PRELIMINARY GEOTECHNICAL ENGINEERING REPORT

CAUSEWAY FLOOD PROTECTION FEASIBILITY EVALUATION—MOSSY OAKS DRAINAGE IMPROVEMENTS

PORT ROYAL, SOUTH CAROLINA

FEBRUARY 15, 2019

INSIGHT NUMBER 19-0001

Prepared for:
Infrastructure Consulting & Engineering
Beaufort, South Carolina

Prepared by:
Insight Group, LLC
3359 Meeting Street, Suite 101
North Charleston, South Carolina

INSIGHT GROUP
A CHRISTOPHER COMPANY

DRAFT

February 15, 2019

Infrastructure Consulting & Engineering

Attn: Mr. Jared Fralix, PE
VP of Site Development
O: 843 522 0246
Jared.Fralix@ice-eng.com

Re: Preliminary Geotechnical Report
Causeway Flood Protection Feasibility Geotechnical Evaluation
Mossy Oaks Drainage Improvements Project
Port Royal, South Carolina
Insight Group Number: 19-0001

Dear Mr. Fralix:

The purpose of this report is to present geotechnical recommendations for the feasibility of converting the Spanish Moss Trail causeway to levee / flood protection systems at the two outfall locations. This report presents our understanding of the proposed improvements, the site and subsurface conditions, and conclusions and recommendations.

We appreciate the opportunity to be of service to ICE and the City of Beaufort on this project. If you have any questions concerning this submittal, or if we may be of further service, please contact us.

Sincerely,
Insight Group

Ryan N. Keiper, P.E.
Geotechnical Consultant

Reg Christopher, P.E.
Consultant

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APPENDICES

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1 INTRODUCTION

Insight Group has completed the feasibility evaluation for the Mossy Oaks Drainage Improvements project in Port Royal, South Carolina in general accordance with our proposal dated January 3, 2019. This report presents the results of our geotechnical testing and analysis to evaluate the potential for and expected improvements required to convert the two existing Spanish Moss Trail causeways into flood protection systems for the community.

Insight Group evaluated the subsurface conditions with eight Cone Penetration Test (CPT) soundings extending to 36 and 42 feet below existing grade. At the two CPT soundings performed near the middle of each causeway (CPT/DP-2 and CPT/DP-6), we collected continuous direct-push soil samples to 16.3 feet and 10.4 feet, respectively. We also collected bulk samples of the existing causeway material at CPT-1, CPT-3, CPT-5 and CPT-7. Tests CPT-1 through CPT-4 correspond to Basin 2 and CPT-5 through CPT-8 to Basin 1. CPT-4, CPT-8 and several hand auger borings, infiltration testing, etc. are for evaluation of proposed culverts, retentions ponds and other aspects of the project; these are not directly applicable to this flood protection feasibility evaluation.

CPT sounding records and boring logs are attached in Exhibit B. Exhibit A shows the test locations at the site. The CPT soundings were conducted in general accordance with ASTM D5778.

2 PROJECT INFORMATION

2.1 Site Location and Current Condition

The project site is located in Port Royal, South Carolina. There are two drainage basins identified, each with a corresponding outfall. Basin 1 is to the north and Basin 2 to the south. The Spanish Moss Trail, a railroad line converted to a pedestrian path, bisects the marsh areas at the two outfalls. We understand the railroad line was constructed as part of the line to Yemassee, South Carolina by Port Royal Railroad between 1860 and 1870, and was in operation until 2006.

Approximate coordinates of the causeway at Basin 1 are 32.4069, -80.6985 and at Basin 2 are 32.3960, -80.7023. Figure 1 shows conditions of the causeway.

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Figure 1. Spanish Moss Trail and Conditions at Outfall #2 Culvert (Looking West)

2.2 Project Description

The Mossy Oaks Drainage Improvement project will evaluate, design and construct measures to improve drainage and mitigate flooding of the Mossy Oaks neighborhood and residences. Currently, the team is evaluating the Spanish Moss Trail causeways for use as flood protection. The existing culverts will be replaced with twin 60-inch pipes with flap gates. Alternatives such as sheeting cutoff / flood walls and heightening the current embankments are being considered.

Insight Group is providing geotechnical services, including field testing, and laboratory testing for this feasibility analysis. The U.S. Army Corps of Engineers document "Design and Construction of Levees EM 1110-2-1913" is being used as the design framework.

The geotechnical flood-protection scope focuses on the Spanish Moss Trail causeways bisecting both outfall locations. It is important that final flood protection evaluation is comprehensive and addresses all potential in-flow locations. The project will also install new pipes and improve ponds/ditches, which will be addressed in a separate submittal. Figure 2 shows the project area and the two outfall locations.

Figure 2. Project Area and FEMA Flood Zones

Table 1 lists the approximate elevations of the Spanish Moss Trail causeways and flood heights.

Table 1. Causeway and Water Level Elevations

Item	Description
General Lowest Mossy Oaks Residence Finished Floor Elevations	7.0 ft. NAVD88
Spanish Moss Trail Causeway (Both Basin 1 and 2 Outfall)	Approximate Crest Elevation 9.8 ft. NAVD88
Mean High Water	Elevation 3.4 ft. NAVD88
Spring Tide	Elevation 5.8 ft. NAVD88
10-Yr Storm Tide (Hurricane Matthew)	Elevation 7.6 ft. NAVD88
25-Yr Storm Tide	Elevation 10.3 ft. NAVD88

3 GEOTECHNICAL SUBSURFACE CONDITIONS

3.1 Soil Profile

The filed investigation indicates the subsurface conditions at the two Spanish Moss Trail causeways can be generalized by the following soil profiles:

Table 2. Basin 1 Causeway - Generalized Subsurface Conditions (CPT-5, CPT/DP-6, CPT-7)

Layer	Depth (feet)		Approximate Layer Thickness (feet)	Description
	from	to		
1	0	14	14	Historic Rail Causeway Fill Concrete Pavement (not sampled) Uncontrolled fill[1] consisting of fine sand and silty sand with organics and some intermixed shells 6-inch layer of asphalt base about 1-ft. below grade
2	14	25	11	Native clay / silt, soft to stiff, undrained shear strength 500 to 850 psf, organic marsh odor *This layer increases in thickness from south to north. At CPT-5, the clay includes interbedded sand layers and terminates at 20 feet deep; at CPT-7 it extends to 29 feet.*
3	25	40[2]	15	Medium dense to dense sand and silty sand with some interbedded clay layers

1. Uncontrolled fill is material that was placed without moisture and density control. This material is typically variable in composition, consistency, density, moisture, and depth.
2. Termination of deepest test.

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Table 3. Basin 2 Causeway - Generalized Subsurface Conditions (CPT-1, CPT/DP-2, CPT-3)

Layer	Depth (feet)		Approximate Layer Thickness (feet)	Description
	from	to		
1	0	11	11	Historic Rail Causeway Fill Concrete Pavement (not sampled) Uncontrolled fill[1] consisting of fine sand, silty sand, some clay, generally with organics and some intermixed shells 8-inch layer of asphalt base about 1-ft. below grade Oyster shells with some clayey sand intermixed from about 5 to 9 feet
2	11	21	10	Native, medium-dense and dense sand and silty sand, organic marsh odor
3	21	23	2	Native, stiff sandy clay / silt
4	23	34	11	Native, medium-dense sand and silty sand
5	34	40	6	Native clay / silt, soft to stiff, undrained shear strength 600 to 800 psf
6	40	42[2]	2	Native, dense sand and silty sand

1. Uncontrolled fill is material that was placed without moisture and density control. This material is typically variable in composition, consistency, density, moisture, and depth.
2. Termination of deepest test.

The testing indicates that the causeway fill material is about 11 to 14 feet thick. Historic fill is often variable and can include debris.

3.2 Groundwater

The project area experiences tidal water fluctuations. The observed groundwater depths at the time testing are listed in Table 4.

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Table 4. Observed Groundwater Depths at Time of Testing

Test	Estimated Groundwater Depth (ft)	Test	Estimated Groundwater Depth (ft)
CPT-1	8.5	CPT-5	8
CPT/DP-2	7.5	CPT/DP-6	6.5
CPT-3	7.5	CPT-7	5.5

Groundwater levels were measured using the following criteria:

- Physical observation within HAB or CPT testing void.
- Where not encountered within the testing void, groundwater levels are estimated using the hydrostatic line (height of water below the ground surface) on the CPT porewater pressure (U) graph shown on the CPT logs.
- Unless otherwise specified on the logs or in the report, all groundwater measurements are collected during or immediately after drilling.

Groundwater levels will fluctuate. Tidal conditions should be evaluated prior to commencing construction to determine its effect on site work and excavations.

4 FEASIBILITY RECOMMENDATIONS

4.1 Design Requirements

Based on the results of the subsurface exploration, laboratory testing, and our analyses, it is our recommendation that the causeways can be used as flood protection systems. We estimate design differential hydraulic head across the flood wall would be about 3 to 5 feet, assuming flood tides of +10 feet NAVD88 or higher and water levels within the community below +7 feet NAVD88. We will coordinate design requirements with the stakeholders in final design.

4.2 Flood Cutoff Wall

Due to materials in the soil profile that have high hydraulic conductivity, a cutoff system will be needed to block seepage through and under the causeway. Uncontrolled seepage can erode material from the backside slope through “piping” and often propagate and lead to complete failure of the system. The clean sands and especially the layer of oyster shells encountered at Basin 2 are highly susceptible to seepage.

Furthermore, compressible and low-strength soils are present under the causeways, which will settlement and may become unstable if additional fill is added build-up the freeboard elevation.

Cutoff walls are used to block / minimize seepage. A cutoff wall can extend through and under the causeways to form a hydraulic barrier to prevent uncontrolled seepage. There are several types of cutoff walls for flood protection, which generally have two categories:

- Soil replacement / treatment: cement soil mixing, slurry trench excavation, secant soil-mix columns
- Sheet pile walls: steel (Waterloo™ Barrier), HDPE or vinyl, aluminum

We recommend that a vinyl or aluminum sheet piling system, such as those manufactured by CMI, could provide an efficient solution to convert the two causeways into flood protection systems. We have seen this product used successfully for similar projects. The sheet would be installed down to the required cutoff elevation and could extend up above the causeway to provide flood protection above the current trail elevation. Such a system would eliminate the need to place additional fill on the causeways, inducing settlement and likely requiring impact the marsh. An aesthetic cap is often installed along the top of the wall. The CMI sheeting is typically installed using their steel "claw" system, which installs the sheets using steel outer casing to penetrate through debris or dense layers without damaging the sheets. The "claw" is retracted, leaving the sheets in place. Figure 3 shows a CMI rendering of a typical flood protection sheet pile system.

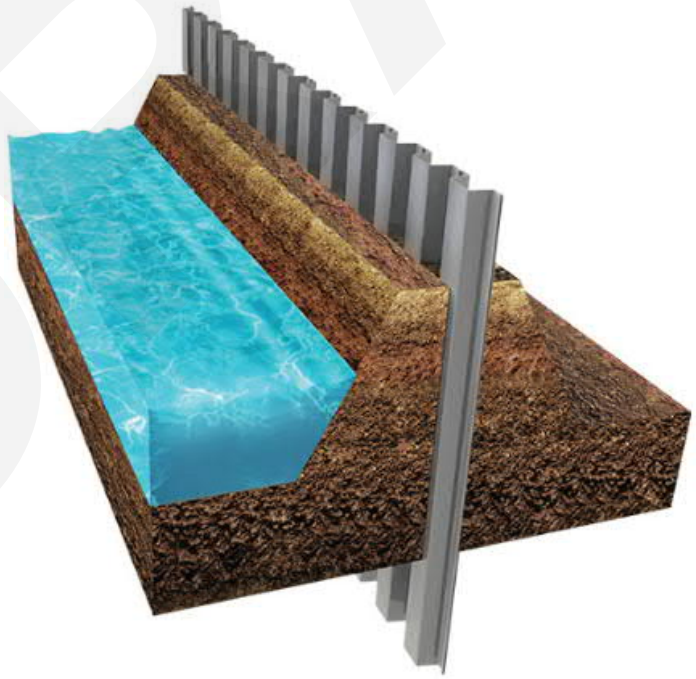

Figure 3. Rendering of Flood Protection Sheet Pile System (www.CMISheetPiling.com)

Figure 4 is an example wall installed in Mount Pleasant, South Carolina.

Figure 4. CMI Aluminum Sheet Pile Wall for Flood Protection (www.CMISheetPiling.com)

At this preliminary phase, we estimate the following quantities for the project. These are intended for preliminary cost estimations only. Final design will provide recommended quantities for construction.

- Estimated cutoff wall lengths of about 20 to 30 feet
  (anticipated elevation between -10 feet and -20 feet NAVD88 and top of freeboard estimated at +12 feet)
- Length along Basin 1 causeway of about 615 feet
- Length along Basin 2 causeway of about 250 feet

Final design and construction will need to integrate the cutoff wall with the replacement culverts to avoid seepage around the culvert. Depending on the bottom elevation of the proposed culverts, this may require a cofferdam for dewatering during construction.

To keep out flood waters using a flood protection system, a comprehensive review of all potential in-flow locations and mechanisms is needed. Drainage systems with inlets lower than the flood elevations, other low spots and seepage potential around the community perimeter can circumvent flood walls. We will work with ICE and the City of Beaufort to ensure the flood walls fit as a part of the overall plan for the Mossy Oaks community.

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5 LIMITATIONS OF REPORT

These services and this report have been performed in accordance with the local standard of practice. These recommendations apply only to the specific project referenced herein. Conclusions and recommendations are based on the observations and collected measurements. Subsurface tests were performed at discrete locations; subsurface conditions can vary between test locations. Insight Group should review final plans and specifications for construction.

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APPENDICES

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Notes:
Figure provided by ICE

INSIGHT GROUP
3359 Meeting St. N. Charleston, SC 29405
Phone: (843) 779 9824 InsightGrp.com

Project Name: Mossy Oaks Drainage

Project Number: 19-0001

Date: 2/15/2019

Site Location

Mossy Oaks Drainage Improvements
Preliminary Geotechnical Report

Port Royal South Carolina

Exhibit

A

Legend

Cone Penetration Test / Direct Push Boring to Collect Samples

Hand Auger Boring

INSIGHT GROUP
3359 Meeting St. N. Charleston, SC 29405
Phone: (843) 779 9824 InsightGrp.com

Project Name: Mossy Oaks Drainage

Project Number: 19-0001

Date: 2/15/2019

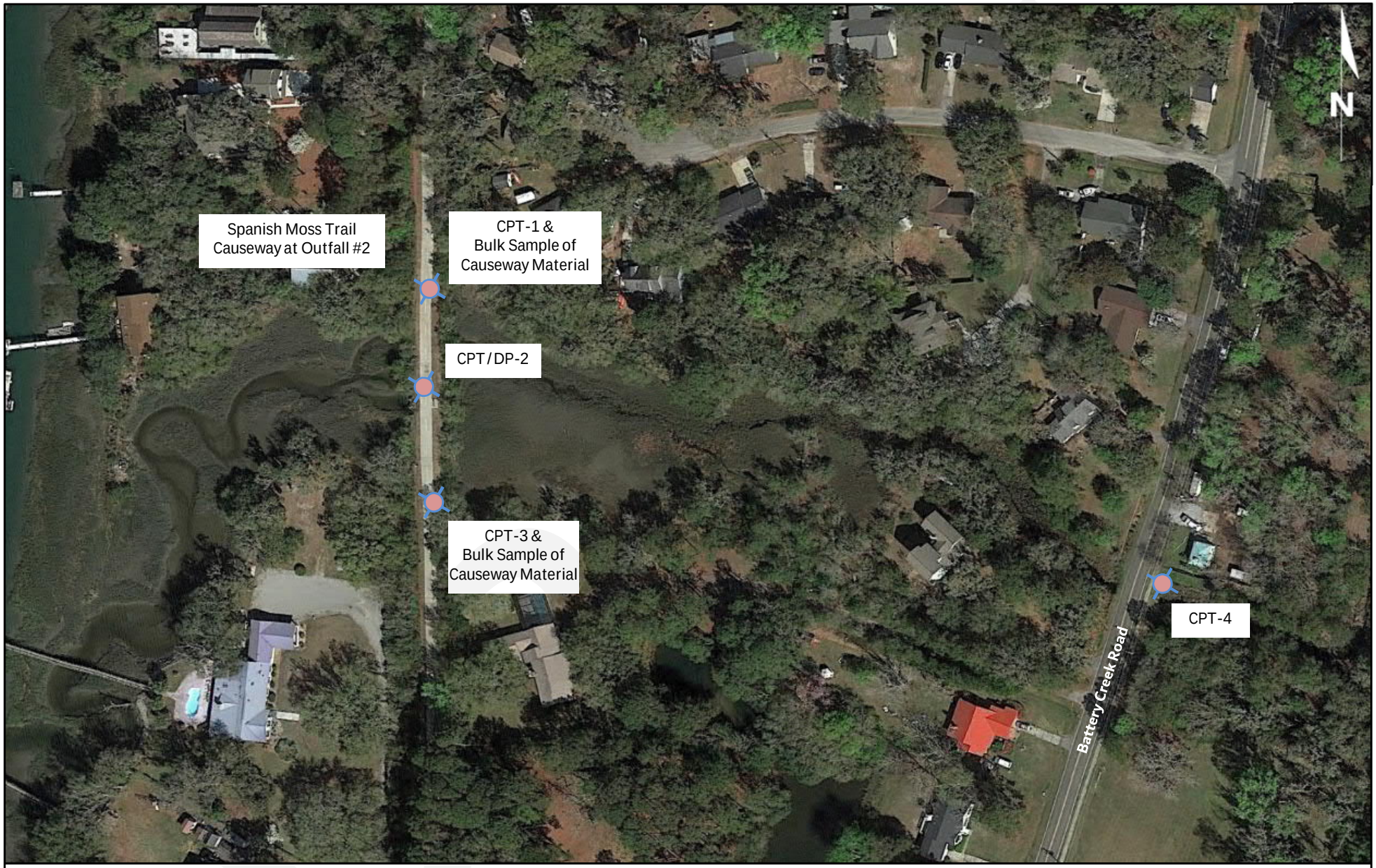
Test Location Plan

Mossy Oaks Drainage Improvements
Preliminary Geotechnical Report

Port Royal South Carolina

Exhibit

A



Legend

- Cone Penetration Test / Direct Push Boring to Collect Samples
- Hand Auger Boring

INSIGHT GROUP
3359 Meeting St. N. Charleston, SC 29405
Phone: (843) 779 9824 InsightGrp.com

Project Name: Mossy Oaks Drainage

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Date: 2/15/2019

Test Location Plan

Mossy Oaks Drainage Improvements
Preliminary Geotechnical Report

Port Royal South Carolina

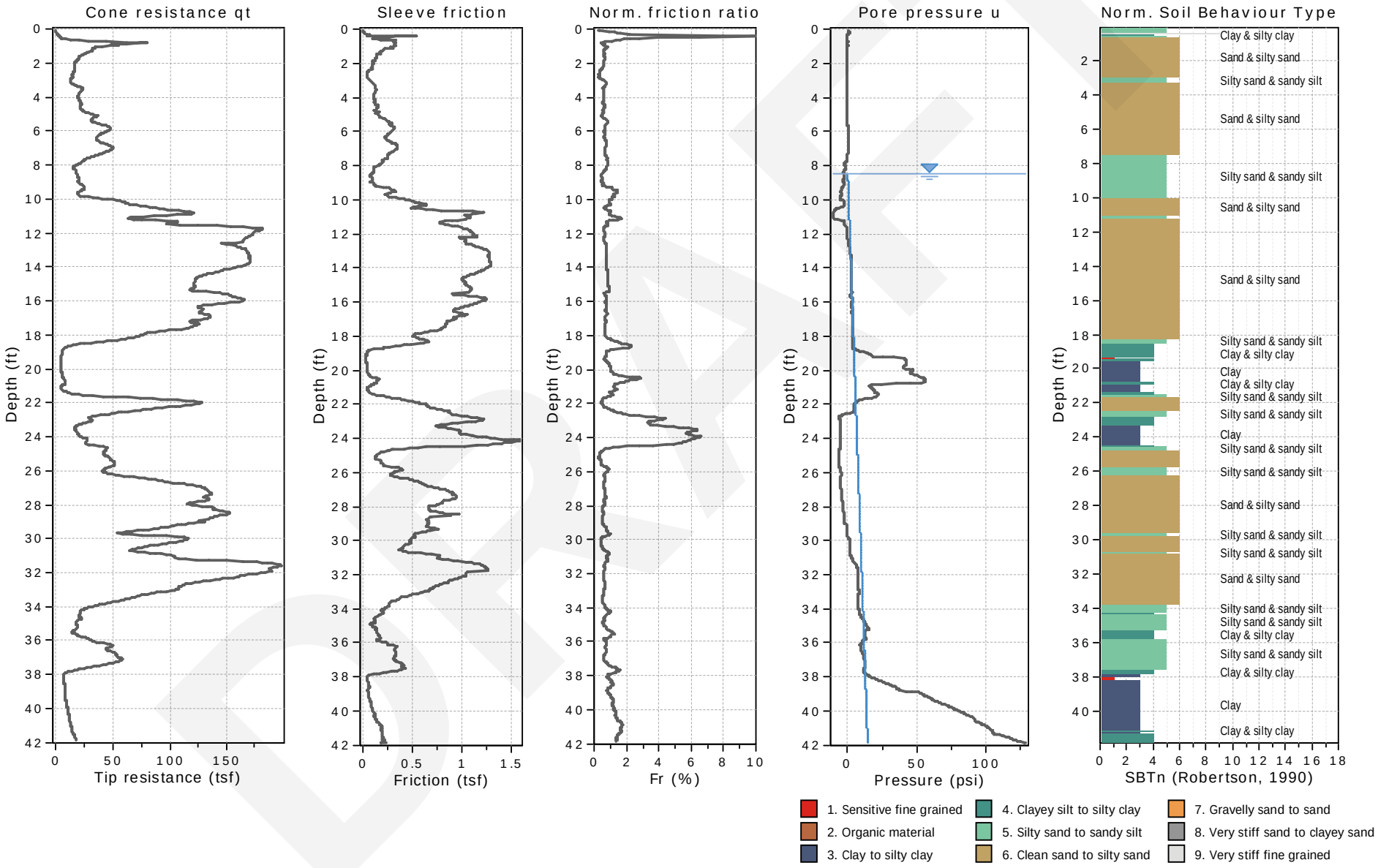
Exhibit

A

Insight Group
Geotechnical, Construction and Environmental Consultants
North Charleston, South Carolina
www.InsightGrp.com

CPT-1
Total depth: 41.86 ft, Date: 2/4/2019
Cone Type: Mkj610
Cone Operator: JMB

Project: 19-0001 Mossy Oaks Drainage
Location: Port Royal, SC



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Insight Group
Geotechnical, Construction and Environmental Consultants
North Charleston, South Carolina
www.InsightGrp.com

CPT-2

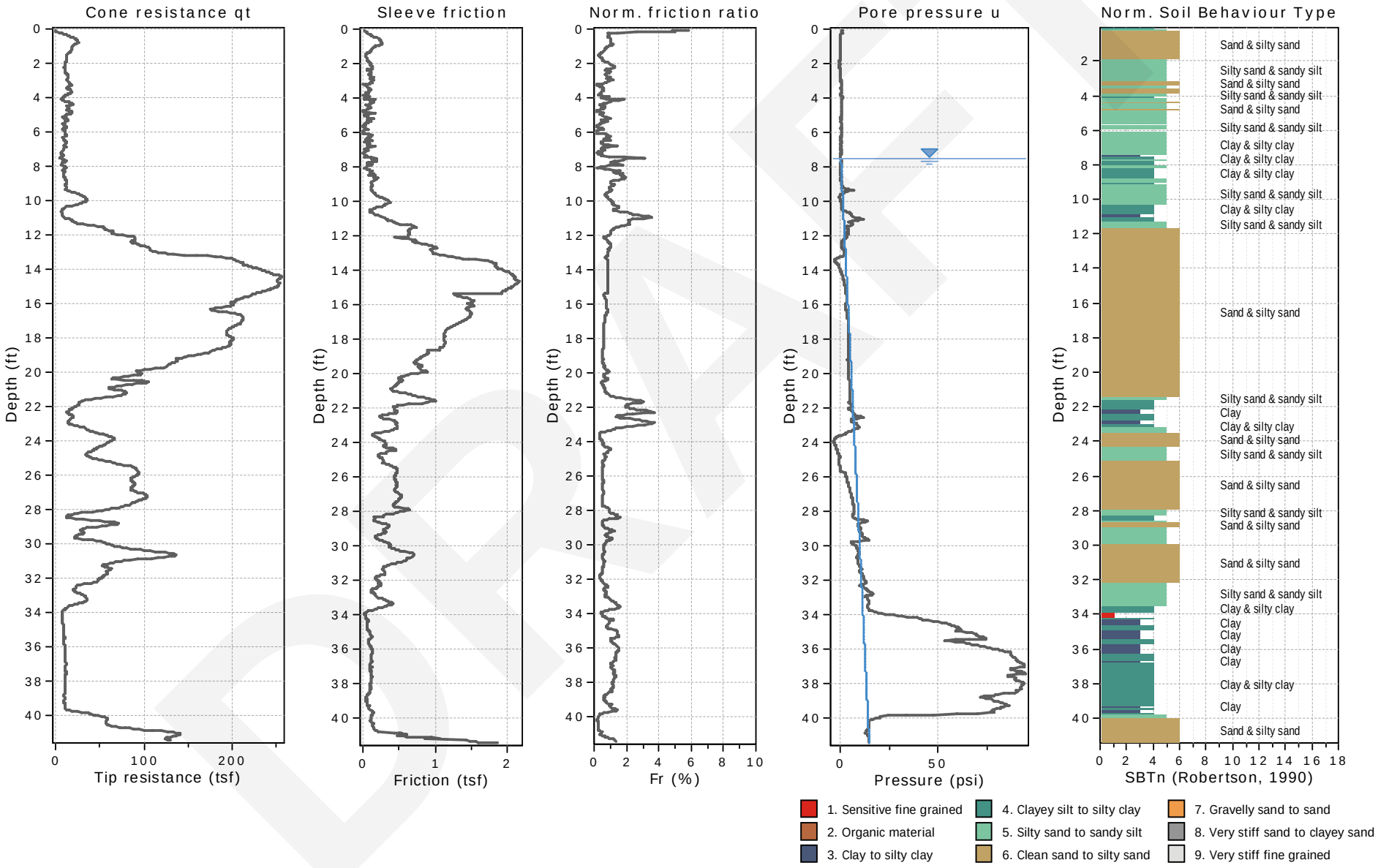
Project: 19-0001 Mossy Oaks Drainage

Location: Port Royal, SC

Total depth: 41.44 ft, Date: 2/4/2019

Cone Type: Mkj610

Cone Operator: JMB



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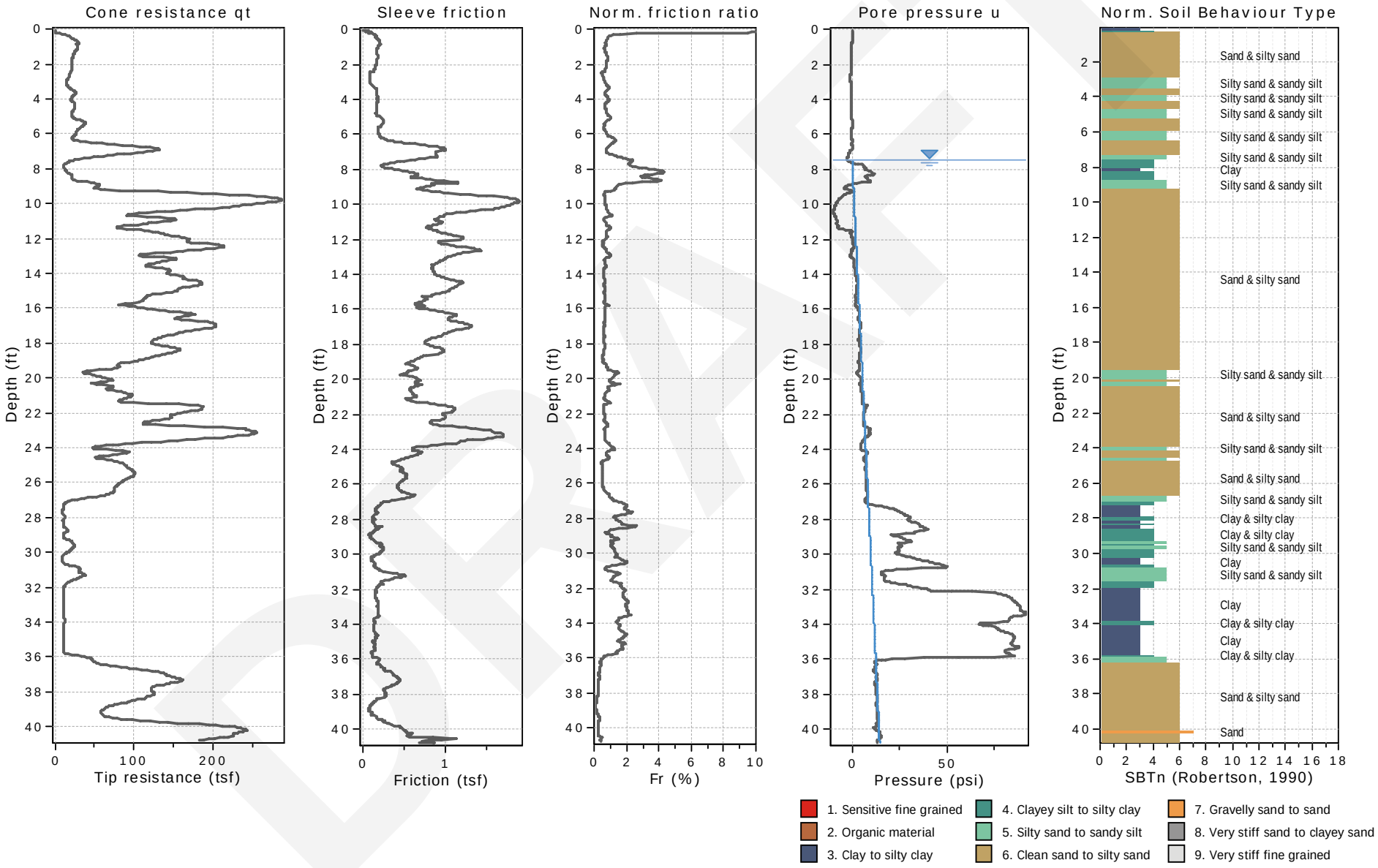
Insight Group
Geotechnical, Construction and Environmental Consultants
North Charleston, South Carolina
www.InsightGrp.com

Project: 19-0001 Mossy Oaks Drainage
Location: Port Royal, SC

CPT-3
Total depth: 40.78 ft, Date: 2/4/2019
Cone Type: Mkj610
Cone Operator: JMB



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Insight Group
Geotechnical, Construction and Environmental Consultants
North Charleston, South Carolina
www.InsightGrp.com

CPT-4

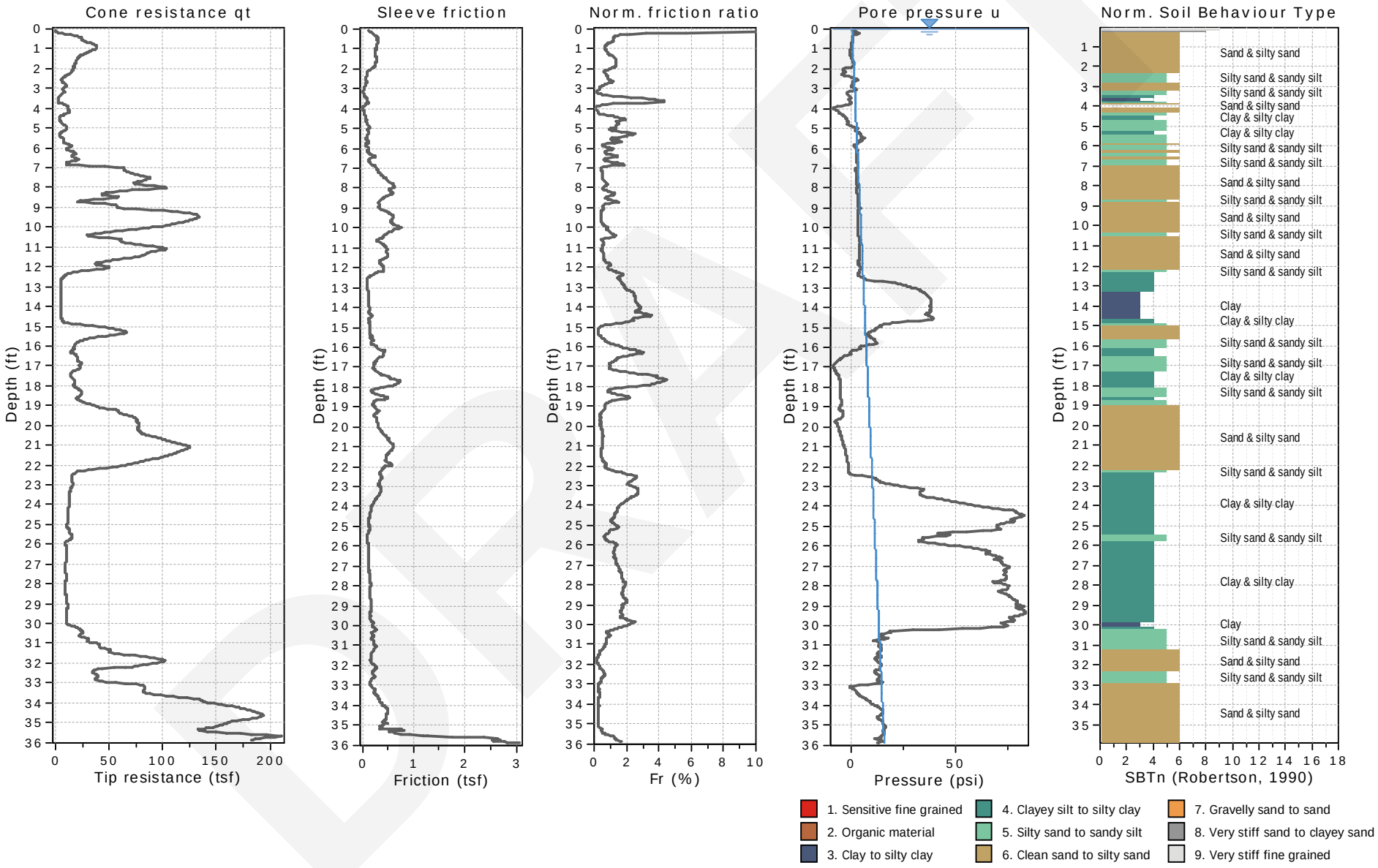
Total depth: 35.89 ft, Date: 2/4/2019

Cone Type: Mkj610

Cone Operator: JMB

Project: 19-0001 Mossy Oaks Drainage

Location: Port Royal, SC



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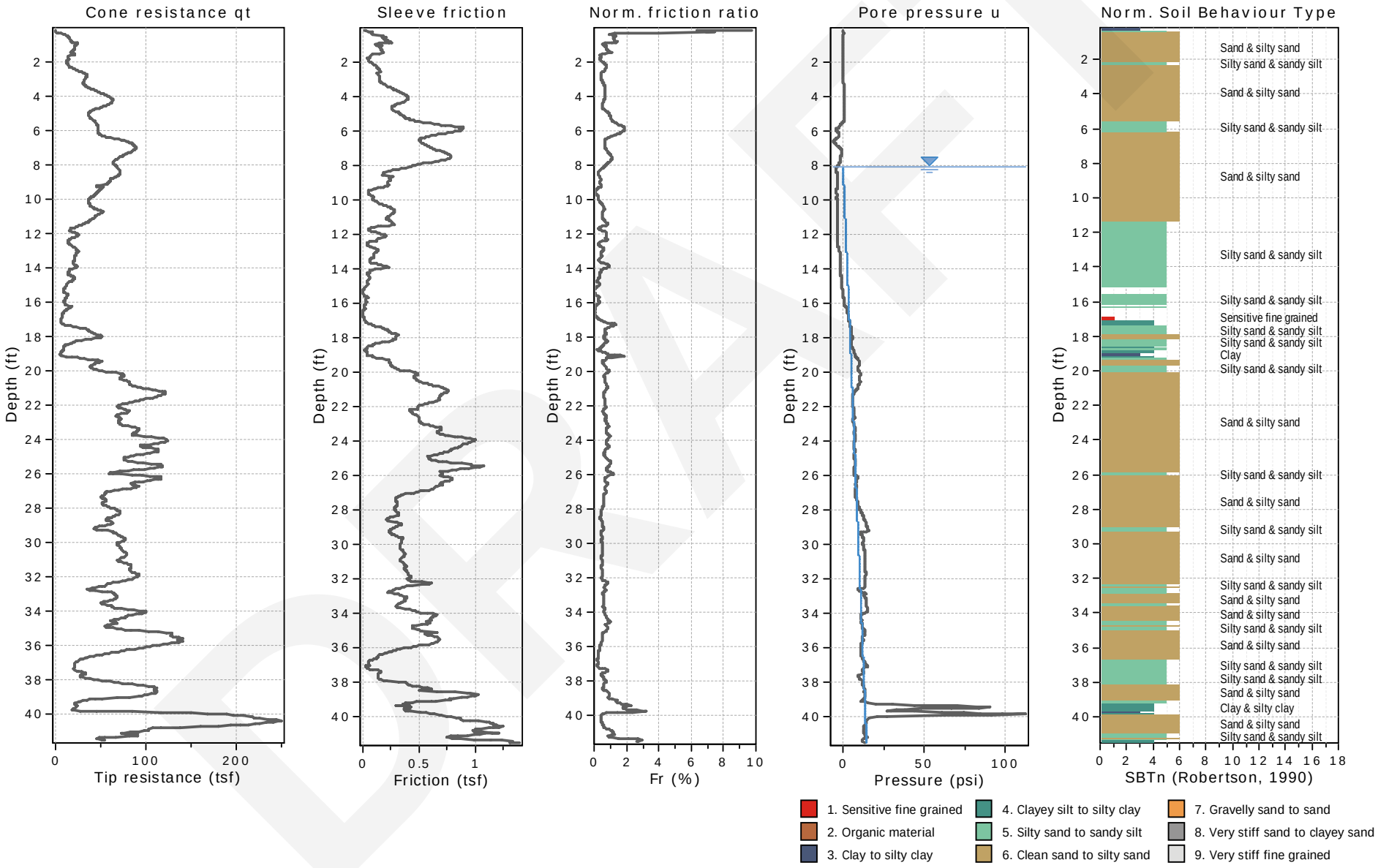
Insight Group
Geotechnical, Construction and Environmental Consultants
North Charleston, South Carolina
www.InsightGrp.com

CPT-5
Total depth: 41.50 ft, Date: 2/4/2019
Cone Type: Mkj610
Cone Operator: JMB

Project: 19-0001 Mossy Oaks Drainage
Location: Port Royal, SC



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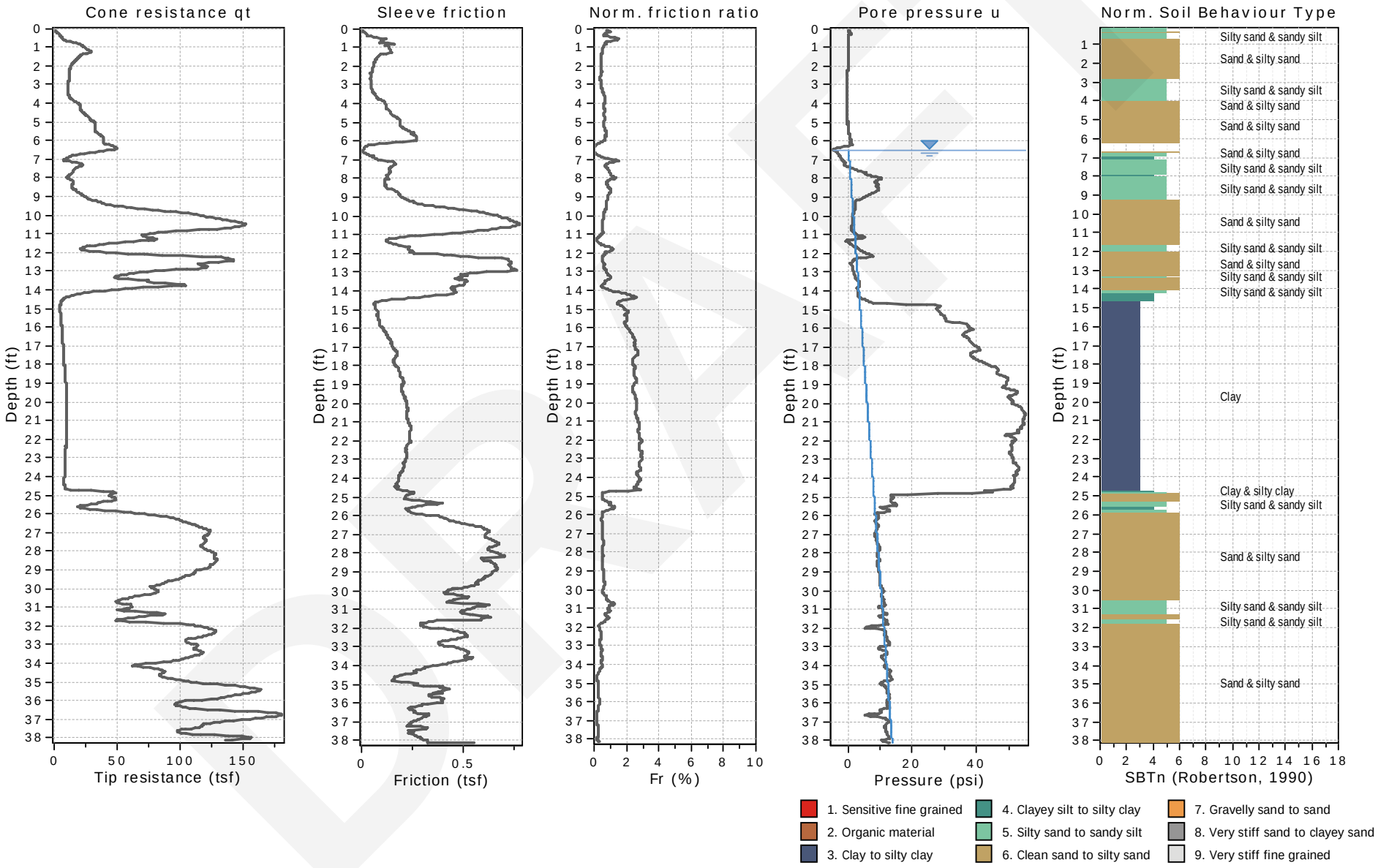
Insight Group
Geotechnical, Construction and Environmental Consultants
North Charleston, South Carolina
www.InsightGrp.com

CPT-6
Total depth: 38.12 ft, Date: 2/4/2019
Cone Type: Mkj610
Cone Operator: JMB

Project: 19-0001 Mossy Oaks Drainage
Location: Port Royal, SC



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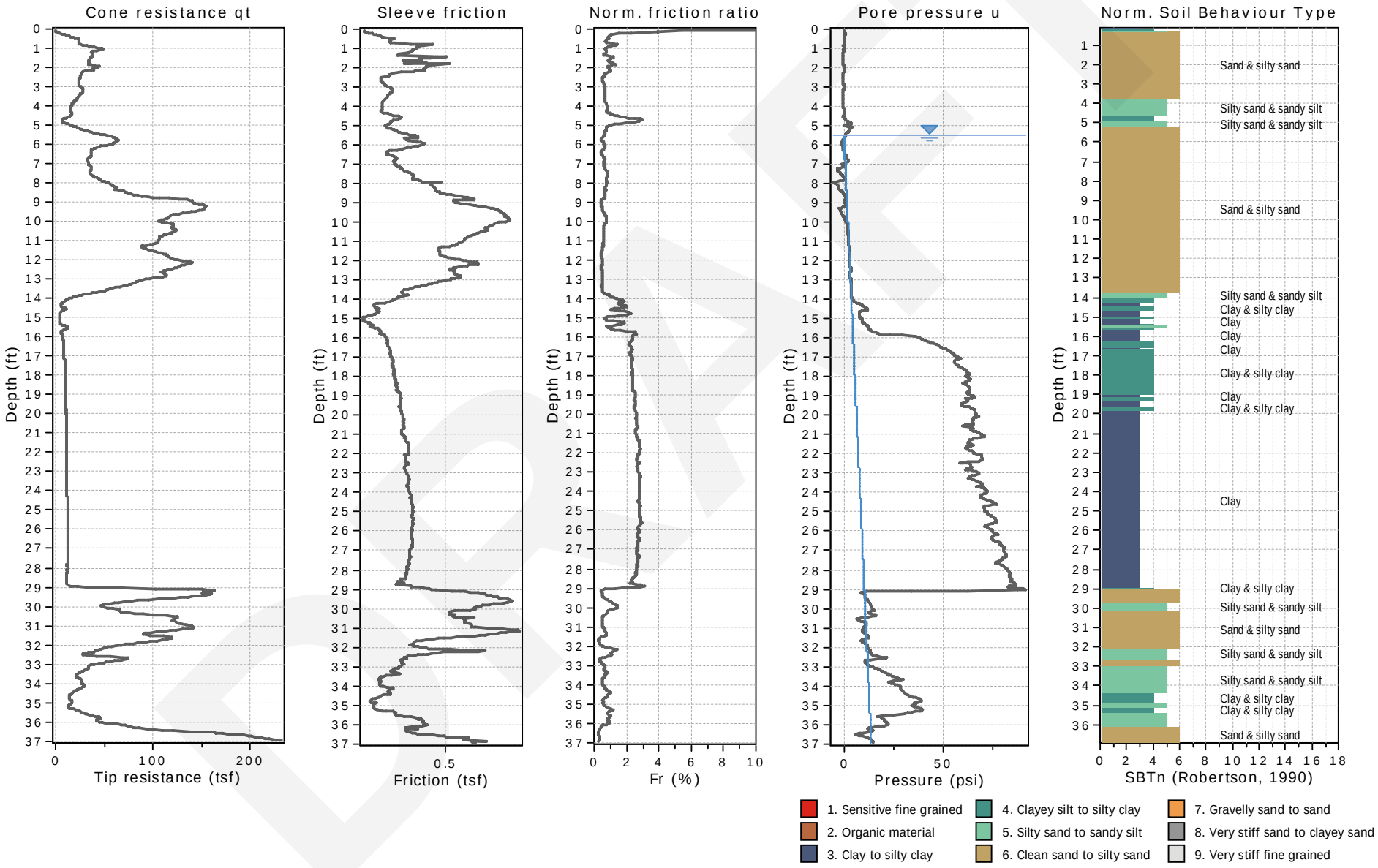
Insight Group
Geotechnical, Construction and Environmental Consultants
North Charleston, South Carolina
www.InsightGrp.com

CPT-7
Total depth: 36.94 ft, Date: 2/4/2019
Cone Type: Mkj610
Cone Operator: JMB

Project: 19-0001 Mossy Oaks Drainage
Location: Port Royal, SC



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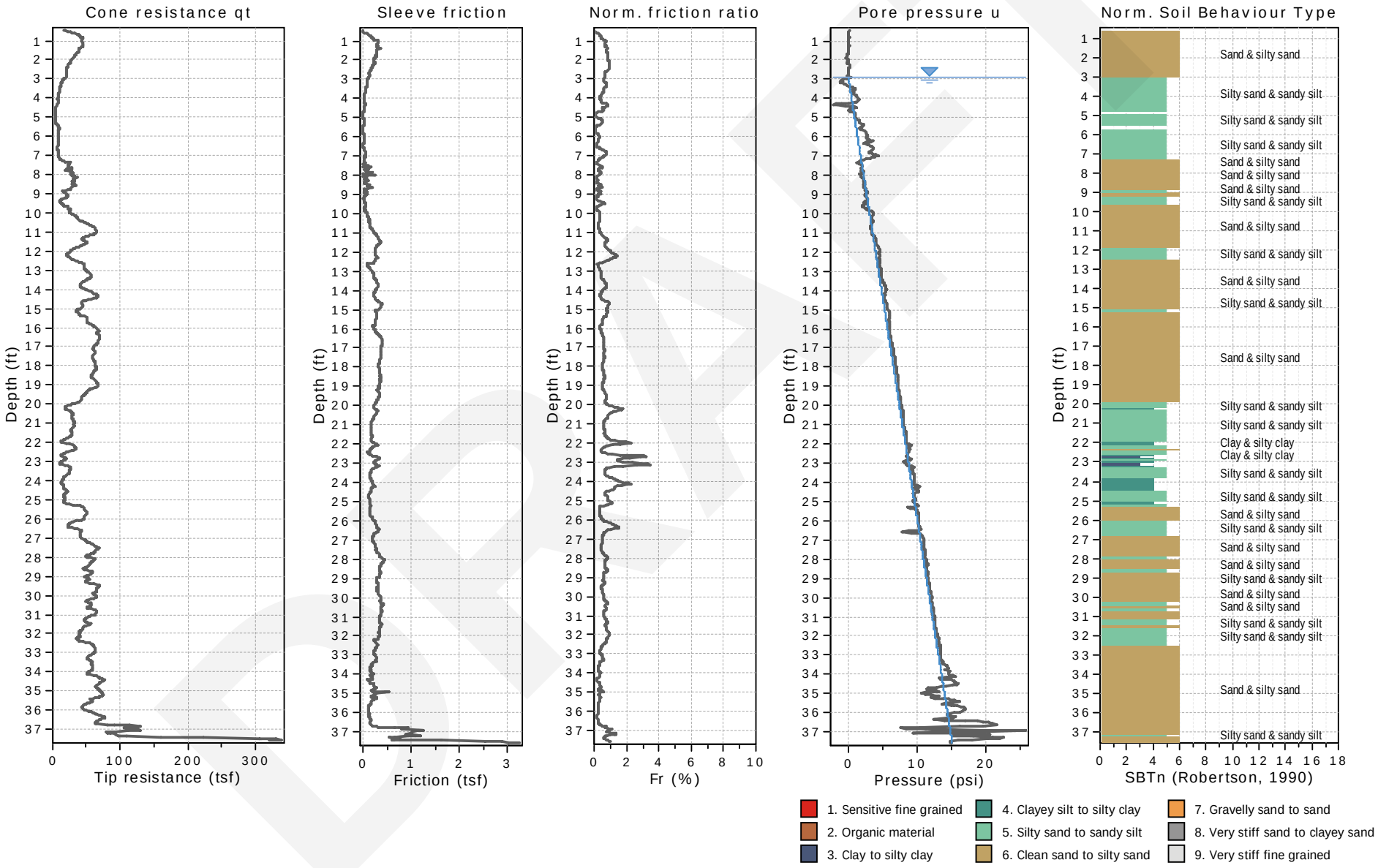
Insight Group
Geotechnical, Construction and Environmental Consultants
North Charleston, South Carolina
www.InsightGrp.com

CPT-8
Total depth: 37.57 ft, Date: 2/4/2019
Cone Type: Mkj610
Cone Operator: JMB

Project: 19-0001 Mossy Oaks Drainage
Location: Port Royal, SC



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BORING NUMBER DP-2

Insight Group
3359 Meeting Street Suite 101
N. Charleston, SC 29409

INSIGHT GROUP NUMBER: 19-0001

PROJECT: Mossy Oaks Drainage
Port Royal, South Carolina

CLIENT: Inrastructure Consulting & Engineering
Beaufort, South Carolina

DATE STARTED 2/4/19 **COMPLETED** 2/4/19

GROUND ELEVATION

DRILLER/OPERATOR J. Bray

GROUND WATER LEVELS:

ADVANCEMENT METHOD Direct Push

▽ **Estimated During Sampling:** 7.5 ft.

ADVANCEMENT RIG Pagani 150-63 **LOGGED BY** Z. Driggers

NOTES

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0		SM		Moist, brown, rounded, fine grained, with trace organics, grass roots, **SILTY SAND WITH GRAVEL (SM)** *(FILL)*
			0.8	
				Moist, black, well graded gravel with some oyster shell fragments, **ASPHALT BASE** *(FILL)*
			1.5	
	DP	SP-SM		Moist, light brown, rounded, fine grained, trace organics, with nodules of some plasticity, **POORLY GRADED SAND WITH SILT (SP-SM)** *(FILL)*
	GB 1			Root / wood mulch at 2.5 feet, *(FILL)*
			3.5	
		CH	3.8	Moist, dark red, some trace organics and shell fragments, **FAT CLAY WITH SAND (CH)** *(FILL)*
		SM		Moist, brown, rounded, fine grained, **SILTY SAND (SM)** *(FILL)*
			4.4	
		CH		Moist, dark red, with trace shells, **FAT CLAY WITH SAND (CH)** *(FILL)*
5			5.0	
	DP			Oyster shells with some clayey sand intermixed, *(FILL)*
				▽
	DP			
			9.2	
		SM		Moist to wet, gray, rounded, fine grained, with some wood pieces at bottom of layer, **SILTY SAND (SM)** *(FILL)*
10			10.5	
				Wet, light gray, rounded, fine grained, strong organic (marsh) odor, with interbedded clean sand lenses, **CLAYEY SAND (SC)** *(HOLOCENE)*
	GB 2			
	DP	SC		
			13.7	
				Wet, light gray, rounded, fine grained, strong organic (marsh) odor, **POORLY GRADED SAND WITH SILT (SP-SM)** *(HOLOCENE)*
15	DP	SP-SM		
			16.3	
				Terminated at 16.3 feet

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BORING NUMBER DP-6

Insight Group
3359 Meeting Street Suite 101
N. Charleston, SC 29409

INSIGHT GROUP NUMBER: 19-0001

PROJECT: Mossy Oaks Drainage
Port Royal, South Carolina

CLIENT: Inrastructure Consulting & Engineering
Beaufort, South Carolina

DATE STARTED 2/5/19 **COMPLETED** 2/5/19

GROUND ELEVATION

DRILLER/OPERATOR J. Bray

GROUND WATER LEVELS:

ADVANCEMENT METHOD Direct Push

▽ **Estimated During Sampling:** 6.5 ft.

ADVANCEMENT RIG Pagani 150-63 **LOGGED BY** Z. Driggers

NOTES

DEPTH (ft)	SAMPLE TYPE NUMBER	U.S.C.S.	GRAPHIC LOG	MATERIAL DESCRIPTION
0		SM		Moist, brown, rounded, fine grained, with organics, leaves, grass, **SILTY SAND (SM)** *(FILL)*
		SM	0.2	Moist, brown, rounded, fine grained, trace organics, **SILTY SAND (SM)** *(FILL)*
			0.7	Moist, black, well graded gravel with some oyster shell fragments, **ASPHALT BASE** *(FILL)*
	DP	SP-SM	1.2	Moist, light gray to dark brown, rounded, fine grained, **POORLY GRADED SAND WITH SILT (SP-SM)** *(FILL)*
		SC	4.0	Moist to wet, dark brown, rounded, fine grained, **CLAYEY SAND (SC)** *(FILL)*
5	DP	SP-SM	4.3	Wet, gray, rounded, fine grained, **POORLY GRADED SAND WITH SILT (SP-SM)** *(FILL)*
		SM	7.0	Wet, dark brown, rounded, fine grained, with trace organics, **SILTY SAND (SM)** *(FILL)*
	GB 1 DP	SP-SM	8.5	Wet, light brown to gray, rounded, fine grained, strong organic (marsh) odor, **POORLY GRADED SAND WITH SILT (SP-SM)** *(HOLOCENE)*
10			10.4	Terminated at 10.4 feet

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