

**MAINE DEPARTMENT OF TRANSPORTATION
HIGHWAY PROGRAM
GEOTECHNICAL SECTION
AUGUSTA, MAINE**

GEOTECHNICAL DESIGN REPORT

For the Construction of:

**SOUTH CROOKED BROOK BRIDGE
ROUTE 1
DANFORTH, MAINE**

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Washington County
WIN 22849.00

April 22, 2019

Soils Report 2019-13
Bridge No. 6594

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1.0 INTRODUCTION

The purpose of this Geotechnical Design Report is to present subsurface information and make geotechnical recommendations for the replacement of an existing large culvert (#46692) on Route 1 in Danforth, Maine. A subsurface investigation has been completed at the site to evaluate subsurface conditions and to develop geotechnical design and construction recommendations for the replacement structure. This report presents the subsurface information obtained during the subsurface investigation and soil laboratory testing programs, and provides design and construction recommendations and geotechnical design parameters for the culvert replacement.

The existing structure consists of approximately 55-foot long, 72-inch diameter, twin corrugated metal pipe (CMP) culverts. The CMPs are in poor condition and one is plugged. Route 1 is a Highway Corridor Priority 1 road.

The proposed replacement structure will be a 16-foot span by 6-foot rise by 84-foot long precast concrete box culvert on a skew of approximately 4 degrees to the roadway centerline. The invert of the proposed culvert is approximately 10 feet below the existing road grade at the roadway centerline. The roadway embankment slopes at the proposed culvert inlet and outlet shall be no steeper than 2H:1V to protect against erosion.

2.0 GEOLOGIC SETTING

The existing culvert carries South Crooked Brook under Route 1 in Danforth and is located approximately 0.12 of a mile north of the Brookton Township town line as shown on Sheet 1 – Location Map.

According to the Maine Geological Survey (MGS) map titled Reconnaissance Surficial Geology of the Danforth Quadrangle, Maine Open File 80-3 (1980) the surficial soils at the site consist of swamp and tidal marsh deposits. These soils consist of peat, silt, sand and clay. The soils encountered in the explorations were not consistent with this map.

According to the map titled Bedrock Geology of Maine (1985) published by the MGS, the bedrock in the vicinity of the site consists of interbedded pelite and sandstone.

3.0 SUBSURFACE INVESTIGATION

One (1) boring (HB-DAN-101) and one (1) probe (HB-DAN-102) were drilled for this project on October 5, 2017 by the MaineDOT drill crew using a trailer mounted drill rig. Exploration locations are shown on Sheet 2 – Boring Location Plan & Interpretive Subsurface Profile with Boring Logs. Details and sampling methods used, field data obtained, and soil and groundwater conditions encountered are presented on the Boring Log in Appendix A.

Boring HB-DAN-101 was drilled using solid stem auger and cased wash boring techniques. Soil samples were obtained in boring HB-DAN-101 at 5-foot intervals using Standard Penetration Test

(SPT) methods. The MaineDOT drill rig is equipped with an automatic hammer to drive the split spoon. The MaineDOT calibrated automatic hammer delivers approximately 42 percent more energy during driving than the standard rope and cathead system. All N-values discussed in this report are corrected values (N_{60}) computed by applying an average energy transfer factor of 0.854 to the raw field N-values. The bedrock was cored in boring HB-DAN-101 using an NQ 2-inch core barrel and the Rock Quality Designation (RQD) of the core was calculated. Probe HB-DAN-102 was drilled using solid stem auger techniques. No soil samples were obtained in the probe.

The MaineDOT Geotechnical Team member selected the boring and probe locations, drilling methods, designated type and depth of sampling, reviewed field logs for accuracy and identified field and laboratory testing requirements. An experienced Northeast Transportation Training and Certification Program (NETTCP) certified subsurface inspector logged the subsurface conditions encountered. The boring and probe were located in the field by taping to surveyed site features after completion of the drilling program.

4.0 LABORATORY TESTING

A laboratory testing program was conducted to assist in soil classification, evaluation of engineering properties of the soils and geologic assessment of the project site. Laboratory testing consisted of four (4) standard grain size analyses with natural water content. The results of the laboratory testing program are discussed in the following section and are included in Appendix B – Laboratory Test Results. Laboratory test information is also shown on the Boring Logs in Appendix A.

5.0 SUBSURFACE CONDITIONS

Subsurface conditions encountered at the test boring and probe generally consisted fill sand overlying native glacial till. An interpretive subsurface profile depicting the generalized soil stratigraphy at the boring location is shown on Sheet 2 - Boring Location Plan & Interpretive Subsurface Profile with Boring Logs.

Boring HB-DAN-101 was drilled to refusal at a depth of approximately 21.0 feet below ground surface (bgs). Bedrock was cored in the boring for a total depth of approximately 26.0 feet bgs. Probe HB-DAN-102 to a depth of approximately 20.0 feet bgs and did not encounter a refusal surface.

The table below summarizes the field and laboratory information obtained in boring HB-DAN-101:

Approx. Depth BGS ¹ (feet)	Soil Description	AASHTO ² Classification	USCS ³	WC% ⁴
0.0-0.3	Pavement			
0.3 – 10.0	Fill – Brown, moist, fine to coarse sand, some gravel, little silt.	A-1-b	SM	8.1
9.0 – 21.0	Glacial Till – Interbedded grey, wet, fine to coarse sand, some silt, little to some gravel and grey, wet, fine to coarse sandy gravel, little silt.	A-2-4 or A-1-a	SM or GM	6.9 to 10.9
21.0-26.0	Bedrock – Interbedded pelite and sandstone.	--	--	--

¹BGS = below ground surface

²AASHTO = American Association of State Highway and Transportation Officials

³USCS = Unified Soil Classification System

⁴WC% = Water content in percent

One (1) corrected N-value obtained in the fill was 17 blows per foot (bpf) indicating that the fill is medium dense in consistency. Two (2) N-values obtained in the till were 26 bpf and 27 bpf, indicating that the till is medium dense in consistency. The Rock Quality Designation (RQD) of the bedrock was determined to be 0 percent in boring HB-DAN-101 which correlates to a Rock Quality of Very Poor.

Groundwater was not recorded in the boring or the probe. Groundwater levels can be expected to fluctuate subject to seasonal variations, local soil conditions, topography, precipitation, and construction activity.

6.0 GEOTECHNICAL DESIGN AND CONSTRUCTION RECOMMENDATIONS

The proposed replacement structure will consist of a 16-foot span by 6-foot rise by 84-foot long precast concrete box culvert on a skew of approximately 4 degrees to the roadway centerline. The proposed structure inlet and outlet slopes shall be riprapped with slopes no steeper than 2H:1V to protect against erosion. The following sections discuss geotechnical recommendations for the design and construction of the proposed culvert.

6.1 Precast Concrete Box Culvert Design and Construction

The proposed replacement structure will consist of a 16-foot span by 6-foot rise by 84-foot long precast concrete box culvert at a skew of approximately 4 degrees to the roadway centerline. The proposed box culvert shall be designed and constructed in accordance with MaineDOT Standard Specification 534.

The inverts of the proposed box culvert range from approximately 381.0 feet at the inlet to approximately 381.4 feet at the outlet with a 0.5 percent slope.

The full nature of the culvert bearing surface will not become evident until the culvert excavation is made. Any cobbles or boulders in excess of 6 inches encountered at the bedding elevation shall be removed and replaced with compacted Granular Borrow Material for Underwater Backfill or Crushed Stone ¾-Inch. The prepared subgrade shall be proof-rolled using a static roller to visually confirm the prepared subgrade is firm and stable. The exposed subgrade shall be free of ponded water so that bedding material placement and compaction can be completed in the dry.

The proposed structure shall be bedded on a 1-foot thick layer of Granular Borrow, Material for Underwater Backfill meeting the requirements of MaineDOT Standard Specification 703.19. The soil envelope and backfill shall consist of Standard Specification 703.19 - Granular Borrow with a maximum particle size of 4 inches. The granular borrow bedding and backfill material shall be placed in lifts of 6 to 8 inches loose measure and compacted to the manufacturer's specifications or, in the absence of manufacturer's specifications, the bedding and backfill soil shall be compacted to at least 92 percent of the AASHTO T-180 maximum dry density.

6.2 Settlement

No settlement issues are anticipated at the site. No changes to the existing vertical or horizontal alignment are currently planned for this project. The proposed precast concrete box culvert is larger than the existing culvert and will result in a net unloading of the site soils at the structure location. Any settlement due to elastic compression of the subgrade soils and bedding material will be immediate and negligible.

6.3 Bearing Resistance

The factored bearing resistances for the precast concrete box culvert bearing on compacted granular bedding material placed on native soils at the service and strength limit states are presented in the table below. Supporting calculations in accordance with AASHTO LRFD Bridge Design Specifications 8th Edition 2017 (LRFD) are provided in Appendix C – Calculations.

Limit State	Resistance Factor ϕ_b	AASHTO LRFD Reference	Factored Bearing Resistance (ksf)
Service	1.0	Article 10.5.5.1	5.0
Strength	0.45	Table 10.5.5.2.2-1	8.0

6.4 Modulus of Subgrade Reaction

A modulus of subgrade reaction (k_s) equal to 250 pounds per cubic inch shall be used for the structural design of the box culvert's base slab. Calculations are included in Appendix C - Calculations.

6.5 Scour and Riprap

Both the inlet and outlet of the precast concrete box culvert shall be protected against scour with riprap conforming to MaineDOT Standard Specification Section 703.26 Plain and Hand Laid Riprap. Slopes shall be no steeper than 2H:1V. No specific scour protection recommendations are needed other than armoring with riprap. The riprap on the slopes shall be underlain by a non-woven, Class 1 Erosion Control Geotextile meeting the requirements of MaineDOT Standard Specification 722.03 that is underlain by a 1-foot layer of protective aggregate cushion consisting of Granular Borrow Material for Underwater Backfill (703.19). The toe of the riprap sections shall be keyed into the existing soils 1 foot below the streambed elevation.

6.6 Seismic Design Considerations

In conformance with LRFD Article 3.10.1, seismic analysis is not required for buried structures, except where they cross active faults. There are no known active faults in Maine; therefore, seismic analysis is not required.

6.7 Construction Considerations

Construction activities may include construction of cofferdams and earth support systems to control stream flow during construction. Construction activities will also include common earth excavation. Construction of the proposed precast concrete box culvert will require deep soil excavation. Earth support systems shall be implemented if laying back slopes is not feasible. It is likely that the use of complex (four-sided) braced excavations with dewatering will be necessary due to the depth of the excavation. If this is the case, adequate embedment into the till will be necessary to allow for the excavation and maintenance of a stable excavation bottom. All earth support systems shall be designed by a Professional Engineer licensed in the State of Maine. Regardless of the method of excavation, all excavations and earth support systems shall meet all applicable OSHA regulations.

The Contractor shall control groundwater and surface water infiltration using temporary ditches, sumps, granular drainage blankets, stone ditch protection or hand-laid riprap with geotextile underlayment to divert groundwater and surface water as needed to maintain a stable excavation and allow work in the dry.

Using the excavated native soils as backfill around the culvert shall not be permitted. The native soils may only be used as common borrow in accordance with MaineDOT Standard Specifications 203 and 703.

The Contractor will have to excavate the existing subbase and subgrade fill soils in the vicinity of the culvert. These materials should not be used to re-base the roadway. Excavated subbase sand and gravel may be used as fill below roadway subgrade level in fill areas provided all other requirements of MaineDOT Standard Specifications 203 and 703 are met.

7.0 CLOSURE

This report has been prepared for the use of the MaineDOT Highway Program and their design consultant for specific application to the proposed replacement of a large culvert (#46692) on Route 1 in Danforth, Maine in accordance with generally accepted geotechnical and foundation engineering practices. No other intended use or warranty is expressed or implied.

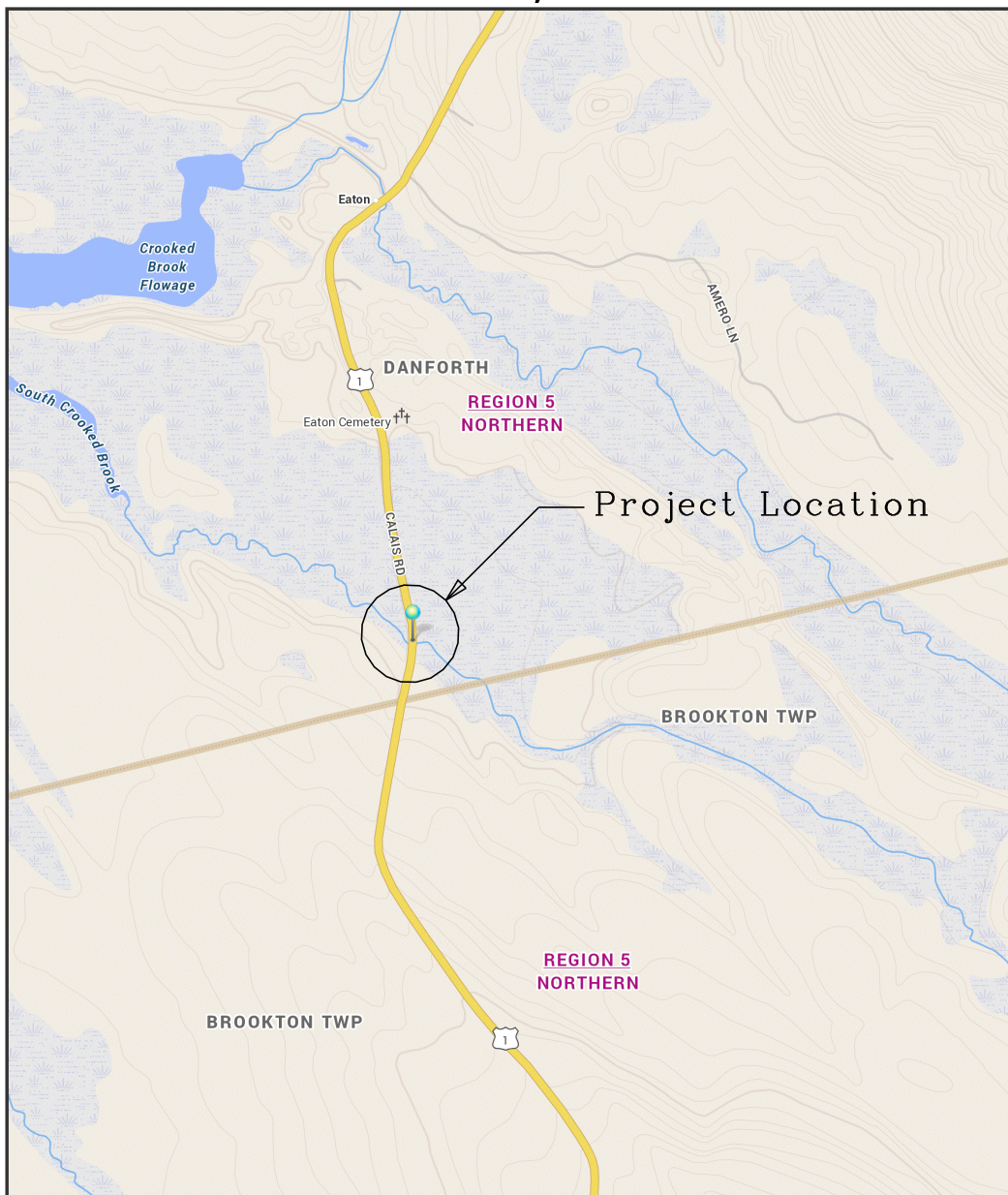
In the event that any changes in the nature, design, or location of the proposed project are planned, this report should be reviewed by a geotechnical engineer to assess the appropriateness of the conclusions and recommendations and to modify the recommendations as appropriate to reflect the changes in design. These analyses and recommendations are based in part upon a limited subsurface investigation at discrete exploratory location completed at the site. If variations from the conditions encountered during the investigation appear evident during construction, it may also become necessary to re-evaluate the recommendations made in this report.

It is recommended that a geotechnical engineer be provided the opportunity for a review of the design and specifications in order that the earthwork and foundation recommendations and construction considerations presented in this report are properly interpreted and implemented in the design and specifications.

Sheets



DANFORTH, MAINE



The Maine Department of Transportation provides this publication for information only. Reliance upon this information is at user risk. It is subject to revision and may be incomplete depending upon changing conditions. The Department assumes no liability if injuries or damages result from this information. This map is not intended to support emergency dispatch.

0.3 Miles
1 inch = 0.35 miles

Date: 3/21/2019
Time: 9:50:27 AM

SHEET NUMBER

1

OF 2

DANFORTH
U.S. ROUTE 1

LOCATION MAP

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

022849.00

WIN

022849.00

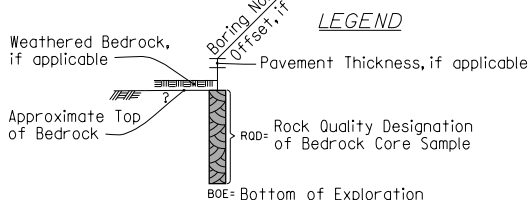
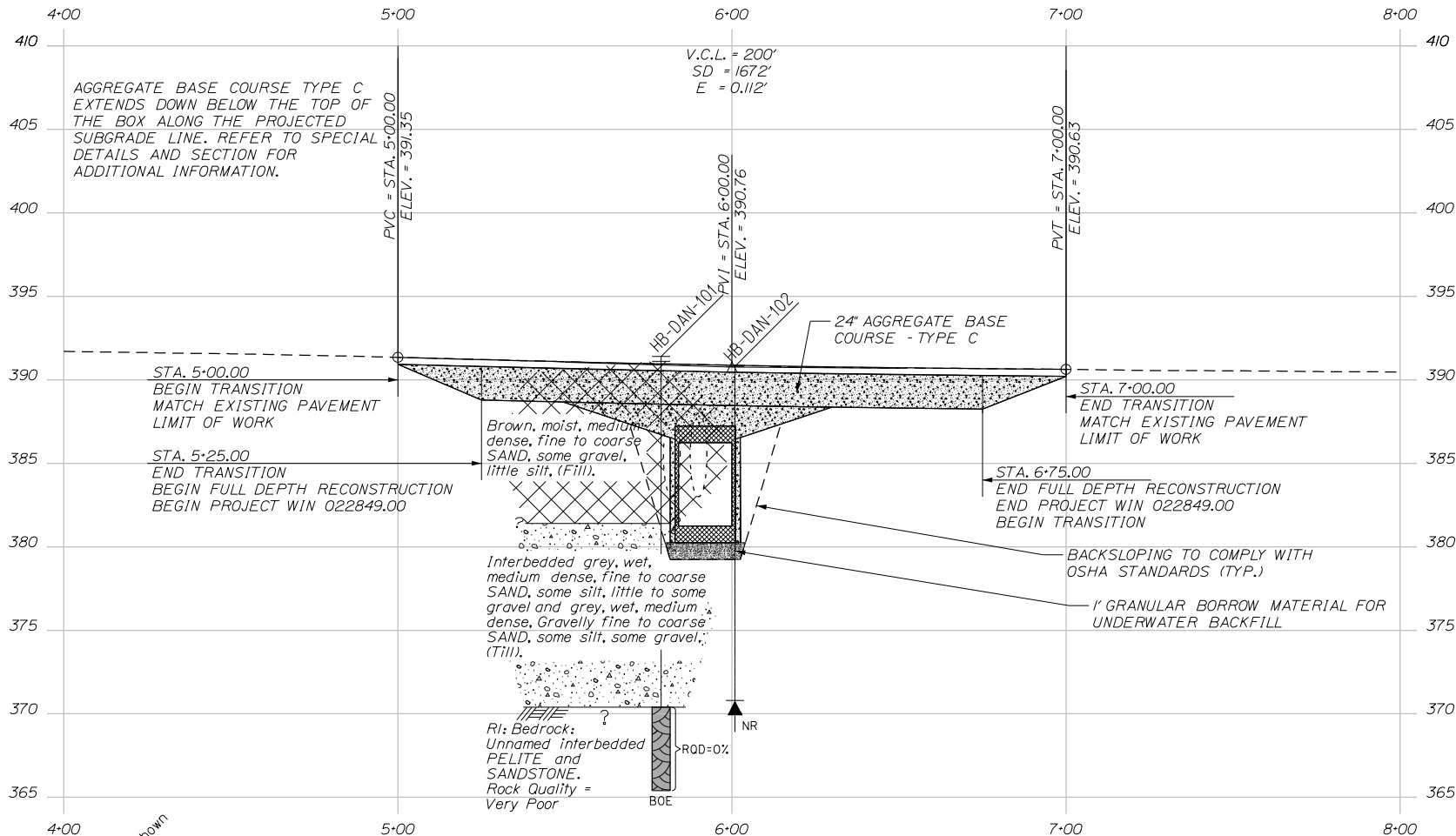
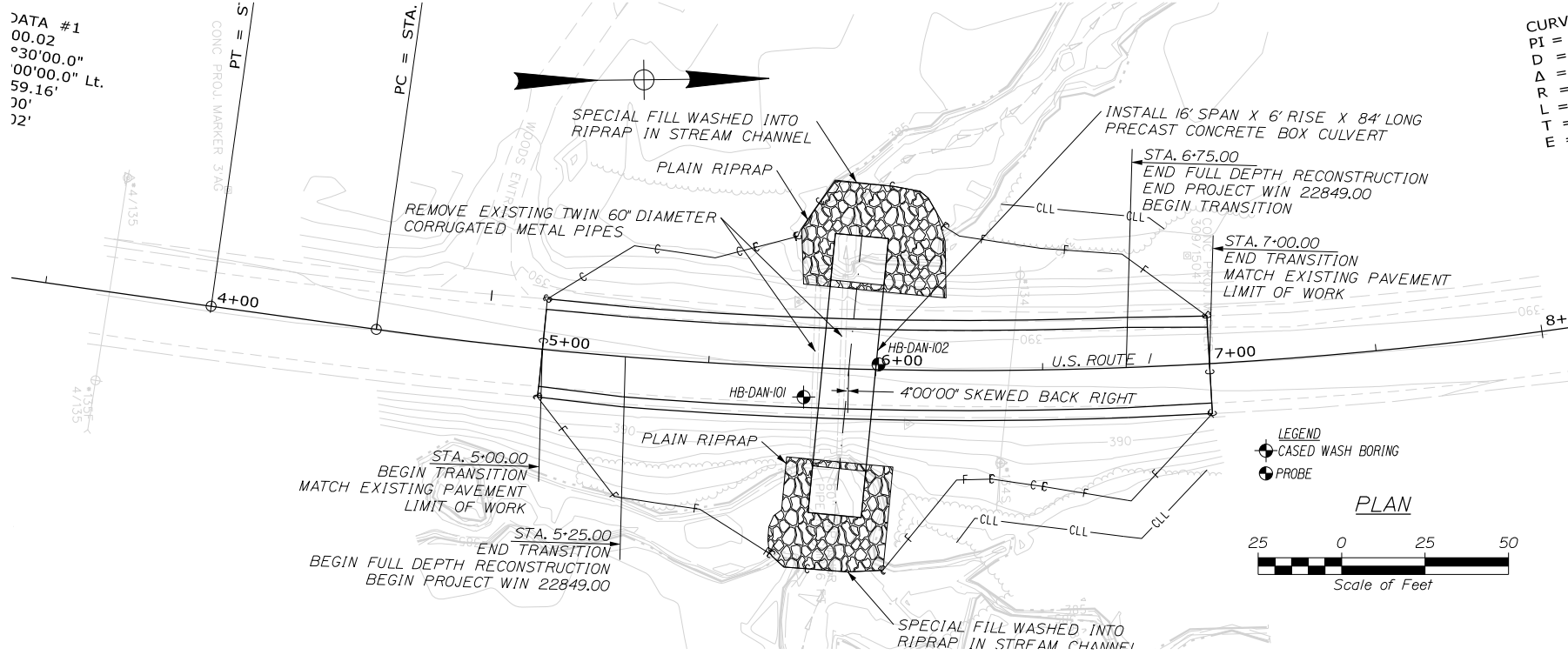
HIGHWAY PLANS

Date: 4/22/2019

Username: cody.a.russell

Division: GEOTECH

Filename: ... \MSTAND02_BLP\SP WBL1.dgn



Note: This generalized interpretive soil profile is intended to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized, and have been developed by interpretations of widely spaced explorations and samples. Actual soil and bedrock transitions may vary and are probably more erratic. For more specific information refer to the exploration logs.

Maine Department of Transportation			
Self/Book Exploration Log		Projects Route 1 Large Culvert	
US CUSTOMARY UNITS		Location: Danforth, Maine	
Boring No.: HB-DAN-101		WIN: 22849.00	
Driller: MATHIAS	Elevation (ft.): 391.4	Auger ID/OD: 5" Dia. Solid Stem	
Operator: Travis/James/Tyson	Duration: NAVD83	Samplers: Standard Split Spoon	
Logged By: B. Wfider	Rtg Type: CME 45C	Home Wt./Fall: 140W/30"	
Date Start/Finish: 10/5/2017 08:00-12:00	Drilling Method: Cased Wash Boring	Core Barrel: ND-2"	
Boring Location: 5+78.8, 8.9 ft Rt.	Casing ID/OD: NW-3"	Water Level: None Observed	
Hammer Efficiency Factor: 0.854			
Sample Information		Visual Description and Remarks	
Depth (ft.)	Sample No.	Pen. (lb./in.)	Sample Depth (ft.)
5	10	24/14	5.00 - 7.00
10	20	24/19	10.00 - 12.00
15	30	24/7	15.00 - 17.00
20	40	12/10	20.00 - 21.00
25	50	60/36	21.00 - 28.00
Sample Information		Visual Description and Remarks	
Depth (ft.)	Sample No.	Pen. (lb./in.)	Sample Depth (ft.)
5	10	24/14	5.00 - 7.00
10	20	24/19	10.00 - 12.00
15	30	24/7	15.00 - 17.00
20	40	12/10	20.00 - 21.00
25	50	60/36	21.00 - 28.00
Sample Information		Visual Description and Remarks	
Depth (ft.)	Sample No.	Pen. (lb./in.)	Sample Depth (ft.)
5	10	24/14	5.00 - 7.00
10	20	24/19	10.00 - 12.00
15	30	24/7	15.00 - 17.00
20	40	12/10	20.00 - 21.00
25	50	60/36	21.00 - 28.00

Maine Department of Transportation			
Self/Book Exploration Log		Projects Route 1 Large Culvert	
US CUSTOMARY UNITS		Location: Danforth, Maine	
Boring No.: HB-DAN-102		WIN: 22849.00	
Driller: MATHIAS	Elevation (ft.): 390.8	Auger ID/OD: 5" Dia.	
Operator: Travis/James/Tyson	Duration: NAVD83	Samplers: N/A	
Logged By: B. Wfider	Rtg Type: CME 45C	Home Wt./Fall: N/A	
Date Start/Finish: 10/5/2017-10/5/2017	Drilling Method: Solid Stem Auger	Core Barrel: N/A	
Boring Location: 6+00.9, 1.6 ft Lt.	Casing ID/OD: N/A	Water Level: None Observed	
Hammer Efficiency Factor: 0.854			
Sample Information		Visual Description and Remarks	
Depth (ft.)	Sample No.	Pen. (lb./in.)	Sample Depth (ft.)
5	10	24/14	5.00 - 7.00
10	20	24/19	10.00 - 12.00
15	30	24/7	15.00 - 17.00
20	40	12/10	20.00 - 21.00
25	50	60/36	21.00 - 28.00
Sample Information		Visual Description and Remarks	
Depth (ft.)	Sample No.	Pen. (lb./in.)	Sample Depth (ft.)
5	10	24/14	5.00 - 7.00
10	20	24/19	10.00 - 12.00
15	30	24/7	15.00 - 17.00
20	40	12/10	20.00 - 21.00
25	50	60/36	21.00 - 28.00

Appendix A

Boring Logs

UNIFIED SOIL CLASSIFICATION SYSTEM					MODIFIED BURMISTER SYSTEM				
MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES					
COARSE-GRAINED SOILS (more than half of material is larger than No. 200 sieve size)	GRAVELS (more than half of coarse fraction is larger than No. 4 sieve size)	CLEAN GRAVELS	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.	<u>Descriptive Term</u>		<u>Portion of Total (%)</u>		
		(little or no fines)	GP	Poorly-graded gravels, gravel sand mixtures, little or no fines.	trace	0 - 10			
					little	11 - 20			
					some	21 - 35			
					adjective (e.g. sandy, clayey)	36 - 50			
	SANDS (more than half of coarse fraction is smaller than No. 4 sieve size)	GRAVEL WITH FINES (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixtures.	TERMS DESCRIBING DENSITY/CONSISTENCY				
		GC	Clayey gravels, gravel-sand-clay mixtures.						
		CLEAN SANDS	SW	Well-graded sands, gravelly sands, little or no fines	<u>Density of Cohesionless Soils</u>		<u>Standard Penetration Resistance N-Value (blows per foot)</u>		
		(little or no fines)	SP	Poorly-graded sands, gravelly sand, little or no fines.	Very loose	0 - 4			
					Loose	5 - 10			
FINE-GRAINED SOILS (more than half of material is smaller than No. 200 sieve size)	SILTS AND CLAYS (liquid limit less than 50)		SM	Silty sands, sand-silt mixtures	Medium Dense	11 - 30			
			SC	Clayey sands, sand-clay mixtures.	Dense	31 - 50			
					Very Dense	> 50			
		SILTS AND CLAYS (liquid limit greater than 50)				<u>Approximate Undrained Shear Strength (psf)</u>			
						<u>Field Guidelines</u>			
	HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.					

Desired Soil Observations (in this order, if applicable):			
Color (Munsell color chart)			
Moisture (dry, damp, moist, wet)			
Density/Consistency (from above right hand side)			
Texture (fine, medium, coarse, etc.)			
Name (sand, silty sand, clay, etc., including portions - trace, little, etc.)			
Gradation (well-graded, poorly-graded, uniform, etc.)			
Plasticity (non-plastic, slightly plastic, moderately plastic, highly plastic)			
Structure (layering, fractures, cracks, etc.)			
Bonding (well, moderately, loosely, etc.,)			
Cementation (weak, moderate, or strong)			
Geologic Origin (till, marine clay, alluvium, etc.)			
Groundwater level			

Desired Rock Observations (in this order, if applicable):			
Color (Munsell color chart)			
Texture (aphanitic, fine-grained, etc.)			
Rock Type (granite, schist, sandstone, etc.)			
Hardness (very hard, hard, mod. hard, etc.)			
Weathering (fresh, very slight, slight, moderate, mod. severe, severe, etc.)			
Geologic discontinuities/jointing:			
-dip (horiz - 0-5 deg., low angle - 5-35 deg., mod. dipping - 35-55 deg., steep - 55-85 deg., vertical - 85-90 deg.)			
-spacing (very close - <2 inch, close - 2-12 inch, mod. close - 1-3 feet, wide - 3-10 feet, very wide >10 feet)			
-tightness (tight, open, or healed)			
-infilling (grain size, color, etc.)			
Formation (Waterville, Ellsworth, Cape Elizabeth, etc.)			
RQD and correlation to rock mass quality (very poor, poor, etc.)			
ref: ASTM D6032 and AASHTO Standard Specification for Highway Bridges, 17th Ed. Table 4.4.8.1.2A			
Recovery (inch/inch and percentage)			
Rock Core Rate (X.X ft - Y.Y ft (min:sec))			

Sample Container Labeling Requirements:			
WIN	Blow Counts		
Bridge Name / Town	Sample Recovery		
Boring Number	Date		
Sample Number	Personnel Initials		
Sample Depth			

Maine Department of Transportation Geotechnical Section Key to Soil and Rock Descriptions and Terms Field Identification Information			
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Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS				Project: Route 1 Large Culvert Location: Danforth, Maine				Boring No.: HB-DAN-101 WIN: 22849.00				
Driller: MaineDOT				Elevation (ft.): 391.4				Auger ID/OD: 5" Dia. Solid Stem				
Operator: Travis/James/Tyson				Datum: NAVD88				Sampler: Standard Split Spoon				
Logged By: B. Wilder				Rig Type: CME 45C				Hammer Wt./Fall: 140#/30"				
Date Start/Finish: 10/5/2017; 08:00-12:00				Drilling Method: Cased Wash Boring				Core Barrel: NQ-2"				
Boring Location: 5+78.8, 8.9 ft Rt.				Casing ID/OD: NW-3"				Water Level*: None Observed				
Hammer Efficiency Factor: 0.854				Hammer Type: Automatic ☒ Hydraulic ☐ Rope & Cathead ☐								
Definitions: D = Split Spoon Sample MD = Unsuccessful Split Spoon Sample Attempt U = Thin Wall Tube Sample MU = Unsuccessful Thin Wall Tube Sample Attempt V = Field Vane Shear Test, PP = Pocket Penetrometer MV = Unsuccessful Field Vane Shear Test Attempt R = Rock Core Sample SSA = Solid Stem Auger HSA = Hollow Stem Auger RC = Roller Cone WOH = Weight of 140lb. Hammer WOR/C = Weight of Rods or Casing WO1P = Weight of One Person S _u = Peak/Remolded Field Vane Undrained Shear Strength (psf) S _u (lab) = Lab Vane Undrained Shear Strength (psf) q _p = Unconfined Compressive Strength (ksf) N-uncorrected = Raw Field SPT N-value Hammer Efficiency Factor = Rig Specific Annual Calibration Value N ₆₀ = SPT N-uncorrected Corrected for Hammer Efficiency N ₆₀ = (Hammer Efficiency Factor/60%)*N-uncorrected T _v = Pocket Torvane Shear Strength (psf) WC = Water Content, percent LL = Liquid Limit PL = Plastic Limit PI = Plasticity Index G = Grain Size Analysis C = Consolidation Test												
Depth (ft.)	Sample Information								Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N ₆₀	Casing Blows					
0							SSA	391.1		3½" HMA.	G#302629 A-1-b, SM WC=8.1%	
5	1D	24/14	5.00 - 7.00	5/6/6/8	12	17						Brown, moist, medium dense, fine to coarse SAND, some gravel, little silt, (Fill).
10	2D	24/19	10.00 - 12.00	6/9/10/25	19	27	19	381.4		Grey, wet, medium dense, fine to coarse SAND, some silt, little gravel, (Till).	G#302631 A-2-4, SM WC=10.9%	
							14					
							101					
							187					
							116					
15	3D	24/7	15.00 - 17.00	13/12/6/8	18	26	92			Grey, wet, medium dense, fine to coarse Sandy GRAVEL, little silt, (Till).		
							46					
							38					
							77			Roller Coned ahead to 20.0 ft bgs.		
20	4D	12/10	20.00 - 21.00	17/50	---		a108	370.4		Grey, wet, fine to coarse SAND, some silt, some gravel, (Till). a108 blows for 1.0 ft.	G#302633 A-2-4, SM WC=8.8%	
	R1	60/36	21.00 - 26.00	RQD = 0%			NQ-2			Top of Bedrock at Elev. 370.4 R1: Interbedded PELITE and SANDSTONE. Rock Quality = Very Poor R1: Core times (min:sec) 21.0-22.0 ft (1:27) 22.0-23.0 ft (3:06) 23.0-24.0 ft (1:44) 24.0-25.0 ft (3:15)		
25												
Remarks:												
Stratification lines represent approximate boundaries between soil types; transitions may be gradual. * Water level readings have been made at times and under conditions stated. Groundwater fluctuations may occur due to conditions other than those present at the time measurements were made.										Page 1 of 2 Boring No.: HB-DAN-101		

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS				Project: Route 1 Large Culvert Location: Danforth, Maine				Boring No.: HB-DAN-101 WIN: 22849.00																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
Driller: MaineDOT				Elevation (ft.): 391.4				Auger ID/OD: 5" Dia. Solid Stem																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
Operator: Travis/James/Tyson				Datum: NAVD88				Sampler: Standard Split Spoon																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
Logged By: B. Wilder				Rig Type: CME 45C				Hammer Wt./Fall: 140#/30"																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
Date Start/Finish: 10/5/2017; 08:00-12:00				Drilling Method: Cased Wash Boring				Core Barrel: NQ-2"																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
Boring Location: 5+78.8, 8.9 ft Rt.				Casing ID/OD: NW-3"				Water Level*: None Observed																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
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Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS				Project: Route 1 Large Culvert Location: Danforth, Maine				Boring No.: HB-DAN-102 WIN: 22849.00			
Drilling Contractor: MaineDOT				Elevation (ft.) 390.8				Auger ID/OD: 5" Dia.			
Operator: Travis/James/Tyson				Datum: NAVD88				Sampler: N/A			
Logged By: B. Wilder				Rig Type: CME 45C				Hammer Wt./Fall: N/A			
Date Start/Finish: 10/5/2017-10/5/2017				Drilling Method: Solid Stem Auger				Core Barrel: N/A			
Boring Location: 6+00.9, 1.6 ft Lt.				Casing ID/OD: N/A				Water Level*: None Observed			
Definitions: D = Spilt Spoon Sample S = Sample off Auger Flights B = Bucket Sample off Auger Flights MD = Unsuccessful Split Spoon Sample Attempt U = Thin Wall Tube Sample MV = Unsuccessful Field Vane Shear Test Attempt V = Field Vane Shear Test, PP= Pocket Penetrometer MU = Unsuccessful Thin Wall Tube Sample Attempt R = Rock Core Sample SSA = Solid Stem Auger HSA = Hollow Stem Auger RC = Roller Cone WOH = Weight of 140lb. Hammer WOR/C = Weight of Rods or Casing WO1P = Weight of 1 Person S_u = Peak/Remolded Field Vane Undrained Shear Strength (psf) S_u(lab) = Lab Vane Undrained Shear Strength (psf) q_p = Unconfined Compressive Strength (ksf) N-value = Raw Field SPT N-value T_v = Pocket Torvane Shear Strength (psf) WC = Water Content, percent ≈ = Similar or Equal too LL = Liquid Limit PL = Plastic Limit PI = Plasticity Index G = Grain Size Analysis C = Consolidation Test											
Depth (ft.)	Sample Information								Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.	
	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (6 in.) Shear Strength (psf) or RQD (%)	N-value	Casing Blows	Elevation (ft.)	Graphic Log			
0						SSA			Probe, no soil samples taken.		
5											
10											
15											
20							370.8		Bottom of Exploration at 20.0 feet below ground surface.		
25											
Remarks:											
Stratification lines represent approximate boundaries between soil types; transitions may be gradual.									Page 1 of 1		
* Water level readings have been made at times and under conditions stated. Groundwater fluctuations may occur due to conditions other than those present at the time measurements were made.									Boring No.: HB-DAN-102		

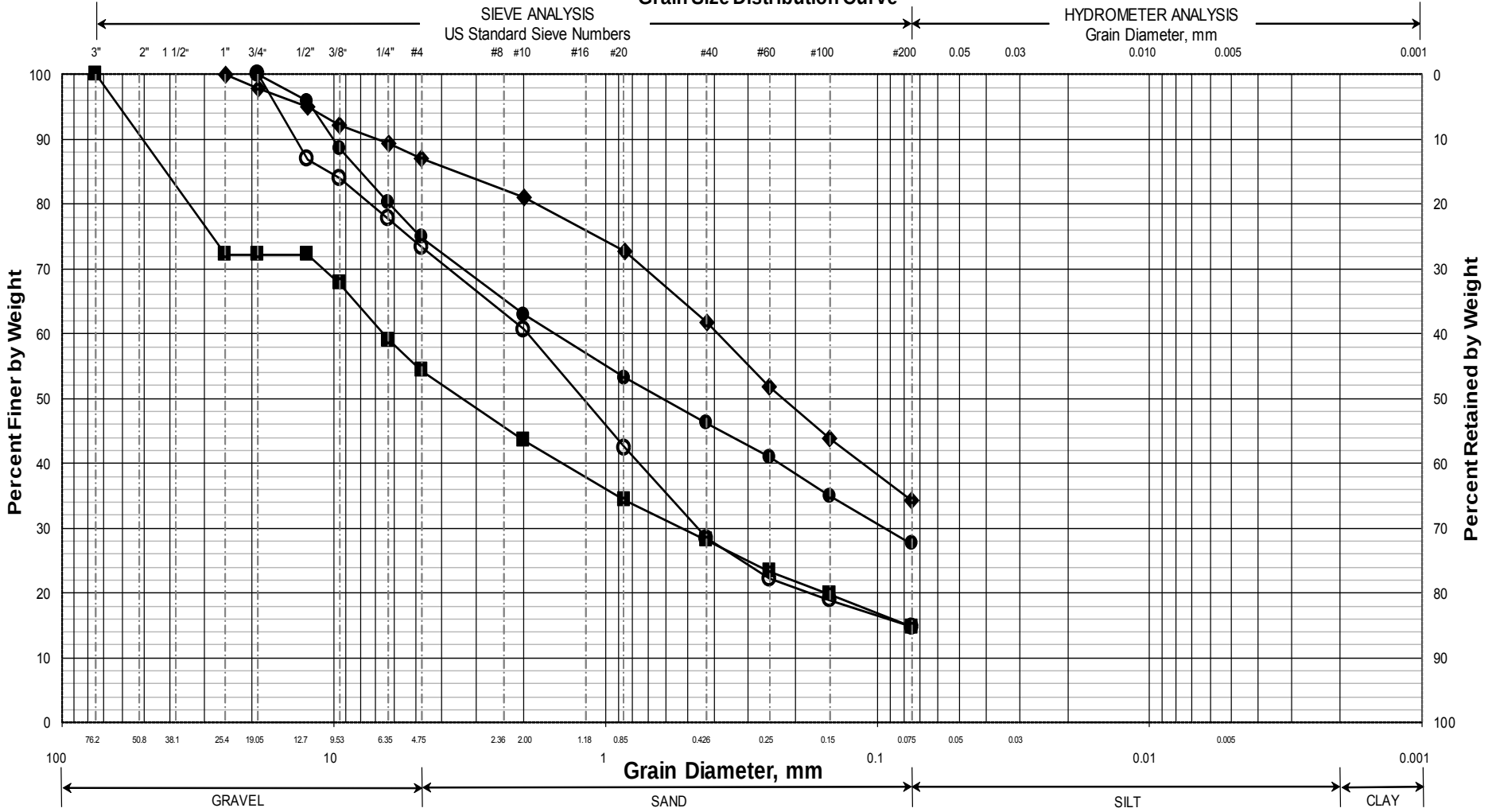
Appendix B

Laboratory Test Results

Work Number: 22849.00

PI = Plasticity Index as determined by AASHTO 90-96 and/or ASTM D4318-98

Grain Size Distribution Curve



UNIFIED CLASSIFICATION

[illegible]

WIN
022849.00
Town
Danforth
Reported by/Date
WHITE, TERRY A 10/13/2018

Appendix C

Calculations

Bearing Resistance - Existing Soils:

Part 1 - Service Limit State

Nominal and factored Bearing Resistance - Box Culvert on Sand

Presumptive Bearing Resistance for Service Limit State ONLY

Reference: AASHTO LRFD Bridge Design Specifications 8th Edition 2017
Table C10.6.2.6.1-1 Presumptive Bearing Resistances for Spread Footings at the
Service Limit State Modified after US Department of Navy (1982)

Type of Bearing Material: sand (SM)

Based on N-values, soils are medium dense at the bearing elevation

Density In Place: medium dense

Bearing Resistance: Ordinary Range (ksf) 4 to 8

Recommended Value of Use:

$$q_{nom} := 5 \cdot \text{ksf}$$

Resistance factor at the **service limit state** = 1.0 (LRFD Article 10.5.5.1)

$$\phi_{service_bc} := 1.0$$

$$q_{factored_service_bc} := q_{nom} \cdot \phi_{service_bc}$$

$$q_{factored_service_bc} = 5 \cdot \text{ksf}$$

Note: This bearing resistance is settlement limited (1 inch) and applies only at the service limit state.

Part 2 - Strength Limit State

Nominal and factored Bearing Resistance - Box Culvert Sand

Reference: AASHTO LRFD Bridge Design Specifications 8th Edition 2017 - Article 10.6.3.1

Assumptions:

1. The box will be founded at ~ Elev 381.0 feet to 381.4 feet

Bottom of Construction will be 2 feet below box invert

$$D_{footing} := 2.0 \cdot \text{ft}$$

2. Assumed parameters for fill soils:

Saturated unit weight: $\gamma_s := 125 \cdot \text{pcf}$

Internal friction angle: $\phi_{ns} := 32 \cdot \text{deg}$

Undrained shear strength: $c_{ns} := 0 \cdot \text{psf}$

3. Box Culvert parameters

Width of box culvert, B $B_{box} := 16 \cdot \text{ft}$

Length of box culvert, L $L_{box} := 84 \cdot \text{ft}$

Nominal Bearing Resistance per LRFD Equation 10.6.3.1.2a-1

$$q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + 0.5 \gamma B N_{\gamma m} C_{w\gamma}$$

Bearing Capacity Factors - LRFD Table 10.6.3.1.2a-1

For $\phi=32$ deg $N_c := 35.5$ $N_q := 23.2$ $N_\gamma := 30.2$

Shape Correction Factors LRFD Table 10.6.3.1.2a-3

for $\phi=32$ degrees

$$s_c := 1 + \left(\frac{B_{box}}{L_{box}} \right) \left(\frac{N_q}{N_c} \right) \quad s_c = 1.12$$

$$s_\gamma := 1 - 0.4 \left(\frac{B_{box}}{L_{box}} \right) \quad s_\gamma = 0.9238$$

$$s_q := 1 + \left(\frac{B_{box}}{L_{box}} \cdot \tan(\phi_{ns}) \right) \quad s_q = 1.12$$

Load Inclination Factors:

Assume all are 1.0 (LRFD Article C10.6.3.1.2a)

$i_c := 1.0$ $i_q := 1.0$ $i_\gamma := 1.0$

Depth Correction Factor LRFD Table 10.6.3.1.2a-4

$$\frac{D_{footing}}{B_{box}} = 0.125 \quad \text{for } \phi=32 \text{ degrees} \quad d_q := 1.2$$

$$N_{cm} := N_c \cdot s_c \cdot i_c \quad N_{cm} = 39.919 \quad \text{LRFD Eq. 10.6.3.1.2a-2}$$

$$N_{qm} := N_q \cdot s_q \cdot d_q \cdot i_q \quad N_{qm} = 31.15 \quad \text{LRFD Eq. 10.6.3.1.2a-3}$$

$$N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma \quad N_{\gamma m} = 27.9 \quad \text{LRFD Eq. 10.6.3.1.2a-4}$$

Coefficients for Groundwater Depths LRFD Table 10.6.3.1.2a-2

Depth the water table: $D_w := 0 \cdot \text{ft}$ $C_{wq} := 0.5$ $C_{w\gamma} := 0.5$

$$q_{nominal} := c_{ns} \cdot N_{cm} + \gamma_s \cdot D_{footing} \cdot N_{qm} \cdot C_{wq} + 0.5(\gamma_s) B_{box} \cdot N_{\gamma m} \cdot C_{w\gamma}$$

$$q_{nominal} = 17.8 \cdot \text{ksf}$$

Factored Bearing Resistance for Strength Limit State

Resistance Factor: $\phi_b := 0.45$ LRFD Table 10.5.5.2.2-1

$$q_{factored} := q_{nominal} \cdot \phi_b$$

$$q_{factored} = 8 \cdot \text{ksf}$$

Recommend a limiting factored bearing resistance of 8.0 ksf for the Strength Limit State.

Modulus of Subgrade Reaction:

Reference: Foundation Analysis and Design 5th Edition JE Bowles Section 9-6

Width of box culvert, B $B_{\text{box}} := 16 \cdot \text{ft}$

Length of box culvert, L $L_{\text{box}} := 84 \cdot \text{ft}$

Thickness of box culvert, t $t_{\text{box}} := 12 \cdot \text{in}$ assumed

Depth of box, D $D_{\text{box}} := 10 \cdot \text{ft}$

Bearing Resistance: $q_{\text{factored_service_bc}} = 5 \cdot \text{ksf}$ Calculated above

Modulus of Elasticity: Site soils at bearing elevation are Sand (medium dense)
 From Bowles Table 2-8 Modulus E_s for Glacial Till, dense ranges from 3100 - 15000 ksf

Poisson's Ratio: Use Modulus of Elasticity, $E_s := 3100 \cdot \text{ksf}$
 Site soils are Sand (medium dense)
 From Bowles Table 2-7 Poisson's Ratio μ for Sand/Till ranges from 0.3 - 0.4

Use Poisson's Ratio, $\mu := 0.35$

$$E_{\text{prime_s}} := \frac{1 - \mu^2}{E_s} \quad E_{\text{prime_s}} = 0.000283 \cdot \frac{\text{ft}^2}{\text{kip}}$$

Analyze corner:

Take H as 5*B as recommended in Bowles Chapter 5

$$H_{\text{inf}} := \frac{5 \cdot B_{\text{box}}}{B_{\text{box}}} \quad H_{\text{inf}} = 5 \quad \text{N in Table 5-2}$$

$$\frac{L_{\text{box}}}{B_{\text{box}}} = 5.25 \quad \text{M in Table 5-2}$$

From Table 5-2 for N=5 and M=5.25

$$I_1 := 0.551$$

$$I_2 := 0.113 \quad \text{by interpolation}$$

Determine Steinbrenner influence factor - Bowles Section 5-6:

$$I_s := I_1 + \left[\frac{1 - (2 \cdot \mu)}{1 - \mu} \right] \cdot I_2 \quad I_s = 0.6032$$

Determine Influence factor for footing depth - Bowles Figure

5-7

$$\text{Depth ratio: } \frac{D_{\text{box}}}{B_{\text{box}}} = 0.625 \quad \frac{L_{\text{box}}}{B_{\text{box}}} = 5.25 \quad \mu = 0.35 \quad I_F := 0.85$$

Calculate modulus of subgrade reaction - Bowles Eq. 9-7

$$k_s := \frac{1}{B_{\text{box}} \cdot E_{\text{prime_s}} \cdot I_s \cdot I_F} \quad \text{Bowles Eq. 9-7}$$

$$k_s = 249 \cdot \text{pci}$$

Recommend Modulus of Subgrade Reaction of 250 pci