MAINE DEPARTMENT OF TRANSPORTATION
HIGHWAY/BRIDGE PROGRAM
GEOTECHNICAL SECTION
AUGUSTA, MAINE

GEOTECHNICAL DESIGN REPORT

For the Construction of:

WEBBER POND OUTLET BRIDGE
STATE ROUTE 32
BREMEN, MAINE

Prepared by:
Kalia Breskin, P.E.
Senior Geotechnical Engineer

STATE OF MAINE
Kalia Breskin
8581
LICENSED
PROFESSIONAL ENGINEER

Reviewed by:
Meredith Kirkmann
Geotechnical Design Engineer

Lincoln County

Soils Report No. 2014-11
Bridge No. 6483

WIN 18103.00

May 2, 2014

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GEOTECHNICAL DESIGN SUMMARY

The purpose of this report is to present subsurface information and make geotechnical recommendations for the replacement of a Corrugated Metal Pipe (CMP) culvert with stone headwalls which carries Muscongus Brook under State Route 32 in the Town of Bremen, approximately 1.3 miles southerly of the intersection of Route 32 and the Biscay Road. The proposed replacement structure will be a single-span three-sided box culvert. The project will include approximately 400-feet of full or partial highway reconstruction. The following design and construction sections are discussed in detail in the attached report:

Box Culvert – The new 3-sided box culvert will have a span of 14-feet and a rise of 8-feet to meet requirements for fish and wildlife passage. The structure will be 80-feet long. Concrete footings with pedestal walls to support the sides of the box will be constructed on the bedrock channel.

Bearing Resistance – The factored bearing resistance at the strength limit state for the structure on heavily fractured bedrock shall not exceed 15 ksf for base width of 6.5 feet. A factored bearing resistance of 20 ksf shall be used to control settlement when analyzing the service limit state.

Scour and Riprap – For scour protection and protection of the structure, the bridge approach slopes and slopes at abutments should be armored with 3 feet of plain riprap. The toe of the riprap section shall be constructed 1 foot below the streambed elevation in areas where the streambed is not bedrock. The riprap section should be underlain by a 6-inch thick layer of bedding material conforming to item number 703.19 of the Standard Specification and Class "1" Erosion Control Geotextile.

Seismic Design Considerations – Seismic analysis is not required for single span bridges regardless of seismic zone. However, superstructure connections and minimum support lengths should be designed in accordance with LRFD requirements.

Pavement Section – The pavement structural section should include a minimum section of 4-inches of Hot Mix Asphalt (HMA) and 18-inches of gravel meeting the requirements of MaineDOT Standard Specification 703.06.

Construction Considerations - The bedrock surface is likely to be rough with intersection fractures. The bedrock surface shall be cleared of all loose fractured bedrock, loose decomposed bedrock and soil. The cleanliness and condition of the bedrock surface shall be confirmed by the Resident prior to placing concrete.

It is anticipated that there will be seepage of water from fractures and joints exposed in the bedrock surface. If areas of groundwater seepage are encountered during construction, it may become necessary to control groundwater or flatten the construction slopes used.

Excavated soils may be used as common borrow in accordance with MaineDOT Standard Specifications 203 and 703, but these soils may not be used as gravel in the new roadway construction.

1.0 INTRODUCTION

The purpose of this Geotechnical Design Report is to present geotechnical recommendations for the proposed replacement of an existing box culvert which carries Muscongus Brook under State Route 32 in the Town of Bremen. State Route 32 is a Priority 4 Highway Corridor. The project also includes approximately 400 feet of approach roadway construction. A subsurface investigation has been completed for this site. This report presents the soils and bedrock information obtained at the site and geotechnical design recommendations.

The existing 4-foot CMP culvert is badly deformed and deteriorated. This structure carries Muscongus Brook under State Route 32. The structure is undersized for the current site hydraulic needs, although the stream is constricted upstream by the culvert under the original roadway, and downstream by stone structures from the old mill at this location. Flow from Webber Pond in controlled by a culvert through the beaver dam that forms the pond outlet.

Existing roadway lanes are 11 feet wide with gravel shoulders, and there is no guardrail at the Muscongus Brook crossing. The existing highway alignment will be maintained in the replacement. Bedrock surface under the existing structure slopes steeply down to the channel at approximately elevation 52 on both sides of the culvert. The streambed appears to be soil upstream but has been scoured to bedrock downstream. The original roadway crossed over a small box culvert immediately upstream of the structure to be replaced. No impacts to the original structure are proposed.

The proposed replacement structure will be a precast 3-sided box culvert with a span of 14-feet and a rise of 8-feet. The proposed roadway approaches will have 11-foot lanes and 4-foot shoulders. State Route 32 is a Priority 4 Highway Corridor with projected year 2023 Annual Average Daily Traffic (AADT) of 1080 cars and 9% heavy trucks.

2.0 GEOLOGIC SETTING

The existing culvert carries Muscongus Brook under State Route 32 near the outlet of Webber Pond as shown on Sheet 1 - Location Map found at the end of this report.

Mapping by the Natural Resources Conservation Service (NRCS) indicates that soils in the site vicinity are Lyman rock outcrop-Tunbridge complex with fines contents on the order of 42% and bedrock at depths less than 1.5 feet.

According to the Surficial Geology map of the Louds Island Quadrangle, Maine published by the Maine Geologic Survey (Open-File 76-36) the surficial soils in the vicinity of the site consist of Till with shallow bedrock.

According to the Bedrock Geologic Map of the Bath 1:100,000 Quadrangle published by the Maine Geologic Survey, the bedrock in the vicinity of the site consists of “Medium gray to

purplish gray quartz-plagioclase-biotite-hornblende granofels and gneiss with greenish gray clac-silicate interbeds; some rusty quartz-biotite schist zones" of the Bucksport Formation.

3.0 SUBSURFACE INVESTIGATION

Subsurface conditions at the site were explored by drilling two test borings and four auger probes, and conducting a geophysical survey to map the bedrock surface. Initial borings and probes were drilled on April 29, 2011, and the final boring and rock core were drilled on March 4, 2014 by MaineDOT. The borings and probes were drilled using a 5-inch solid-stem auger. Soil samples were obtained using Standard Penetration Test (SPT) test methods with a 40 lb. hammer dropped 30". The standard penetration resistances (N-values) discussed in this report have been corrected for average energy transfer. A 5-foot rock core was obtained using an NQ-2" core barrel.

Test boring HB-BREM-101 was drilled at the southwest corner of the structure, and auger probes to locate the bedrock surface were drilled at the other three corners. Boring SB-BREM-201 was drilled in the Right lane very close to the existing culvert. The exploration locations are shown on Sheet 2 - Boring Location Plan and Interpretive Subsurface Profile found at the end of this report. Details and sampling methods used, field data obtained, and soil and groundwater conditions encountered are presented in the boring logs provided in Appendix A – Boring Logs found end of this report.

Auger probes to the assumed bedrock surface were conducted using solid stem augers. The borings were located in the field using a tape during the exploration program. Boring logs and rock core photographs are provided in Appendix A – Boring Logs found end of this report.

Geophysical investigations were conducted by Hager-Richter Geoscience, Inc. of Salem, NH in September 2011 using Seismic Refraction and Ground Penetrating Radar (GPR) traverses. The purpose of the investigation was to determine the depth and configuration of the bedrock surface in the vicinity of the proposed construction. Seismic refraction profiling was acquired along three traverses 94-foot long traverses located along the shoulders and the approximate centerline oriented parallel to the travel lanes. GPR data was acquired over a 24-foot by 60-foot grid centered over the existing box culvert. The Geophysical Survey report is presented in Appendix B found end of this report.

4.0 LABORATORY TESTING

Laboratory testing for samples obtained in the boring consisted of two (2) standard grain analyses with natural water content. The results of these laboratory tests are provided in Appendix C - Laboratory Data found at the end of this report. Moisture content information and other soil test results are included on the Boring Logs in Appendix A and on Sheet 3 – Boring Logs found at the end of this report.

5.0 SUBSURFACE CONDITIONS

Subsurface conditions encountered at the borings were generally fill soils underlain by a thin layer of native soils over bedrock. An interpretive subsurface profile depicting the site stratigraphy is shown on Sheet 2 – Boring Location Plan and Interpretive Subsurface Profile found at the end of this report. The following paragraphs discuss the subsurface conditions encountered at the site in detail:

5.1 Fill

Fill material was encountered beneath the pavement in all of the borings. The upper stratum of fill material consisted of loose, damp to moist coarse grained soils with cobbles, boulders and bricks. Fill soils below a depth of 8-feet were brown, wet, medium dense silty fine to coarse sand with trace gravel and occasional cobbles. The thickness of the fill was approximately 6.7 feet in boring HB-BREM-101, and soils became wet at a depth of 8'in SB-BREM-201. The corrected SPT N-values in the upper fill were 13 to 19 blows per foot (bpf) indicating that the fill is generally medium dense in consistency, however these blow counts may reflect the presence of cobbles and boulders. Natural water contents obtained from the lower fill samples ranged from approximately 11.1% to 15.9%. Grain size analyses conducted on samples of the fill indicate that the soil is classified as an A-2-4 and A-1-b by the AASHTO Classification System and SM or GM by the Unified Soil Classification System.

Boring SB-BREM-201 was taken at Station 10+07.2, 8 feet Right, and is very close to the existing culvert. Strata of cobbles were found in this boring from 14.5-feet to 15.3-feet below ground surface (bgs) and from 19-feet to 22.3-feet bgs. It appears that the refusals encountered in other borings may have been cobble or boulder refusal; this would account for the discrepancy between boring refusals and geophysical data.

5.2 Native Soils

A thin layer of native soils was encountered beneath the fill in boring HB-BREM-101. The native soils encountered consisted of dense gravelly Till. This boring was terminated in dense material, however all auger probes were extended to refusal. The thickness of the native soils layer was at least 1.8 foot. No SPT testing was done in this layer and no samples were taken.

5.3 Bedrock

Boring SB-BREM-201 was extended to include a 5-foot bedrock core from elevation 49.7-feet to 44.7-feet, a depth of 27.3-feet below the roadway surface adjacent to the existing culvert. Bedrock in this core was identified as white to grey coarse grained, hard and fresh microcline (Feldspar), quartz biotie and trace garnet and amphibole (hornblende) pegmatite over dark grey metamorphic schist. The rock core was heavily fractured, with only 15% of the core in pieces larger than 4-inches.

Bedrock is visible in the streambed downstream from the old mill stonework and upstream from the upstream stone box. Boring HB-BREM-101 and auger probes PA-1, PA-2, and PA-3 encountered refusal at shallow depths. SB-BREM-201 and PA-4 were substantially deeper right at the existing pipe. The bedrock surface was mapped using GPR through the roadway. Although GPR data is not precise, it corresponds reasonably well with boring and auger refusals. The bedrock contours developed from the GPR data are shown in the Geophysical Report in Appendix B found at the end of this report. A depiction of the approximate bedrock surface based on GPR at the site is also shown on Sheet 2 at the end of this report.

5.4 Groundwater

Groundwater was not observed in the borings or auger probes. Groundwater levels are expected to fluctuate seasonally depending upon the local precipitation magnitudes.

5.5 Existing Pavement Structure

The existing pavement structure observed at the boring location was found to have 5.5 inches of Hot Mix Asphalt (HMA) in HB-BREM-101 and 14.4 inches of HMA pavement in SB-BREM-201. No change in soils was noted on the boring logs to indicate the thickness of the existing pavement structural section.

6.0 GEOTECHNICAL DESIGN RECOMMENDATIONS

The following section discusses geotechnical design recommendations for a 3-sided concrete box culvert.

6.1 Foundation

The proposed structure will be founded on the bedrock surface. A cast-in place concrete footing with base of 6.33-feet and variable height will be constructed at bedrock surface for each wall. The concrete footings shall be formed directly on the bedrock surface. The bedrock surface shall be cleaned of all weathered, loose and potentially erodible or scourable materials. The bedrock surface shall be stepped or benched as needed to provide a surface with a maximum slope in any direction of 6H:1V to ensure the stability of the footings.

6.2 Bearing Resistance

Due to the poor condition of the bedrock indicated in the core, the bedrock was analyzed as dense soil with friction angle, ϕ, of 45°. A factored bearing resistance of 20 ksf shall be used to control settlement when analyzing the service limit state as allowed in LRFD C10.6.2.6.1. The factored bearing resistance at the strength limit state shall not exceed 17 ksf. See Appendix D - Calculations for supporting documentation.

6.3 Scour and Riprap

For scour protection and protection of the structure, the bridge approach slopes should be armored with 3 feet of plain riprap. Refer to MaineDOT Bridge Design Guide (BDG) Section 2.3.11 for information regarding scour design.

Stone riprap shall conform to item number 703.26 of the MaineDOT Special Provision 703 and shall be placed at a maximum slope of 1.75H:1V. Where possible, the riprap section

shall be underlain by a 1 foot thick layer of bedding material conforming to item number 703.19 of the Standard Specification and Class "1" Erosion Control Geotextile per Standard Details 610(02) through 610(04).

6.4 Frost Protection

The footings for this structure will be founded directly on bedrock. For foundations on bedrock, heave due to frost is not a design issue and no requirements for minimum depth of embedment are necessary.

6.5 Seismic Design Considerations

In conformance with LRFD Article 4.7.4.2 seismic analysis is not required for single-span bridges regardless of seismic zone. According to Figure 2-2 of the MaineDOT BDG, the Route 32 Struts are not on the National Highway System (NHS). The bridge is not classified as a major structure since the construction costs will not exceed $10 million. These criteria eliminate the MaineDOT BDG requirement to design the foundations for seismic earth loads. However, superstructure connections and minimum support length requirements shall be satisfied per LRFD Articles 3.10.9 and 4.7.4.4, respectively.

6.6 Pavement Design

Projected Year 2023 traffic loading on State Route 32 is low with AADT of 1080 and 9% heavy trucks. Although Falling Weight Deflectometer (FWD) testing was not done for this project, a Resilient Modulus of 4500 psi should be used for pavement design. The minimum pavement thickness of 4 inches Hot Mix Asphalt (HMA) and 18 inches of ASC-Gravel would be adequate for these loadings.

6.7 Construction Considerations

The bedrock surface is likely to be rough with intersection fractures. The bedrock surface shall be cleared of all loose fractured bedrock, loose decomposed bedrock and soil. The cleanliness and condition of the bedrock surface shall be confirmed by the Resident prior to placing concrete.

It is anticipated that there will be seepage of water from fractures and joints exposed in the bedrock surface. If areas of groundwater seepage are encountered during construction, it may become necessary to control groundwater or flatten the construction slopes used.

Excavated soils may be used as common borrow in accordance with MaineDOT Standard Specifications 203 and 703, but these soils may not be used as gravel in the new roadway construction.

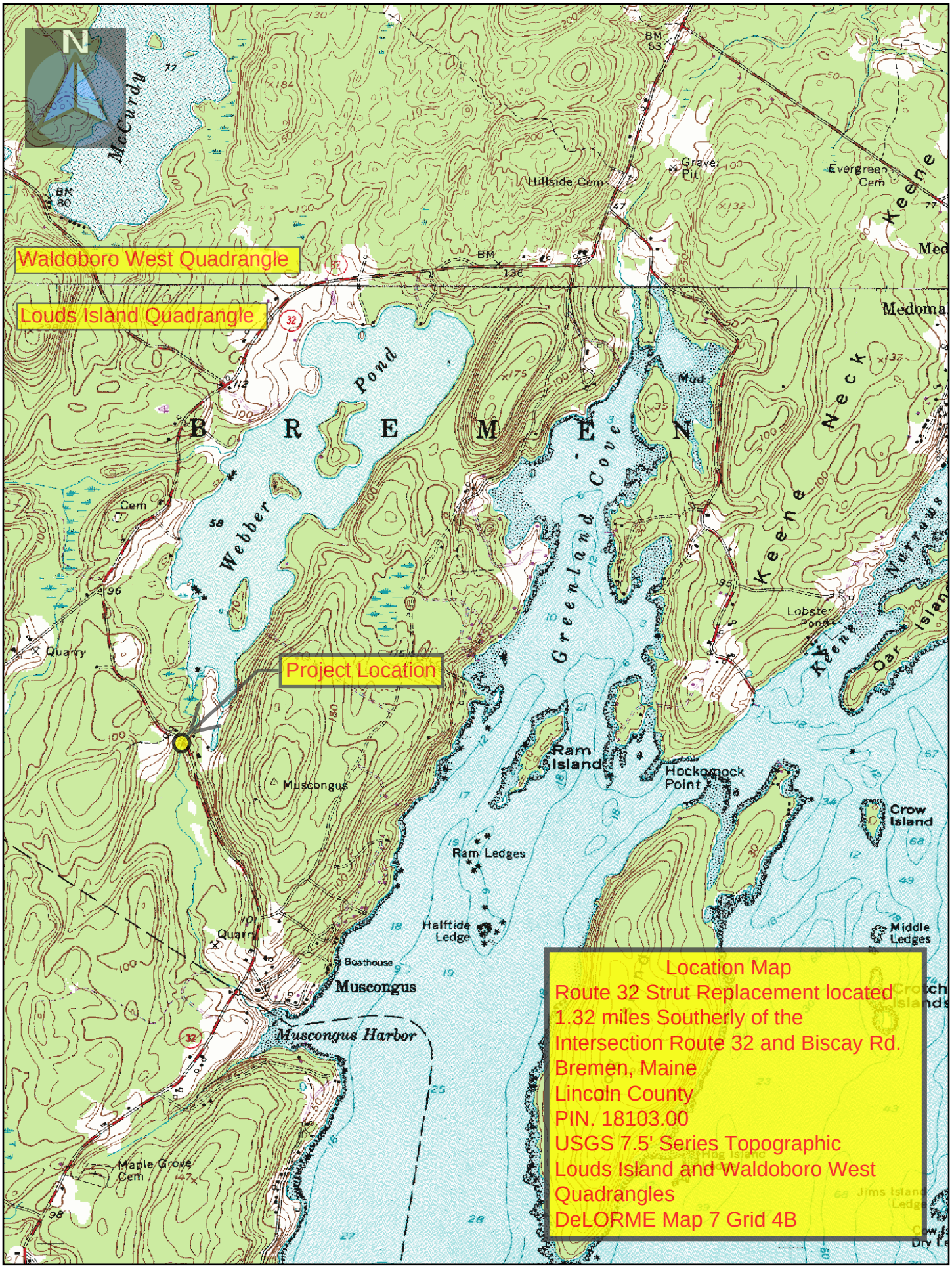
7.0 CLOSURE

This report has been prepared for the use of the MaineDOT Highway Program for specific application to the proposed construction of the Webber Pond Outlet Bridge on State Route 32 on Muscongus Brook. No other intended use or warranty is 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 recommendation as appropriate to reflect the changes in design. Further, the analyses and recommendations are based in part upon limited soil explorations at discrete locations 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.

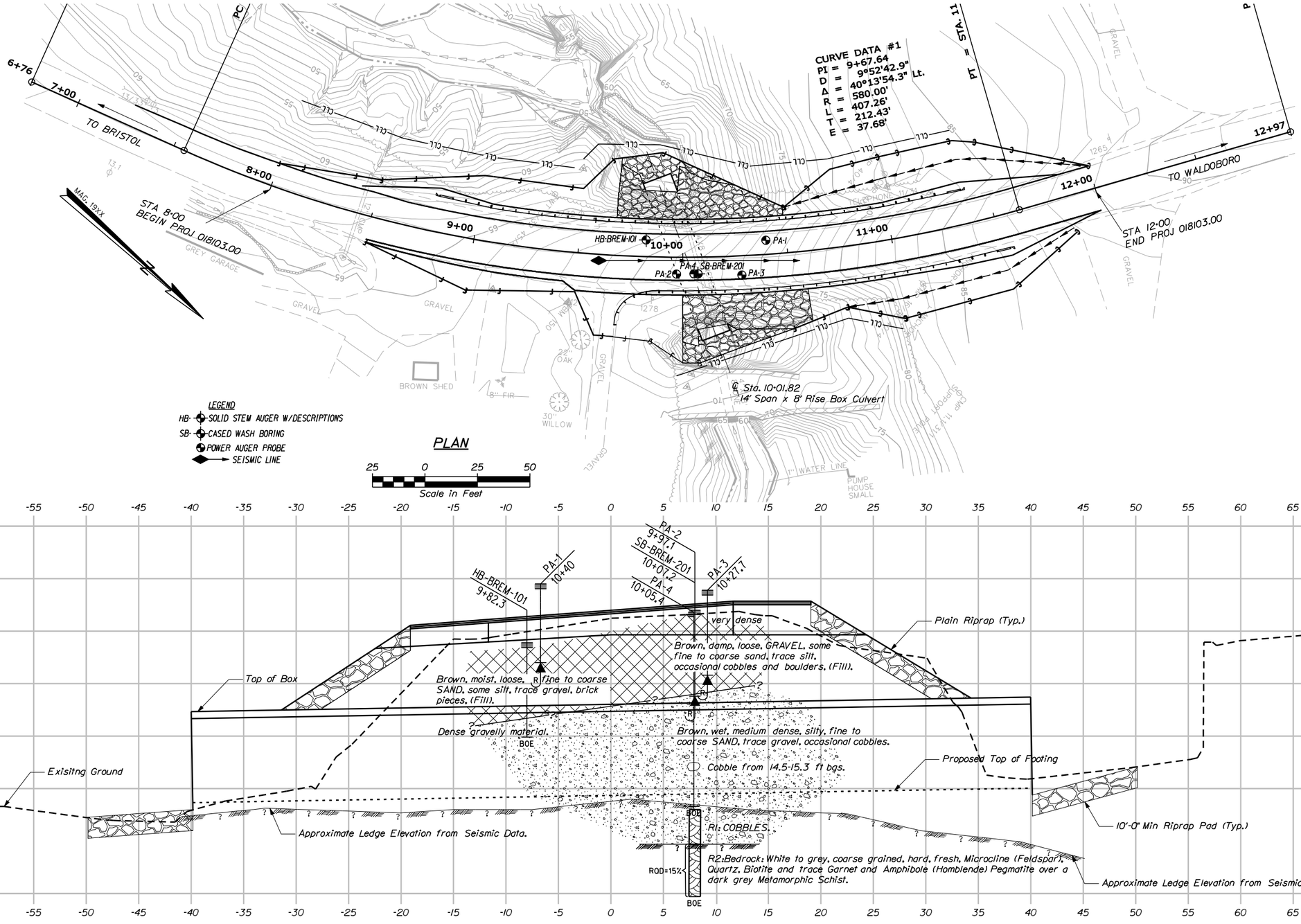
We also recommend that we be provided the opportunity for a general review of the final design plans and specifications in order to verify that the earthwork and foundation recommendations have been properly interpreted and implemented in the design.

Sheets



Map Scale 1:24000

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



LEGEND

Boring No. / Station

Weathered ROCK

Pavement Thickness if applicable

Strata Interface

Top of Intack Bedrock

ROD= Rock Quality Designation for Rock Core Sample

Boring

BOE= Bottom Of Exploration

Note: This generalized interpretive soil cross section 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 transitions may vary and are probably more erratic. For more specific information refer to the exploration logs.

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

WIN 18103.00

HIGHWAY PLANS

	BY	DATE
PROJ. MANAGER		
DESIGN-DETAILED		
CHECKED-REVIEWED		
DESIGN2-DETAILED2	K.BRESKIN	T.WHITE
DESIGN3-DETAILED3		JAN 2014
REVISIONS 1		
REVISIONS 2		
REVISIONS 3		
REVISIONS 4		
FIELD CHANGES		

SIGNATURE

P.E. NUMBER

DATE

BREMEN
ROUTE 32 STRUT

GEOPLAN & INTERPRETIVE
SUBSURFACE CROSS SECTION

SHEET NUMBER

1

OF 2

Filename: ...\GEOTECH\MSTA\001_GP&ISCS1.dgn Division: GEOTECH Username: terry.white Date:4/30/2014

Filename: ...\msta\002_BORING LOGS1.dgn Division: GEOTECH Username: terry.white Date:4/30/2014

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Route 32 Strut Replacement
Location: Bremen, Maine

Boring No.: HB-BREM-101
WIN: 18103.00

Driller:	MaineDOT	Elevation (ft.)	68.9	Auger ID/OD:	5" Dia.
Operator:	Giguere/Giles	Datum:	NAVD88	Sampler:	Standard Split Spoon
Logged By:	B. Wilder	Rig Type:	CME 45C	Hammer Wt./Fall:	140#/30"
Date Start/Finish:	4/29/11; 08:00-08:30	Drilling Method:	Solid Stem Auger	Core Barrel:	N/A
Boring Location:	9+82.3, 8.0 ft Lt.	Casing ID/OD:	N/A	Water Level*:	None Observed
Hammer Efficiency Factor: 0.84		Hammer Type:	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

Definitions:
D = Split Spoon Sample
MD = Unsuccessful Split Spoon Sample attempt
U = Thin Wall Tube Sample
MU = Unsuccessful Thin Wall Tube Sample attempt
V = Insitu Vane Shear Test, PP = Pocket Penetrometer
MV = Unsuccessful Insitu Vane Shear Test attempt
R = Rock Core Sample
SSA = Solid Stem Auger
HSA = Hollow Stem Auger
RC = Roller Cone
WOH = weight of 140lb. hammer
WOR/C = weight of rods or casing
WO1P = Weight of one person
S_u = Insitu Field Vane Shear Strength (psf)
T_v = Pocket Torvane Shear Strength (psf)
q_p = Unconfined Compressive Strength (ksf)
N-uncorrected = Raw field SPT N-value
Hammer Efficiency Factor = Annual Calibration Value
N_{60} = SPT N-uncorrected corrected for hammer efficiency
N_{60} = (Hammer Efficiency Factor/60%)*N-uncorrected
$S_{u(lab)}$ = Lab Vane Shear Strength (psf)
WC = water content, percent
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index
G = Grain Size Analysis
C = Consolidation Test

Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N_{60}	Casing Blows	Elevation (ft.)	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class
0							SSA	68.44	5½ PAVEMENT. 0.46	
	1D	24/14	3.00 - 5.00	2/2/2/3	4	6			Brown, moist, loose, fine to coarse SAND, some silt, trace gravel, brick pieces. (Fill).	G#266475 A-2-4, SM WC=15.0%
5	2D	24/12	5.00 - 7.00	2/3/2/2	5	7			Similar to above.	G#266474 A-1-b, GM WC=11.1%
								61.70	7.20	
								59.90	Dense Gravelly material at 7.2 ft bgs. (on auger flights). Auger Refusal at 8.1 ft bgs. Auger ahead to 9.0 ft bgs. dense material. 8.00	
10									Bottom of Exploration at 9.00 feet below ground surface. STOPPED BORING	
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.

Page 1 of 1

Boring No.: HB-BREM-101

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Route 32 Strut Replacement
Location: Bremen, Maine

Boring No.: SB-BREM-201
WIN: 18103.00

Driller:	MaineDOT	Elevation (ft.)	72.0	Auger ID/OD:	5" Dia.
Operator:	Giles/Daggett	Datum:	NAVD88	Sampler:	Standard Split Spoon
Logged By:	B. Wilder	Rig Type:	CME 45C	Hammer Wt./Fall:	140#/30"
Date Start/Finish:	3/4/2014; 10:30-12:00	Drilling Method:	Cased Wash Boring	Core Barrel:	N/A
Boring Location:	10+07.2, 8.0 ft Rt.	Casing ID/OD:	HW	Water Level*:	None Observed
Hammer Efficiency Factor: 0.867		Hammer Type:	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

Definitions:
D = Split Spoon Sample
MD = Unsuccessful Split Spoon Sample attempt
U = Thin Wall Tube Sample
MU = Unsuccessful Thin Wall Tube Sample attempt
V = Insitu Vane Shear Test, PP = Pocket Penetrometer
MV = Unsuccessful Insitu Vane Shear Test attempt
R = Rock Core Sample
SSA = Solid Stem Auger
HSA = Hollow Stem Auger
RC = Roller Cone
WOH = weight of 140lb. hammer
WOR/C = weight of rods or casing
WO1P = Weight of one person
S_u = Insitu Field Vane Shear Strength (psf)
T_v = Pocket Torvane Shear Strength (psf)
q_p = Unconfined Compressive Strength (ksf)
N-uncorrected = Raw field SPT N-value
Hammer Efficiency Factor = Annual Calibration Value
N_{60} = SPT N-uncorrected corrected for hammer efficiency
N_{60} = (Hammer Efficiency Factor/60%)*N-uncorrected
$S_{u(lab)}$ = Lab Vane Shear Strength (psf)
WC = water content, percent
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index
G = Grain Size Analysis
C = Consolidation Test

Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N_{60}	Casing Blows	Elevation (ft.)	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class
0			0.00 - 1.20				SSA	71.58	5" Pavement. 0.42	
5	1D	24/6	4.50 - 6.50	1/3/6/2	9	13			Brown, damp, loose, GRAVEL, some fine to coarse sand, trace silt, occasional cobbles, occasional boulders. (Fill).	G#243177 A-1-a, GP-GM WC=4.4%
								64.00	8.00	
10	2D	24/16	10.00 - 12.00	3/6/7/7	13	19			Brown, wet, medium dense, silty, fine to coarse SAND, trace gravel ,occasional cobbles.	G#243176 A-4, SM WC=15.9%
									Cobble from 14.5-15.3 ft bgs.	
20	R1	39.6/10	19.00 - 22.30				NO-2	53.00	R1:COBBLES. 19.00	
							183		Set in HW Casing.	
							160			
	R2	60/55	22.30 - 27.30	RQD = 15%			0100	49.70	0100 blows for 0.3 ft. 22.30	
25									Top of Bedrock at Elev. 49.7 ft. R2:Bedrock:White to Grey Coarse Grained. Hard and Fresh. Microcline (Feldspar), Quartz, Biotite and trace Garnet and Amphibole (Hornblende) Pegmatite over a dark grey Metamorphic Schist. The Microcline has a very pronounced cleavage that facilitated the core breaks.The segments are ,5" to 2" long and are seldom intact core segments. The bottom 2' is a Soft Weathered (with no staining) Biotite, Amphibole (Hornblende), Feldspar, Quartz Schist. There is little sense of foliation and the rock core broke along soft zones and older joints. Two segments are 3" - 5" the remainder are small fragments. R2:Core Times (min:sec) 22.3-23.3 ft (4:36) 23.3-24.3 ft (4:26) 24.3-25.3 ft (4:43) 25.3-26.3 ft (4:34) 26.3-27.3 ft (4:35) 92% Recovery	
								44.70	27.30	
30									Bottom of Exploration at 27.30 feet below ground surface.	
35										
40										
45										
50										

Remarks:

Stratification lines represent approximate boundaries between soil types; transitions may be gradual.

* Water level readings have been made at times and under conditions stated. Groundwater fluctuations may occur due to conditions other than those present at the time measurements were made.

Page 1 of 1

Boring No.: SB-BREM-201

State of Maine - Department of Transportation
Power Auger Probe Summary Sheet

Town(s): Bremen **Project Number: 18103.00**

Station (Feet)	Offset (Feet)	Weathered Rock (Feet)	Refusal (Feet)	No Refusal (Feet)	Water Depth (Ft.)	Comments / Date 4/29/2011
PA-1						
10+40	6.7 Lt.		7.5			5.5" Pavement.
PA-2						
9+97.1	8.0 Rt.		8.5			Shoulder EP
PA-3						
10+27.7	9.2 Rt.		8.1			5.5" Pavement
						cobble 2.5-3.5 ft bgs
						very dense
PA-4						
10+05.4	7.9 Rt.			18.5		5" Pavement
						twisted off auger bit

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

HIGHWAY PLANS

WIN 18103.00

	BY	DATE	SIGNATURE
PROJ. MANAGER			
DESIGN-DETAILED			P.E. NUMBER
CHECKED-REVIEWED			
DESIGN2-DETAILED2	K.BRESKIN	APR 2014	
DESIGN3-DETAILED3	T.WHITE		DATE
REVISIONS 1			
REVISIONS 2			
REVISIONS 3			
REVISIONS 4			
FIELD CHANGES			

BREMEN
ROUTE 32 STRUT

BORING LOGS &
POWER AUGER PROBES

SHEET NUMBER
1
OF 2

Appendix A

Boring Logs and
Rock Core Photographs

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Route 32 Strut Replacement
Location: Bremen, Maine

Boring No.: HB-BREM-101
WIN: 18103.00

Driller:	MaineDOT	**Elevation (ft.)**	68.9	**Auger ID/OD:**	5" Dia.
Operator:	Giguere/Giles	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	B. Wilder	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	4/29/11; 08:00-08:30	**Drilling Method:**	Solid Stem Auger	**Core Barrel:**	N/A
Boring Location:	9+82.3, 8.0 ft Lt.	**Casing ID/OD:**	N/A	**Water Level*:**	None Observed
Hammer Efficiency Factor:	0.84	**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

Definitions:
D = Split Spoon Sample
MD = Unsuccessful Split Spoon Sample attempt
U = Thin Wall Tube Sample
MU = Unsuccessful Thin Wall Tube Sample attempt
V = Insitu Vane Shear Test, PP = Pocket Penetrometer
MV = Unsuccessful Insitu Vane Shear Test attempt
R = Rock Core Sample
SSA = Solid Stem Auger
HSA = Hollow Stem Auger
RC = Roller Cone
WOH = weight of 140lb. hammer
WOR/C = weight of rods or casing
WO1P = Weight of one person
S_u = Insitu Field Vane Shear Strength (psf)
T_v = Pocket Torvane Shear Strength (psf)
q_p = Unconfined Compressive Strength (ksf)
N-uncorrected = Raw field SPT N-value
Hammer Efficiency Factor = Annual Calibration Value
N_{60} = SPT N-uncorrected corrected for hammer efficiency
N_{60} = (Hammer Efficiency Factor/60%)*N-uncorrected
$S_{u(lab)}$ = Lab Vane Shear Strength (psf)
WC = water content, percent
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index
G = Grain Size Analysis
C = Consolidation Test

Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N_{60}	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
0							SSA	68.44		5½" PAVEMENT. 0.46	
	1D	24/14	3.00 - 5.00	2/2/2/3	4	6				Brown, moist, loose, fine to coarse SAND, some silt, trace gravel, brick pieces, (Fill).	G#266475 A-2-4, SM WC=15.0%
5	2D	24/12	5.00 - 7.00	2/3/2/2	5	7				Similar to above.	G#266474 A-1-b, GM WC=11.1%
								61.70		7.20 Dense Gravelly material at 7.2 ft bgs, (on auger flights). Auger Refusal at 8.1 ft bgs. Auger ahead to 9.0 ft bgs, dense material.	
								59.90		9.00 **Bottom of Exploration at 9.00 feet below ground surface.** STOPPED BORING	
10											
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-BREM-101

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Route 32 Strut Replacement
Location: Bremen, Maine

Boring No.: SB-BREM-201
WIN: 18103.00

Driller:	MaineDOT	**Elevation (ft.)**	72.0	**Auger ID/OD:**	5" Dia.
Operator:	Giles/Daggett	**Datum:**	NAVD88	**Sampler:**	Standard Split Spoon
Logged By:	B. Wilder	**Rig Type:**	CME 45C	**Hammer Wt./Fall:**	140#/30"
Date Start/Finish:	3/4/2014; 10:30-12:00	**Drilling Method:**	Cased Wash Boring	**Core Barrel:**	N/A
Boring Location:	10+07.2, 8.0 ft Rt.	**Casing ID/OD:**	HW	**Water Level*:**	None Observed
Hammer Efficiency Factor:	0.867	**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

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R = Rock Core Sample
SSA = Solid Stem Auger
HSA = Hollow Stem Auger
RC = Roller Cone
WOH = weight of 140lb. hammer
WOR/C = weight of rods or casing
WO1P = Weight of one person
S_u = Insitu Field Vane Shear Strength (psf)
T_v = Pocket Torvane Shear Strength (psf)
q_p = Unconfined Compressive Strength (ksf)
N-uncorrected = Raw field SPT N-value
Hammer Efficiency Factor = Annual Calibration Value
N_{60} = SPT N-uncorrected corrected for hammer efficiency
N_{60} = (Hammer Efficiency Factor/60%)*N-uncorrected
$S_{u(lab)}$ = Lab Vane Shear Strength (psf)
WC = water content, percent
LL = Liquid Limit
PL = Plastic Limit
PI = Plasticity Index
G = Grain Size Analysis
C = Consolidation Test

Sample Information

Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N_{60}	Casing Blows	Elevation (ft.)	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
0			0.00 - 1.20				SSA	71.58	5" Pavement. 0.42	
	1D	24/6	4.50 - 6.50	1/3/6/2	9	13			Brown, damp, loose, GRAVEL, some fine to coarse sand, trace silt, occasional cobbles, occasional boulders, (Fill).	G#243177 A-1-a, GP-GM WC=4.4%
5								64.00	8.00	
10	2D	24/16	10.00 - 12.00	3/6/7/7	13	19			Brown, wet, medium dense, silty, fine to coarse SAND, trace gravel , occasional cobbles.	G#243176 A-4, SM WC=15.9%
15									Cobble from 14.5-15.3 ft bgs.	
	R1	39.6/10	19.00 - 22.30				NQ-2	53.00	19.00 R1:COBBLES. Set in HW Casing.	
20							183			
							160			
	R2	60/55	22.30 - 27.30	RQD = 15%			a100	49.70	a100 blows for 0.3 ft. 22.30 Top of Bedrock at Elev. 49.7 ft. R2:Bedrock:White to Grey Coarse Grained, Hard and Fresh, Microcline (Feldspar), Quartz, Biotite and trace Garnet and Amphibole (Hornblende) Pegmatite over a dark grey Metamorphic Schist. The	
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.: SB-BREM-201

Maine Department of Transportation

Soil/Rock Exploration Log
US CUSTOMARY UNITS

Project: Route 32 Strut Replacement
Location: Bremen, Maine

Boring No.: SB-BREM-201
WIN: 18103.00

Driller:	MaineDOT	**Elevation (ft.)**	72.0	**Auger ID/OD:**	5" Dia.
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Date Start/Finish:	3/4/2014; 10:30-12:00	**Drilling Method:**	Cased Wash Boring	**Core Barrel:**	N/A
Boring Location:	10+07.2, 8.0 ft Rt.	**Casing ID/OD:**	HW	**Water Level*:**	None Observed
Hammer Efficiency Factor:	0.867	**Hammer Type:**	Automatic ☒ Hydraulic ☐ Rope & Cathead ☐		

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RC = Roller Cone
WOH = weight of 140lb. hammer
WOR/C = weight of rods or casing
WO1P = Weight of one person
S_u = Insitu Field Vane Shear Strength (psf)
T_v = Pocket Torvane Shear Strength (psf)
q_p = Unconfined Compressive Strength (ksf)
N-uncorrected = Raw field SPT N-value
Hammer Efficiency Factor = Annual Calibration Value
N_{60} = SPT N-uncorrected corrected for hammer efficiency
N_{60} = (Hammer Efficiency Factor/60%)*N-uncorrected
$S_{u(lab)}$ = Lab Vane Shear Strength (psf)
WC = water content, percent
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G = Grain Size Analysis
C = Consolidation Test

Depth (ft.)	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (/6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N_{60}	Casing Blows	Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
25								44.70		Microcline has a very pronounced cleavage that facilitated the core breaks. The segments are ½" to 2" long and are seldom intact core segments. The bottom 2' is a Soft Weathered (with no staining) Biotite, Amphibole (Hornblende), Feldspar, Quartz Schist. There is little sense of foliation and the rock core broke along soft zones and older joints. Two segments are 3" - 5" the remainder are small fragments. R2:Core Times (min:sec) 22.3-23.3 ft (4:36) 23.3-24.3 ft (4:26) 24.3-25.3 ft (4:43) 25.3-26.3 ft (4:34) 26.3-27.3 ft (4:35) 92% Recovery	
30											
35											
40											
45											
50											

27.30

Bottom of Exploration at 27.30 feet below ground surface.

Remarks:

Stratification lines represent approximate boundaries between soil types; transitions may be gradual.

* Water level readings have been made at times and under conditions stated. Groundwater fluctuations may occur due to conditions other than those present at the time measurements were made.

State of Maine - Department of Transportation

Power Auger Probe Summary Sheet

Town(s): Bremen Project Number: 18103.00

Station (Feet)	Offset (Feet)	Weathered Rock (Feet)	Refusal (Feet)	No Refusal (Feet)	Water Depth (Ft.)	Comments / Date 4/29/2011
PA-1						
10+40	6.7 Lt.		7.5			5.5" Pavement.
PA-2						
9+97.1	8.0 Rt.		8.5			Shoulder EP
PA-3						
10+27.7	9.2 Rt.		8.1			5.5" Pavement
						cobble 2.5-3.5 ft bgs
						very dense
PA-4						
10+05.4	7.9 Rt.			18.5		5" Pavement
						twisted off auger bit

MaineDOT Drill Crew
Logged By: B. Wilder
Drill Rig: CME 45C

5" Solid Stem Auger

Bristol - Bristol 3/14

18103.00 [redacted] 17531.00

R1-SB-Bre [redacted] 2014		R42
22.3-27.3	55%/60" = 92% Railway	41%/60" = 15%
Bristol R1-12.3-17.3	100% Railway	R4P 45%/hr. 7%

THE LUFKIN RULE CO.

1 2 3 4 5 6 7 8 9

BB-MR-103 R1 85.1'-89.4'
REC = 43"/52" = 83%
RQD = 21"/52" = 40%

4-15-03
4/BB-WSB-107
RZ-61.5-66.5
100%
RECOVERY
3F 1 2 3 4 5 6 7 8 9 4F 1

%RECOVERY
RQD= 30"/60" 50%
100% RECOVERY
RQD= 43"/60 72%
END OF R1

Appendix B

Geophysical Survey Report

HAGER-RICHTER
GEOSCIENCE, INC.

GEOPHYSICAL SURVEY
ROUTE 32
BREMEN, MAINE
PIN 18103.00

MAINE DOT CONTRACT
NO. 20110613000000006486

Prepared for:

Maine Department of Transportation
Highway Program
16 State House Station
Augusta, Maine 04333-0016

Prepared by:

Hager-Richter Geoscience, Inc.
8 Industrial Way - D10
Salem, New Hampshire 03079

File 11ER44
January, 2012

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0. EXECUTIVE SUMMARY

Hager-Richter Geoscience, Inc. conducted a geophysical survey along a portion of State Route 32, Waldoboro Road, in Bremen, Maine for the Maine Department of Transportation (MaineDOT) in December, 2011. The geophysical survey was performed in support of a geotechnical investigation of the Site by the Maine Department of Transportation (MaineDOT) for the replacement of a culvert passing under State Route 32 at a location that is 2,800 feet south of the intersection of Route 32 and Rial Herald Road in Bremen.

The geophysical survey was conducted using the ground penetrating radar (GPR) and seismic refraction methods. The GPR survey was conducted on the roadway and shoulders in an approximately 24-foot by 60-foot area centered on the culvert. Seismic refraction profiling was conducted along three 94-foot long seismic lines located along each shoulder and the approximate centerline of the roadway. MaineDOT required data on the bedrock depth in the area as part of a geotechnical investigation for replacing the existing culvert.

Based on the results of the geophysical survey conducted by Hager-Richter Geoscience, Inc. along a portion of State Route 32 in Bremen, Maine for the Maine Department of Transportation (MaineDOT) in December, 2011, we conclude the following:

- A bedrock trough is present at the location of the culvert under the roadway
- The depth of bedrock along the seismic line varies from about 3 to 21 feet below ground surface
- The elevation of competent bedrock along the seismic line varies between 51 and 67 feet for an total relief of 16 feet

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1. INTRODUCTION

Hager-Richter Geoscience, Inc. conducted a geophysical survey along a portion of State Route 32, Waldoboro Road, in Bremen, Maine for the Maine Department of Transportation (MaineDOT) in December, 2011. The geophysical survey was performed in support of a geotechnical investigation of the Site by MaineDOT for the replacement of a culvert passing under State Route 32 at a location that is 2,800 feet south of the intersection of Route 32 and Rial Herald Road in Bremen.

The general location of the Site is shown in Figure 1. One boring (HB-BREM-101) and three power auger probes (PA-1, PA-2, and PA-3) were drilled in the roadway within 35 feet of the culvert and encountered refusal at depths ranging from approximately 7.5 feet to 8.5 feet below the road surface. Logs for the boring and probes are included in Appendix 2. MaineDOT required information on the depth of bedrock in an approximately 20-foot by 30-foot area of the roadway centered on the culvert.

Hager-Richter conducted a GPR survey on the roadway and shoulders in an approximately 24-foot by 60-foot area centered on the culvert. In addition, seismic refraction profiling was conducted along three 94-foot long seismic lines - one line along each shoulder and one line near the centerline of the roadway. Figure 2 is a modified site plan showing the GPR survey area and the locations of the seismic lines.

Route 32 is a two-lane road that gently dips from northwest to southeast as it crosses the subject culvert. According to plans provided by MaineDOT, the concrete box culvert is approximately 4 feet wide and 8 feet tall and is embedded within a raised road bed that is approximately 12 - 15 feet above the stream level. Bedrock underlying the site is reported to be a relatively unweathered granite.

Hager-Richter personnel were on-site on December 8, 2011. Steven Grant, P.G., and Bryan Carnahan conducted the survey. The fieldwork was coordinated with Ms. Kitty Breskin, P.E., of MaineDOT. Ms. Berta Estes, also of MaineDOT, was onsite during the field work and specified the area of interest. MaineDOT provided plans showing site features, surface topography, and the locations of borings and probes. Data analysis and interpretation were completed at the Hager-Richter offices. Original data and field notes will be retained in the Hager-Richter files for a minimum of three years.

2. EQUIPMENT AND PROCEDURES

2.1 GPR

2.1.1 General. The GPR survey was conducted using a Sensors & Software Smart Cart Noggin Plus digital subsurface imaging radar system. This system includes a survey wheel that triggers the recording of the data at fixed intervals, thereby increasing the accuracy of the locations of features detected along the survey lines. The Noggin Plus system was used with a 250 MHz antenna and a 200 nsec time window.

2.1.2 Limitations of the Method. There are limitations of the GPR technique as used to detect and/or locate targets such as those of the objectives of this survey: (1) surface conditions, (2) electrical conductivity of the ground, (3) contrast of the electrical properties of the target and the surrounding soil, and (4) spacing of the traverses. Of these restrictions, only the last is controllable by us.

The condition of the ground surface can affect the quality of the GPR data and the depth of penetration of the GPR signal. Sites covered with snow piles, high grass, bushes, landscape structures, debris, obstacles, soil mounds, etc. limit the survey access and the coupling of the GPR antenna with the ground. In many cases, the GPR signal will not penetrate below concrete pavement, especially inside buildings, and a target may not be detectable. The GPR method also commonly does not provide useful data under canopies found at some facilities.

The electrical conductivity of the ground determines the attenuation of the GPR signals, and thereby limits the maximum depth of exploration. For example, the GPR signal does not penetrate clay-rich soils, and targets buried in clay might not be detected.

A definite contrast in the electrical conductivities of the surrounding ground and the target material is required to obtain a reflection of the GPR signal. If the contrast is too small then the reflection may be too weak to recognize, possibly due to deeply corroded metal in the target, the target can be missed.

2.1.3 Site Specific. GPR traverses were conducted in two directions in the 24-foot by 60-foot area of interest. GPR traverses oriented approximately parallel to the roadway were spaced 2 feet apart and traverses oriented perpendicular to the roadway were spaced 5 feet apart. MaineDOT provided site plans showing site features, surface topography, and boring and probe locations. Hager-Richter located the GPR traverses in the field using site features such as the

road, culvert, numbered utility poles and probe and boring locations. The locations of the GPR survey area is shown on Figure 2.

2.2 SEISMIC REFRACTION

2.2.1 General. The general equipment and procedures for seismic refraction surveys as conducted by Hager-Richter are described in the Appendix. Details specific to this site are given below in section 2.1.3, Site Specific.

2.2.2 Limitations of the Method. The accuracy (standard deviation) of the apparent *depths* of relatively competent bedrock determined by the seismic refraction survey is about ± 10% of the apparent depth of bedrock, or ± 2 feet, whichever is greater. **The bedrock model shown as a profile, bedrock elevation contour plot, or listed as tabular data should not be used for contract bedrock removal quantities.** Like all geophysical methods, the seismic refraction method is based on the assumption that the local geology is uncomplicated. In particular, the seismic refraction method assumes that interfaces between geologic materials correlate with sharp increases in seismic velocity and that the interfaces are relatively flat-lying. The method is not very sensitive to lateral variations within layers, and relatively subtle features such as fracture zones within bedrock are generally difficult to detect unless there is a topographic expression of the feature. The accuracy of the method is degraded in areas with strong topographic relief at the surface and/or where the interfaces have apparent dips greater than about 20°.

Where two materials do not exhibit contrasting velocities, or where velocities gradually increase with depth, a clear refracted signal is not generated, and the seismic refraction method cannot be used to distinguish the two materials. In some cases, the "geophysical contact" between materials with contrasting velocities does not correlate exactly with the "geologic contact." For example, where a highly weathered bedrock is overlain by a dense material such as till, the velocity range of the weathered bedrock might overlap or approach the velocity range of the till, and the two materials cannot be distinguished seismically. In such cases, the depth determined by seismic refraction is the depth of *competent* bedrock, which might be located at some depth below the geologic contact.

The depth relations of the water table and bedrock may constitute a significant problem for the seismic refraction technique. This problem is that of a "blind layer." A blind layer occurs where the thickness of the saturated overburden is less than about half the depth of bedrock. In such cases, the water-saturated material immediately above bedrock is "blind" in the sense that no refracted seismic energy from it will be received as a first arrival of seismic energy, and all

methods used to reduce the seismic data to determine the depth of bedrock, the objective of this survey, use *only* first arrivals. Thus, the saturated layer will not be detected where it is close to bedrock, and most methods of seismic data reduction will indicate that bedrock is considerably deeper than it actually is. Although GRM, the method used by Hager-Richter to reduce the seismic refraction data, does not use first arrivals through the water saturated zone (because there is none to use) in such cases, GRM determines the depth of bedrock correctly by using the *average* velocity of the saturated and unsaturated zones.

A "hidden layer" occurs where a lower velocity material underlies a higher velocity material, a common situation in stratified sediments. An example is where sands are present under layers of clay or till. As in the case of a "blind layer," most methods of seismic refraction data reduction will indicate that bedrock is shallower than it actually is, if a hidden layer is present but not detected. Internal tests in the seismic refraction data reduction software that we use (IXRefraX by Interpex) indicate that such layers might be present, and an average velocity of the two layers is used to determine the depth of bedrock.

2.2.3 Site Specific. The original scope of work specified two parallel seismic lines, each centered in one of the travel lanes. However, shot points conducted on thick asphalt can result in a loss of data quality, so the scope was changed in the field to conduct three lines - two lines on the unpaved shoulders (thus avoiding shot points on asphalt) and one line near the road centerline.

The seismic refraction survey consisted of three parallel 94-foot lines totaling 282 linear feet. MaineDOT provided site plans showing site features, surface topography, and boring and probe locations. Hager-Richter located the seismic lines in the field using site features such as the roadway and numbered utility poles. The locations of the seismic lines are shown on Figure 2. Elevations along the seismic line were determined from site plans provided by MaineDOT.

A geophone spacing of 2 feet was used for the seismic lines. The seismic source was a 14-pound sledge hammer striking an aluminum plate. Seven shot points were used for each line -- three internal shot points, one shot point at each end of the line, and external shots located in-line but offset from each end of the line.

3. RESULTS AND DISCUSSIONS

3.1 GENERAL

The geophysical survey of the roadway in the vicinity of a concrete box culvert consisted of a 24-foot by 60-foot GPR survey area of the roadway and shoulders and three 94-foot long seismic refraction lines located approximately along the centerline of Route 32 and along the road shoulders. The locations of the GPR survey area and the seismic refraction traverses are shown in Figure 2. The results of the seismic refraction survey are shown in profile form in Figure 3, as a bedrock elevation contour plot in Figure 4, and are listed in Table 1.

3.2 GPR

3.2.1 General. The GPR survey of the 24-foot by 60-foot area of interest consisted of GPR traverses oriented approximately parallel to the roadway and spaced 2 feet apart and traverses oriented perpendicular to the roadway and spaced 5 feet apart. The location of the GPR survey area is shown in Figure 2.

Apparent GPR signal penetration in areas surfaced with asphalt was generally good, with two-way traveltime reflections received from 35 to 55ns. Based on velocity matching calibrations made for the site (see below) and on handbook time-to-depth conversions for the GPR signal in average to sandy soils, the GPR signal penetration is estimated to have been approximately 7 to 11 feet for the majority of the roadway. GPR signal penetration was greater on the shoulders of the road (75 ns, or approximately 15 feet).

3.2.2 Data Quality. Strong GPR reflections consistent with those expected for the top of bedrock were not detected, with the possible exception of the eastern corner of the GPR survey area. It is likely that the GPR signal penetration for most of the GPR survey area was not sufficient to produce reflections from bedrock, which is consistent with the results of the seismic refraction survey (see Section 3.3) that show that bedrock depths for most of the central portion of the survey area are greater than 15 feet.

Reflections that are possibly attributable to bedrock in the eastern corner of the GPR survey area were received from a depth of approximately 5-7 feet in the eastern corner and dip toward the west before being lost due to insufficient GPR signal penetration. The depth of 5-7 feet determined by the GPR method is consistent with the depth of 6 feet determined by the seismic refraction method for bedrock at this location. Because possible bedrock was detected in

such a small portion of the survey area with the GPR method, the seismic refraction method was used to generate all models of the bedrock surface.

Approximate two-way travel times for GPR signal reflections from the interpreted top of bedrock were converted to approximate depths in meters below ground surface using estimates of two-way slowness (a parameter equal to two times the inverse of the velocity of propagation of the GPR signal). Estimates of two-way slowness were made by velocity matching calibrations using Sensors and Software's EKKO View software on multiple hyperbolic reflections from small objects detected across the area of interest.

3.3 SEISMIC REFRACTION

3.3.1 General. The seismic refraction survey consisted of three transects designated as Seismic Line 1 through 3. The locations of the seismic lines are shown in Figure 2. The results of the seismic survey are shown in profile form in Figure 3, as a contour plot of bedrock elevation in Figure 4, and are listed in Table 1.

3.3.2 Data Quality. The quality of the seismic refraction data ranges from good to excellent. A measure of the accuracy of the data can be obtained by comparing the depths determined seismically with depths reported from nearby borings that intersect bedrock, and the internal consistency of the data can be assessed by comparison of the depths determined at intersecting seismic lines or with results from other geophysical methods. For the present survey, one boring (HB-BREM-101) and three power auger probes (PA-1, PA-2, and PA-3) were drilled in the roadway within 35 feet of the culvert and encountered refusal at depths ranging from approximately 7.5 feet to 8.5 feet below the road surface. Such depths of refusal are significantly shallower than the seismically determined depths of bedrock, as is apparent from an examination of the seismic profiles (Figure 3), and it is our interpretation that the boring and auger probe refusals are not due to bedrock. It is possible that the refusals are caused by stonework in the raised roadbed surrounding the culvert.

For the present survey, the seismic lines are parallel, so it is not possible to compare depths determined at intersecting seismic lines. Comparison with results from the GPR survey are not possible for the majority of the survey area because of the lack of GPR reflections from bedrock. However, as discussed in Section 3.2.2, GPR reflections were received from a depth of approximately 5-7 feet in the far eastern corner of the GPR survey area, and may represent bedrock reflections. This depth is consistent with the seismically determined depth of bedrock of 6 feet at this location (Station 0+18 on Seismic Line 1). Based on the good quality of the seismic data for this project and on the results from other similar seismic refraction surveys, we estimate

the accuracy (standard deviation) of the apparent depths of competent bedrock determined by the seismic refraction survey in most locations to be about ± 10% of the depth of bedrock, or ± 2 feet), whichever is greater.

3.3.3 Interpretation of Velocities. Materials with two distinct velocity ranges were detected at the Site. The upper material exhibits a velocity range of 1,100 ft/s to 1,500 ft/s and is interpreted to consist of mostly unsaturated soils and fill materials.

The lower material exhibits a velocity range of 13,500 to 15,900 ft/s and is interpreted to be competent bedrock. Where the top of bedrock is highly fractured and/or deeply weathered, it might exhibit lower velocities that cannot be detected as a distinct layer on the basis of the seismic refraction data. Thus, the top of rock determined on the basis of seismic refraction data generally is the top of *competent* bedrock, which might be located somewhat below the geologic contact between the overburden and bedrock.

3.3.4 Bedrock Depths and Configuration. Seismic profiles for the three lines (Figure 3) show a prominent bedrock trough present in the vicinity of the culvert. The bedrock trough is also apparent in Figure 4, which is a contour plot of the bedrock elevation generated from the seismic data. Bedrock highs are located in the far eastern and western corners of the area surveyed by seismic refraction. The depth of competent bedrock along the seismic lines varies between about 3 and 21 feet below ground surface. The elevation of competent bedrock in the locations surveyed varies between 51 and 67 feet for a total relief of 16 feet.

The contours shown on Figure 4 represents interpolations based on the seismic data. The contours shown represent non-unique models for bedrock elevation, and the elevation of competent bedrock at any particular location between actual data points may differ from that shown. Bedrock elevations based on additional data, such as additional borings or seismic data, may differ significantly from those shown on the plates. **The bedrock model shown as profiles, bedrock elevation contour plot, or listed as tabular data should not be used for contract bedrock removal quantities.**

4. CONCLUSIONS

Based on the results of the geophysical survey conducted by Hager-Richter Geoscience, Inc. along a portion of State Route 32 in Bremen, Maine for the Maine Department of Transportation (MaineDOT) in December, 2011, we conclude the following:

- A bedrock trough is present at the location of the culvert under the roadway
- The depth of bedrock along the seismic line varies from about 3 to 21 feet below ground surface
- The elevation of competent bedrock along the seismic line varies between 51 and 67 feet for a total relief of 16 feet

5. LIMITATIONS

This report was prepared for the exclusive use of the Maine Department of Transportation (Client). No other party shall be entitled to rely on this Report or any information, documents, records, data, interpretations, advice or opinions given to Client by Hager-Richter Geoscience, Inc. (H-R) in the performance of its work. The Report relates solely to the specific project for which H-R has been retained and shall not be used or relied upon by Client or any third party for any variation or extension of this project, any other project or any other purpose without the express written permission of H-R. Any unpermitted use by Client or any third party shall be at Client's or such third party's own risk and without any liability to H-R.

H-R has used reasonable care, skill, competence and judgment in the preparation of this Report consistent with professional standards for those providing similar services at the same time, in the same locale, and under like circumstances. Unless otherwise stated, the work performed by H-R should be understood to be exploratory and interpretational in character and any results, findings or recommendations contained in this Report or resulting from the work proposed may include decisions which are judgmental in nature and are not necessarily based solely on pure science or engineering. It should be noted that our conclusions might be modified if subsurface conditions were better delineated with additional subsurface exploration including, but not limited to, test pits, soil borings with collection of soil and water samples, and laboratory testing.

Except as expressly provided in this limitations section, H-R makes no other representation or warranty of any kind whatsoever, oral or written, expressed or implied; and all implied warranties of merchantability and fitness for a particular purpose, are hereby disclaimed.

MaineDOT Contract No. 20110613000000006486
Geophysical Survey
Route 32
Bremen, Maine
PIN# 18103.00 HR- File 11ER44 January, 2012

TABLE 1
SEISMIC REFRACTION RESULTS
ROUTE 32
BREMEN, MAINE
PIN# 18103.00

Line	Location (ft)	Easting (ft)	Northing (ft)	Surface Elevation (ft)	Bedrock Depth (ft)	Bedrock Elevation (ft)
1	0+00	1554766.46	175223.43	69	3	66
1	0+02	1554765.11	175224.90	69	3	67
1	0+04	1554763.75	175226.37	69	3	67
1	0+06	1554762.40	175227.84	69	3	66
1	0+08	1554761.05	175229.31	70	3	67
1	0+10	1554759.69	175230.78	70	3	67
1	0+12	1554758.34	175232.25	70	4	66
1	0+14	1554756.98	175233.73	70	5	65
1	0+16	1554755.63	175235.20	70	5	65
1	0+18	1554754.27	175236.67	70	6	64
1	0+20	1554752.92	175238.14	70	6	64
1	0+22	1554751.56	175239.61	70	7	63
1	0+24	1554750.21	175241.08	70	9	62
1	0+26	1554748.86	175242.56	71	9	61
1	0+28	1554747.50	175244.03	71	11	60

Line	Location (ft)	Easting (ft)	Northing (ft)	Surface Elevation (ft)	Bedrock Depth (ft)	Bedrock Elevation (ft)
1	0+30	1554746.15	175245.50	71	12	59
1	0+32	1554744.79	175246.97	71	13	58
1	0+34	1554743.44	175248.44	71	14	57
1	0+36	1554742.08	175249.91	71	15	56
1	0+38	1554740.73	175251.38	71	16	56
1	0+40	1554739.37	175252.86	71	17	55
1	0+42	1554738.02	175254.33	72	18	54
1	0+44	1554736.67	175255.80	72	18	54
1	0+46	1554735.31	175257.27	72	18	53
1	0+48	1554733.96	175258.74	72	19	53
1	0+50	1554732.60	175260.21	72	19	53
1	0+52	1554731.25	175261.69	72	19	54
1	0+54	1554729.89	175263.16	73	18	55
1	0+56	1554728.54	175264.63	73	18	55
1	0+58	1554727.18	175266.10	73	19	54
1	0+60	1554725.83	175267.57	73	19	54

Estimated standard deviation of depth of interfaces for seismic lines is normally taken as 10% or 2 feet, whichever is greater. Depths of bedrock determined here are depths of competent bedrock. Heavily weathered or highly fractured bedrock may occur at shallower depths. Easting and northing coordinates and elevations for the seismic lines were determined from topographic plans provided by Maine DOT.

MaineDOT Contract No. 20110613000000006486
Geophysical Survey
Route 32
Bremen, Maine
PIN# 18103.00 HR- File 11ER44 January, 2012

TABLE 1 (CONTINUED)
SEISMIC REFRACTION RESULTS

Line	Location (ft)	Easting (ft)	Northing (ft)	Surface Elevation (ft)	Bedrock Depth (ft)	Bedrock Elevation (ft)
1	0+62	1554724.48	175269.04	73	19	54
1	0+64	1554723.12	175270.51	73	20	53
1	0+66	1554721.77	175271.99	74	21	53
1	0+68	1554720.41	175273.46	74	21	53
1	0+70	1554719.06	175274.93	74	21	53
1	0+72	1554717.70	175276.40	74	21	53
1	0+74	1554716.35	175277.87	75	20	55
1	0+76	1554714.99	175279.34	75	19	56
1	0+78	1554713.64	175280.82	75	18	57
1	0+80	1554712.28	175282.29	75	18	57
1	0+82	1554710.93	175283.76	75	18	57
1	0+84	1554709.58	175285.23	76	18	58
1	0+86	1554708.22	175286.70	76	17	58
1	0+88	1554706.87	175288.17	76	17	59
1	0+90	1554705.51	175289.64	76	17	60
1	0+92	1554704.16	175291.12	76	17	60
1	0+94	1554702.80	175292.59	76	17	60
2	0+00	1554757.63	175215.30	69	4	65
2	0+02	1554756.28	175216.77	69	4	65
2	0+04	1554754.93	175218.24	69	4	65

Line	Location (ft)	Easting (ft)	Northing (ft)	Surface Elevation (ft)	Bedrock Depth (ft)	Bedrock Elevation (ft)
2	0+06	1554753.57	175219.71	69	4	65
2	0+08	1554752.22	175221.18	69	5	65
2	0+10	1554750.86	175222.66	69	6	64
2	0+12	1554749.51	175224.13	69	6	64
2	0+14	1554748.15	175225.60	70	6	64
2	0+16	1554746.80	175227.07	70	7	63
2	0+18	1554745.44	175228.54	70	7	62
2	0+20	1554744.09	175230.01	70	8	62
2	0+22	1554742.74	175231.49	70	9	62
2	0+24	1554741.38	175232.96	70	10	61
2	0+26	1554740.03	175234.43	70	11	60
2	0+28	1554738.67	175235.90	70	12	59
2	0+30	1554737.32	175237.37	71	13	58
2	0+32	1554735.96	175238.84	71	13	58
2	0+34	1554734.61	175240.31	71	14	57
2	0+36	1554733.25	175241.79	71	16	55
2	0+38	1554731.90	175243.26	71	16	55
2	0+40	1554730.55	175244.73	71	17	55
2	0+42	1554729.19	175246.20	72	17	54
2	0+44	1554727.84	175247.67	72	18	54

Estimated standard deviation of depth of interfaces for seismic lines is normally taken as 10% or 2 feet, whichever is greater. Depths of bedrock determined here are depths of competent bedrock. Heavily weathered or highly fractured bedrock may occur at shallower depths. Easting and northing coordinates and elevations for the seismic lines were determined from topographic plans provided by Maine DOT.

MaineDOT Contract No. 20110613000000006486
Geophysical Survey
Route 32
Bremen, Maine
PIN# 18103.00 HR- File 11ER44 January, 2012

TABLE 1 (CONTINUED)
SEISMIC REFRACTION RESULTS

Line	Location (ft)	Easting (ft)	Northing (ft)	Surface Elevation (ft)	Bedrock Depth (ft)	Bedrock Elevation (ft)
2	0+46	1554726.48	175249.14	72	18	54
2	0+48	1554725.13	175250.62	72	19	53
2	0+50	1554723.77	175252.09	72	18	54
2	0+52	1554722.42	175253.56	72	18	54
2	0+54	1554721.06	175255.03	73	18	55
2	0+56	1554719.71	175256.50	73	18	55
2	0+58	1554718.35	175257.97	73	19	54
2	0+60	1554717.00	175259.44	73	19	54
2	0+62	1554715.65	175260.92	73	19	54
2	0+64	1554714.29	175262.39	74	20	54
2	0+66	1554712.94	175263.86	74	20	54
2	0+68	1554711.58	175265.33	74	19	55
2	0+70	1554710.23	175266.80	74	19	55
2	0+72	1554708.87	175268.27	74	19	56
2	0+74	1554707.52	175269.75	75	18	56
2	0+76	1554706.16	175271.22	75	18	57
2	0+78	1554704.81	175272.69	75	18	57
2	0+80	1554703.46	175274.16	75	18	57
2	0+82	1554702.10	175275.63	76	18	57
2	0+84	1554700.75	175277.10	76	18	58

Line	Location (ft)	Easting (ft)	Northing (ft)	Surface Elevation (ft)	Bedrock Depth (ft)	Bedrock Elevation (ft)
2	0+86	1554699.39	175278.57	76	17	59
2	0+88	1554698.04	175280.05	76	17	60
2	0+90	1554696.68	175281.52	77	16	61
2	0+92	1554695.33	175282.99	77	15	61
2	0+94	1554693.97	175284.46	77	15	62
3	0+00	1554745.86	175204.46	67	9	59
3	0+02	1554744.51	175205.93	67	9	59
3	0+04	1554743.15	175207.41	67	9	59
3	0+06	1554741.80	175208.88	67	10	57
3	0+08	1554740.44	175210.35	68	10	57
3	0+10	1554739.09	175211.82	68	11	57
3	0+12	1554737.74	175213.29	68	12	56
3	0+14	1554736.38	175214.76	68	12	56
3	0+16	1554735.03	175216.24	68	13	55
3	0+18	1554733.67	175217.71	68	14	54
3	0+20	1554732.32	175219.18	68	15	53
3	0+22	1554730.96	175220.65	68	16	53
3	0+24	1554729.61	175222.12	69	17	51
3	0+26	1554728.25	175223.59	69	17	52
3	0+28	1554726.90	175225.06	69	17	52

Estimated standard deviation of depth of interfaces for seismic lines is normally taken as 10% or 2 feet, whichever is greater. Depths of bedrock determined here are depths of competent bedrock. Heavily weathered or highly fractured bedrock may occur at shallower depths. Easting and northing coordinates and elevations for the seismic lines were determined from topographic plans provided by Maine DOT.

MaineDOT Contract No. 20110613000000006486
Geophysical Survey
Route 32
Bremen, Maine
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TABLE 1 (CONTINUED)
SEISMIC REFRACTION RESULTS

Line	Location (ft)	Easting (ft)	Northing (ft)	Surface Elevation (ft)	Bedrock Depth (ft)	Bedrock Elevation (ft)
3	0+30	1554725.55	175226.54	69	17	52
3	0+32	1554724.19	175228.01	69	17	52
3	0+34	1554722.84	175229.48	69	16	53
3	0+36	1554721.48	175230.95	69	16	53
3	0+38	1554720.13	175232.42	69	17	52
3	0+40	1554718.77	175233.89	69	17	52
3	0+42	1554717.42	175235.37	69	17	52
3	0+44	1554716.06	175236.84	69	16	53
3	0+46	1554714.71	175238.31	69	17	53
3	0+48	1554713.36	175239.78	69	17	53
3	0+50	1554712.00	175241.25	70	17	53
3	0+52	1554710.65	175242.72	70	17	53
3	0+54	1554709.29	175244.19	70	18	52
3	0+56	1554707.94	175245.67	71	18	52
3	0+58	1554706.58	175247.14	71	18	53
3	0+60	1554705.23	175248.61	71	17	54
3	0+62	1554703.87	175250.08	72	16	55
3	0+64	1554702.52	175251.55	72	16	56
3	0+66	1554701.16	175253.02	74	17	56
3	0+68	1554699.81	175254.49	74	17	56
3	0+70	1554698.46	175255.97	73	17	57
3	0+72	1554697.10	175257.44	73	17	57
3	0+74	1554695.75	175258.91	73	16	57
3	0+76	1554694.39	175260.38	73	16	57
3	0+78	1554693.04	175261.85	74	16	57
3	0+80	1554691.68	175263.32	74	15	58
3	0+82	1554690.33	175264.80	74	15	59
3	0+84	1554688.97	175266.27	74	15	60
3	0+86	1554687.62	175267.74	75	13	62
3	0+88	1554686.27	175269.21	75	12	64
3	0+90	1554684.91	175270.68	75	12	64
3	0+92	1554683.56	175272.15	76	12	64
3	0+94	1554682.20	175273.62	76	12	64

Estimated standard deviation of depth of interfaces for seismic lines is normally taken as 10% or 2 feet, whichever is greater. Depths of bedrock determined here are depths of competent bedrock. Heavily weathered or highly fractured bedrock may occur at shallower depths. Easting and northing coordinates and elevations for the seismic lines were determined from topographic plans provided by Maine DOT.

N

APPROXIMATE SCALE (feet)

0 1000 2000

LOCATION

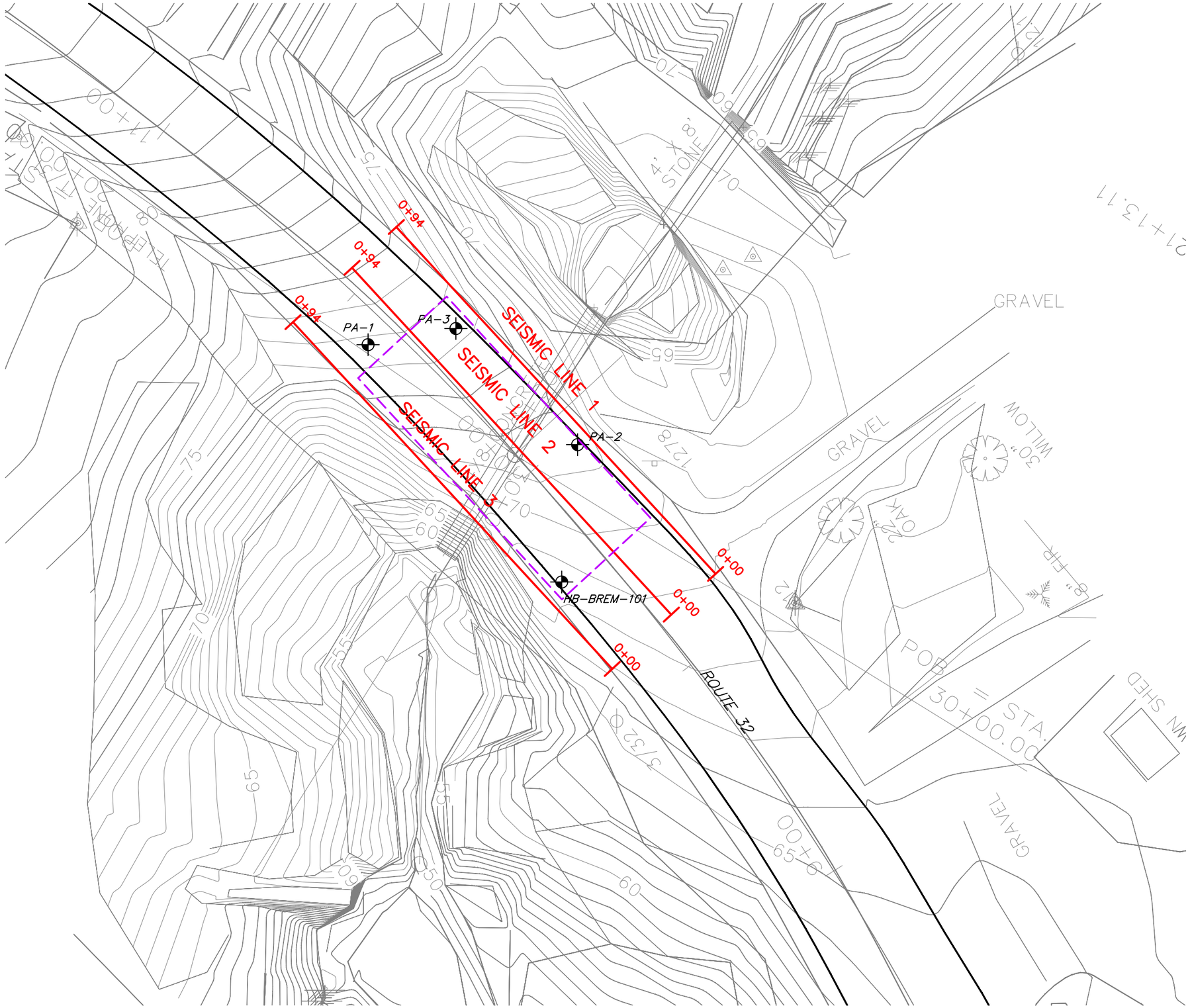
NOTE:

Modified from Google Earth aerial photograph.

Figure 1
General Site Loaction
Route 32 – PIN 18103.00
Bremen, Maine

File 11ER44	January, 2012

HAGER–RICHTER GEOSCIENCE, INC.
Salem, New Hampshire



LEGEND

- SEISMIC LINE
- APPROXIMATE PROBE LOCATION
- GPR SURVEY AREA

SCALE (feet)

0 20 40

NOTE:

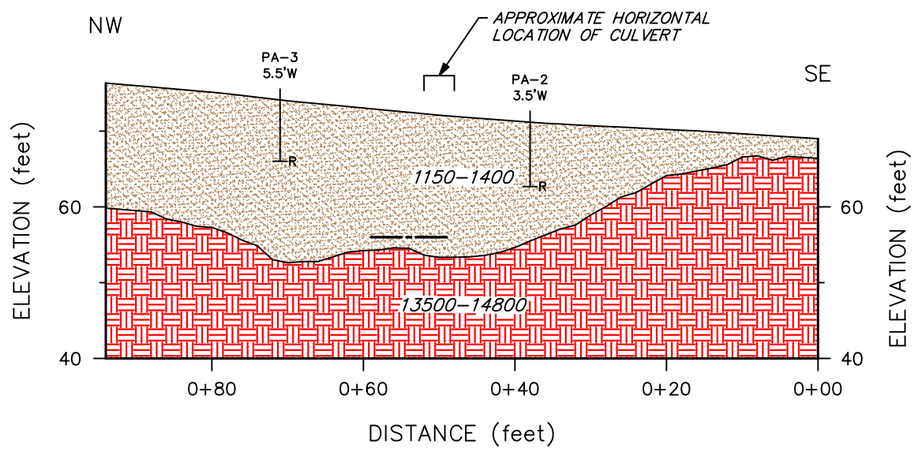
Modified from site plan provided by Maine Department of Transportation.

Figure 2
Site Plan
Route 32 – PIN 18103.00
Bremen, Maine

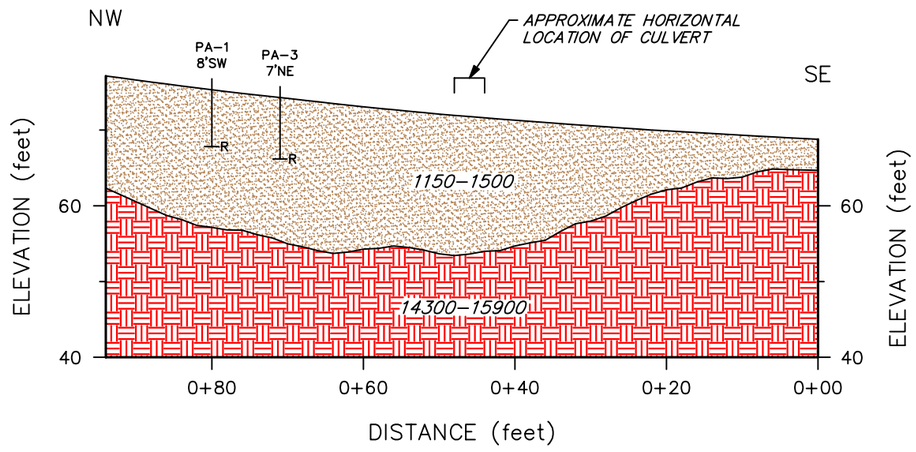
File 11ER44	January, 2012

HAGER–RICHTER GEOSCIENCE, INC.
Salem, New Hampshire

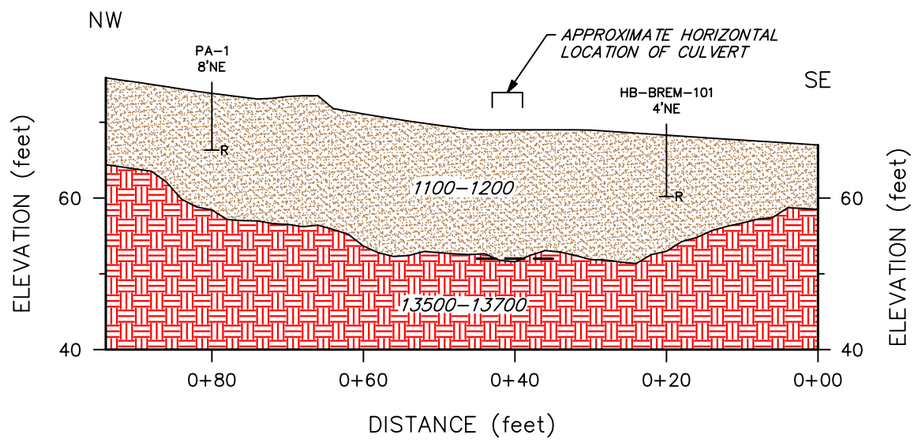
SEISMIC LINE 1



SEISMIC LINE 2



SEISMIC LINE 3



LEGEND

- Unsaturated soils
- Competent bedrock
- 13500–14800 — Velocity (fps)
- Interface determined from seismic refraction data
- PA–3 5.5'W — Boring with identification, distance and direction from traverse, and depth of refusal, based on logs provided by Maine Department of Transportation.
- Approximate elevation of stream at culvert entrance located approximately 18' northeast of line.
- Approximate elevation of stream at culvert entrance located approximately 10' southwest of line.

SCALE (feet)

0 20 40

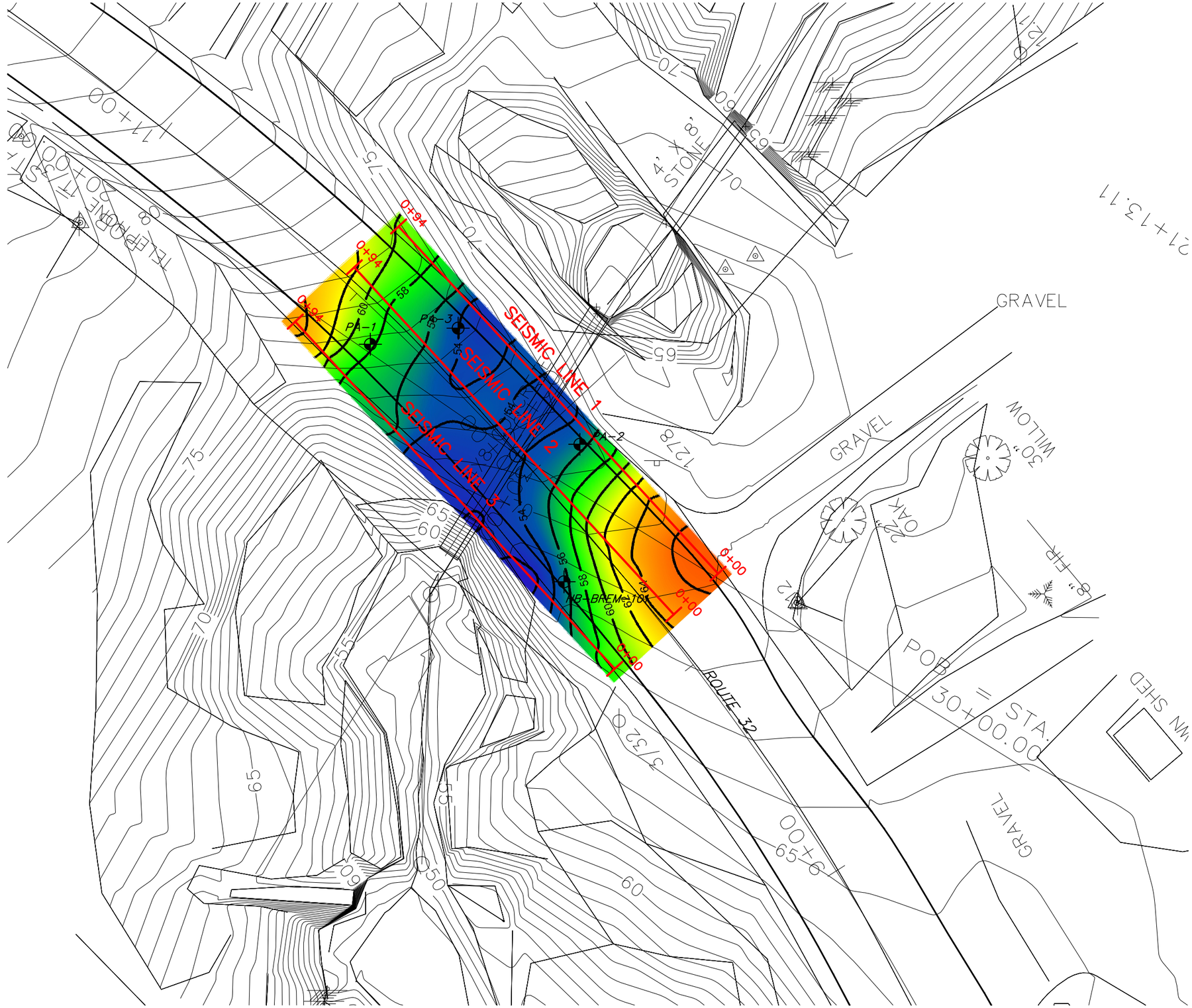
NOTES:

1. Estimated standard deviation of depth of bedrock is ±10% or 2 feet, whichever is greater.
2. The depths determined for bedrock are depths of competent rock; weathered and/or fractured bedrock might occur at shallower depths.
3. Surface elevations determined from plans provided by Maine Department of Transportation.
4. Data were analyzed using the Generalized Reciprocal Method.

Figure 3
Seismic Lines 1–3
Route 32 – PIN 18103.00
Bremen, Maine

File 11ER44	January, 2012

HAGER–RICHTER GEOSCIENCE, INC.
Salem, New Hampshire



LEGEND

SEISMIC LINE

APPROXIMATE PROBE LOCATION

SCALE (feet)

0 20 40

NOTES:

1. Modified from site plan provided by Maine Department of Transportation.
2. Bedrock elevation contour Interval = 2 Feet.
3. The bedrock elevations shown on this plot are a non-unique model. The contours represent interpolations based on the available data, including seismic refraction data and boring information. The elevations of the bedrock surface at any particular location may differ from that shown. Bedrock elevations based on additional data may differ significantly.
4. The bedrock elevations determined should not be used for contract bedrock removal quantities.

Figure 4
Bedrock Topography
Route 32 – PIN 18103.00
Bremen, Maine

File 11ER44	January, 2012

HAGER-RICHTER GEOSCIENCE, INC.
Salem, New Hampshire

MaineDOT Contract No. 20110613000000006486
Geophysical Survey
Route 32
Bremen, Maine
PIN# 18103.00 HR- File 11ER44 January, 2012

APPENDIX 1
SEISMIC REFRACTION METHOD

MaineDOT Contract No. 20110613000000006486
Geophysical Survey
Route 32
Bremen, Maine
PIN# 18103.00 HR- File 11ER44 January, 2012

SEISMIC REFRACTION METHOD

Equipment. We used two Geometrics Geode units connected to, and controlled by, a notebook PC computer. The software provides for the acquisition, display, plotting, filtering and storage of seismic data. The seismogram image presented in real time on the notebook screen allows the operator to verify the quality of the data. The stored digital data are transferred to our server at the end of the field day for storage, backup, and future data processing.

The Geodes were coupled to two 24-element seismic spread cables for a total of up to 48 geophones. Each deployment of (up to) 48 co-linear geophones is called a spread, and multiple end-to-end spreads can be conducted to survey long transects. The geophones measure only the vertical component, and their resonant frequency is 12 Hz.

Seismic energy is provided by a 14-lb sledge hammer striking an aluminum base plate, an EWG, or a Betsy seisgun. The Betsy seisgun uses a shotgun blank as the seismic source and is not classified as a weapon or explosive under Federal regulations. The EWG is an accelerated weight drop, using industrial elastics to accelerate the weight. The number of stacks per shot point is variable, and the quality of the stacked seismic signal for each shot point was verified in the field. Six to nine shot points were used for each 48-geophone spread -- one off each end of the cable, one at each end of the cable, and two to five internal to the spread. This configuration provides reversed profiles.

Data Analysis and Interpretation. The seismic data were analyzed using the Generalized Reciprocal Method (GRM) of seismic refraction interpretation. The method is described in detail in Palmer (1980).[1] GRM allows for some variation in the surface topography as well as lateral variation in the seismic velocity of the upper layers. The method uses the principle of migration whereby the refractor need only be planar over a short distance, thus allowing the calculation of depth to an undulating interface. In addition, GRM is relatively insensitive to dip angles as high as 20°, unlike most other methods that can be sensitive to dips as low as 5°. GRM also allows for the calculation of depth below each geophone instead of below only the shot points as in the Time-Intercept and Crossover Distance methods. The GRM software that we use for data analysis (IXRefraX by Interpex) contains several internal tests for data consistency.

The results are used to construct an interpreted velocity profile of the subsurface for each seismic line. The velocities of seismic waves are functions of the types of geologic material

[1] Palmer, Derecke (1980) The Generalized Reciprocal Method of Seismic Refraction Interpretation, Society of Exploration Geophysicists, 104 p.

through which they pass. One can thus infer the general subsurface stratigraphy from the velocities determined. Seismic velocities are expressed in feet per second (ft/s).

A widespread misconception about the seismic refraction method is that one cannot detect velocity inversions (layers of lower velocity material underlying higher velocity material) or hidden layers (layers of intermediate velocity too thin to produce first arrival signals), common conditions in stratified sediments. If present and undetected, such layers can cause large errors in the depths calculated for the various layers. However, using GRM, the presence of such layers can be inferred readily, and more importantly, the method uses average velocities for the detected and undetected layers to determine accurate depths to the refractors that are detected. Typical uncertainties in depths determined seismically are 10% or 2 feet, whichever is larger.

Limitations of the Method. Like all geophysical methods, the seismic refraction method is based on the assumption that the local geology is uncomplicated. In particular, the seismic refraction method assumes that interfaces between geologic materials correlate with sharp increases in seismic velocity and that the interfaces are relatively flat-lying. The method is not very sensitive to lateral variations within layers, and relatively subtle features such as fracture zones within bedrock are generally difficult to detect unless there is a topographic expression of the feature. The accuracy of the method is degraded in areas with strong topographic relief and/or where the interfaces have apparent dips greater than about 20°.

Where two materials do not exhibit contrasting velocities, or where velocities gradually increase with depth, a clear refracted signal is not generated, and the seismic refraction method cannot be used to distinguish the two materials. In some cases, the "geophysical contact" between materials with contrasting velocities does not correlate exactly with the "geologic contact." For example, where a highly weathered bedrock is overlain by a dense material such as till, the velocity range of the weathered bedrock might overlap or approach the velocity range of the till, and the two materials cannot be distinguished seismically. In such cases, the depth determined by seismic refraction is the depth of *sound* bedrock, which might be located at some depth below the geologic contact.

The depth relations of the water table and bedrock may constitute a significant problem for the seismic refraction technique. This problem is that of a "blind layer." A blind layer occurs where the thickness of the saturated overburden is less than about half the depth of bedrock. In such cases, the water-saturated material immediately above bedrock is "blind" in the sense that no refracted seismic energy from it will be received as a first arrival of seismic energy, and all methods used to reduce the seismic data to determine the depth of bedrock, the objective of this survey, use *only* first arrivals. Thus, the saturated layer will not be detected where it is close to bedrock, and most methods of seismic data reduction will indicate that bedrock is considerably

deeper than it actually is. Although GRM, the method used by Hager-Richter to reduce the seismic refraction data, does not use first arrivals through the water saturated zone (because there is none to use) in such cases, GRM determines the depth of bedrock correctly by using the *average* velocity of the saturated and unsaturated zones.

A "hidden layer" occurs where a lower velocity material underlies a higher velocity material, a common situation in stratified sediments. An example is where sands are present under layers of clay or till. As in the case of a "blind layer," most methods of seismic refraction data reduction will indicate that bedrock is shallower than it actually is, if a hidden layer is present but not detected. Internal tests in the seismic refraction data reduction software that we use (IXRefraX by Interpex) indicate that such layers might be present, and an average velocity of the two layers is used to determine the depth of bedrock.

APPENDIX 2
TABLE OF BORING AND POWER AUGER LOGS

State of Maine - Department of Transportation

Power Auger Probe Summary Sheet

Town(s): Bremen Project Number: 18103.00

Station (Feet)	Offset (Feet)	Weathered Rock (Feet)	Refusal (Feet)	No Refusal (Feet)	Water Depth (Ft.)	Comments / Date 4/29/2011
PA-1						
???+??	7.0 Lt.		7.5			5.5" Pavement.
PA-2						
???+??	11.0 Rt.		8.5			Shoulder EP
PA-3						
???+??	8.0 Rt.		8.1			5.5" Pavement
						cobble 2.5-3.5 ft bgs
						very dense

MaineDOT Drill Crew
Logged By: B. Wilder
Drill Rig: CME 45C

5" Solid Stem Auger

Maine Department of Transportation

SOIL/ROCK EXPLORATION LOG

US Customary Units

Project: Bremen
Location: RTE # 32

Boring No: HB-Brem-101
PIN: 18103.00

Drilling Contractor:	Me DOT	Drilling Method:	—
Operator/Assistant:	Colvere	Casing ID/OD:	—
Logged By:	WALDER	Auger ID/OD:	SSA = 5"
Rig Type:	CME45C	Sampler:	Standard SPTS
Date Start/Finish:	4-29-11	Hammer Wt./ Fall:	140# 30" Auto
Time Start/Finish:	8:00-8:30	Core Barrel:	—
Boring Location:	See Sketch	Water Level:	—
Elevation:			

Definitions:
D = Split Spoon Sample
MD = Unsuccessful Split Spoon Sample Attempt
U = Thin Wall Tube Sample
R = Rock Core Sample
V = Insitu Vane Shear Test
MV = Unsuccessful Vane Attempt
q_p = Unconfined Compressive Strength (ksf)
S_u = Insitu Field Vane Shear Strength (psf)
SSA = Solid Stem Auger
HSA = Hollow Stem Auger
RC = Roller Cone
WOH = Weight of 140 lb. Hammer
WOR = Weight of Rods
WO1P = Weight of 1 Person

Depth (ft)	Sample No.	Pen/Rec (in.)	Depth (ft)	Blows (/6") Shear Strength (psf) or RQD (%)	N-value	Casing Blows	Sample Description and Classification	Rock Core Log
						A	5 1/2" Pavement	
	1D	24"/14"	3-5'	2/2/2/3	4		Brown Moist, loose, F-C Sand T. Gravel, Some Silt, (Brick Pieces) (Fill)	
	2D	24"/12	5-7'	2/3/2/2	5		Similar to Above	
						A	~7.2 Dense Material (Gravel) on Auger	
							8.1-9.0 8.1 Ref	
							Augered to 9.0	

Remarks:

Page 1 of 1

Boring No: HB-Brem-103

Rev. 1/2003

State of Maine - Department of Transportation

Laboratory Testing Summary Sheet

Town(s): Bremen Project Number: 18103.00

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-BREM-101, 1D			3.0-5.0	266475	1	15.0			SM	A-2-4	II
HB-BREM-101, 2D			5.0-7.0	266474	1	11.1			GM	A-1-b	I

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

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

Appendix C

Laboratory Data

State of Maine - Department of Transportation

Laboratory Testing Summary Sheet

Town(s): Bremen Project Number: 18103.00

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-BREM-101, 1D	9+82.3	8.0 Lt.	3.0-5.0	266475	1	15.0			SM	A-2-4	II
HB-BREM-101, 2D	9+82.3	8.0 Lt.	5.0-7.0	266474	1	11.1			GM	A-1-b	I
SB-BREM-201, 1D	10+07.2	8.0 Rt.	4.5-6.5	243177	2	4.4			GP-GM	A-1-a	0
SB-BREM-201, 2D	10+07.2	8.0 Rt.	10.0-12.0	243176	2	15.9			SM	A-4	III

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.

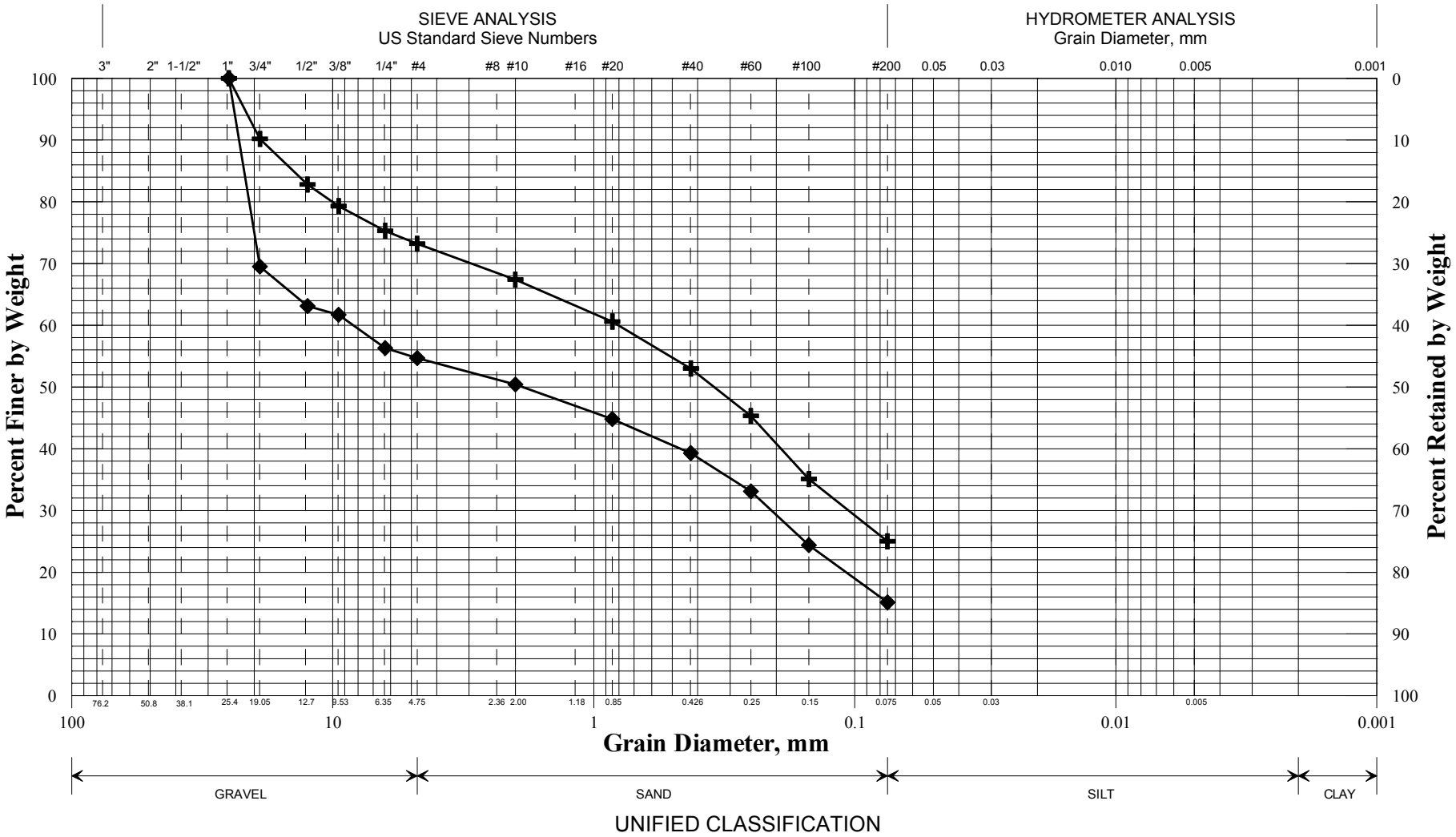
GSDC = Grain Size Distribution Curve as determined by AASHTO T 88-93 (1996) and/or ASTM D 422-63 (Reapproved 1998)

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

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

State of Maine Department of Transportation
GRAIN SIZE DISTRIBUTION CURVE



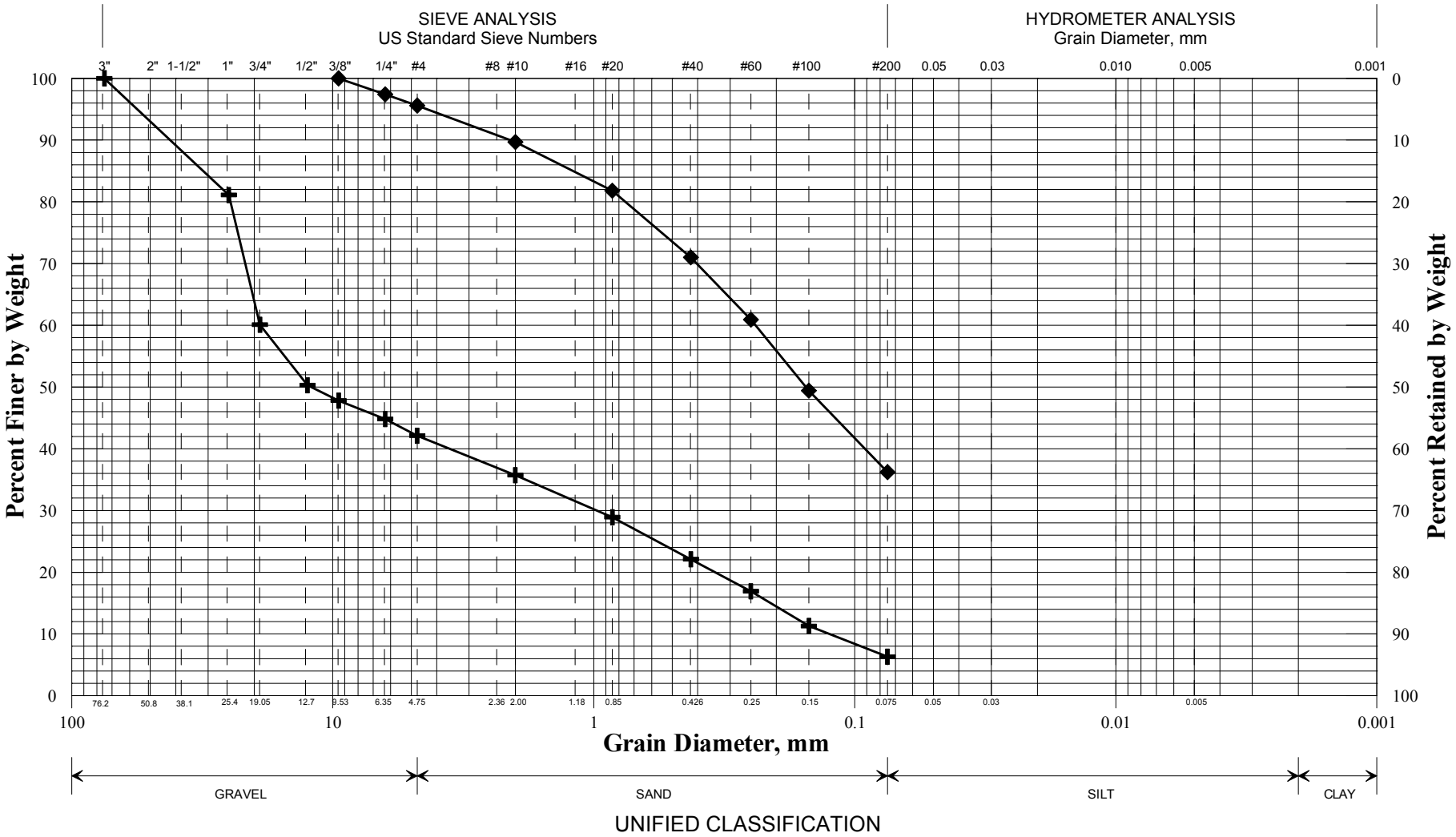
UNIFIED CLASSIFICATION

	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	W, %	LL	PL	PI
✚	HB-BREM-101/1D	9+82.3	8.0 LT	3.0-5.0	SAND, some gravel, some silt.	15.0			
◆	HB-BREM-101/2D	9+82.3	8.0 LT	5.0-7.0	Sandy GRAVEL, little silt.	11.1			
■									
●									
▲									
✖									

WIN
018103.00
Town
Bremen
Reported by/Date
WHITE, TERRY A 5/17/2011

SHEET 1

State of Maine Department of Transportation
GRAIN SIZE DISTRIBUTION CURVE



UNIFIED CLASSIFICATION

	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	W, %	LL	PL	PI
✚	SB-BREM-201/1D	10+07.2	8.0 RT	4.5-6.5	GRAVEL, some sand, trace silt.	4.4			
◆	SB-BREM-201/2D	10+07.2	8.0 RT	10.0-12.0	Silty SAND, trace gravel.	15.9			
■									
●									
▲									
✖									

WIN
018103.00
Town
Bremen
Reported by/Date
WHITE, TERRY A 4/8/2014

MaineDOT

GEOTECHNICAL TEST REPORT
Central Laboratory

SAMPLE INFORMATION

Reference No.	Boring No./Sample No.	Sample Description	Sampled	Received
266475	HB-BREM-101/1D	GEOTECHNICAL (DISTURBED)	4/29/2011	5/6/2011

Sample Type: **GEOTECHNICAL** Location: **OTHER** Station: **9+82.3** Offset, ft: **8.0** **LT** Dbfg, ft: **3.0-5.0**

WIN/Town **018103.00 - BREMEN** Sampler: **WILDER, BRUCE H**

TEST RESULTS

Sieve Analysis (T 27, T 11)

Wash Method

Procedure A

SIEVE SIZE U.S. [SI]	% Passing
3 in. [75.0 mm]	
1 in. [25.0 mm]	100.0
¾ in. [19.0 mm]	90.2
½ in. [12.5 mm]	82.8
⅜ in. [9.5 mm]	79.3
¼ in. [6.3 mm]	75.3
No. 4 [4.75 mm]	73.2
No. 10 [2.00 mm]	67.4
No. 20 [0.850 mm]	60.6
No. 40 [0.425 mm]	53.0
No. 60 [0.250 mm]	45.3
No. 100 [0.150 mm]	35.1
No. 200 [0.075 mm]	25.0

Miscellaneous Tests

Liquid Limit @ 25 blows (T 89), %	
Plastic Limit (T 90), %	
Plasticity Index (T 90), %	
Specific Gravity, Corrected to 20°C (T 100)	
Loss on Ignition (T 267)	
Loss, %	
H2O, %	
Water Content (T 265), %	15.0

Consolidation (T 216)

Trimmings, Water Content, %	

	Initial	Final		Void Ratio	% Strain
Water Content, %			Pmin		
Dry Density, lbs/ft³			Pp		
Void Ratio			Pmax		
Saturation, %			Cc/C'c		

Vane Shear Test on Shelby Tubes (Maine DOT)

Depth taken in tube, ft	3 In.		6 In.		Water Content, %	Description of Material Sampled at the Various Tube Depths
	U. Shear tons/ft²	Remold tons/ft²	U. Shear tons/ft²	Remold tons/ft²		

Comments:

AUTHORIZATION AND DISTRIBUTION

Reported by: **FOGG, BRIAN** Date Reported: **5/13/2011**

Paper Copy: Lab File; Project File; Geotech File

MaineDOT

GEOTECHNICAL TEST REPORT
Central Laboratory

SAMPLE INFORMATION

Reference No.	Boring No./Sample No.	Sample Description	Sampled	Received
266474	HB-BREM-101/2D	GEOTECHNICAL (DISTURBED)	4/29/2011	5/6/2011

Sample Type: **GEOTECHNICAL** Location: **OTHER** Station: **9+82.3** Offset, ft: **8.0** **LT** Dbfg, ft: **5.0-7.0**

WIN/Town **018103.00 - BREMEN** Sampler: **WILDER, BRUCE H**

TEST RESULTS

Sieve Analysis (T 27, T 11)

Wash Method

Procedure A

SIEVE SIZE U.S. [SI]	% Passing
3 in. [75.0 mm]	
1 in. [25.0 mm]	**100.0**
¾ in. [19.0 mm]	**69.5**
½ in. [12.5 mm]	**63.1**
⅜ in. [9.5 mm]	**61.7**
¼ in. [6.3 mm]	**56.3**
No. 4 [4.75 mm]	**54.7**
No. 10 [2.00 mm]	**50.4**
No. 20 [0.850 mm]	**44.8**
No. 40 [0.425 mm]	**39.3**
No. 60 [0.250 mm]	**33.1**
No. 100 [0.150 mm]	**24.4**
No. 200 [0.075 mm]	**15.1**

Miscellaneous Tests

Liquid Limit @ 25 blows (T 89), %	
Plastic Limit (T 90), %	
Plasticity Index (T 90), %	
Specific Gravity, Corrected to 20°C (T 100)	
Loss on Ignition (T 267)	
Loss, %	
H2O, %	
Water Content (T 265), %	**11.1**

Consolidation (T 216)

Trimmings, Water Content, %	

	Initial	Final		Void Ratio	% Strain
Water Content, %			Pmin		
Dry Density, lbs/ft³			Pp		
Void Ratio			Pmax		
Saturation, %			Cc/C'c		

Vane Shear Test on Shelby Tubes (Maine DOT)

Depth taken in tube, ft	3 In.		6 In.		Water Content, %	Description of Material Sampled at the Various Tube Depths
	U. Shear tons/ft²	Remold tons/ft²	U. Shear tons/ft²	Remold tons/ft²		

Comments:

AUTHORIZATION AND DISTRIBUTION

Reported by: **FOGG, BRIAN** Date Reported: **5/13/2011**

Paper Copy: Lab File; Project File; Geotech File

MaineDOT

GEOTECHNICAL TEST REPORT
Central Laboratory

SAMPLE INFORMATION

Reference No.	Boring No./Sample No.	Sample Description	Sampled	Received
243177	SB-BREM-201/1D	GEOTECHNICAL (DISTURBED)	3/4/2014	3/19/2014

Sample Type: **GEOTECHNICAL** Location: **OTHER** Station: **10+07.2** Offset, ft: **8.0** **RT** Dbfg, ft: **4.5-6.5**

WIN/Town **018103.00 - BREMEN** Sampler: **WILDER, BRUCE H**

TEST RESULTS

Sieve Analysis (T 27, T 11)

Wash Method

Procedure A

SIEVE SIZE U.S. [SI]	% Passing
3 in. [75.0 mm]	100.0
1 in. [25.0 mm]	81.1
¾ in. [19.0 mm]	60.1
½ in. [12.5 mm]	50.3
⅜ in. [9.5 mm]	47.8
¼ in. [6.3 mm]	44.8
No. 4 [4.75 mm]	42.1
No. 10 [2.00 mm]	35.7
No. 20 [0.850 mm]	28.9
No. 40 [0.425 mm]	22.1
No. 60 [0.250 mm]	16.9
No. 100 [0.150 mm]	11.3
No. 200 [0.075 mm]	6.3

Miscellaneous Tests

Liquid Limit @ 25 blows (T 89), %	
Plastic Limit (T 90), %	
Plasticity Index (T 90), %	
Specific Gravity, Corrected to 20°C (T 100)	
Loss on Ignition (T 267)	
Loss, %	
H2O, %	
Water Content (T 265), %	4.4

Consolidation (T 216)

Trimmings, Water Content, %	

	Initial	Final		Void Ratio	% Strain
Water Content, %			Pmin		
Dry Density, lbs/ft³			Pp		
Void Ratio			Pmax		
Saturation, %			Cc/C'c		

Vane Shear Test on Shelby Tubes (Maine DOT)

Depth taken in tube, ft	3 In.		6 In.		Water Content, %	Description of Material Sampled at the Various Tube Depths
	U. Shear tons/ft²	Remold tons/ft²	U. Shear tons/ft²	Remold tons/ft²		

Comments:

AUTHORIZATION AND DISTRIBUTION

Reported by: **FOGG, BRIAN** Date Reported: **3/27/2014**

Paper Copy: Lab File; Project File; Geotech File

MaineDOT

GEOTECHNICAL TEST REPORT
Central Laboratory

SAMPLE INFORMATION

Reference No.	Boring No./Sample No.	Sample Description	Sampled	Received
243176	SB-BREM-201/2D	GEOTECHNICAL (DISTURBED)	3/4/2014	3/19/2014

Sample Type: **GEOTECHNICAL** Location: **OTHER** Station: **10+07.2** Offset, ft: **8.0** **RT** Dbfg, ft: **10.0-12.0**

WIN/Town **018103.00 - BREMEN** Sampler: **WILDER, BRUCE H**

TEST RESULTS

Sieve Analysis (T 27, T 11)

Wash Method

Procedure A

SIEVE SIZE U.S. [SI]	% Passing
3 in. [75.0 mm]	
1 in. [25.0 mm]	
¾ in. [19.0 mm]	
½ in. [12.5 mm]	
⅜ in. [9.5 mm]	**100.0**
¼ in. [6.3 mm]	**97.4**
No. 4 [4.75 mm]	**95.6**
No. 10 [2.00 mm]	**89.7**
No. 20 [0.850 mm]	**81.8**
No. 40 [0.425 mm]	**71.0**
No. 60 [0.250 mm]	**60.9**
No. 100 [0.150 mm]	**49.4**
No. 200 [0.075 mm]	**36.2**

Miscellaneous Tests

Liquid Limit @ 25 blows (T 89), %	
Plastic Limit (T 90), %	
Plasticity Index (T 90), %	
Specific Gravity, Corrected to 20°C (T 100)	
Loss on Ignition (T 267)	
Loss, %	
H2O, %	
Water Content (T 265), %	**15.9**

Consolidation (T 216)

Trimmings, Water Content, %	

	Initial	Final		Void Ratio	% Strain
Water Content, %			Pmin		
Dry Density, lbs/ft³			Pp		
Void Ratio			Pmax		
Saturation, %			Cc/C'c		

Vane Shear Test on Shelby Tubes (Maine DOT)

Depth taken in tube, ft	3 In.		6 In.		Water Content, %	Description of Material Sampled at the Various Tube Depths
	U. Shear tons/ft²	Remold tons/ft²	U. Shear tons/ft²	Remold tons/ft²		

Comments:

AUTHORIZATION AND DISTRIBUTION

Reported by: **FOGG, BRIAN** Date Reported: **3/27/2014**

Paper Copy: Lab File; Project File; Geotech File

Appendix D

Calculations

CIP Spread Footing on Fractured Bedrock

At-Rest Earth Pressures

At-rest earth pressure coefficient:

$\beta := 0 \cdot deg$ slope angle of backfill soils from horizontal

$\phi := 32 \cdot deg$ assumed effective friction angle for granular borrow (BDG Table 3-3)

$K_o := 1 - \sin(\phi)$ $K_o = 0.4701$

Service Limit State Bearing Resistance

Nominal and factored Bearing Resistance

Presumptive Bearing Resistance for Service Limit State ONLY

Reference: AASHTO LRFD Bridge Design Specifications 5th Edition
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: Weathered or broken bedrock of any kind except shale.

Consistency In Place: heavily fractured - RQD=15%

Bearing Resistance: Ordinary Range (ksf)
16 - 24

Recommended Value of Use: 20 ksf

Recommended Value: $20 \cdot ksf = 10 \cdot tsf$ $tsf := g \cdot \left(\frac{ton}{ft^2}\right)$

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

Strength Limit State Bearing Resistance

Determine Bearing Resistance of cast-in-place spread footings on bedrock using RMR method from AASHTO LRFD Section 10.4.6.4 Rock Mass Strength

References

1. AASHTO LRFD Bridge Design Specifications, 6th Edition, 2012
2. Wyllie, Duncan C, "Foundations on Rock", Second Edition, 2009
3. "The Hoek-Brown Failure Criterion - A 1988 Update", E. Hoek and E.T.Brown

Parent or country rock is granite with interbeds/veins of pegmatite or schist

RQD = 15%, very poor

Determine RMR from Table 10.4.6.4-1: Geomechanics classification of rock mass

1. Strength of Rock Table 4.4.8.1.2B Std Specification, 17th ed. 2002
   typical range of Uniaxial compressive strength (Co) as a function of rock category and type

   Type E - coarse-grained igneous and metamorphic crystalline rock
   Granite qu = 300 - 7000 ksf or 2100 to 49000 psi

$q_u := 10000 \cdot psi$ $q_u = 1440 \cdot ksf$ from Table 10.4.6.4-1, 1080-2160 ksf, Relative Rating = 7

2. Drill core quality, RQD from Table 10.4.6.4-1, <25% Relative Rating = 3
3. Spacing of joints from Table 10.4.6.4-1, 2 inches to 1 foot Relative Rating = 10
4. Condition of joints slightly rough, separation<0.05", some soft walls Relative Rating = 12
5. Groundwater conditions - under moderate pressure at footing elevation Relative Rating = 4

Initial RMR = 36

Assume orthogonal joints, rating adjustment = -7 Adjusted $RMR := 29$

Table 10.4.6.4-3 Geomechanics Rock Mass Classes Determined from Total Rating
40 - 21, Class IV, Poor Rock

Determine Rock type from Table 10.4.6.4-4:
Rock Type E - Coarse grained igneous and metamorphic crystalline rocks

Determine Rock Property constants m and s

Reference: "The Hoek-Brown Failure Criterion - a 1988 Update", E.Hoek and E.T.Brown

for a disturbed rock mass from Table 10.4.6.4-4 $m_i := 25$ for intact rock, Type E

$$m := m_i \cdot \exp\left[\frac{(RMR - 100)}{14}\right] \qquad s := \exp\left[\frac{(RMR - 100)}{6}\right]$$

$m = 0.1568$ $s = 7.2585 \times 10^{-6}$

Determine nominal and factored bearing resistance of bedrock:

$C_{f1} := 1.0$ from Willie, Table 5.4, pg 138 for strip foundation

$q_{uc} := \begin{pmatrix} 5000 \\ 10000 \end{pmatrix} \cdot psi$ AASHTO Table 4.4.8.1.2B, low end for granite

Nominal Bearing Resistance

$$q_{nom} := C_{f1} \cdot \sqrt{s} \cdot q_{uc} \cdot \left(1 + \sqrt{m \cdot s^{-.5} + 1}\right)$$ Equation 5.4, pg 138, Wyllie

$$q_{nom} = \begin{pmatrix} 16.9 \\ 33.7 \end{pmatrix} \cdot ksf$$

Factored Bearing Resistance - Strength Limit State:

Use resistance factor of 0.45 for footings on rock, LRGFD Table 10.5.5.2.2-1

$\phi_{bc} := 0.45$ $q_f := q_{nom} \cdot \phi_{bc}$

$$q_f = \begin{pmatrix} 8 \\ 15 \end{pmatrix} \cdot ksf$$

Use 15 KSF for Strength Limit State