic Clay, extremely soft and wet (OL)

Initial W/C (%): 92.7

Dry Density (pcf): 50.3

LL: 78.6

PL: 41.8

PI: 36.8

Gs: 3.19 (Assumed)

Organic Content (%):

Initial Height (in.): 0.747

Diameter (in.): 2.506

$e_0 = 2.957$

Preconsolidation Pressure (Pc):

0.41 tsf

Compression Index (Cc):

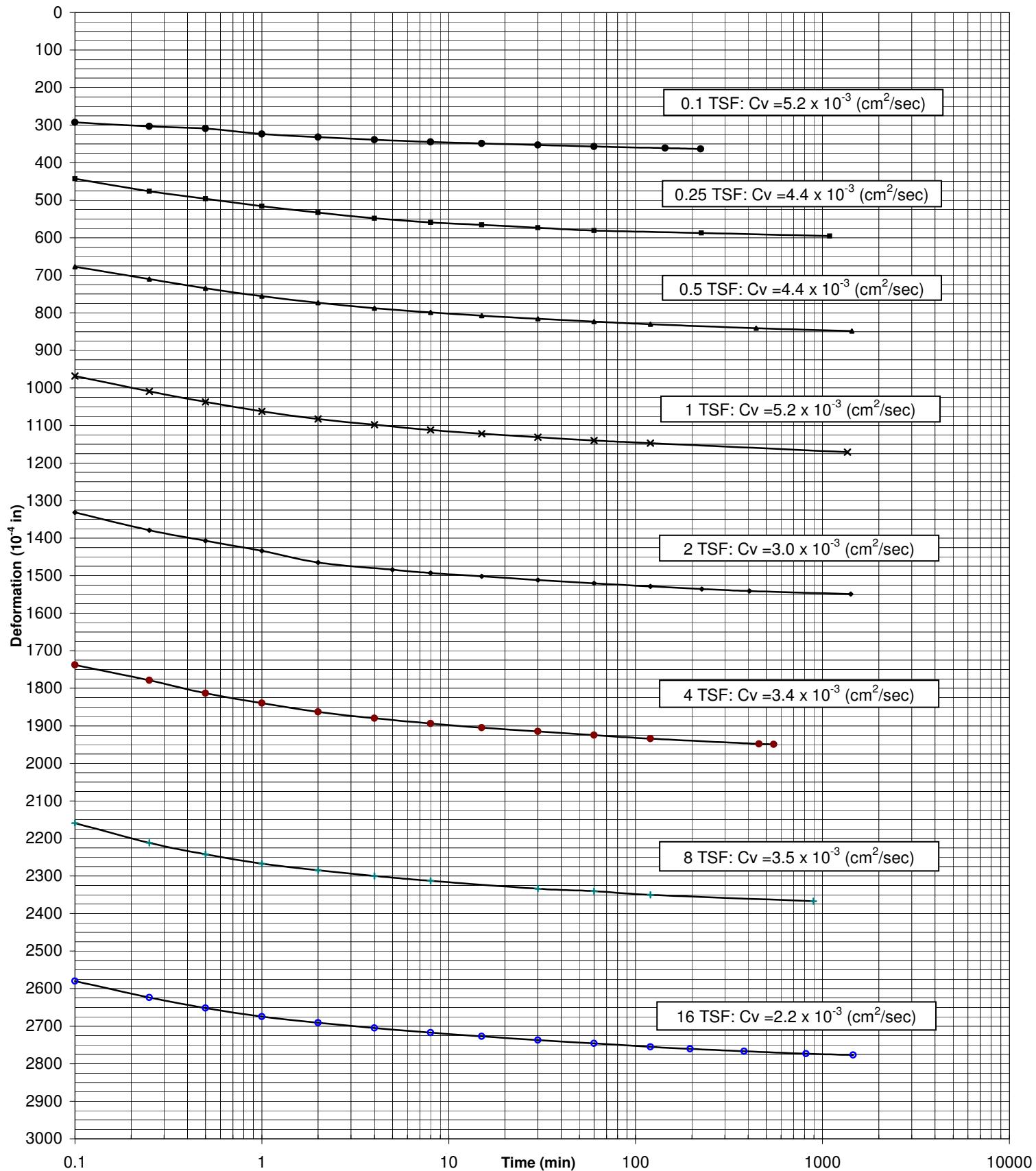
0.73

Recompression Index (Cr):

≥ 0.03

Remarks:

Consolidation Log of Time Curves



Project: Spirit Lake Sediment Site - Former US Steel Duluth Works

Date: 1/24/12

Sample #: 305

Boring #: UC-96

Depth ft: 5-7.5

Job #: 8192-A

2401 W 66th Street

Laboratory Test Summary

Project: Spirit Lake Sediment Site - Former US Steel Duluth Works

Job: 8192-B

Client: Barr Engineering Company

Date: 3/13/12

Boring No.	305A					
Sample						
Depth (ft)	17.5-20					
Type or BPF	TWT					
Classification	Lean Clay with organic fines (CL/CL-ML)					

Organic Content (ASTM:D2974)

Organic Content (%)	9.6					
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2401 W 66th Street



Richfield, Minnesota 55423-2031