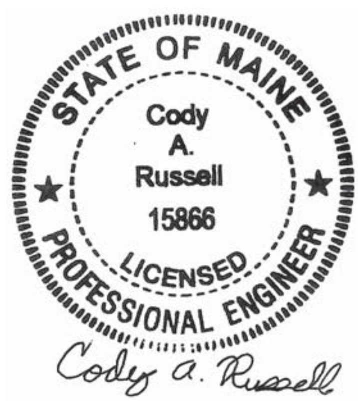
MAINE DEPARTMENT OF TRANSPORTATION
HIGHWAY PROGRAM
GEOTECHNICAL SECTION
AUGUSTA, MAINE

GEOTECHNICAL DESIGN REPORT

For the Construction of:

STOWER BROOK BRIDGE
ROUTE 1
STOCKTON SPRINGS, MAINE

Prepared by:
Cody Russell, P.E.
Geotechnical Engineer



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

Waldo County
WIN 21831.00

Soils Report 2020-08
Bridge No. 5928

March 23, 2020

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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 (#94441) on Route 1 in Stockton Springs, 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 twin approximately 84-inch diameter corrugated metal pipe (CMP) culverts, one approximately 152 feet in length and the other approximately 146 feet in length on a skew of approximately 51 degrees to the roadway centerline. The CMPs are failing, with joint separation evident in the structure and sink holes forming in the inslope. Route 1 is a Highway Corridor Priority 1 road.

The proposed replacement structure will be a 21-foot span by 10-foot rise by 200-foot long precast concrete box culvert on a skew of approximately 51 degrees to the roadway centerline. To facilitate fish passage, Habitat Connectivity Design elements will be used inside the precast concrete box culverts as shown on the Streambed Details Sheets in the Plans. The invert of the proposed culvert is approximately 26 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 Stower Brook under Route 1 in Stockton Springs and is located approximately 0.09 of a mile north of the Muskrat Pond Road as shown on Sheet 1 – Location Map.

According to the Maine Geological Survey (MGS) map titled Surficial Geology Bucksport Quadrangle, Maine, Open File 13-14 (2013) the surficial soils at the site consist of Presumpscot Formation. Presumpscot Formation consists of fine-grained marine silt and clay.

According to the map titled Bedrock Geologic Map of Maine (1985) published by the MGS, the bedrock in the vicinity of the site consists of sulfidic/carbonaceous pelite of the Penobscot Formation.

3.0 SUBSURFACE INVESTIGATION

One (1) boring (HB-STSP-101) and one (1) probe (HB-STSP-102) were drilled for this project on March 6, 2017 by New England Boring Contractors (NEBC) using a track mounted drill rig. Exploration locations are shown on Sheet 2 – Boring Location Plan & Interpretive Subsurface

Profile. 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-STSP-101 was drilled using hollow stem auger drilling techniques. Soil samples were obtained in boring HB-STSP-101 at 5-foot intervals using Standard Penetration Test (SPT) methods. The NEBC drill rig is equipped with a manually operated hammer to drive the split spoon. Probe HB-STSP-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 geotechnical engineer 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 one (1) standard grain size analysis with natural water content, seven (7) standard grain size analyses with hydrometer and natural water content, and two (2) Atterberg Limits tests. 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 Presumpscot Formation silt. An interpretive subsurface profile depicting the generalized soil stratigraphy at the boring location is shown on Sheet 2 – Boring Location Plan & Interpretive Subsurface Profile.

Boring HB-STSP-101 was drilled to a depth of approximately 37.0 feet below ground surface (bgs) and did not encounter a refusal surface. Probe HB-STSP-102 was drilled to a depth of approximately 35.0 feet bgs and did not encounter a refusal surface.

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

Approx. Depth BGS[1] (feet)	Soil Description	AASHTO[2] Classification	USCS[3]	WC%[4]
0.0 – 0.5	Pavement	--	--	--
0.0 – 26.0	Fill – Light brown to brown, dry to moist, fine to coarse sand, little to some gravel, little to some silt, little to some silt. Grey-brown, moist to wet, silt, some fine to coarse sand, little clay, little gravel. Brown to grey-brown, wet, fine to coarse sand, little silt, little gravel, trace clay.	A-1-b or A-4 A-4 A-2-4	SW-SM or SC-SM CL SC-SM	0.1 to 10.0 13.0 12.0 to 27.4
26.0 – 37.0	Presumpscot Formation – Grey-brown, wet, silt, little to some fine to medium sand, trace to some clay.	A-4	ML	23.1 to 23.9

[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

Five (5) N-values obtained in the sand fill ranged from 4 to 29 blows per foot (bpf) indicating that the sand fill is loose to medium dense in consistency. One (1) N-value obtained in the silt fill was 17 bpf indicating that the silt fill is very stiff in consistency. Two N-values obtained in the native Presumpscot Formation silt ranged from 4 to 6 bpf indicating that the silt is soft to medium stiff in consistency. Atterberg Limits tests performed on two (2) samples of Presumpscot Formation silt determined that the silt is nonplastic.

Groundwater level was recorded at a depth of approximately 15.0 feet bgs in boring HB-STSP-101. Groundwater level was not recorded in 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 21-foot span by 10-foot rise by 200-foot long precast concrete box culvert on a skew of approximately 51 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 21-foot span by 10-foot rise by 200-foot long precast concrete box culvert at a skew of approximately 51 degrees to the roadway centerline. The proposed box culvert shall be designed and constructed in accordance with MaineDOT Standard Specification 534.

The invert of the proposed box culvert will be set at approximate elevation 29.0 feet with a 0.0 percent slope. To facilitate fish passage, Habitat Connectivity Design elements will be used inside the precast concrete box culverts as shown on the Streambed Details Sheets in the Plans.

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. If silt is encountered at the bedding elevation it should be excavated using a smooth-edged backhoe bucket to minimize disturbance. Any disturbed soils at the bedding elevation resulting from excavation activities should be removed by hand prior to placement of the bedding material. 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. The proposed precast concrete box culvert is larger than the existing culverts and will result in a net unloading of the site soils at the structure location. Placement of fill soils at the location of the existing structure is not anticipated to exceed the past loading condition of the site soils. 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	3.0
Strength	0.45	Table 10.5.5.2.2-1	10.0

6.4 Modulus of Subgrade Reaction

A modulus of subgrade reaction (k_s) equal to 30 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 native silts 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

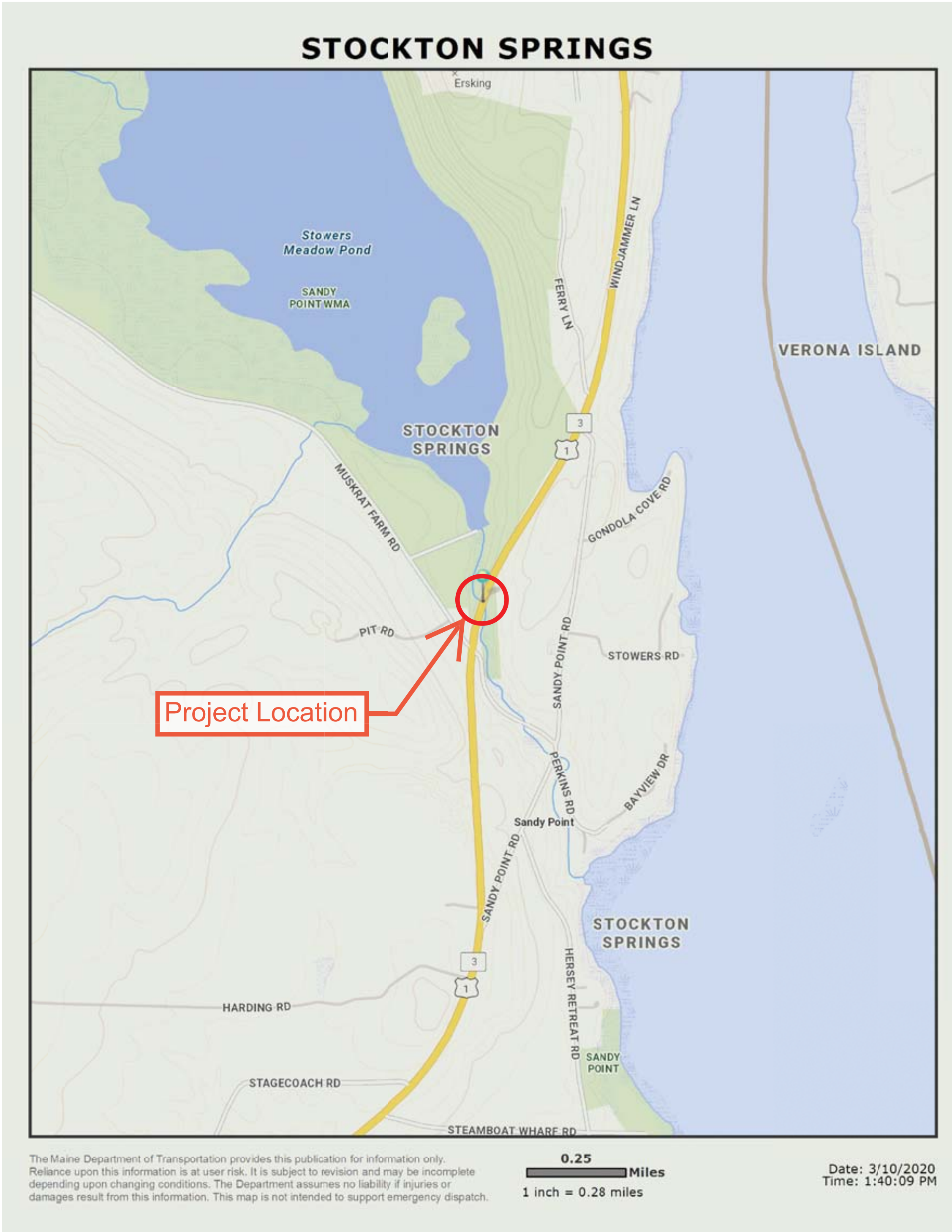
This report has been prepared for the use of the MaineDOT Highway Program for specific application to the proposed replacement of an existing large culvert (#94441) under Route 1 in Stockton Springs, Maine in accordance with generally accepted geotechnical and foundation engineering practices. No other 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.

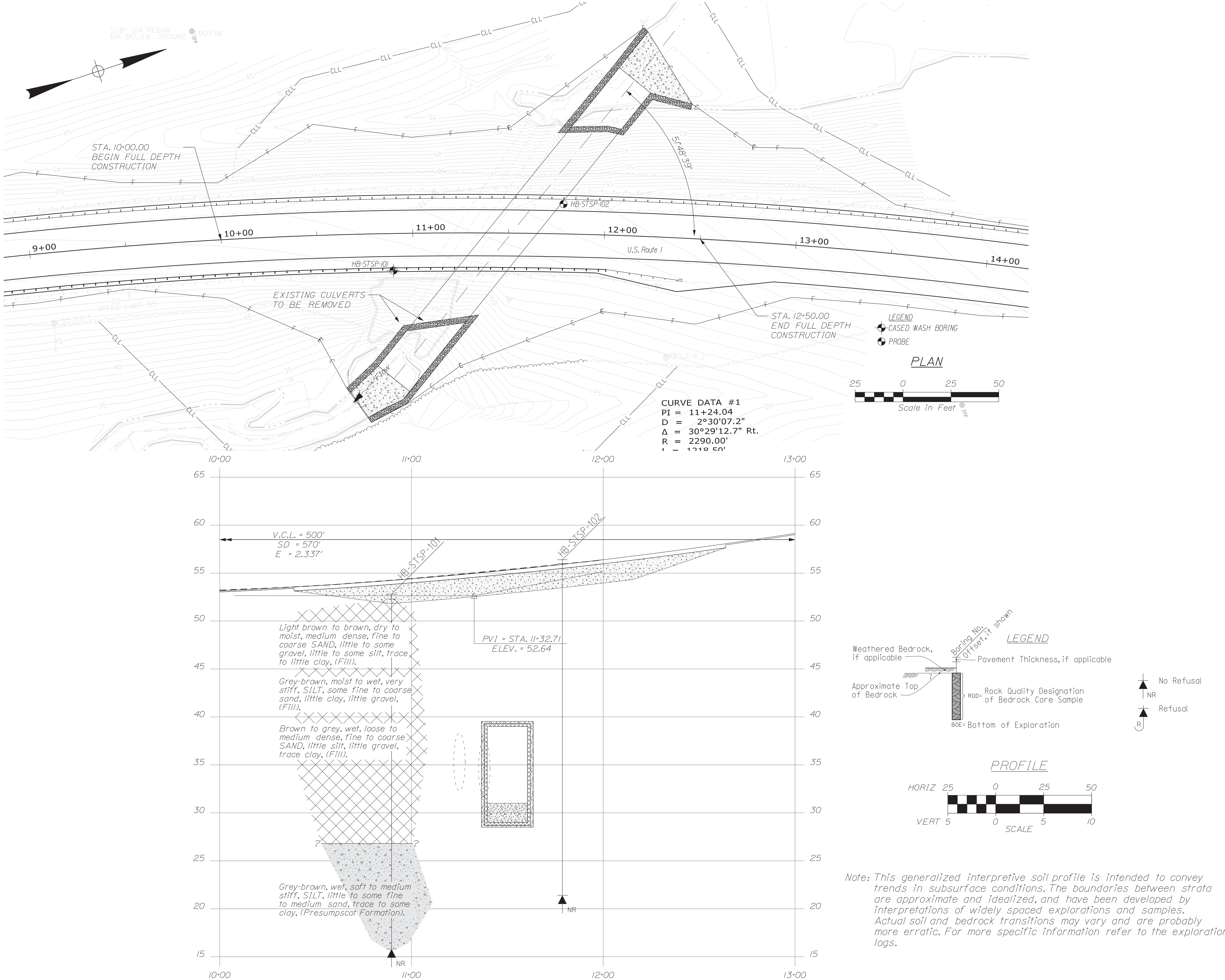
Sheets

Username: Cody.A.Russell Division: GEOTECH Date:3/10/2020



SHEET NUMBER	STOCKTON SPRINGS ROUTE 1	STATE OF MAINE DEPARTMENT OF TRANSPORTATION
1		021831.00
OF 2	LOCATION MAP	WIN 21831.00 HIGHWAY PLANS

Filename: ...\GEOTECH\MSTA\002_BLP&SP1.dgn Division: GEOTECH Username: Cody.A.Russell Date:3/23/2020



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.

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

021831.00

WIN 21831.00

HIGHWAY PLANS

	BY	DATE
PROJ. MANAGER		
DESIGN-DETAILED		
CHECKED-REVIEWED		
DESIGN2-DETAILED2	C.RUSSELL	
DESIGN3-DETAILED3	T.WHITE	MAR 2020
REVISIONS 1		
REVISIONS 2		
REVISIONS 3		
REVISIONS 4		
FIELD CHANGES		

SIGNATURE

P.E. NUMBER

DATE

STOCKTON SPRINGS ROUTE 1

BORING LOCATION PLAN & INTERPRETIVE SUBSURFACE PROFILE

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

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):

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

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

Rock Quality Based on RQD

Rock 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 quality (very poor, poor, etc.)
ref: ASTM D6032 and FHWA NHI-16-072 GEC 5 - Geotechnical Site Characterization, Table 4-12
Recovery (inch/inch and percentage)
Rock Core Rate (X.X ft - Y.Y ft (min:sec))

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

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: Large Culvert Replacement on U.S. Route 1
Location: Stockton Springs, Maine

Boring No.: HB-STSP-101
WIN: 21831.00

Drilling Contractor:	New England Boring	**Elevation (ft.)**	52.8	**Auger ID/OD:**	2.25/5.875"
Operator:	Schaefer/Titus	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	Be Schonewald	**Rig Type:**	Mobile Drill B-53 (Track)	**Hammer Wt./Fall:**	140#/30'
Date Start/Finish:	3/6/2017; 10:20-13:15	**Drilling Method:**	Solid Stem Auger	**Core Barrel:**	N/A
Boring Location:	10+89.6, 19.2 ft Rt.	**Casing ID/OD:**	N/A	**Water Level*:**	15.0 ft bgs. Caved at 23.4 ft

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	52.3		6" HMA. (0.5)	
	1D	24/3	1.00 - 3.00	8/14/15/19	29				Light brown, dry, medium dense, fine to coarse SAND, some gravel, little silt, (Granular Fill).	G#270165 A-1-b, SW-SM WC=0.1%
5	2D	24/14	5.00 - 7.00	10/12/11/13	23				Brown, damp to moist, medium dense, fine to coarse SAND, some silt, little clay, little gravel; some what layered; appears disturbed, (Common Fill).	G#270166 A-4, SC-SM WC=10.0%
10	3D	24/12	10.00 - 12.00	8/6/11/9	17				Grey-brown, moist to wet, very stiff, SILT, some fine to coarse sand, little clay, little gravel; somewhat layered; appears disturbed, (Common Fill).	G#270167 A-4, CL WC=13.0%
15	4D	24/10	15.00 - 17.00	3/2/2/3	4				Brown, wet, loose, fine to coarse SAND, little silt, little gravel, trace clay, (Common Fill).	G#270168 A-2-4, SC-SM WC=12.0%
20	5D	24/10	20.00 - 22.00	10/7/6/5	13				Grey-brown, wet, medium dense, fine to coarse SAND, little silt, little gravel, trace clay, (Common Fill).	G#270169 A-2-4, SC-SM WC=12.0%
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.

Maine Department of Transportation

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25	6D	24/15	25.00 - 27.00	2/3/4/4	7		26.8		Grey with brown pockets, wet, loose, fine to coarse SAND, little silt, trace gravel, trace clay. —26.0— Brown pockets contain organic silt and fibers; appears to be original ground.	G#270170 A-2-4, SC-SM WC=27.4%
30	7D	24/18	30.00 - 32.00	3/2/4/5	6				Grey-brown, wet, medium stiff, SILT, some fine to medium sand, trace clay, (Marine Sands and Silts, Stratified).	G#270171 A-4, ML WC=23.1% Non-Plastic
35	8D	24/24	35.00 - 37.00	1/2/2/1	4		15.8		Grey-brown, wet, soft, SILT, some clay, little fine to medium sand, (Marine Sands and Silts, Stratified). —37.0—	G#270172 A-4, ML WC=23.9% Non-Plastic
									Bottom of Exploration at 37.0 feet below ground surface. NO REFUSAL	
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

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US CUSTOMARY UNITS

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Location: Stockton Springs, Maine

Boring No.: HB-STSP-102
WIN: 21831.00

Drilling Contractor:	New England Boring	**Elevation (ft.)**	56.4	**Auger ID/OD:**	4.5" OD
Operator:	Schaefer/Titus	**Datum:**	NAVD88	**Sampler:**	N/A
Logged By:	Be Schonewald	**Rig Type:**	Mobile Drill B-53 (Track)	**Hammer Wt./Fall:**	140#/30'
Date Start/Finish:	3/6/2017; 10:20-13:15	**Drilling Method:**	Auger Probe	**Core Barrel:**	N/A
Boring Location:	11+78.7, 15.6 ft Lt.	**Casing ID/OD:**	N/A	**Water Level*:**	Caved at 23.2 ft bgs.

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	56.0		5" HMA. 0.4	
									Auger cuttings from 0.42-10.0 ft bgs; Brown, moist, Gravelly, fine to coarse SAND, some silt, boney.	
5										
									Difficult drilling at 8.5 ft bgs; gravel angular and fresh; possible boulder. Drop through at 11.0 ft bgs; nested.	
10										
15										
									Apparent stratum change at 18.0 ft bgs, based on drilling behavior. Softer; easier drilling.	
20										
									Softer, easier drilling at 21.0 ft bgs, auger cuttings: fine to coarse Sandy SILT, some fine gravel.	
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.

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Large Culvert Replacement on U.S. Route 1
Location: Stockton Springs, Maine

Boring No.: HB-STSP-102
WIN: 21831.00

Drilling Contractor:	New England Boring	**Elevation (ft.)**	56.4	**Auger ID/OD:**	4.5" OD
Operator:	Schaefer/Titus	**Datum:**	NAVD88	**Sampler:**	N/A
Logged By:	Be Schonewald	**Rig Type:**	Mobile Drill B-53 (Track)	**Hammer Wt./Fall:**	140#/30'
Date Start/Finish:	3/6/2017; 10:20-13:15	**Drilling Method:**	Auger Probe	**Core Barrel:**	N/A
Boring Location:	11+78.7, 15.6 ft Lt.	**Casing ID/OD:**	N/A	**Water Level*:**	Caved at 23.2 ft bgs.

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.
25										
									Auger cuttings wet at approximately 28.0 ft bgs.	
30									Auger cuttings 30.0-35.0 ft bgs: Grey-brown, wet, fine Sandy SILT, trace to little gravel, trace medium to coarse sand.	
35							21.4		35.0	
									Bottom of Exploration at 35.0 feet below ground surface. NO REFUSAL	
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.

Appendix B

Laboratory Test Results

State of Maine - Department of Transportation

Laboratory Testing Summary Sheet

Town(s): Stockton Springs Work Number: 21831.00

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-STSP-101, 1D	10+89.6	19.2 Rt.	1.0-3.0	270165	1	0.1			SW-SM	A-1-b	0
HB-STSP-101, 2D	10+89.6	19.2 Rt.	5.0-7.0	270166	1	10.0			SC-SM	A-4	III
HB-STSP-101, 3D	10+89.6	19.2 Rt.	10.0-12.0	270167	1	13.0			CL	A-4	IV
HB-STSP-101, 4D	10+89.6	19.2 Rt.	15.0-17.0	270168	1	12.0			SC-SM	A-2-4	II
HB-STSP-101, 5D	10+89.6	19.2 Rt.	20.0-22.0	270169	2	12.0			SC-SM	A-2-4	III
HB-STSP-101, 6D	10+89.6	19.2 Rt.	25.0-27.0	270170	2	27.4			SC-SM	A-2-4	II
HB-STSP-101, 7D	10+89.6	19.2 Rt.	30.0-32.0	270171	2	23.1	-N	P-	ML	A-4	IV
HB-STSP-101, 8D	10+89.6	19.2 Rt.	35.0-37.0	270172	2	23.9	-N	P-	ML	A-4	IV

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.

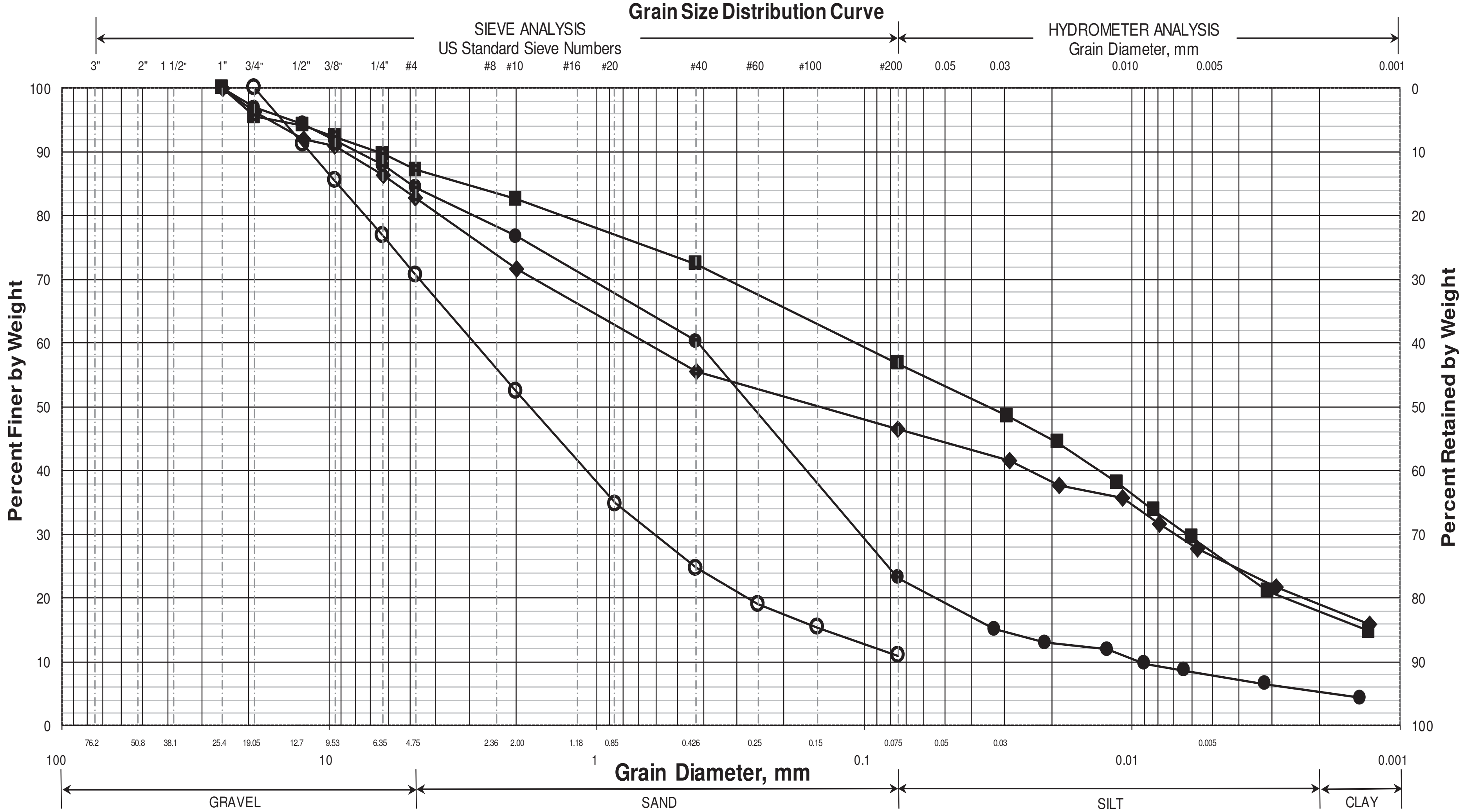
GSDC = Grain Size Distribution Curve as determined by AASHTO T 88-93 (1996) and/or ASTM D 422-63 (Reapproved 1998)

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



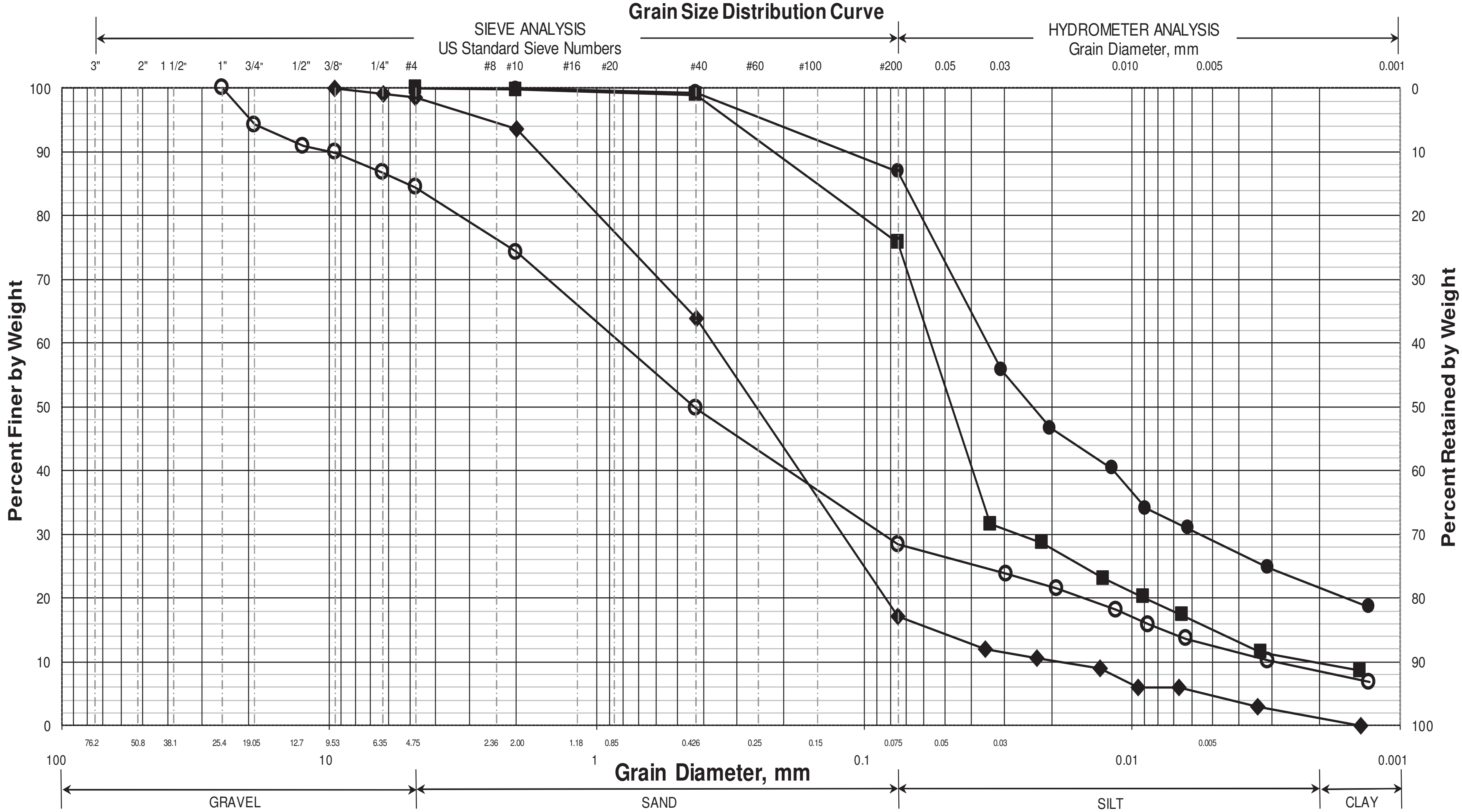
UNIFIED CLASSIFICATION

	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	WC, %	LL	PL	PI
○	HB-STSP-101/1D	10+89.6	19.2 RT	1.0-3.0	SAND, some gravel, little silt.	0.1			
◆	HB-STSP-101/2D	10+89.6	19.2 RT	5.0-7.0	SAND, some silt, little clay, little gravel.	10.0			
■	HB-STSP-101/3D	10+89.6	19.2 RT	10.0-12.0	SILT, some sand, little clay, little gravel.	13.0			
●	HB-STSP-101/4D	10+89.6	19.2 RT	15.0-17.0	SAND, little silt, little gravel, trace clay.	12.0			
▲									
×									

WIN
021831.00
Town
Stockton Springs
Reported by/Date
WHITE, TERRY A 3/4/2020

SHEET 1

Maine Department of Transportation
Grain Size Distribution Curve



UNIFIED CLASSIFICATION

	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	WC, %	LL	PL	PI
○	HB-STSP-101/5D	10+89.6	19.2 RT	20.0-22.0	SAND, little silt, little gravel, trace clay.	12.0			
◆	HB-STSP-101/6D	10+89.6	19.2 RT	25.0-27.0	SAND, little silt, trace gravel, trace clay.	27.4			
■	HB-STSP-101/7D	10+89.6	19.2 RT	30.0-32.0	SILT, some sand, trace clay.	23.1			NP
●	HB-STSP-101/8D	10+89.6	19.2 RT	35.0-37.0	SILT, some clay, little sand.	23.9			NP
▲									
×									

WIN	
021831.00	
Town	
Stockton Springs	
Reported by/Date	
WHITE, TERRY A	3/4/2020

SHEET 2

Appendix C

Calculations

Bearing Resistance - Existing Soils:

Part 1 - Service Limit State

Nominal and factored Bearing Resistance - Box Culvert on Silt

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: silt (ML)

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

Density In Place: medium stiff

Bearing Resistance: Ordinary Range (ksf) 2 to 6

Recommended Value of Use: $q_{nom} := 3 \cdot ksf$

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

$q_{factored\_service\_bc} := q_{nom} \cdot \phi_{service\_bc}$ $q_{factored\_service\_bc} = 3 \cdot ksf$

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 on Silt

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

Assumptions:

1. The box will be founded at ~ Elev 28.0 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 $B_{box} := 21 \cdot ft$

   Length of box culvert, L $L_{box} := 200 \cdot ft$

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

$$s_c := 1 + \left(\frac{B_{box}}{L_{box}}\right)\left(\frac{N_q}{N_c}\right) \qquad s_c = 1.07$$

$$s_\gamma := 1 - 0.4\left(\frac{B_{box}}{L_{box}}\right) \qquad s_\gamma = 0.958$$

$$s_q := 1 + \left(\frac{B_{box}}{L_{box}} \cdot \tan(\phi_{ns})\right) \qquad s_q = 1.07$$

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

$\frac{D_{footing}}{B_{box}} = 0.0952$ for ϕ=32 degrees $d_q := 1.2$

$N_{cm} := N_c \cdot s_c \cdot i_c$ $N_{cm} = 37.936$ LRFD Eq. 10.6.3.1.2a-2

$N_{qm} := N_q \cdot s_q \cdot d_q \cdot i_q$ $N_{qm} = 29.67$ LRFD Eq. 10.6.3.1.2a-3

$N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma$ $N_{\gamma m} = 28.93$ LRFD Eq. 10.6.3.1.2a-4

Coefficients for Groundwater Depths LRFD Table 10.6.3.1.2a-2

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

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

$$q_{nominal} = 22.7 \cdot ksf$$

Factored Bearing Resistance for Strength Limit State

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

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

$$q_{factored} = 10.2 \cdot ksf$$

Recommend a limiting factored bearing resistance of 10.0 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 $B_{box} = 21\ ft$

Length of box culvert, L $L_{box} = 200\ ft$

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

Depth of box, D $D_{box} := 26 \cdot ft$

Bearing Resistance: $q_{factored\_service\_bc} = 3 \cdot ksf$ Calculated above

Modulus of Elasticity: Site soils at bearing elevation are Silt (medium stiff)
From Bowles Table 2-8 Modulus Es for silt, medium stiff ranges from 42 - 420 ksf

Use: Modulus of Elasticity, Es $E_s := 420 \cdot ksf$

Poisson's Ratio: Site soils are silt (medium stiff)
From Bowles Table 2-7 Poisson's Ration μ for Silt ranges from 0.3 - 0.35

Use: Possion's Ratio, μ $\mu := 0.35$

$$E_{prime\_s} := \frac{1-\mu^2}{E_s} \qquad E_{prime\_s} = 0.002089 \cdot \frac{ft^2}{kip}$$

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

$$\frac{L_{box}}{B_{box}} = 9.5238$$ M in Table 5-2

From Table 5-2 for N=5 and M=9.5238

$I_1 := 0.535$
$I_2 := 0.139$ by interpolation

Determine Steinbrenner influence factor - Bowles Section 5-6:

$$I_s := I_1 + \left[\frac{1-(2 \cdot \mu)}{1-\mu}\right] \cdot I_2 \qquad I_s = 0.5992$$

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

Depth ratio: $\frac{D_{box}}{B_{box}} = 1.2381$ $\frac{L_{box}}{B_{box}} = 9.5238$ $\mu = 0.35$ $I_F := 0.75$

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

$$k_s = 29 \cdot pci$$

Recommend Modulus of Subgrade Reaction of 30 pci