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

Prepared by:
Cody Russell, E.I.
Assistant Geotechnical Engineer

Reviewed by:
Kathleen Maguire, P.E.
Senior Geotechnical Engineer

Washington County
WIN 22849.00

Soils Report 2019-13
Bridge No. 6594

April 22, 2019

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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.	--	--	--

[1]BGS = below ground surface
[2]AASHTO = American Association of State Highway and Transportation Officials
[3]USCS = Unified Soil Classification System
[4]WC% = 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

Date:3/21/2019

Division: GEOTECH

Username: Terry.White

DANFORTH, MAINE

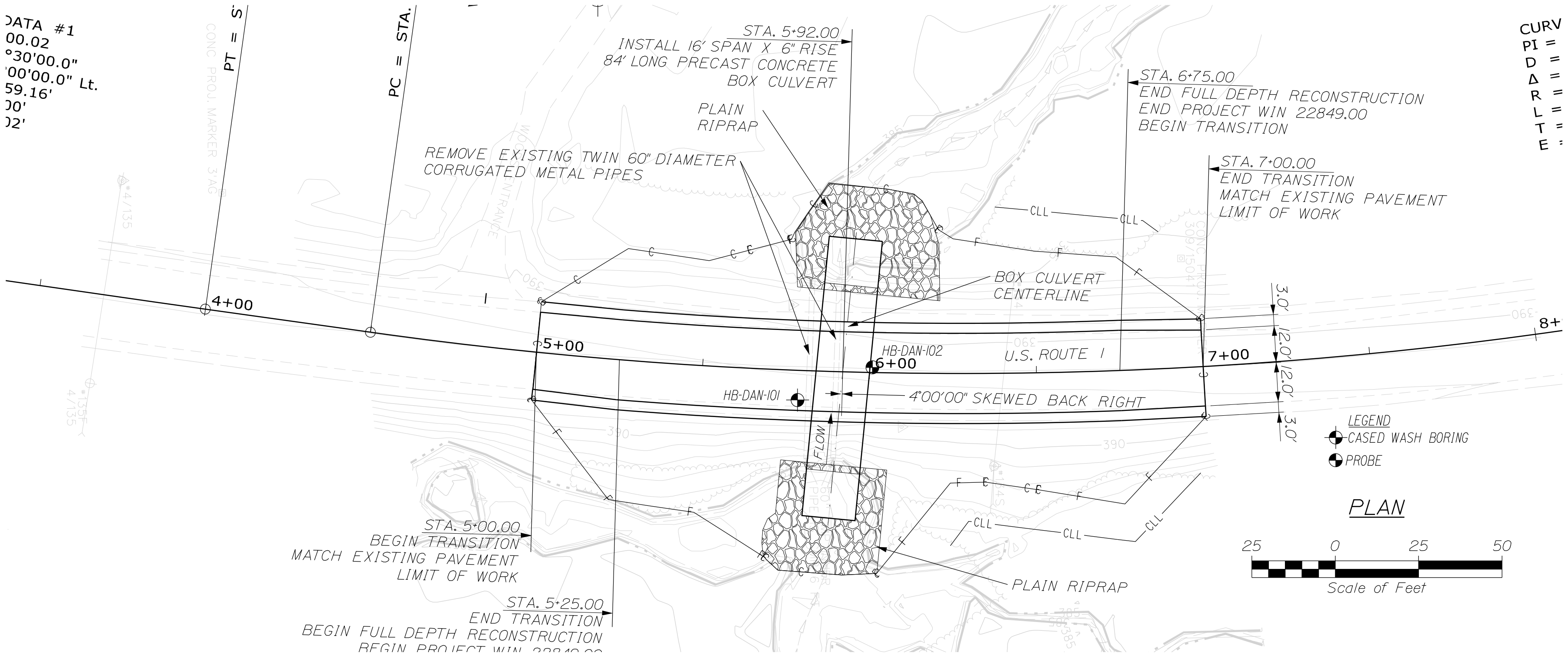
0.3 Miles

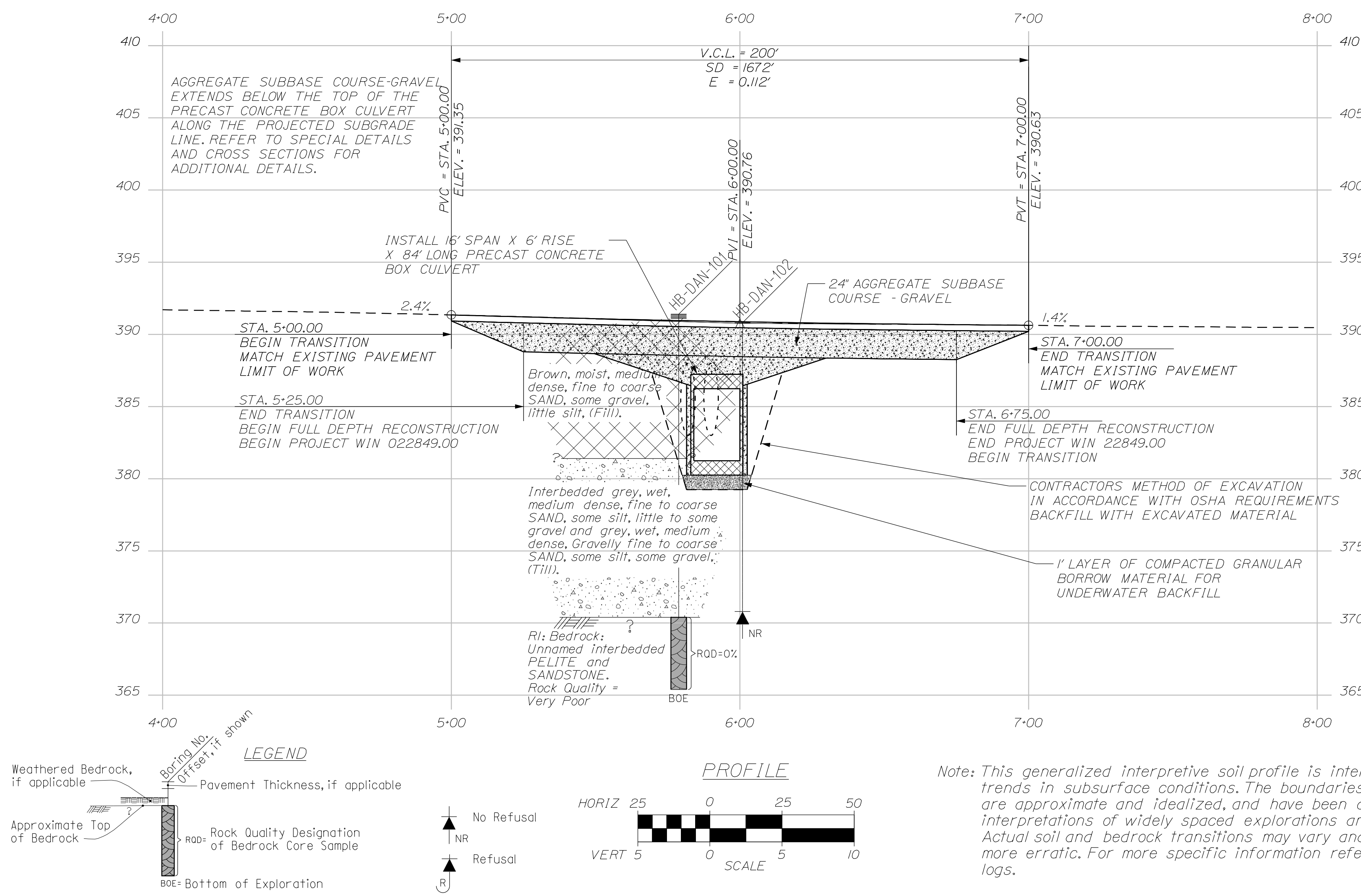
1 inch = 0.35 miles

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

SHEET NUMBER	DANFORTH	STATE OF MAINE DEPARTMENT OF TRANSPORTATION
1	U.S. ROUTE 1	022849.00
OF 2	LOCATION MAP	WIN 022849.00 HIGHWAY PLANS

Filename: ...\MSTA\002_BLP&ISP WBL1.dgn   Division: GEOTECH   Username: Cody.A.Russell   Date:10/28/2019





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

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 No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N_{60}	Casing Blows	Elevation (ft.)	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
0							SSA	391.1	3.5" HMA. (0.3)	
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).	G#302629 A-1-b, SM WC=8.1%
10	2D	24/19	10.00 - 12.00	6/9/10/25	19	27	19	381.4	(10.0) 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).	G#302632 A-1-a, GM WC=6.9%
							46			
							38		Roller Coned ahead to 20.0 ft bgs.	
							77			
							73			
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. (21.0)	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) 25.0-26.0 ft (2:00) 60% Recovery	
25								365.4	(26.0) Bottom of Exploration at 26.0 feet below ground surface.	

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 1
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-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 = Split 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 No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-value	Casing Blows	Elevation (ft.)	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class
0						SSA		Probe, no soil samples taken.	
5									
10									
15									
20							370.8	(20.0) Bottom of Exploration at 20.0 feet below ground surface.	
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 1
Boring No.: HB-DAN-102

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

02284900

WIN
22849.00

HIGHWAY PLANS

		BY	DATE
PROJ. MANAGER	R.SOUCY		
DESIGN-DETAILED	C.HELSTROM	D.WARDWELL	05/2019
CHECKED-REVIEWED	C.HELSTROM	R.SOUCY	05/2019
DESIGN2-DETAILED2	C.RUSSELL	T.WHITE	NOV 2107
DESIGN3-DETAILED3			
REVISIONS 1			
REVISIONS 2			
REVISIONS 3			
REVISIONS 4			
FIELD CHANGES			

SIGNATURE
P.E. NUMBER
DATE

DANFORTH - U.S. ROUTE 1
SOUTH CROOKED BROOK BRIDGE

BORING LOCATION PLAN & INTERPRETIVE SUBSURFACE PROFILE WITH BORING LOGS

SHEET NUMBER
2
OF 2

Appendix A

Boring Logs

UNIFIED SOIL CLASSIFICATION 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 (little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.
			GP	Poorly-graded gravels, gravel sand mixtures, little or no fines.
		GRAVEL WITH FINES (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixtures.
			GC	Clayey gravels, gravel-sand-clay mixtures.
	SANDS (more than half of coarse fraction is smaller than No. 4 sieve size)	CLEAN SANDS (little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines
			SP	Poorly-graded sands, gravelly sand, little or no fines.
		SANDS WITH FINES (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures
			SC	Clayey sands, sand-clay mixtures.
FINE-GRAINED SOILS (more than half of material is smaller than No. 200 sieve size)	SILTS AND CLAYS (liquid limit less than 50)		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity.
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
			OL	Organic silts and organic silty clays of low plasticity.
	SILTS AND CLAYS (liquid limit greater than 50)		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
			CH	Inorganic clays of high plasticity, fat clays.
			OH	Organic clays of medium to high plasticity, organic silts.
	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

Maine Department of Transportation
Geotechnical Section
Key to Soil and Rock Descriptions and Terms
Field Identification Information

MODIFIED BURMISTER SYSTEM

Descriptive Term	Portion of Total (%)
trace	0 - 10
little	11 - 20
some	21 - 35
adjective (e.g. sandy, clayey)	36 - 50

TERMS DESCRIBING DENSITY/CONSISTENCY

Coarse-grained soils (more than half of material is larger than No. 200 sieve): Includes (1) clean gravels; (2) silty or clayey gravels; and (3) silty, clayey or gravelly sands. Density is rated according to standard penetration resistance (N-value).

Density of Cohesionless Soils	Standard Penetration Resistance N-Value (blows per foot)
Very loose	0 - 4
Loose	5 - 10
Medium Dense	11 - 30
Dense	31 - 50
Very Dense	> 50

Fine-grained soils (more than half of material is smaller than No. 200 sieve): Includes (1) inorganic and organic silts and clays; (2) gravelly, sandy or silty clays; and (3) clayey silts. Consistency is rated according to undrained shear strength as indicated.

Consistency of Cohesive soils	SPT N-Value (blows per foot)	Approximate Undrained Shear Strength (psf)	Field Guidelines
Very Soft	WOH, WOR, WOP, <2	0 - 250	Fist easily penetrates
Soft	2 - 4	250 - 500	Thumb easily penetrates
Medium Stiff	5 - 8	500 - 1000	Thumb penetrates with moderate effort
Stiff	9 - 15	1000 - 2000	Indented by thumb with great effort
Very Stiff	16 - 30	2000 - 4000	Indented by thumbnail
Hard	>30	over 4000	Indented by thumbnail with difficulty

Rock Quality Designation (RQD):

$$\text{RQD (\%)} = \frac{\text{sum of the lengths of intact pieces of core* > 4 inches}}{\text{length of core advance}}$$

*Minimum NQ rock core (1.88 in. OD of core)

Correlation of RQD to Rock Mass Quality

Rock Mass Quality	RQD (%)
Very Poor	≤25
Poor	26 - 50
Fair	51 - 75
Good	76 - 90
Excellent	91 - 100

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

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project:	Route 1 Large Culvert			**Boring No.:**	HB-DAN-101
Location:	Danforth, Maine			**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 No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N60	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
0							SSA	391.1		3½" HMA. 0.3	
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).	G#302629 A-1-b, SM WC=8.1%
10	2D	24/19	10.00 - 12.00	6/9/10/25	19	27	19	381.4		10.0 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).	G#302632 A-1-a, GM WC=6.9%
							46				
							38				
							77			Roller Coned ahead to 20.0 ft bgs.	
							73				
20	4D	12/10	20.00 - 21.00	17/50	---		a108			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	370.4		21.0 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.

Boring No.: HB-DAN-101

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project:	Route 1 Large Culvert			**Boring No.:**	HB-DAN-101
Location:	Danforth, Maine			**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 140 lb. 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 No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N_{60}	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
25										25.0-26.0 ft (2:00) 60% Recovery	
								365.4		26.0	
										Bottom of Exploration at 26.0 feet below ground surface.	
30											
35											
40											
45											
50											

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.

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project:	Route 1 Large Culvert	**Boring No.:**	HB-DAN-102		
Location:	Danforth, Maine	**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 No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-value	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
0						SSA			Probe, no soil samples taken.	
5										
10										
15										
20							370.8		20.0	
									Bottom of Exploration at 20.0 feet below ground surface.	
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.

<u>Appendix B</u>

Laboratory Test Results

State of Maine - Department of Transportation

Laboratory Testing Summary Sheet

Town(s): Danforth   Work Number: 22849.00

Boring & Sample Identification Number	Station (Feet)	Offset (Feet)	Depth (Feet)	Reference Number	G.S.D.C. Sheet	W.C. %	L.L.	P.I.	Classification		
									Unified	AASHTO	Frost
HB-DAN-101, 1D	5+78.8	8.9 Rt.	5.0-7.0	302629	1	8.1			SM	A-1-b	II
HB-DAN-101, 2D	5+78.8	8.9 Rt.	10.0-12.0	302631	1	10.9			SM	A-2-4	II
HB-DAN-101, 3D	5+78.8	8.9 Rt.	15.0-17.0	302632	1	6.9			GM	A-1-a	I
HB-DAN-101, 4D	5+78.8	8.9 Rt.	20.0-21.0	302633	1	8.8			SM	A-2-4	II

Classification of these soil samples is in accordance with AASHTO Classification System M-145-40. This classification is followed by the "Frost Susceptibility Rating" from zero (non-frost susceptible) to Class IV (highly frost susceptible). The "Frost Susceptibility Rating" is based upon the MaineDOT and Corps of Engineers Classification Systems.

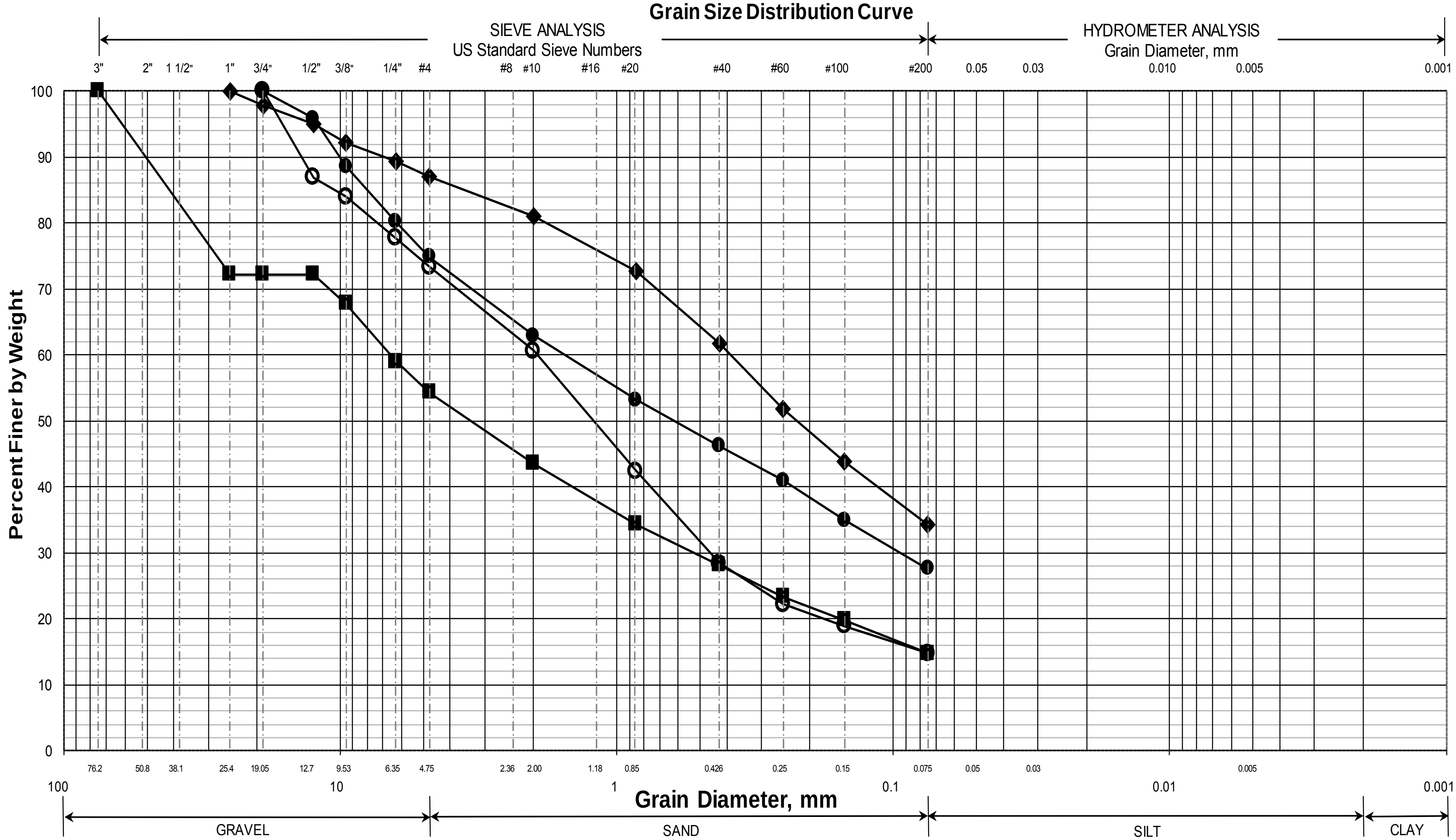
GSDC = Grain Size Distribution Curve as determined by AASHTO T 88-93 (1996) and/or ASTM D 422-63 (Reapproved 1998)

WC = water content as determined by AASHTO T 265-93 and/or ASTM D 2216-98

LL = Liquid limit as determined by AASHTO T 89-96 and/or ASTM D 4318-98   NP = Non Plastic

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

Maine Department of Transportation
Grain Size Distribution Curve



UNIFIED CLASSIFICATION

	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	WC, %	LL	PL	PI
○	HB-DAN-101/1D	5+78.8	8.9 RT	5.0-7.0	SAND, some gravel, little silt.	8.1			
◆	HB-DAN-101/2D	5+78.8	8.9 RT	10.0-12.0	SAND, some silt, little gravel.	10.9			
■	HB-DAN-101/3D	5+78.8	8.9 RT	15.0-17.0	Sandy GRAVEL, little silt.	6.9			
●	HB-DAN-101/4D	5+78.8	8.9 RT	20.0-21.0	SAND, some silt, some gravel.	8.8			
▲									
×									

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

SHEET 1

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

Resistance factor at the **service limit state** = 1.0 (LRFD Article 10.5.5.1) $\phi_{service\_bc} := 1.0$

$q_{factored\_service\_bc} := q_{nom} \cdot \phi_{service\_bc}$ $q_{factored\_service\_bc} = 5 \cdot ksf$

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

2. Assumed parameters for fill soils:

   Saturated unit weight: $\gamma_s := 125 \cdot pcf$

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

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

3. Box Culvert parameters

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

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

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 ϕ=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 ϕ=32 degrees

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

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

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

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

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

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

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

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

Coefficients for Groundwater Depths LRFD Table 10.6.3.1.2a-2

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

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

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

Factored Bearing Resistance for Strength Limit State

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

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

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

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 $B_{box} := 16 \cdot ft$

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

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

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

Bearing Resistance: $q_{factored\_service\_bc} = 5 \cdot ksf$ Calculated above

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

Use: Modulus of Elasticity, Es $E_s := 3100 \cdot ksf$

Poisson's Ratio: Site soils are Sand (medium dense)
From Bowles Table 2-7 Poisson's Ration μ for Sand/Till ranges from 0.3 - 0.4

Use: Possion's Ratio, μ $\mu := 0.35$

$$E_{prime\_s} := \frac{1 - \mu^2}{E_s} \qquad E_{prime\_s} = 0.000283 \cdot \frac{ft^2}{kip}$$

Analyze corner:

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

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

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

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

$I_1 := 0.551$

$I_2 := 0.113$

by interpolation

Determine Steinbrenner influence factor - Bowles Section 5-6:

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

Determine Influence factor for footing depth - Bowles Figure 5-7

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

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

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

$$k_s = 249 \cdot pci$$

Recommend Modulus of Subgrade Reaction of 250 pci