

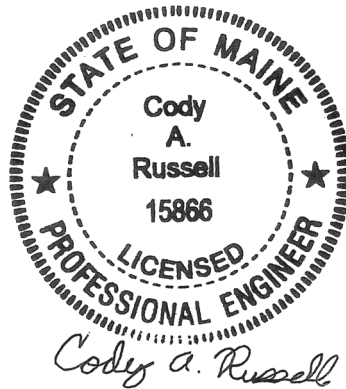
**MAINE DEPARTMENT OF TRANSPORTATION
HIGHWAY PROGRAM
GEOTECHNICAL SECTION
AUGUSTA, MAINE**

GEOTECHNICAL DESIGN REPORT

For the Construction of

**SEALANDER BROOK BRIDGE
ROUTE 161
WOODLAND, MAINE**

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Aroostook County
WIN 23036.00
Bridge No. 6685

Soils Report 2023-04
Federal Project No. 2303600
February 22, 2023

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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 an existing large culvert on Route 161 in Woodland, 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 (#135124) consists of twin 95-foot long, 72-inch diameter corrugated metal pipe (CMP) culverts on State Route 161 in Woodland. The existing culverts are in poor condition with a failing wooden headwall that is causing sagging in the roadway shoulder. State Route 161 is a Highway Corridor Priority 2 road.

The proposed replacement structure will be a 15-foot span by 10-foot rise by 102-foot long precast concrete box culvert on a skew of approximately 5 degrees to the roadway centerline. The invert of the proposed culvert is approximately 20 feet below the existing road grade at the roadway centerline. To facilitate fish passage, Habitat Connectivity Design elements will be used inside the proposed precast concrete box culvert as shown on the Streambed Details Sheet in the Plans. 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 Sealander Brook under Route 161 in Woodland and is located 0.06 of a mile northwest of Goodwin Road as shown on Sheet 1 – Location Map.

According to the Maine Geological Survey (MGS) map titled Reconnaissance Surficial Geology of the Caribou Quadrangle, Maine Open File No. 86-59 (1986) the surficial soils at the site consist of Till. These soils typically consist of a mixture of sand, silt, clay, and cobbles.

According to the map titled Bedrock Geologic Map of Maine (1985) published by the MGS, the bedrock in the vicinity of the site consists undifferentiated, interbedded Pelite and Limestone and/or Dolostone of the Carys Mill Formation.

3.0 SUBSURFACE INVESTIGATION

One (1) boring (HB-WOOD-101) and one (1) probe (HB-WOOD-102) were drilled on opposite, diagonal corners of the existing structure on November 1, 2017 by the MaineDOT drill crew using a trailer mounted CME 45C 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 Logs in Appendix A.

Boring HB-WOOD-101 and probe HB-WOOD-102 were drilled using solid stem auger drilling techniques. Soil samples were obtained in boring HB-WOOD-101 at 5-foot intervals using Standard Penetration Test (SPT) methods. The MaineDOT drilled 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 of 0.854 to the raw field N-values. No soil samples were obtained in probe HB-WOOD-102.

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. A Northeast Transportation Training and Certification Program (NETTCP) certified subsurface inspector logged subsurface conditions encountered in the explorations. 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 analyses with natural water content and four (4) grain size analyses with hydrometer and 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 borings generally consisted of fill overlying 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-WOOD-101 was drilled to a depth of approximately 26.5 feet below ground surface (bgs) where it encountered a refusal surface. The exact nature of the refusal surface was not determined in the boring. Probe HB-WOOD-102 was drilled to a depth of approximately 29.0 feet bgs, without encountering a refusal surface.

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

Approx. Depth BGS ¹ (feet)	Soil Description	AASHTO ² Classification	USCS ³	WC% ⁴
0.0 – 0.4	HMA Pavement	--	--	--
0.4 – 15.5	Fill – Brown, damp, fine to coarse sand, some gravel, some silt, trace clay.	A-2-4	SC-SM	9.7
	Old pavement layer – 6.0 to 6.4 feet bgs Brown, damp, gravel, some fine to coarse sand, little to some silt, trace clay.	A-2-4	GC-GM	11.7 to 12.0
15.5 – 26.5	Glacial Till – Grey, wet, gravel, some fine to coarse sand, little silt, trace clay	A-2-4	GC-GM	12.0
	Grey, wet, fine to coarse sandy gravel, little silt, trace clay.	A-1-b	GC-CM or GM	8.0 to 9.8

¹BGS = below ground surface

²AASHTO = American Association of State Highway and Transportation Officials

³USCS = Unified Soil Classification System

⁴WC% = Water content in percent

Two (2) SPT N₆₀-values obtained in the fill were 23 blows per foot (bpf) and 34 bpf indicating that the fill is medium dense to dense in consistency. SPT N₆₀-values obtained in the till ranged from 27 bpf to 185 bpf, indicating that the till is medium dense to very dense in consistency.

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 following sections discuss geotechnical recommendations for the design and construction of the proposed precast concrete box culvert.

6.1 Precast Concrete Box Culvert Design and Construction

The proposed replacement structure will be a 15-foot span by 10-foot rise by 102-foot long precast concrete box on a skew of approximately 5 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 proposed box culvert shall be designed and constructed in accordance with MaineDOT Standard Specification 534.

The invert of the proposed precast concrete box culvert ranges from approximate elevation 571.5 feet at the inlet end to approximate elevation 570.5 feet at the outlet end with a slope of approximately 1.0%. To facilitate fish passage, Habitat Connectivity Design elements will be used inside the precast concrete box culvert 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. Any disturbed soils at the bedding elevation resulting from excavation activities should be removed by hand prior to placement of the bedding material. The prepared subgrade shall be proofrolled 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. All subgrade surfaces should be protected from construction traffic in order to limit disturbance.

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 structure is larger than the existing structure 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 9th Edition 2020 (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	10.0
Strength	0.45	Table 10.5.5.2.2-1	10.5

6.4 Modulus of Subgrade Reaction

A modulus of subgrade reaction (k_s) equal to 300 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 bedding material 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 will 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 soil and underlying bedrock 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 project design consultant for specific application to the proposed replacement of an existing large culvert (#135124) under State Route 161 in Woodland, Maine in accordance with generally accepted geotechnical and foundation engineering practices. No other intended use or warranty is expressed or implied.

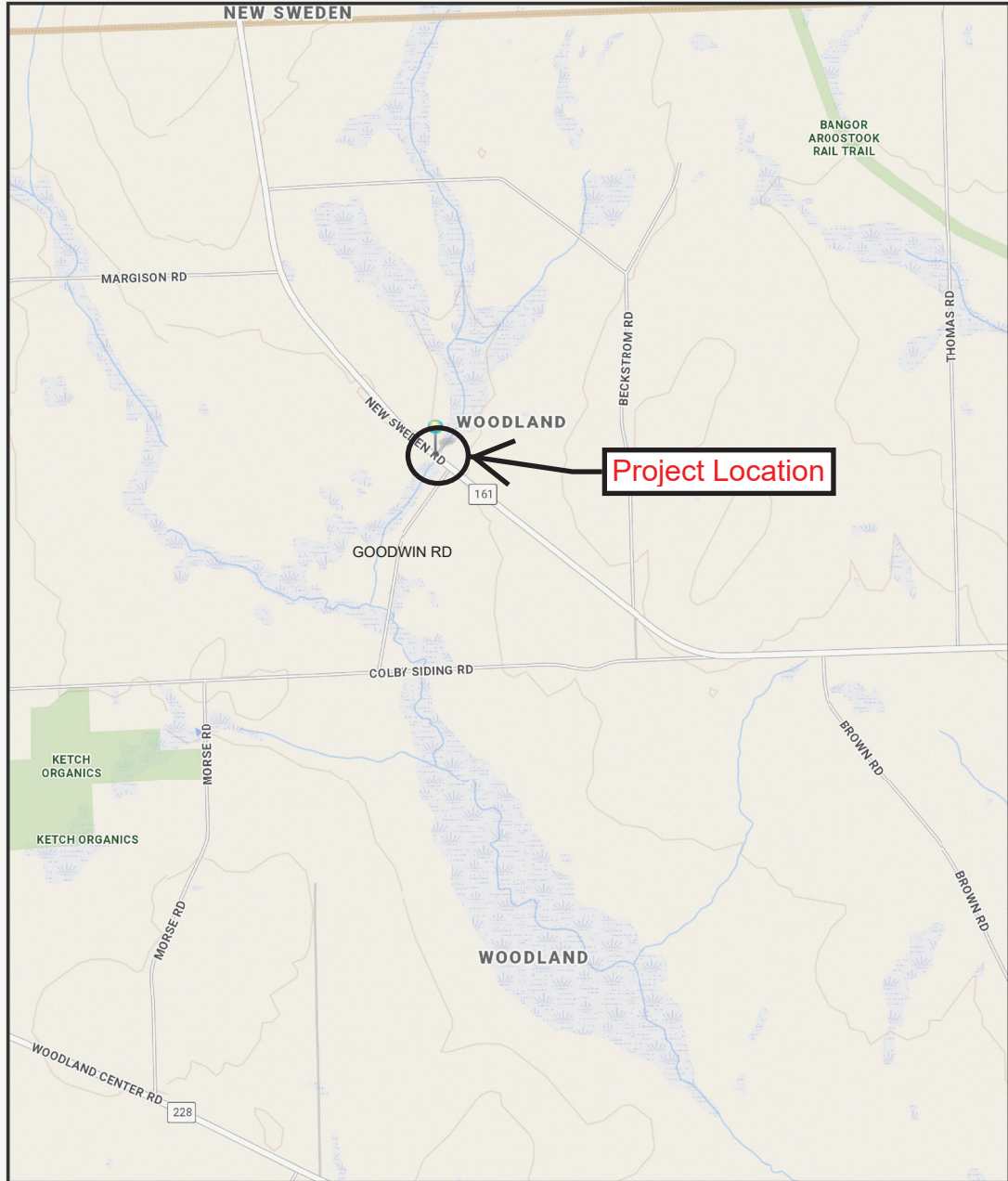
In the event that any changes in the nature, design, or location of the proposed project are planned, this report should be reviewed by a geotechnical engineer to assess the appropriateness of the conclusions and recommendations and to modify the recommendations as appropriate to reflect the changes 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



WOODLAND, MAINE

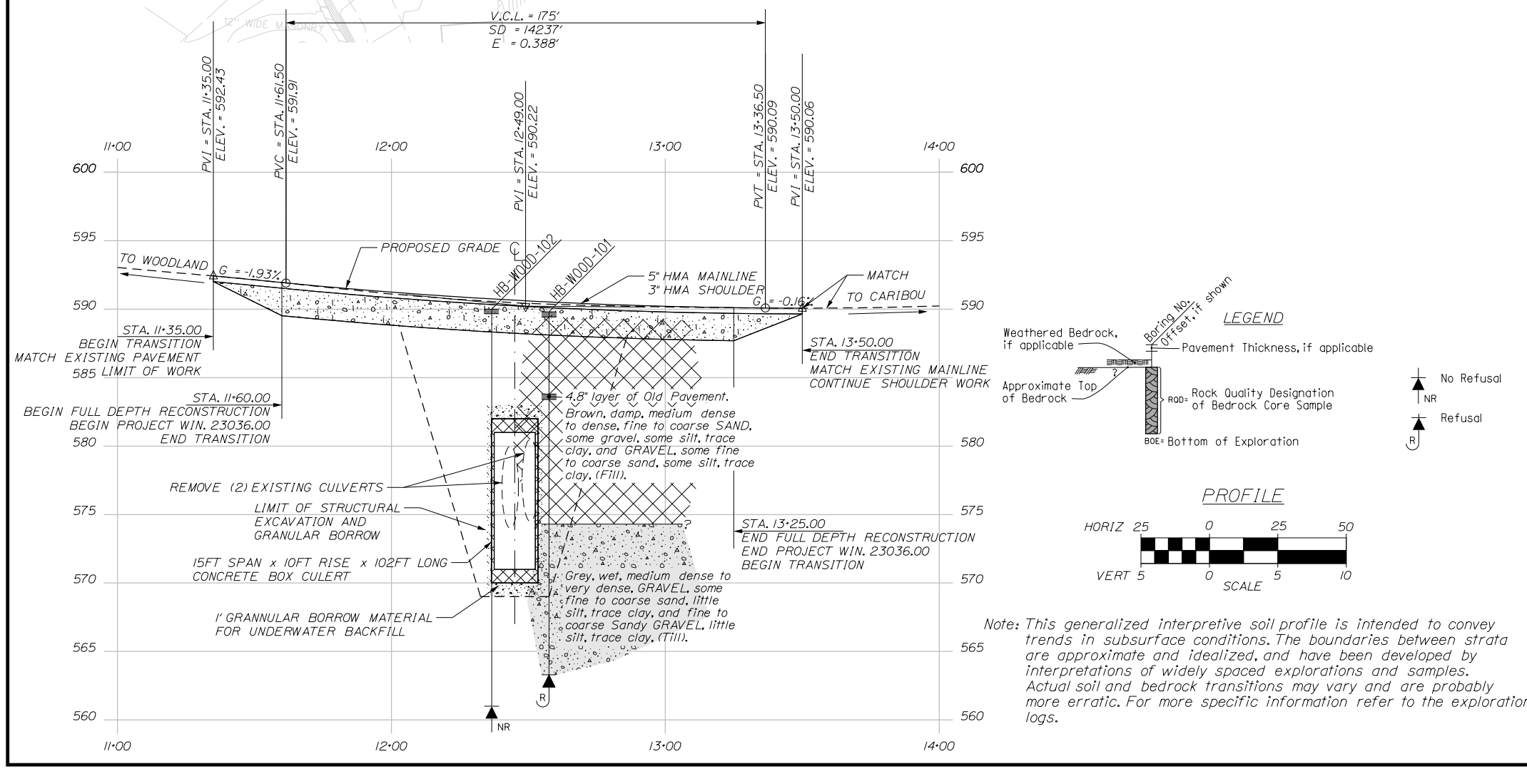
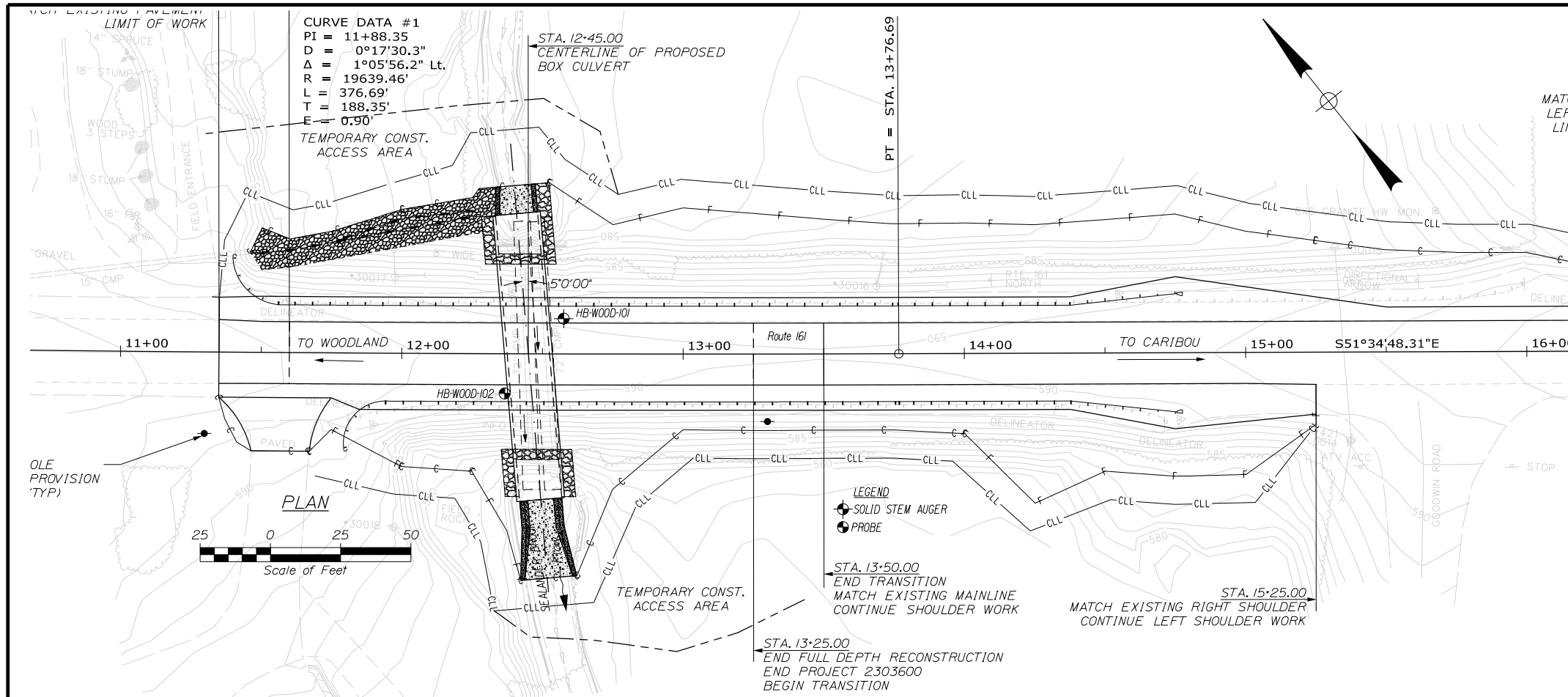


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0.5 Miles
1 inch = 0.57 miles

Date: 1/4/2023
Time: 8:28:27 AM

SHEET NUMBER 1	WOODLAND ROUTE 161	STATE OF MAINE DEPARTMENT OF TRANSPORTATION	
		2303600	
OF 2	LOCATION MAP	WIN	HIGHWAY PLANS
		23036.00	



Maine Department of Transportation Soil/Bore Exploration Log US CUSTOMARY UNITS		Project: Route 161 Large Culvert Location: Woodland, Maine		Boring No.: HB-WOOD-101			
Operator: Traxys/ysen	Elevation (ft.): 589.8	Driller: NAD08	Auger ID/OD: 5" Dia.	WIN: 23036.00			
Logged By: B. W. J. J.	Rig Type: CM 45C	Sampler: N/A	Sampler Wt./Fall: 140#/30"				
Date Start/End: 11/17/2017-12/08-14/20	Drilling Method: Solid Stem Auger	Core Barrels: N/A	Water Level: None Observed				
Boring Location: 12x57.5, 12.6 ft Lt.	Coring ID/OD: N/A	Water Level: None Observed					
Efficiency Factor: 0.854	Sampler Type: Automatic ID	Sampler: Hydraulic	Sampler: None				
Depth (ft.)	Sample No.	Pen. (lb)	Depth (ft.)	Pen. (lb)	Visual Description and Remarks	Laboratory Test Results/ASTM and Unified Class	
0			0		4.5' HMA		
5	10	24/18	5.00 - 7.00	5/12/12/7	24 34	Brown, damp, dense, fine to coarse SAND, some gravel, some silt, trace clay. (F111)	GR30583 2-4, GC-5M UC-9.75
10	20	24/17	10.00 - 12.00	6/17/9/11	16 23	Boulder from 8.1-9.9 ft bgs.	
15	30	24/16	15.00 - 17.00	6/9/10/13	19 27	Grey, wet, medium dense, GRAVEL, some fine to coarse sand, little silt, trace clay. (F111)	GR30584 2-4, GC-5M UC-11.05
20	40	24/16	20.00 - 22.00	15/22/23/30	45 64	Grey, wet, very dense, fine to coarse SANDY GRAVEL, little silt, trace clay. (F111)	GR30585 2-4, GC-5M UC-8.05
25	50	18/13	25.00 - 26.50	19/69/61	130 185	Grey, wet, very dense, fine to coarse SANDY GRAVEL, little silt, trace clay. (F111)	GR30586 1-1-b, GC-5M UC-9.85
26.5					Bottom of Exploration at 26.5 feet below ground surface.	NO REFUSAL	

Maine Department of Transportation Soil/Bore Exploration Log US CUSTOMARY UNITS		Project: Route 161 Large Culvert Location: Woodland, Maine		Boring No.: HB-WOOD-102		
Operator: Traxys/ysen	Elevation (ft.): 590.0	Driller: NAD08	Auger ID/OD: 5" Dia.	WIN: 23036.00		
Logged By: B. W. J. J.	Rig Type: CM 45C	Sampler: N/A	Sampler Wt./Fall: N/A			
Date Start/End: 11/17/2017-11/17/2017	Drilling Method: Solid Stem Auger	Core Barrels: N/A	Water Level: None Observed			
Boring Location: 12x36.6, 14.1 ft Lt.	Coring ID/OD: N/A	Water Level: None Observed				
Efficiency Factor: 0.854	Sampler Type: Automatic ID	Sampler: Hydraulic	Sampler: None			
Depth (ft.)	Sample No.	Pen. (lb)	Depth (ft.)	Pen. (lb)	Visual Description and Remarks	Laboratory Test Results/ASTM and Unified Class
0			0		4' HMA	
5			5		Stiff Soil as HB-WOOD-101	
10			10			
15			15			
20			20			
25			25		Very dense from 23.0-29.0 ft bgs.	
29.0					Bottom of Exploration at 29.0 feet below ground surface.	NO REFUSAL

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION
2303600
WIN
23036.00

WOODLAND ROUTE 161
BORING LOCATION PLAN & INTERPRETIVE SUBSURFACE PROFILE WITH BORING LOGS

PROJ. MANAGER	ROGER SOUCY	DATE	BY	DATE
DESIGN-DETAILED	WARDWELL	01-2022	WARDWELL	01-2022
CHECKED-REVIEWED	HELSTROM	01-2022	SOUCY	01-2022
DESIGNS-DETAILED	C. RUSSELL	JAN 2023	T. WHITE	JAN 2023
DESIGNS-DETAILED				
REVISIONS 1				
REVISIONS 2				
REVISIONS 3				
REVISIONS 4				
FIELD CHANGES				

SHEET NUMBER
2
OF 2

Appendix A

Boring Logs

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS	Project: Route 161 Large Culvert Replacement Location: Woodland, Maine	Boring No.: <u>HB-WOOD-101</u> WIN: <u>23036.00</u>
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Driller: MaineDOT	Elevation (ft.): 589.8	Auger ID/OD: 5" Dia.
Operator: Travis/Tyson	Datum: NAVD88	Sampler: Standard Split Spoon
Logged By: B. Wilder	Rig Type: CME 45C	Hammer Wt./Fall: 140#/30"
Date Start/Finish: 11/1/2017; 12:00-14:00	Drilling Method: Soidl Stem Auger	Core Barrel: N/A
Boring Location: 12+57.5, 12.6 ft Lt.	Casing ID/OD: N/A	Water Level*: None Observed

Hammer Efficiency Factor: 0.854 Hammer Type: Automatic Hydraulic Rope & Cathead

Definitions:
D = Split Spoon Sample R = Rock Core Sample S_u = Peak/Remolded Field Vane Undrained Shear Strength (psf) T_v = Pocket Torvane Shear Strength (psf)
MD = Unsuccessful Split Spoon Sample Attempt SSA = Solid Stem Auger S_{u(lab)} = Lab Vane Undrained Shear Strength (psf) WC = Water Content, percent
U = Thin Wall Tube Sample HSA = Hollow Stem Auger q_p = Unconfined Compressive Strength (ksf) LL = Liquid Limit
MU = Unsuccessful Thin Wall Tube Sample Attempt RC = Roller Cone N-uncorrected = Raw Field SPT N-value PL = Plastic Limit
V = Field Vane Shear Test, PP = Pocket Penetrometer WOH = Weight of 140lb. Hammer Hammer Efficiency Factor = Rig Specific Annual Calibration Value PI = Plasticity Index
MV = Unsuccessful Field Vane Shear Test Attempt WOR/C = Weight of Rods or Casing N₆₀ = SPT N-uncorrected Corrected for Hammer Efficiency G = Grain Size Analysis
WO1P = Weight of One Person N₆₀ = (Hammer Efficiency Factor/60%)*N-uncorrected 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								589.4	SSA	4 1/2" HMA.		
5	1D	24/18	5.00 - 7.00	5/12/12/7	24	34		583.8		Brown, damp, dense, fine to coarse SAND, some gravel, some silt, trace clay, (Fill).	G#303083 A-2-4, SC-SM WC=9.7%	
								583.4		Old Pavement from 6.0-6.4 ft bgs.		
10	2D	24/17	10.00 - 12.00	6/7/9/11	16	23				Boulder from 8.7-9.9 ft bgs.		
										Brown, damp, medium dense, GRAVEL, some fine to coarse sand, some silt, trace clay, (Fill).	G#303084 A-2-4, GC-GM WC=11.7%	
15	3D 3D	24/16	15.00 - 17.00	6/9/10/13	19	27		574.3		Grey, wet, medium dense, GRAVEL, some fine to coarse sand, little silt, trace clay, (Till).	G#303085 A-2-4, GC-GM WC=12.0%	
20	4D	24/16	20.00 - 22.00	15/22/23/30	45	64				Grey, wet, very dense, fine to coarse Sandy GRAVEL, little silt, trace clay, (Till).	G#303086 A-1-b, GC-GM WC=8.0%	
25												


Remarks:

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS	Project: Route 161 Large Culvert Replacement Location: Woodland, Maine	Boring No.: HB-WOOD-101 WIN: 23036.00
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Driller: MaineDOT	Elevation (ft.): 589.8	Auger ID/OD: 5" Dia.
Operator: Travis/Tyson	Datum: NAVD88	Sampler: Standard Split Spoon
Logged By: B. Wilder	Rig Type: CME 45C	Hammer Wt./Fall: 140#/30"
Date Start/Finish: 11/1/2017; 12:00-14:00	Drilling Method: Soild Stem Auger	Core Barrel: N/A
Boring Location: 12+57.5, 12.6 ft Lt.	Casing ID/OD: N/A	Water Level*: None Observed

Hammer Efficiency Factor: 0.854 **Hammer Type:** Automatic Hydraulic Rope & Cathead

Definitions: R = Rock Core Sample S_u = Peak/Remolded Field Vane Undrained Shear Strength (psf) T_v = Pocket Torvane Shear Strength (psf)
 D = Split Spoon Sample SSA = Solid Stem Auger S_{u(lab)} = Lab Vane Undrained Shear Strength (psf) WC = Water Content, percent
 MD = Unsuccessful Split Spoon Sample Attempt HSA = Hollow Stem Auger q_p = Unconfined Compressive Strength (ksf)
 U = Thin Wall Tube Sample RC = Roller Cone N-uncorrected = Raw Field SPT N-value
 MU = Unsuccessful Thin Wall Tube Sample Attempt WOH = Weight of 140 lb. Hammer Hammer Efficiency Factor = Rig Specific Annual Calibration Value
 V = Field Vane Shear Test, PP = Pocket Penetrometer WOR/C = Weight of Rods or Casing N₆₀ = SPT N-uncorrected Corrected for Hammer Efficiency
 MV = Unsuccessful Field Vane Shear Test Attempt WO1P = Weight of One Person Ng₆₀ = (Hammer Efficiency Factor/60%)*N-uncorrected C = Consolidation Test

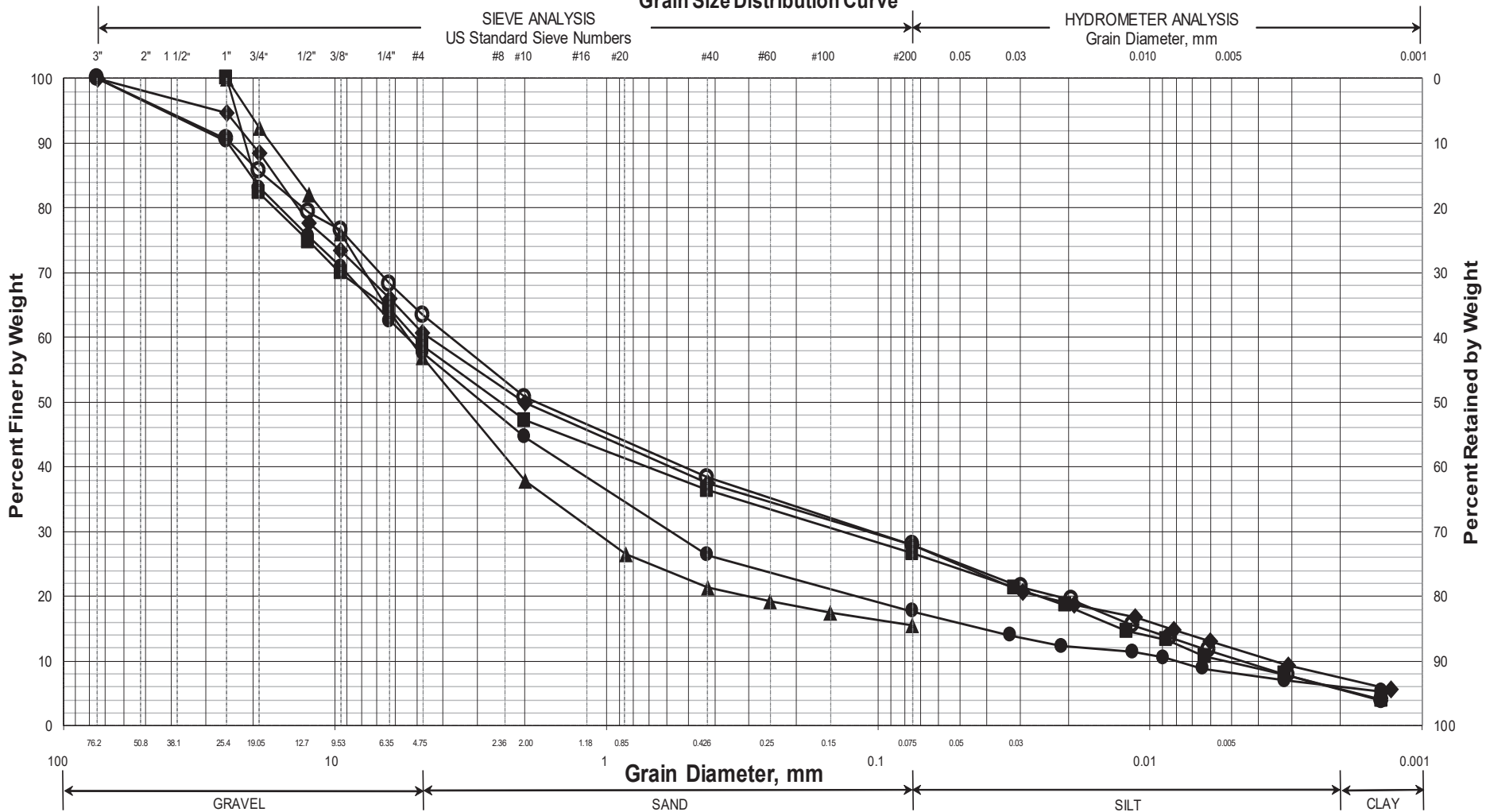
Depth (ft.)	Sample Information								Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N ₆₀	Casing Blows					
25	5D	18/13	25.00 - 26.50	19/69/61	130	185			563.3		Grey, wet, very dense, fine to coarse Sandy GRAVEL, little silt, (Till).	G#303087 A-1-b, GM WC=9.8%
											Bottom of Exploration at 26.5 feet below ground surface. SPOON REFUSAL	
30												
35												
40												
45												
50												

Remarks:

Appendix B

Laboratory Test Results

Maine Department of Transportation Grain Size Distribution Curve



UNIFIED CLASSIFICATION

	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	WC, %	LL	PL	PI
○	HB-WOOD-101/1D	12+57.5	12.6 LT	5.0-7.0	SAND, some gravel, some silt, trace clay.	9.7			
◆	HB-WOOD-101/2D	12+57.5	12.6 LT	10.0-12.0	GRAVEL, some sand, some silt, trace clay.	11.7			
■	HB-WOOD-101/3D	12+57.5	12.6 LT	15.5-17.0	GRAVEL, some sand, little silt, trace clay.	12.0			
●	HB-WOOD-101/4D	12+57.5	12.6 LT	20.0-22.0	Sandy GRAVEL, little silt, trace clay.	8.0			
▲	HB-WOOD-101/5D	12+57.5	12.6 LT	25.0-27.0	Sandy GRAVEL, little silt.	9.8			
X									

WIN
023036.00
Town
Woodland
Reported by/Date
WHITE, TERRY A 1/4/2023

Appendix C

Calculations

Bearing Resistance - Existing Soils:

Part 1 - Service Limit State

Nominal and factored Bearing Resistance - Box Culvert on Gravel

Presumptive Bearing Resistance for Service Limit State ONLY

Reference: AASHTO LRFD Bridge Design Specifications 9th Edition 2020
Table C10.6.2.5.1-1 Presumptive Bearing Resistances for Spread Footings at the Service Limit State Modified after US Department of Navy (1982)

Type of Bearing Material: Gravel (GC-GM)

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

Density In Place: Medium Dense to Dense

Bearing Resistance: Ordinary Range (ksf) 8 to 14

Recommended Value of Use:

$$q_{nom} := 10 \cdot \text{ksf}$$

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

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

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

$$q_{factored_service_bc} = 10 \cdot \text{ksf}$$

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 on Gravel

Reference: AASHTO LRFD Bridge Design Specifications 9th Edition 2020 - Article 10.6.3.1

Assumptions:

1. The box will be founded at ~ Elev 571.0 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 $B_{box} := 15 \cdot \text{ft}$

Length of box culvert, L $L_{box} := 102 \cdot \text{ft}$

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

$$s_c := 1 + \left(\frac{B_{\text{box}}}{L_{\text{box}}} \right) \left(\frac{N_q}{N_c} \right) \quad s_c = 1.1$$

$$s_\gamma := 1 - 0.4 \left(\frac{B_{\text{box}}}{L_{\text{box}}} \right) \quad s_\gamma = 0.9412$$

$$s_q := 1 + \left(\frac{B_{\text{box}}}{L_{\text{box}}} \cdot \tan(\phi_{ns}) \right) \quad s_q = 1.09$$

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

$$d_q := 1 + 2 \cdot \tan(\phi_{ns}) \cdot (1 - \sin(\phi_{ns}))^2 \cdot \tan\left(\frac{D_{\text{footing}}}{B_{\text{box}}}\right)^{-1} \quad d_q = 3.0589$$

LRFD Eq.
 10.6.3.1.2a-10

$N_{cm} := N_c \cdot s_c \cdot i_c$ $N_{cm} = 38.9118$ LRFD Eq.
 10.6.3.1.2a-2

$N_{qm} := N_q \cdot s_q \cdot d_q \cdot i_q$ $N_{qm} = 77.49$ LRFD Eq.
 10.6.3.1.2a-3

$N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma$ $N_{\gamma m} = 28.42$ LRFD Eq.
 10.6.3.1.2a-4

Coefficients for Groundwater Depths LRFD Table 10.6.3.1.2a-2

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

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

$q_{\text{nominal}} = 23 \cdot \text{ksf}$

Factored Bearing Resistance for Strength Limit State

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

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

$q_{\text{factored}} = 10.4 \cdot \text{ksf}$

Recommend a limiting factored bearing resistance of 10.5 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 $B_{\text{box}} = 15 \text{ ft}$
 Length of box culvert, L $L_{\text{box}} = 102 \text{ ft}$
 Thickness of box culvert, t $t_{\text{box}} := 12 \cdot \text{in}$ assumed
 Depth of box, D $D_{\text{box}} := 19.7 \cdot \text{ft}$
 Bearing Resistance: $q_{\text{factored_service_bc}} = 10 \cdot \text{ksf}$ Calculated above
 Modulus of Elasticity: Site soils at bearing elevation are Gravel. Use values for Sand and Gravel (dense)
 From Bowles Table 2-8 Modulus E_s for Sand and Gravel, dense ranges from 2100 - 4200 ksf

Use Modulus of Elasticity, E_s $E_s := 3200 \cdot \text{ksf}$
 Poisson's Ratio: Site conditions at bearing elevation are Gravel. Use values for Sand, gravelly sand.
 From Bowles Table 2-7 Poisson's Ratio μ for Sand, gravelly sand ranges from 0.3 - 0.4

Use Poisson's Ratio, μ $\mu := 0.35$

$$E_{\text{prime_s}} := \frac{1 - \mu^2}{E_s} \quad E_{\text{prime_s}} = 0.000274 \cdot \frac{\text{ft}^2}{\text{kip}}$$

Analyze corner:

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

$$H_{\text{inf}} := \frac{5 \cdot B_{\text{box}}}{B_{\text{box}}} \quad H_{\text{inf}} = 5 \quad \text{N in Table 5-2} \quad \text{From Table 5-2 for N=5 and M=6.8}$$

$$\frac{L_{\text{box}}}{B_{\text{box}}} = 6.8 \quad \text{M in Table 5-2} \quad I_1 := 0.544$$

$$I_2 := 0.1264 \quad \text{by interpolation}$$

Determine Steinbrenner influence factor - Bowles Section 5-6:

$$I_s := I_1 + \left[\frac{1 - (2 \cdot \mu)}{1 - \mu} \right] \cdot I_2 \quad I_s = 0.6023$$

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

$$\text{Depth ratio:} \quad \frac{D_{\text{box}}}{B_{\text{box}}} = 1.3133 \quad \frac{L_{\text{box}}}{B_{\text{box}}} = 6.8 \quad \mu = 0.35 \quad I_F := 0.77$$

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

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

$$k_s = 303 \cdot \text{pci}$$

Recommend Modulus of Subgrade Reaction of 300 pci