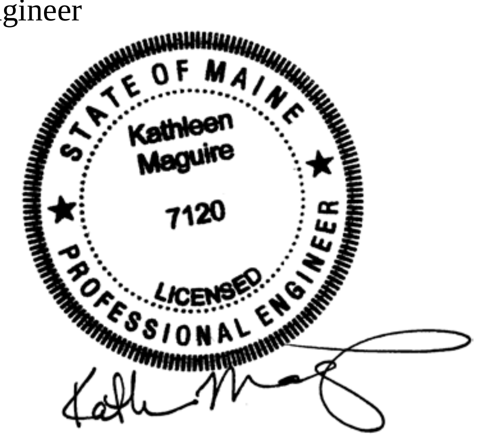
# MAINE DEPARTMENT OF TRANSPORTATION
# HIGHWAY PROGRAM
# GEOTECHNICAL SECTION
# AUGUSTA, MAINE

## GEOTECHNICAL DESIGN REPORT

*For the Construction of:*

**LATHE BRIDGE**
**STATE ROUTE 120**
**ROXBURY, MAINE**


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



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


| | |
|---|---|
| Oxford County | Soils Report 2017-22 |
| WIN 18847.00 | Bridge No. 6573 |

October 31, 2017

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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 State Route 120 in Roxbury, 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 an approximately 106-inch span by 73-inch rise steel multi-plate culvert on a skew of approximately 60 degrees to the roadway centerline on State Route 120 in Roxbury. State Route 120 is a Highway Corridor Priority 4 road.

The proposed replacement structure will be a 14-foot span by 6-foot rise by 120-foot long precast concrete box culvert on a skew of approximately 52 degrees to the roadway centerline. The invert of the proposed culvert is approximately 12 feet below the existing road grade at the roadway centerline. The invert of the proposed culvert will be filled with approximately 2 feet of Special Fill and will include rock vanes and a low flow channel to facilitate fish passage. The roadway embankment slopes at the proposed culvert inlet and outlet shall be no steeper than 2H:1V.

## 2.0 GEOLOGIC SETTING

The existing culvert carries an unnamed stream under Route 120 (Roxbury Notch Road) in Roxbury and is located 0.70 miles northerly of Frye Crossover Road as shown in Sheet - 1 Location Map.

According to the map titled Surficial Geology of the Lewiston 1 x 2 Degree Quadrangle, Maine, 1987 published by the Maine Geological Survey, the surficial soils at the site consist of till. These soils typically consist of loose to very compact, poorly sorted, massive to weakly stratified mixture of sand, silt, and gravel-size rock debris deposited by glacial ice. These soils may also include lenses of water-laid sand and gravel. Scattered boulders on the ground surface are common.

According to the map Geologic map of the Rumford [15-minute] quadrangle, Oxford and Franklin Counties, Maine, 1976 published by the Maine Geological Survey the bedrock at the site is identified as two-mica granodiorite and granite closely associated to the Bunker Pond and Phillips plutons.

## 3.0 SUBSURFACE INVESTIGATION

Two (2) borings (HB-ROX-101 and HB-ROX-102) were drilled for this project on October 30, 2015 by New England Boring Contractors (NEBC) using a trailer mounted drill rig. Two (2) probes (HB-ROX-201 and HB-ROX-202) were drilled for this project on July 21, 2016 by the

MaineDOT drilling crew using a trailer mounted drill rig. Exploration locations are shown on Sheet 2 - Boring Location Plan & Interpretive Subsurface Cross Section & Profile. Details and sampling methods used, field data obtained, and soil and groundwater conditions encountered are presented in the Boring Logs in Appendix A.

Borings HB-ROX-101 and HB-ROX-102 were drilled using solid stem auger (SSA) and cased wash boring techniques. Soil samples were obtained in the borings at 5-foot intervals using Standard Penetration Test (SPT) methods. The bedrock was cored in both borings using an NQ 2-inch core barrel and the Rock Quality Designation (RQD) of the core was calculated.

Probes HB-ROX-201 and HB-ROX-202 were drilling using SSA techniques. No soil sample were taken in the probes. The purpose of the probes was to better define the depth to refusal at the proposed culvert.

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 in the explorations drilled October 30, 2015 and a Northeast Transportation Training and Certification Program (NETTCP) certified subsurface inspector logged the explorations drilled July 21, 2016. The borings and probes 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 six (6) 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 borings generally consisted of sand fill overlying till overlying bedrock. An interpretive subsurface cross section and profile depicting the generalized soil stratigraphy at the boring locations is shown on Sheet 2 - Boring Location Plan & Interpretive Subsurface Cross Section & Profile.

Boring HB-ROX-101 was drilled to refusal at a depth of approximately 12.5 feet below ground surface (bgs) and bedrock was cored to a total depth of approximately 17.2 feet bgs. Boring HB-ROX-102 was drilled to refusal at a depth of approximately 10.8 feet bgs and bedrock was cored to a total depth of approximately 15.8 feet bgs. Probe HB-ROX-201 was drilled to refusal at a depth of approximately 14.1 feet bgs and probe HB-ROX-202 was drilled to refusal at a depth of approximately 12.5 feet bgs. The exact nature of the refusal surface in the probes was not determined during the drilling activities.

The following paragraphs discuss the subsurface conditions encountered in the borings in detail.

**Fill.** A layer of fill was encountered beneath the pavement in both borings. The fill consisted of:

- Brown, damp, fine to coarse sand, little to some gravel, trace silt, trace organics.

The thickness of the fill ranged from approximately 6.0 feet in boring HB-ROX-101 to approximately 8.0 feet in boring HB-ROX-102. SPT N-values obtained in the fill ranged from 17 to 33 blows per foot (bpf) indicating that the sand is medium dense to dense in consistency. Grain size analyses were conducted on three (3) samples from the fill and resulted in the soil being classified as an A-1-b under the AASHTO Soil Classification System and an SW-SM under the Unified Soil Classification System. The measured natural water contents of the fill samples ranged from approximately 5 to 13 percent.

**Till.** A layer of till was found underlying the fill in both borings. The till consisted of:

- Greyish brown, damp, fine to coarse sand, little to some gravel, little silt.
- White-tan, fine to coarse gravelly sand, trace silt, trace decomposed rock.

The thickness of the till ranged from approximately 2.8 feet in boring HB-ROX-102 to approximately 6.5 feet in HB-ROX-101. One SPT N-value taken in the till was 29 bpf indicating that the till is medium dense in consistency. Grain size analyses were conducted on three (3) samples from the till and resulted in the soil be classified as an A-1-b or A-1-a under the AASHTO Soil Classification System and an SW-SM or SM under the Unified Soil Classification System. The measure natural water contents of the till samples ranged from approximately 7 to 9 percent.

The table below summarizes the top of bedrock and refusal depths and elevations at the exploration locations.

| Boring | Approximate Depth bgs to Bedrock (feet) | Approximate Elevation of Bedrock (feet) | Approximate Depth bgs to Refusal (feet) | Approximate Elevation of Refusal (feet) |
|---|---|---|---|---|
| HB-ROX-101 | 12.5 | 666.1 | -- | -- |
| HB-ROX-102 | 10.8 | 671.9 | -- | -- |
| HB-ROX-201 | -- | -- | 14.1 | 669.9 |
| HB-ROX-202 | -- | -- | 12.5 | 668.8 |

The bedrock was described in the field as very hard, fresh to slightly weathered, fine to medium grained, light greenish grey granite. The Rock Quality Designation (RQD) of the bedrock was determined to be 79 percent in boring HB-ROX-101 and 78 percent in boring HB-ROX-102, which correlates to a Rock Mass Quality of Good.

## 6.0 GEOTECHNICAL DESIGN AND CONSTRUCTION RECOMMENDATIONS

The proposed replacement structure will consist of a 14-foot span by 6-foot rise by 120-foot long precast concrete box culvert on a skew of approximately 52 degrees to the roadway centerline. The invert of the proposed culvert will be filled with approximately 2 feet of Special Fill and will include rock vanes and a low flow channel to facilitate fish passage. 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 be a 14-foot span by 6-foot rise by 120-foot long precast concrete box on a skew of approximately 52 degrees to the roadway centerline. The proposed box culvert shall be designed and constructed in accordance with MaineDOT Standard Specification 534.

The inlet invert of the proposed precast concrete box culvert will be set at approximate elevation 669.55 feet with a 2.3 percent slope and will include rock vanes and a low flow channel to facilitate fish passage.

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 to limit disturbance.

Due to the presence of shallow bedrock at the proposed culvert location, bedrock removal will be necessary to construct the culvert at the planned elevations. Prior to placing the culvert bedding material, the bedrock surface shall be cleaned of all weathered bedrock, fractured material, loose soil, and/or ponded water.

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 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 Bedrock Removal and Bedrock Subgrade Preparation

To construct the culvert at the planned elevations bedrock removal will be necessary. The bedrock surface shall be prepared in accordance with MaineDOT standard practices. Construction activities should not be permitted to create any open fissures in the bedrock to remain. Any irregularities in the existing bedrock surface or irregularities created during the excavation process should be backfilled with crushed stone to the bottom of the required bedding material.

The nature, slope, and degree of fracturing in the bedrock bearing surfaces will not be evident until the excavation for the box culvert is made. The final bedrock surface slope shall be less than 4H:1V or it shall be benched in level steps.

The Contractor shall remove any overburden soil and weathered bedrock that can be removed using ordinary excavation equipment to expose competent bedrock at the required elevation. In accordance with MaineDOT standard practices, the bedrock shall be clean and free of debris, soil, or loose rock. The cleanliness and condition of the bedrock surface should be confirmed and accepted by the Resident prior to placing the structural bedding material. If soil is encountered at bedding material subgrade it shall be over excavated to expose the underlying bedrock surface and backfilled with compacted Granular Borrow Material for Underwater Backfill (703.19) or Crushed Stone ¾-Inch (MaineDOT 703.13). Any cobbles or boulders encountered in excess of 6 inches shall be removed and replaced with compacted Granular Borrow Material for Underwater Backfill or Crushed Stone ¾-Inch.

Blasting shall be conducted in accordance with MaineDOT Standard Specifications Sections 105.2.6 and 203. It is also required that the Contractor conduct pre-blast surveys as well as blast vibration monitoring at nearby structures in accordance with industry standards at the time of the blast.

It is anticipated that there will be seepage of water from fractures and joints exposed in the bedrock surface. Water should be controlled by pumping from sumps. The Contractor should maintain the excavation so that all work is completed in the dry.

### 6.3 Settlement

No settlement issues are anticipated at the site. The proposed culvert will be installed on bedrock.

### 6.4 Bearing Resistance

A factored bearing resistance of 6 kips per square foot (ksf) shall be used when analyzing the service limit state as allowed in AASHTO LRFD Bridge Design Specifications 7$^{th}$ Edition 2014 (LRFD) Article C10.6.2.6.1. The factored bearing pressure at the strength limit state for the precast concrete culvert bearing on compacted bedding material at approximate elevations 667 feet to 670 feet shall not exceed the calculated factored bearing resistance of 7 ksf. Calculations are included in Appendix C.

### 6.5 Modulus of Subgrade Reaction

A modulus of subgrade reaction ($k_s$) equal to 240 pounds per cubic inch shall be used for the structural design of the box culvert's base slab. Calculations are included in Appendix C.

### 6.6 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.

### 6.7 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.

### 6.8 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 fill and underlying bedrock or bracing 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

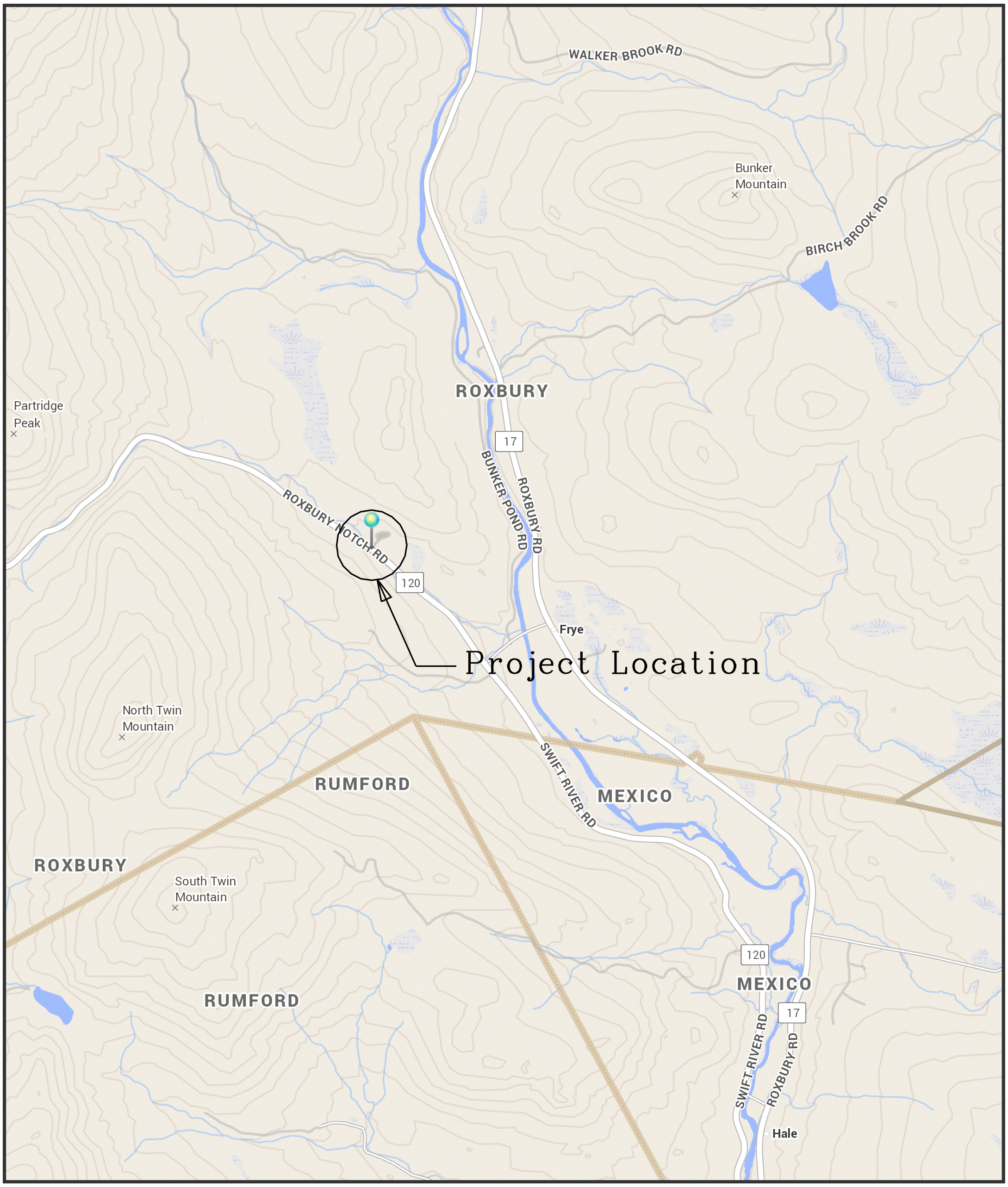
This report has been prepared for the use of the MaineDOT Highway Program for specific application to the proposed replacement of a large culvert under State Route 120 in Roxbury, Maine in accordance with generally accepted geotechnical and foundation engineering practices. No other intended use or warranty 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**

# ROXBURY, MAINE

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0.7 Miles

1 inch = 0.75 miles

Date: 5/8/2017
Time: 8:09:32 AM

Date:11/8/2017

Division: GEOTECH

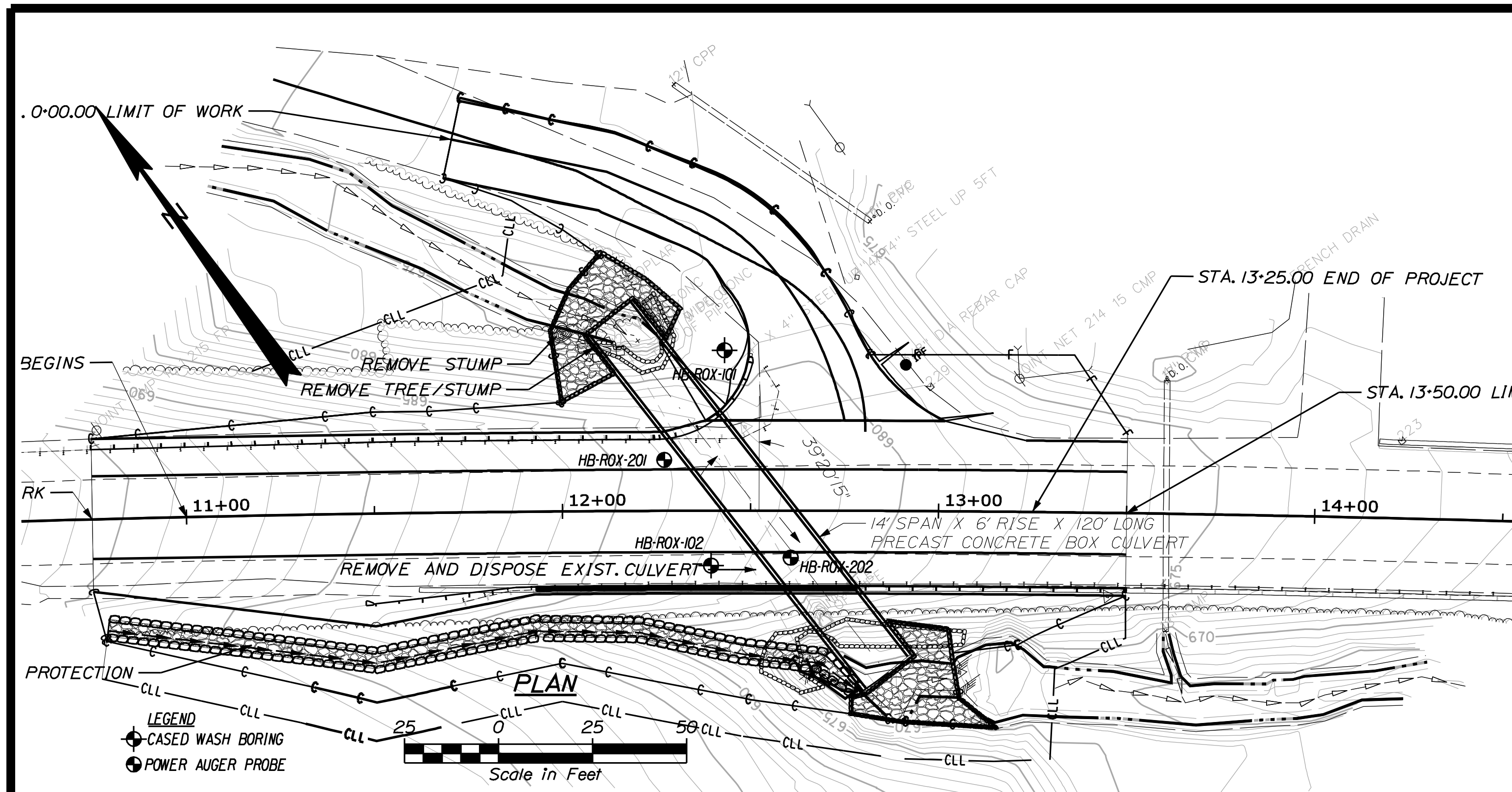
Username: Terry.White

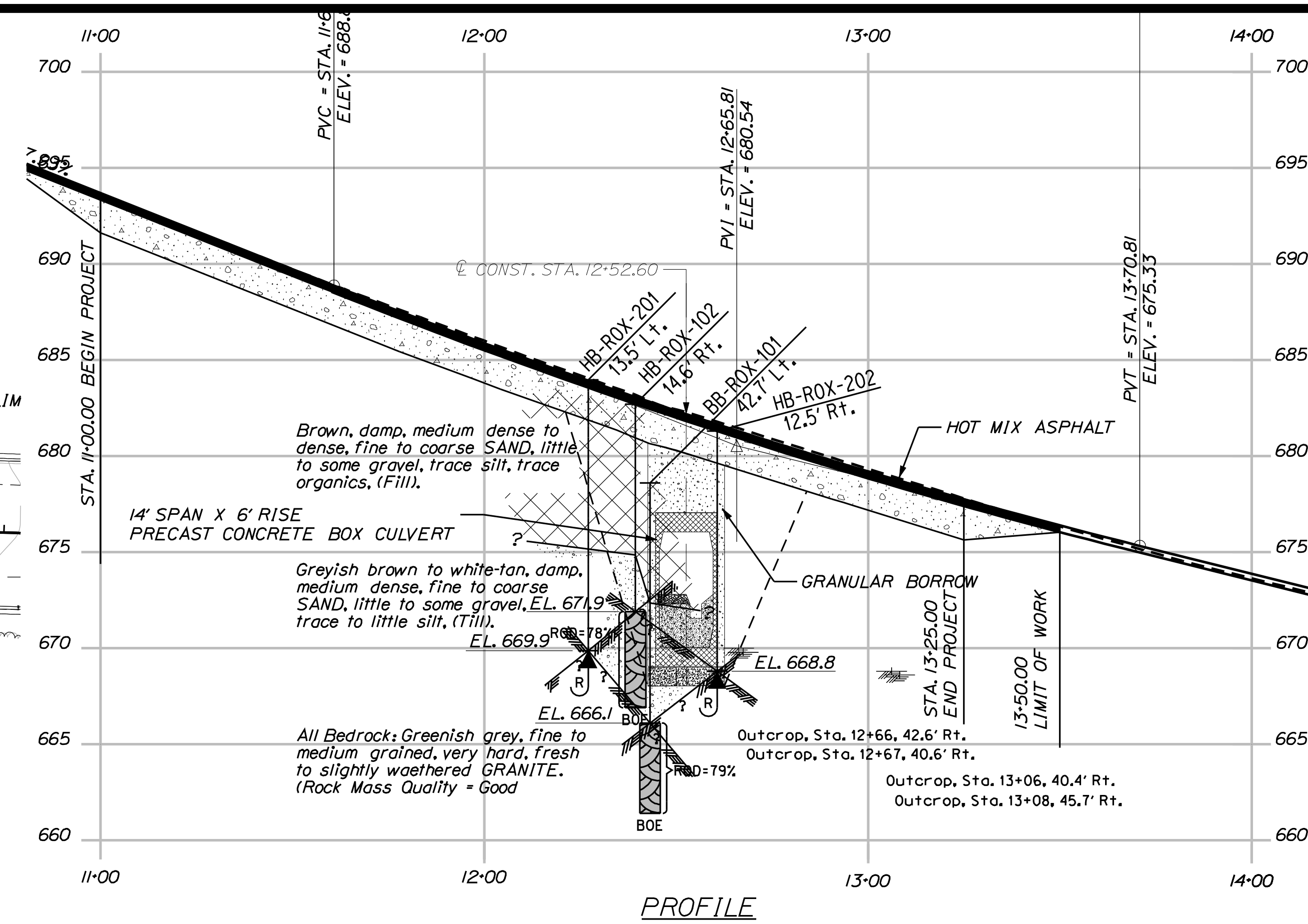
MAG. 19XX

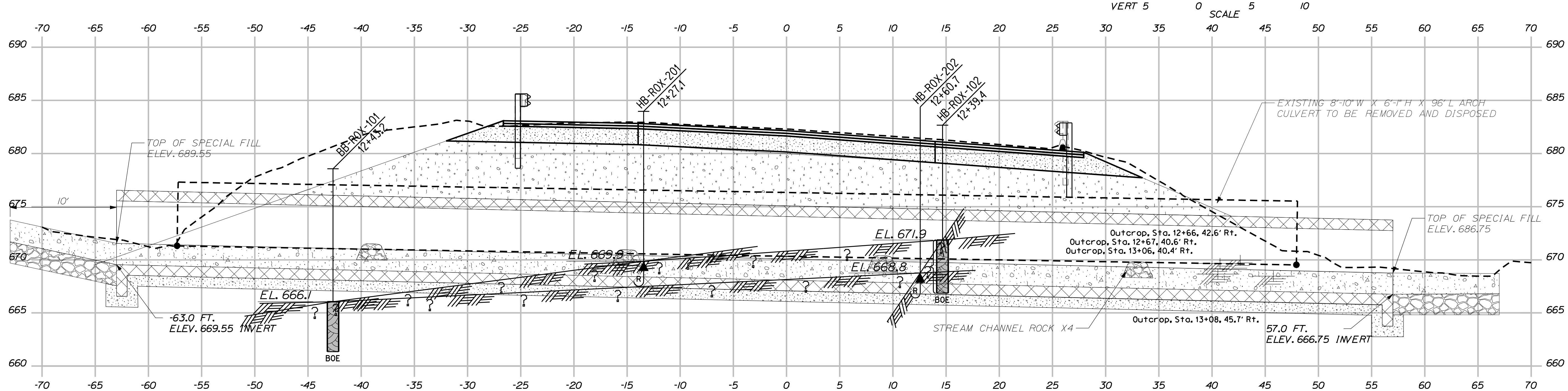
N

| SHEET NUMBER | ROXBURY NOTCH ROAD<br>LARGE CULVERT | STATE OF MAINE<br>DEPARTMENT OF TRANSPORTATION |
|---|---|---|
| 1 | ROXBURY OXFORD COUNTY | WIN 18847.00 |
| OF 2 | LOCATION MAP | WIN<br>18847.00 HIGHWAY PLANS |

Filename: ...\MSTA\002_BLP&ISCS&ISP1.dgn Division: GEOTECH Username: Terry.White Date:11/8/2017



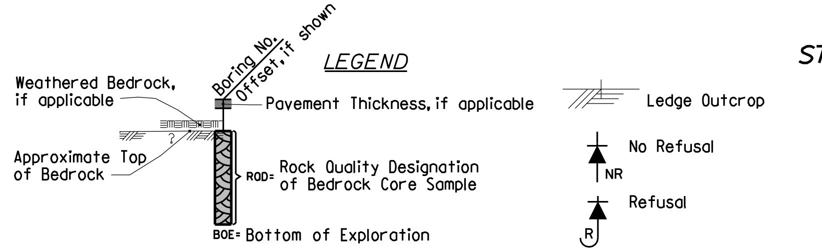




PRECAST CONCRETE BOX CULVERT LONGITUDINAL SECTION
STA. 12+52.60 SKEW (-39°20'15") 14' SPAN x 6' RISE X 120' LONG

CROSS SECTION

HORIZ 5 0 5 10
VERT 5 0 5 10
SCALE




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

WIN 18847.00

BRIDGE NO. 6573 | WIN 18847.00 | HIGHWAY PLANS

| | BY | DATE |
|---|---|---|
| PROJ. MANAGER | | |
| DESIGN-DETAILED | | |
| CHECKED-REVIEWED | C.RUSSELL | |
| DESIGN2-DETAILED2 | T.WHITE | OCT 2017 |
| DESIGN3-DETAILED3 | | |
| REVISIONS 1 | | |
| REVISIONS 2 | | |
| REVISIONS 3 | | |
| REVISIONS 4 | | |
| FIELD CHANGES | | |

SIGNATURE
P.E. NUMBER
DATE

ROXBURY
LATHE BRIDGE

BORING LOCATION PLAN & INTERPRETIVE SUBSURFACE CROSS SECTION & PROFILE

SHEET NUMBER
2
OF 2

# Appendix A

Boring Logs

# Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

**Project:** Lathe Bridge #6573, Route 120 - Roxbury Notch Road
**Location:** Roxbury, Maine

**Boring No.:** HB-ROX-101
**WIN:** 18847.00

| | | | | | |
|---|---|---|---|---|---|
| **Drilling Contractor:** | NEBC | **Elevation (ft.)** | 678.6 | **Auger ID/OD:** | 4.5" Solid Stem to 8.0 ft. |
| **Operator:** | Enos/Share | **Datum:** | NAVD88 | **Sampler:** | Standard Split Spoon |
| **Logged By:** | Be Schonewald | **Rig Type:** | Mobile Drill (truck) | **Hammer Wt./Fall:** | 140#/30" |
| **Date Start/Finish:** | 10/30/2015; 09:05-11:45 | **Drilling Method:** | Cased Wash Boring | **Core Barrel:** | NQ2 |
| **Boring Location:** | 12+43.2, 42.7 ft Lt. | **Casing ID/OD:** | NW | **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 | 1D | 24/8 | 0.00 - 2.00 | 1/9/8/17 | 17 | SSA | | | Brown, damp, medium dense, fine to coarse SAND, some gravel, trace silt, root mat at top of sample. (Fill). | G#301137 A-1-b, SW-SM WC=13.3% |
| 5 | 2D | 20.4/10 | 5.00 - 6.70 | 9/12/17/50(2.4") | 29 | | | | Brown, damp, medium dense, fine to coarse SAND, little gravel, trace silt, (Fill). | |
| | | | | | | | 672.60 | | 6.00 — 2D (6.0-6.7 ft) Greyish brown, damp, medium dense, fine to coarse SAND, some gravel, little silt. (Till). Very boney from 6.5-8.0 ft bgs. | G#301138 A-1-b, SW-SM WC=7.6% |
| | | | | | | SPUN CASE | | | 8.0 ft bgs auger refusal; spin NW casing to 8.5 ft bgs. Attempted core at 8.5 ft bgs. Granite Boulder from 8.5-9.7 ft bgs. | |
| 10 | | | | | | | | | Granite Cobble from 10.0-10.3 ft bgs. | |
| | 3D | 14.4/8 | 11.00 - 12.20 | 9/23/50(3.4") | --- | | | | White-tan, fine to coarse Gravelly SAND, trace silt, trace decomposed rock. | G#301139 A-1-a, SW-SM WC=9.4% |
| | R1 | 56.4/54 | 12.50 - 17.20 | RQD = 79% | | NQ-2 | 666.10 | | 12.50 — Top of Bedrock at Elev. 666.1 ft. R1: Very hard, fresh to slightly weathered, fine to medium grained, light greenish grey GRANITE, with garnet phenocrysts and muscovite-rich. Moderately spaced, low and high angle fractures; undulating, rough, typically discolored, open to wide, with mud infilling. Discoloration (oxidation) of core extends few inches from fractures. Rock Mass Quality = Good. Core Times (min:sec) 12.5-13.5 ft (2:25) 13.5-14.5 ft (1:55) 14.5-15.5 ft (2:25) 15.5-16.5 ft (2:05) 16.5-17.2 ft (-) 96% Recovery | |
| 15 | | | | | | | 661.40 | | | |
| | | | | | | | | | 17.20 — **Bottom of Exploration at 17.20 feet below ground surface.** | |
| 20 | | | | | | | | | | |
| 25 | | | | | | | | | | |

**Remarks:**

Bottom of Boring approximately 10.0 ft below invert of existing culvert.
Boring located near upstream end of culvert; offset 41.5 ft from existing CL; ties as follows: 55.1 ft to mailbox #229; 19.8 ft to survey control point; 63.6 ft to unnumbered electrical drop; 7.5 ft to near steel post

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:** Lathe Bridge #6573
Route 120 - Roxbury Notch Road
**Location:** Roxbury, Maine

**Boring No.:** HB-ROX-102

**WIN:** 18847.00

| | | | | | |
|---|---|---|---|---|---|
| **Drilling Contractor:** | NEBC | **Elevation (ft.)** | 682.7 | **Auger ID/OD:** | 4.5" Solid Stem to 10.0 ft. |
| **Operator:** | Enos/Share | **Datum:** | NAVD88 | **Sampler:** | Standard Split Spoon |
| **Logged By:** | Be Schonewald | **Rig Type:** | Mobile Drill (truck) | **Hammer Wt./Fall:** | 140#/30" |
| **Date Start/Finish:** | 10/30/2015; 12:00-13:55 | **Drilling Method:** | Cased Wash Boring | **Core Barrel:** | NQ2 |
| **Boring Location:** | 12+39.4, 14.6 ft Rt. | **Casing ID/OD:** | NW | **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
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RC = Roller Cone
WOH = Weight of 140lb. Hammer
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$S_u$ = 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 | 682.45 | | 3" HMA. 0.25 | |
| | 1D | 24/11 | 1.00 - 3.00 | 12/13/20/13 | 33 | | | | Brown, damp, dense, fine to coarse SAND, some gravel, trace silt, (Fill). | G#301140 A-1-b, SW-SM WC=4.5% |
| 5 | 2D | 24/12 | 5.00 - 7.00 | 10/13/13/7 | 26 | | | | Brown, damp, medium dense, fine to coarse SAND, some gravel, trace silt, (Fill). | G#301141 A-1-b, SW-SM WC=7.3% |
| | | | | | | | 674.70 | | 8.00 Boney below 8.0 ft bgs. | |
| 10 | 3D | 7.2/7.2 | 10.00 - 10.60 | 40/50(1.2") | --- | NQ-2 | | | Greyish brown, damp, fine to coarse SAND, little silt, little gravel. (Till). | G#301142 A-1-b, SM WC=7.0% |
| | R1 | 60/60 | 10.80 - 15.80 | RQD = 78% | | | 671.90 | | 10.80 Top of Bedrock at Elev. 671.9 ft. R1: Very hard, fresh to slightly weathered, medium grained, light greenish grey, GRANITE, with abundant muscovite and biotite; 1/4" vertical quartzite vein. Close to moderately spaced, typically moderately dipping fractures; undulating, rough, discolored, open to wide, with some mud infilling. Rock Mass Quality = Good Core Times (min:sec) 10.8-11.8 ft (2:00) 11.8-12.8 ft (1:40) 12.8-13.8 ft (1:45) 13.8-14.8 ft (1:40) 14.8-15.8 ft (1:55) 100% Recovery | |
| 15 | | | | | | | 666.90 | | 15.80 **Bottom of Exploration at 15.80 feet below ground surface.** | |
| 20 | | | | | | | | | | |
| 25 | | | | | | | | | | |

**Remarks:**

Boring located near downstream end of culvert; offset 14.2 ft from existing CL; ties as follows: 75.0 ft to mailbox #229; 38.2 ft to survey control point.

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**<br>Soil/Rock Exploration Log<br>US CUSTOMARY UNITS | **Project:** Lathe Bridge #6573<br>Route 120 - Roxbury Notch Road<br>**Location:** Roxbury, Maine | **Boring No.:** HB-ROX-201<br>**WIN:** 18847.00 |
|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| **Drilling Contractor:** | MaineDOT | **Elevation (ft.)** | 684.0 | **Auger ID/OD:** | 5" Dia. |
| **Operator:** | Daggett/Burpee | **Datum:** | NAVD88 | **Sampler:** | N/A |
| **Logged By:** | B. Wilder | **Rig Type:** | CME 45C | **Hammer Wt./Fall:** | N/A |
| **Date Start/Finish:** | 7/21/2016-7/21/2016 | **Drilling Method:** | Solid Stem Auger | **Core Barrel:** | N/A |
| **Boring Location:** | 12+27.1, 13.5 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 to refusal. No samples taken. | |
| 5 | | | | | | | | | | |
| 10 | | | | | | | | | | |
| | | | | | | | 669.90 | | 14.10 | |
| | | | | | | | | | **Bottom of Exploration at 14.10 feet below ground surface.**<br>REFUSAL | |
| 15 | | | | | | | | | | |
| 20 | | | | | | | | | | |
| 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-ROX-201

# Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

**Project:** Lathe Bridge #6573
Route 120 - Roxbury Notch Road
**Location:** Roxbury, Maine

**Boring No.:** HB-ROX-202

**WIN:** 18847.00

| | | | | | |
|---|---|---|---|---|---|
| **Drilling Contractor:** | MaineDOT | **Elevation (ft.)** | 681.3 | **Auger ID/OD:** | 5" Dia. |
| **Operator:** | Daggett/Burpee | **Datum:** | NAVD88 | **Sampler:** | N/A |
| **Logged By:** | B. Wilder | **Rig Type:** | CME 45C | **Hammer Wt./Fall:** | N/A |
| **Date Start/Finish:** | 7/21/2016-7/21/2016 | **Drilling Method:** | Solid Stem Auger | **Core Barrel:** | N/A |
| **Boring Location:** | 12+60.7, 12.5 ft Rt. | **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 to refusal. No samples taken. | |
| 5 | | | | | | | | | | |
| 10 | | | | | | | | | | |
| | | | | | | | 668.80 | | 12.50 | |
| | | | | | | | | | **Bottom of Exploration at 12.50 feet below ground surface.** REFUSAL | |
| 15 | | | | | | | | | | |
| 20 | | | | | | | | | | |
| 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.

# Appendix B

Laboratory Test Results

**State of Maine - Department of Transportation**

**Laboratory Testing Summary Sheet**

# Town(s): Roxbury Work Number: 18847.00

| 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-ROX-101, 1D | 12+43.2 | 42.7 Lt. | 0.0-2.0 | 301137 | 1 | 13.3 | | | SW-SM | A-1-b | 0 |
| HB-ROX-101, 2D | 12+43.2 | 42.7 Lt. | 6.0-6.7 | 301138 | 1 | 7.6 | | | SW-SM | A-1-b | 0 |
| HB-ROX-101, 3D | 12+43.2 | 42.7 Lt. | 11.0-12.2 | 301139 | 1 | 9.4 | | | SW-SM | A-1-a | 0 |
| HB-ROX-102, 1D | 12+39.4 | 14.6 Rt. | 1.0-3.0 | 301140 | 1 | 4.5 | | | SW-SM | A-1-b | 0 |
| HB-ROX-102, 2D | 12+39.4 | 14.6 Rt. | 5.0-7.0 | 301141 | 1 | 7.3 | | | SW-SM | A-1-b | 0 |
| HB-ROX-102, 3D | 12+39.4 | 14.6 Rt. | 10.0-10.6 | 301142 | 1 | 7.0 | | | SM | A-1-b | 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.**

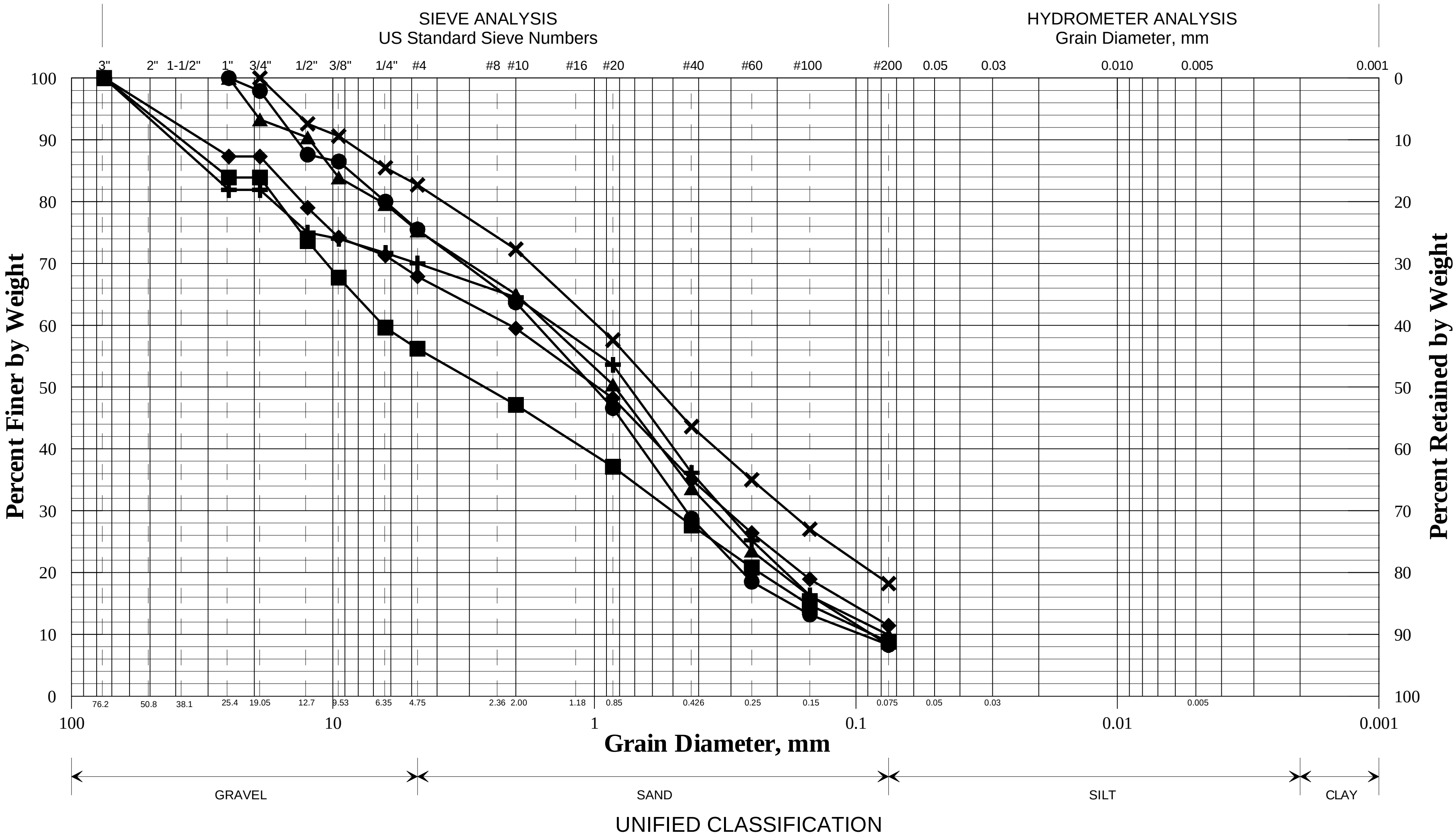
GSDC = Grain Size Distribution Curve as determined by AASHTO T 88-93 (1996) and/or ASTM D 422-63 (Reapproved 1998)

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

## *State of Maine Department of Transportation*
## GRAIN SIZE DISTRIBUTION CURVE




| | Boring/Sample No. | Station | Offset, ft | Depth, ft | Description | W, % | LL | PL | PI |
|---|---|---|---|---|---|---|---|---|---|
| ✚ | HB-ROX-101/1D | 12+43.2 | 42.7 LT | 0.0-2.0 | SAND, some gravel, trace silt. | 13.3 | | | |
| ◆ | HB-ROX-101/2D | 12+43.2 | 42.7 LT | 6.0-6.7 | SAND, some gravel, little silt. | 7.6 | | | |
| ■ | HB-ROX-101/3D | 12+43.2 | 42.7 LT | 11.0-12.2 | Gravelly SAND, trace silt. | 9.4 | | | |
| ● | HB-ROX-102/1D | 12+39.4 | 14.6 RT | 1.0-3.0 | SAND, some gravel, trace silt. | 4.5 | | | |
| ▲ | HB-ROX-102/2D | 12+39.4 | 14.6 RT | 5.0-7.0 | SAND, some gravel, trace silt. | 7.3 | | | |
| ✖ | HB-ROX-102/3D | 12+39.4 | 14.6 RT | 10.0-10.6 | SAND, little silt, little gravel. | 7.0 | | | |

| WIN | |
|---|---|
| 018847.00 | |
| **Town** | |
| Roxbury | |
| **Reported by/Date** | |
| WHITE, TERRY A | 12/21/2015 |

**SHEET 1**

# **Appendix C**

Calculations

# Bearing Resistance - Existing Soils:

## Part 1 - Service Limit State

**Nominal and factored Bearing Resistance - Box Culvert on Gravelly Sand**

**Presumptive Bearing Resistance for Service Limit State ONLY**

Reference: AASHTO LRFD Bridge Design Specifications 7th Edition 2014
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: gravelly sand (SW-SM) (till)

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: $q_{nom} := 6 \cdot ksf$

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

$q_{factored\_service\_bc} := q_{nom} \cdot \phi_{service\_bc}$ $q_{factored\_service\_bc} = 6 \cdot ksf$

*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 Gravelly Sand**

Reference: AASHTO LRFD Bridge Design Specifications 7th Edition 2014 - Article 10.6.3.1

Assumptions:

1. The box will be founded at ~ Elev 667 feet to 670 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 $B_{box} := 14 \cdot ft$

   Length of box culvert, L $L_{box} := 120 \cdot ft$

Nominal Bearing Resistance per LRFD Equation 10.6.3.1.2a-1

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

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

$s_c := 1 + \left(\frac{B_{box}}{L_{box}}\right)\left(\frac{N_q}{N_c}\right)$ $s_c = 1.08$

$s_\gamma := 1 - 0.4\left(\frac{B_{box}}{L_{box}}\right)$ $s_\gamma = 0.9533$

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

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

$\frac{D_{footing}}{B_{box}} = 0.1429$ for ϕ=32 degrees $d_q := 1.2$

$N_{cm} := N_c \cdot s_c \cdot i_c$ $N_{cm} = 38.2067$ LRFD Eq. 10.6.3.1.2a-2

$N_{qm} := N_q \cdot s_q \cdot d_q \cdot i_q$ $N_{qm} = 29.87$ LRFD Eq. 10.6.3.1.2a-3

$N_{\gamma m} := N_\gamma \cdot s_\gamma \cdot i_\gamma$ $N_{\gamma m} = 28.79$ LRFD Eq. 10.6.3.1.2a-4

Coefficients for Groundwater Depths LRFD Table 10.6.3.1.2a-2

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

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

$q_{nominal} = 16.3 \cdot ksf$

**Factored Bearing Resistance for Strength Limit State**

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

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

$q_{factored} = 7.3 \cdot ksf$

Recommend a limiting factored bearing resistance of 7.0 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 $B_{box} := 14 \cdot ft$

Length of box culvert, L $L_{box} := 120 \cdot ft$

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

Depth of box, D $D_{box} := 13 \cdot ft$

Bearing Resistance: $q_{factored\_service\_bc} = 6 \cdot ksf$ Calculated above

Modulus of Elasticity: Site soils are Gravelly Sand (dense)
From Bowles Table 2-8 Modulus Es for sand and gravel, dense ranges from 2,000 - 4,100 ksf
Use: Modulus of Elasticity, Es $E_s := 2500 \cdot ksf$

Poisson's Ratio: Site soils are Sand (dense)
From Bowles Table 2-7 Poisson's Ration μ for Sand/Till ranges from 0.3 - 0.4
Use: Possion's Ratio, μ $\mu := 0.35$

$$E_{prime\_s} := \frac{1-\mu^2}{E_s} \qquad E_{prime\_s} = 0.000351 \cdot \frac{ft^2}{kip}$$

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 5-2

$$\frac{L_{box}}{B_{box}} = 8.5714$$ M in Table 5-2

From Table 5-2 for N=5 and M=8.5

$I_1 := 0.538$

$I_2 := 0.135$

by interpolation

Determine Steinbrenner influence factor - Bowles Section 5-6:

$$I_s := I_1 + \left[\frac{1-(2\cdot\mu)}{1-\mu}\right] \cdot I_2 \qquad I_s = 0.6003$$

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

Depth ratio: $\frac{D_{box}}{B_{box}} = 0.9286$ $\frac{L_{box}}{B_{box}} = 8.5714$ $\mu = 0.35$ $I_F := 0.82$

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

$$k_s = 239 \cdot pci$$

Recommend Modulus of Subgrade Reaction of 240 pci