



REPORT

GEOTECHNICAL DESIGN REPORT

**Johnson Bridge #3275 Over Flat Bay River
Route 1A Culvert Replacement
Harrington, Maine
Maine DOT WIN 21693.00**

Submitted To: WSP USA, Inc.
428 Dow Highway
Elliot, ME 03903

Submitted By: Golder Associates Inc.
174 South Freeport Road, Suite 2D
Freeport, ME 04032

November 19, 2018

Project No.: 1772220

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November 19, 2018

Project No.: 1772220

Adam Stockin, PE
Supervising Structural Engineer
WSP
650 Elm Street, Suite 402
Manchester, NH 03101

**RE: GEOTECHNICAL DESIGN REPORT
JOHNSON BRIDGE #3275 OVER FLAT BAY RIVER
ROUTE 1A CULVERT REPLACEMENT
HARRINGTON, MAINE
MAINEDOT WIN 21693.00**

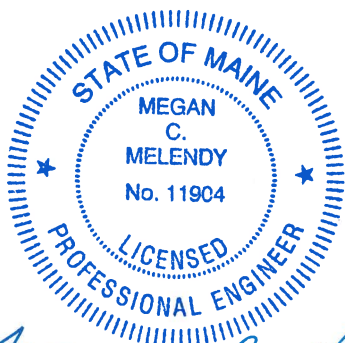
Dear Mr. Stockin:

Golder Associates Inc. (Golder) is pleased to submit this Geotechnical Design Report to WSP for the proposed Route 1A Culvert Replacement for the Johnson Bridge over Flat Bay River in Harrington, Maine. This report presents the subsurface information and field testing data obtained during the field investigations, the results of geotechnical laboratory tests, and geotechnical recommendations for the proposed culvert replacement.

Our work was conducted in accordance with the scope, schedule and budget described in our revised proposal dated February 3, 2017. The terms and conditions governing the work are stated in the Professional Services On-Call/Task Order Subcontract dated February 23, 2017. Please contact us if you have any questions concerning our report or require additional information.

Sincerely,

GOLDER ASSOCIATES INC.




Megan C. Melendy, P.E.
Senior Engineer


Mark S. Peterson, P.E.
Principal

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1.0 INTRODUCTION

This report summarizes the results of Golder Associates Inc.'s (Golder's) geotechnical investigation for replacement of the culvert (Johnson Bridge #3275) carrying State Route 1A over the Flat Bay River in Harrington, Maine (see Figure 1). The purpose of this report is to present soils and bedrock information at the culvert replacement site obtained from subsurface investigations and laboratory tests; discuss geotechnical considerations for the culvert foundation; and present recommended geotechnical parameters for design and construction. Our work was completed in accordance with our Professional Services On-Call/Task Order Subcontract dated February 23, 2017.

1.1 Background

The culvert replacement site is about 1.4 miles east of the Harrington town line where Route 1A crosses over the Flat Bay River. The existing culvert was built in 1979 and consists of a 14 foot (ft) 8 inch (in.) span aluminum pipe plate arch culvert supported on granular borrow materials overlying native Presumpscot Formation clays and silts. The culvert has a 9 ft 8 in. rise and is overlain with about 15 ft of fill. The culvert is currently in poor condition, with scattered holes and corrosion around the top plates' bolt nuts, and at high tide the culvert is fully submerged according to information provided in WSP's Preliminary Design Report (PDR)¹. The roadway is 40 ft wide and is flanked by steel guardrail for the approaches. Prior to the installation of the existing culvert, the crossing consisted of twin timber box culverts supported on piles. The construction documents allowed for the contractor to either completely remove the piles or remove the piles to a depth of two feet below the existing culvert inlet. The approximate location of the original twin timber box culvert piles is shown on Figure 2. The extent of the pile removal is unknown.

The 1978 historical drawings² and the 1979 soils report³ indicate that the overburden consists of approximately 15 to 20 ft of fill at the approaches overlying native silt and clay soils with occasional sand seams to approximately El. -12 ft (NAVD 88 datum), corresponding to approximately 30 ft below the existing road grade. The 1979 data indicated the native silt and clay layer has measured vane shear strength values generally ranging from approximately 800 to 2,000 pounds per square foot (psf). Below El. -12 ft a layer of native silty sand and gravel was encountered, and refusal was encountered as noted in one boring at approximately EL. -23 ft, which corresponds to approximately 40 ft below the existing road grade. Review of the Maine Geological Survey (MGS) bedrock and surficial geology maps for the area indicate the surficial geology consists of glacial outwash sand and gravel.

¹ WSP, September 19, 2018, Preliminary Design Report, Johnson Bridge #3275 over Flat Bay River Harrington, STP-02169(300), WIN 21693.00.

² State of Maine Department of Transportation, 1978. Johnson Bridge Replacement, Curtis Creek U.S. Route 1-A, Harrington, Maine.

³ Maine Department of Transportation Materials & Research Division Soils Section, 1979. Soils Report 79-26, Harrington - Washington County, Br. 3275, Subsurface Investigation for the Proposed Replacement of Johnson Bridge Over Curtis Creek in the Town of Harrington.



Based on discussions with WSP and our review of the Draft PS&E Plans⁴ prepared by WSP, MaineDOT plans to replace the existing culvert with a 16-foot span, 13-foot rise precast concrete, four-sided, box culvert. The proposed box culvert will be about 10 ft shorter than the existing pipe arch and founded at approximately the same stream bed elevation and location as the existing plate arch culvert. However, we understand that WSP estimates that the proposed concrete box culvert will be slightly heavier than the existing culvert (i.e., incremental net load increase of about 130 psf). In addition, we understand that WSP plans to match the existing roadway vertical profile and horizontal alignment and therefore will not be raising the grade of the road or widening the approaches.

⁴ WSP, November 7, 2018, Draft PS&E Plans, titled, "State of Maine Department of Transportation Harrington Washington County Johnson Bridge Over Flat Bay River US Route 1A," Federal Aid Project No. STP-02169(300).



2.0 GEOLOGIC SETTING

2.1 Regional Surficial Geology

The proposed culvert replacement site is located in south-central Maine within the Seaboard Lowlands Physiographic Province⁵. Regional surficial geologic mapping indicates the regional surficial soils are Pleistocene-aged emerged marine sediments deposited in environment when relative sea level was higher than present⁶. A layer of till generally overlies bedrock and consists of a heterogeneous, non-sorted to poorly sorted mixture of clay, silt, sand, pebbles, cobbles and boulders, rarely stratified and deposited directly by glacial ice. The till generally overlies bedrock, and is in turn overlain by Pleistocene-aged ice-contact gravel in end-moraine deposits; glacial stream deposits; emerged marine-beach deposits; glaciomarine silts, clays and fine sands of the Presumpscot Formation; glacial-lake bottom deposits; and eolian, beach/dune, swamp/tidal marsh, and alluvial deposits.⁴

2.2 Regional Bedrock Geology

Regional bedrock geologic mapping indicates the bedrock beneath the site consists of the Ordovician-Precambrian-aged Columbia Falls Formation. The lithology consists of felsic and mafic volcanic rocks metamorphosed to greenschist facies, forming amphibolites and chlorite-biotite schists.^{7,8,9} Regional mapping indicates the foliation strikes east-southeast, with moderate to steep dips to the south-southeast. Devonian biotite granite has also been mapped as a pluton less than a mile south of the site, having intruded the older Columbia Falls Formation.

⁵ Fenneman, N.M., and Johnson, D.W., 1946. Physiographic Divisions of the Conterminous U.S., U.S. Geological Survey, 1 sheet, scale 1:7,000,000.

⁶ Borns, H.W. Jr., and Andersen, B., 1982. Reconnaissance Surficial Geology of the Cherryfield Quadrangle, Maine. Maine Geological Survey, Open-File Report No. 82-2, scale 1:62,500.

⁷ Gilman, R.A., 1961. Reconnaissance Bedrock Geology of the Cherryfield Quadrangle, Maine. Maine Geological Survey Open File No. 61-2, scale 1:62,500.

⁸ Gates, O., 1982. Brittle Fractures in the Eastport 2-Degree Sheet, Maine. Open-File No. 82-29, 17 p.

⁹ Osberg, P.H., Hussey, A.M., and Boone, G.M., 1985. Bedrock Geologic Map of Maine. Maine Geological Survey, scale 1:500,000.



3.0 SUBSURFACE EXPLORATION PROGRAM

On May 31 to June 5, 2017 New England Boring Contractors (NEB) of Hermon, Maine drilled two borings (BB-HAR-101, BB-HAR-102) at the locations shown on Figure 2 using a Mobile B53 rig. Test borings were drilled along the road located on either side of the existing culvert to depths of approximately 56 and 57.5 ft below ground surface (bgs). A Golder engineer was onsite during drilling to monitor the work, select sample/field test intervals, log the conditions encountered and collect soil and rock core samples.

Standard Penetration Test (SPT) sampling was conducted in accordance with ASTM D1586 in both of the borings at intervals varying from continuous to 5 ft. Standard 1-3/8-inch ID split spoons were driven 24 inches by a 140 pound hammer dropped 30 inches using a rope and cathead for BB-HAR-102 and to a depth of 40.0 ft. in BB-HAR-101. NEB switched drill rigs in the middle of BB-HAR-101 and an auto hammer was used in BB-HAR-101 after reaching 40 ft. Golder recorded the number of hammer blows required to advance the sampler at 6-inch increments, assessed lithology, and logged sample recovery lengths. Three inch inner diameter (ID) split spoons were occasionally used to attempt to increase soil recovery as directed by Golder's field engineer. Drill behavior during casing and drill rod advancement and cuttings observed during drilling were also recorded. After reaching bedrock refusal in BB-HAR-102 and -101, NEB obtained 8.5 ft and 9.8 ft, respectively, of NQ sized bedrock core from the borings. Table 1 includes a summary of the boring information including as-drilled elevations (based on taped field measurements and base map information provided by WSP) and boring depth.

Details of the sampling methods used, field data obtained, and soil, bedrock and groundwater conditions encountered are presented on the boring logs included in Appendix A. A hammer efficiency factor of 0.837 was used for the automatic hammer (based on a hammer calibration report provided by NEB) in determining the N_{60} corrections¹⁰ starting at 40.0 ft. bgs, and shown on the logs for BB-HAR-101. A hammer efficiency factor of 0.60 was used for the rope and cathead method in determining the N_{60} corrections shown on the logs everywhere else. Soils were field classified in general accordance with ASTM D 2488 and the MaineDOT Key to Soil and Rock Descriptions and Terms. A description of the boring log symbols and terms used for the soil and rock descriptions precedes the boring logs presented in Appendix A. Photographs of the rock core are included in Appendix B. Table 2 summarizes rock core descriptions, rock mass rating, and quality assessments.

¹⁰ Standard Penetration Test N-values (blows per foot) corrected for hammer energy to determine an equivalent N value for a hammer with 60% efficiency are designated as N_{60} values. N values discussed in the report generally refer to corrected N_{60} values.



4.0 LABORATORY TESTING PROGRAM

Geotechnical laboratory tests were performed on representative soil and rock samples collected during the subsurface investigation to assist in soil classification and anticipated rock strength. Samples were collected at borings BB-HAR-101 and BB-HAR-102.

Testing on the selected samples was conducted by GeoTesting Express in Acton, Massachusetts. Laboratory work was performed in accordance with applicable AASHTO and American Society for Testing Materials (ASTM) testing procedures. The combined testing performed for the investigation is summarized below.

Soil Laboratory Test	Testing Procedure	Number of Tests Completed
Grain Size Analysis, sieve only	AASHTO T88, ASTM D422	6
Grain Size Analysis including Hydrometer	AASHTO T88, ASTM D422	2
Natural Moisture Content	AASHTO T265, ASTM D2216	8
Atterberg Limits	ASTM D4318	2
Uniaxial Compressive Strength of Rock	ASTM D7012C	1

Selected soil testing results are included on the boring logs in Appendix A and summarized on Table 2. Complete laboratory testing results are provided in Appendix C.



5.0 GENERALIZED SUBSURFACE CONDITIONS

Soils encountered at the borings were found to generally include asphalt, common fill and select fill materials placed during culvert installation and construction of the roadway, and naturally occurring Presumpscot Formation clay and sand sediments. The underlying bedrock surface is interpreted to range from about 47 ft below the road grade as shown on the interpreted subsurface profile on Figure 3. Detailed descriptions of the soil and bedrock conditions encountered at the borings are provided on the Boring Logs in Appendix A. The following sections summarize the major stratigraphic units.

Asphalt Pavement

Asphalt pavement ranged from 0.7 to 0.75 ft. thick in the two borings.

Common Fill

Sand and gravel subgrade fill materials about 14 ft thick were encountered directly beneath the asphalt pavement at both boring locations. The 1978 historical drawings specified this layer as Common Borrow materials meeting the requirements of MaineDOT 703.18. A definitive distinction in the upper two split spoon samples could not be made between Common Borrow and roadway subbase material other than the upper samples were slightly denser. The materials generally consist of light brown to brown, dry, loose to dense, fine to coarse sand with little fine gravel and trace silt. A sub-layer (less than 5 ft thick) of dark brown to gray, damp, very stiff, moderately plastic, silty clay with trace gravel was encountered near the bottom of the common fill layer at both borings. Corrected SPT N-values¹¹ ranged from 7 to 42, with an average of 25, indicating a medium dense consistency. A grain size analyses of this layer indicated an AASHTO classifications of A-1-b (1) and A-4 (0); and SP – SM and CL under the Unified Soil Classification System (USCS). The measured water content of the tested sample was 3.7 to 18.6 percent.

Select Fill

Sand and gravel select subgrade fill materials ranging in thickness from about 10 to 12 ft were encountered directly beneath the common fill layer at the boring locations. The 1978 historical drawings specified this layer was required to be Granular Borrow – Material for Underwater Backfill (MaineDOT 703.19). Grainsize analyses performed on samples of select fill collected in this layer either met or slightly exceeded the % fines requirements for Granular Borrow – Material for Underwater Backfill per MaineDOT 703.19.. The select fill materials generally consist of light brown to gray, damp, medium dense, fine to coarse sand, little gravel, trace silt. Corrected SPT N-values in the fill materials ranged from 4 to 28, with an average of 14, indicating a medium dense consistency. A grain size analysis of a sample from this layer indicated an

¹¹ All subsequent references to SPT N-values in this report pertain to the energy corrected N_{60} values shown on the boring logs in Appendix A.



AASHTO classifications of A-1-b (0) and USCS classifications of SP & SW– SM. The measured water content of the tested sample was 8.8 percent.

Glaciomarine Silty Clay

A layer of glaciomarine silty clay (Presumpscot Formation) was encountered below the select fill layer. The silty clay layer was between 8 and 9.5 ft thick at the boring locations, but is assumed to be thicker elsewhere, based on culvert construction details shown on the historical drawings, refer to Figure 3. This layer consists of dark gray, damp, stiff, silty clay with trace fine to medium sand, with moderate plasticity. N-values ranged from 5 to 12, with an average of 8, indicating a medium stiff consistency. Field vane shear tests performed by Golder indicated undrained shear strengths between 1,886 and 1,978 psf indicating a stiff clay. The 1979 soils report indicated subsurface conditions consistent with Golder's finding and reported field vane strengths ranging between about 800 and 2,000 psf with an average of about 1,400 psf throughout the layer. Refer to the 1979 vane shear data shown on Figure 3. Laboratory testing in this layer indicate an AASHTO classification of A-6 (10) and A-4 (0) and USCS of CL. The measured water contents of the tested samples ranged from about 24 to 29 percent.

Presumpscot Sand

A layer of fine to coarse sand material ranging in thickness from 12 to 14 ft. was encountered below the Presumpscot Clay layer. This layer is a gradation of the Presumpscot Formation and consists of light gray, damp, medium dense to very dense, fine to coarse sand with trace to some gravel and little silt. N-values ranged from 15 to 61, with an average of 30, indicating a medium dense consistency. The sand sized particles were found to increase with depth (i.e., the layer consisted of mostly fine sand at the top with more coarse sand found near the bottom of the layer). Laboratory testing in this layer indicate an AASHTO classification of A-1-b (0) and Unified classification of SM – SW. The measured water content of the tested sample was 10.8 percent.

Bedrock

Bedrock was encountered in both borings as determined from rock core (BB-HAR-101 and -102). Bedrock surface depth are interpreted to be between about 47.2 and 47.5 ft. bgs. Rock quality designation (RQD) of the core samples indicated that the bedrock ranges from excellent (94%) in the first run of BB-HAR-101 to very poor (25%) in the first run of BB-HAR-102.

Core samples showed bedrock consisting of pink to light gray, medium to coarse grained biotite-granite. This rock is medium strong, slightly weathered to moderately weathered, with very closely to moderately spaced discontinuities. Rock Mass Rating (RMR) of the rock core runs ranged from 46 to 64 with an average of 56. Laboratory testing indicated an unconfined compressive strength (UCS) of 27,124 psi. A detailed summary of the rock core is presented in Table 2.

**Groundwater**

Groundwater level measurements were measured during drilling, upon completion of the boreholes, and following removal of the casing. Groundwater level measurements taken within each boring were variable during the drilling program and are presented in the boring logs in Appendix A. This observed variation is likely due to influence of the water used during the drilling process and tidal fluctuation. Upon completion of the borings, the groundwater level in each boring was measured at 20.8 ft. bgs. The interpreted groundwater level shown on the subsurface profile (Figure 3) is based on the edge of waterway drainage elevation indicated on the Base Map provided by WSP for the Flat Bay River and the mean high tide elevation taken from the 1978 historical drawings.



6.0 EVALUATIONS AND RECOMMENDATIONS

We understand that WSP plans to replace the existing culvert with a 16-foot span, 13-foot rise precast concrete, four-sided, box culvert. The proposed box culvert will be approximately 10 ft shorter than the existing pipe arch to stay within the right-of-way and founded at approximately the same stream bed elevation and location as the existing plate culvert. There are no plans to raise the grade of the road or widen the approaches. Based on a review of the PS&E plans, the proposed design includes a 1 ft tall headwall, a 2 ft deep toe wall, and a 5 ft long Heavy Riprap apron at the inlet and outlet. Since the proposed box culvert will be approximately 10 ft shorter than the existing culvert, the design plans call for a steepened slope above and adjacent to the inlet and outlet of the culvert. The proposed design requires steepening the slope to 1.5H:1V and armoring with heavy Riprap from the toe of the embankment to El. 8 ft and steepening the slope to 1.75H:1V and armoring with Plain Riprap from El. 8 to the crest. The Riprap slope armoring extends from roughly STA. 46+87 to STA. 47+37 on the southern embankment and to STA. 47+63 on the northern embankment. Based on the subsurface conditions encountered during the subsurface exploration program and discussions with WSP, we conclude the proposed precast concrete box culvert can be satisfactorily supported on the existing native Presumpscot clay layer.

6.1 *Bearing Resistance and Subgrade Modulus*

We recommend that the proposed new box culvert be founded on a minimum 1 foot thick layer of geotextile wrapped Underdrain Backfill Material Type C (703.22) placed on the native Presumpscot Formation silty clay. For this condition we recommend a strength limit state factored bearing resistance of 4.6 ksf be used for design. A service limit state bearing resistance of 4 ksf may be used for the foundation soils to limit settlements to 1 inch, based on AASHTO LRFD Bridge Design Specifications Table C10.6.2.6.1-1. In no instance shall the factored bearing stress exceed the nominal resistance of the culvert concrete (0.3f_c). A modulus of reaction for a 1ft x 1ft steel plate (k_1) equal to 112 pci should be used for structural design of the proposed culvert. Refer to the calculations included in Appendix D.

6.2 *Settlement*

As stated above, we assume that the box culvert will be founded on a layer of compacted granular material bearing on the native silty clay. WSP estimates that the proposed concrete box culvert will be slightly heavier than the existing culvert (i.e., incremental net load increase of about 130 psf). Based on the net change in soil stresses from the existing to proposed conditions provided by WSP, we estimate the settlement of the proposed culvert to be negligible (less than 0.1 inch). Refer to the calculations included in Appendix D.

6.3 *Slope Stability*

To maintain culvert replacement work within the existing right-of-way, the PS&E plans show that up to 75 ft length of embankment sideslope adjacent to the proposed box culvert inlet and outlet will be steepened



to 1.5H:1V and armored with Heavy Riprap (MaineDOT 703.28) from the toe of the embankment to El. 8 ft and steepened to 1.75H:1V and armored with Plain Riprap (MaineDOT 703.26) from El. 8 to the crest. Golder did not observe any signs of existing embankment stability issues during the field investigation. However, since the culvert is founded on clay and the proposed design requires steepening the slope, Golder evaluated the global stability of the proposed embankment. Our analysis considered a final condition, steepened riprap armored embankment slope (i.e., 1.5H:1V from toe to El. 8 and 1.75H:1V from El. 8 to crest) with 500 yr flood design upstream and downstream tailwater elevations (El. 1.29 ft and El. 0.61 ft, respectively) as reported in the Hydraulic Analysis included in the Preliminary Design Report¹². The stability of upstream and downstream slopes were evaluated for the 500 year flood steady state condition and the downstream slopes were evaluated for rapid drawdown conditions. All critical failure surface were identified as surficial occurring in the riprap with no critical surfaces extending into the underlying silty clay strata. As shown in the summary table in the attached calculations included in Appendix D, the minimum calculated factor of safety for the proposed steepened embankment exceeds 1.3 for all conditions evaluated and is considered satisfactory.

6.4 Culvert Bedding and Backfill

Construction and installation of the concrete box culvert should be in accordance with MaineDOT Standard Specification 534. The native Presumpscot silty clay soils at the site are susceptible to disturbance as a result of exposure to water and construction traffic. All subgrade surfaces should be protected from unnecessary construction traffic. If rutting occurs or loose or soft materials are encountered in the excavation, the loose, soft, or disturbed areas should be removed and replaced with granular borrow (MaineDOT 703.19) or $\frac{3}{4}$ inch crushed stone (MaineDOT 703.13). In addition, as discussed above, the original twin timber box culvert was supported on piles and the extent of pile removal is unknown. If piles are encountered during subgrade preparation for installation of the new box culvert, piles should be over-excavated to at least two feet below the bottom of the box culvert and replaced with granular borrow or crushed stone.

The culvert should be bedded on a minimum 1 foot thick layer of compacted Underdrain Backfill Material Type C meeting the requirements of MaineDOT Standard Specifications 703.22 and wrapped in non-woven stabilization/reinforcement geotextile meeting the requirements of MaineDOT Standard Specification 722.01. The soil envelope and backfill around the culvert should consist of Granular Borrow Material for Underwater Backfill meeting the requirements of MaineDOT Standard Specification 703.19 with a maximum particle size of 4 inches. The backfill should be placed and compacted in uniform layers not more than 8-inch loose lifts without disturbance or displacement of the culvert, keeping the fill at approximately the same

¹² WSP, September 2018, Preliminary Design Report Johnson Bridge #3275 over Flat Bay River Harrington, Maine STP-02169(300) WUN 21693.00, Maine Department of Transportation Bridge Program.



elevation on both sides of the structure. The backfill should be compacted to at least 92 percent of the AASHTO T-180 maximum dry density. Hand-operated compactors should be used within five feet of the culvert as well as over the top until it is covered with at least 12 inches of backfill.

6.5 Riprap and Scour

As shown in the PS&E plans, both the inlet and outlet of the culvert should be armored with riprap in accordance with MaineDOT Standard Specification 703 for Plain and Heavy Riprap. The riprap should be toed in a minimum of one foot below the streambed elevation. The riprap slope should be underlain by a non-woven erosion control geotextile meeting the requirements of Standard Specification 722.03. The geotextile should be placed on a minimum 1 foot thick aggregate cushion meeting the requirements of Granular Borrow Material for Underwater Backfill (MaineDOT 703.19). In addition, both the inlet and outlet should include a 3 feet thick by 5 feet long Heavy Riprap Apron. We understand that MaineDOT has allowed for a shorter apron than the standard 10 ft as detailed in Standard Detail 610(04) (top) to maintain the limits of work within the existing right-of-way. The design also includes a 3 feet deep by 1 foot thick toe wall/cut off wall along the width of the culvert to prevent undermining.

6.6 Construction Considerations

We understand that the project is planned to be constructed during a full road closure, so limiting the extents of the excavation may not be required. The contractor should control groundwater and surface water infiltration so that box culvert installation can be completed in the dry. The native soils at the site are susceptible to disturbance as a result of exposure to water and construction traffic. All subgrade surfaces should be protected from unnecessary construction traffic.



7.0 CLOSING

This Geotechnical Design Report was prepared for the exclusive use of WSP for specific application to the proposed Route 1A Culvert Replacement crossing the Flat Bay River in Harrington, Maine in accordance with generally accepted soil and foundation engineering practices practiced in this geographical area and under similar time and financial constraints. Golder makes no other warranty, either express or implied. In the event that any changes in the nature, design or location of the proposed project are planned, Golder should be notified to review the appropriateness of our conclusions and recommendations, and to modify the recommendations as appropriate to reflect the changes in design. In addition, Golder should review the final plans and specifications to evaluate compliance with these recommendations.

Our analyses, and recommendations are based, in part, on information obtained from the referenced subsurface explorations completed at the discrete locations described in the report. Readers of this report should make their own interpretation of the results of the subsurface investigations and laboratory testing. Variations in the nature and extent of subsurface conditions between explorations should be expected. Golder should be notified if conditions encountered during construction vary from those described in this report so that we may re-evaluate, and if necessary, revise the recommendations made in this report.

The professional services provided by Golder for this project include only the geotechnical aspects of the subsurface conditions at this site. The presence or implications of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this report and have not been investigated or addressed.

TABLES

Table 1: Subsurface Exploration Locations
Geotechnical Design Recommendation Report
Route 1A Culvert Replacement
Harrington, Maine
MAINEDOT WIN 21693.00

Test Boring Designation ^{1,2}	As-Drilled Locations ³		Existing Ground Surface Elevation ³ (feet)	Boring Depth ⁴ (feet)
	Northing	Easting		
BB-HAR-101	279077.1	2310110.7	23.0	57.5
BB-HAR-102	279114.3	2310119.2	21.0	56.0

Notes:

1. Test boring locations are shown in Figure 2 - "Boring Location Plan".
2. Borings BB-HAR-101 and BB-HAR-102 were performed by New England Boring Contractors in May and June 2017.
3. As-drilled locations and elevations are approximate and are based on field taped measurements and the basemap provided by WSP.
4. Depth below ground surface.
5. Boring logs presented in Appendix A.

Prepared By: LLM
 Checked By: CJS
 Reviewed By: MCM

Table 2: Summary of Rock Core Quality
Geotechnical Design Report
Route 1A Culvert Replacement
Harrington, Maine
MaineDOT WIN: 21693.00

Test Boring Designation	Core Size	Existing Ground Surface Elevation ¹	Run					TCR ²		RQD ³			Physical Rock Parameters			Lithologic, Rock Mass and Discontinuity Description	
			No.	Midpoint Depth Below Bedrock Surface	Depth Below Ground Surface			Length	%	Length	%	Designation	Weathering ⁴	Estimated Field Strength ⁴	Rock Mass Rating [RMR] ⁵		
					[ft]												[ft]
	[in]	[ft]	[ft]		[ft]	Start	End	Midpoint	[ft]	[ft]		[ft]					
BB-HAR-101	NQ [1.875"]	23.0	R1	2.0	47.7	51.7	49.7	4.0	3.9	97%	3.8	94%	Excellent	Slightly Weathered (W2)	Medium Strong Rock (R3)	64	47.7' - 51.7': Pink, medium to coarse grained BIOTITE-GRANITE, medium strong (R3), slightly weathered (W2), fractures are closely spaced (5" to 12"), horizontal to moderately dipping (0 to 60 degrees ¹), discontinuity surfaces are planar to undulating to curved and rough with calcium-carbonate coatings [DEVONIAN GRANITE].
			R2	6.9	51.7	57.5	54.6	5.8	4.8	83%	1.8	31%	Poor	Moderately Weathered (W3)	Strong Rock (R4)	54	51.7' - 57.5': Pink, medium to coarse grained BIOTITE-GRANITE, strong (R4), moderately weathered (W3), moderately dipping to steep fractures (45 to 60 degrees) from vertical, closely spaced (1" to 7"), some clay infilling (~1mm), discontinuity surfaces are planar to undulating to curved and rough. Weathered zones at 52.7' and 55.8', both about 2" thick [DEVONIAN GRANITE].
BB-HAR-102	NQ [1.875"]	21.0	R1	1.0	47.5	49.5	48.5	2.0	1.7	83%	0.5	25%	Very Poor	Moderately Weathered (W3)	Medium Strong Rock (R3)	46	47.5' - 49.5': Pink to light gray, medium to coarse grained BIOTITE-GRANITE, medium strong (R3), moderately weathered (W3), fractures are moderately dipping to vertical (45 to 90 degrees), very close to closely spaced (1" to 6"), minor clay infilling (<1mm), fracture surfaces are planar and rough [DEVONIAN GRANITE].
			R2	3.5	49.5	52.5	51.0	3.0	2.8	92%	1.5	50%	Poor	Slightly Weathered (W2)	Strong Rock (R4)	60	49.5' - 52.5': Pink to light gray, medium to coarse grained BIOTITE-GRANITE, strong (R4), slightlyly weathered (W2), low angle to vertical fractures (30 to 90 degrees), moderalely close spacing (3" to 9"), minor clay infilling (<1mm), fracture surfaces are planar to undulating to stepped and rough [DEVONIAN GRANITE].
			R3	4.8	52.5	56.0	54.3	3.5	2.6	74%	2.2	62%	Fair	Slightly Weathered (W2)	Strong Rock (R4)	60	52.5' - 56.0': Pink to light gray, medium to coarse grained BIOTITE-GRANITE, strong (R4), slightlyly weathered (W2), fractures are low angle to mederately dipping (20 to 45 degrees), with close to moderately close spacing (2" to 14"), minor clay infilling (<1mm), fracture surfaces are planar to undulating and rough [DEVONIAN GRANITE].

Notes:

1. As-drilled locations and elevations are approximate and are based on field taped measurements and the basemap provided by WSP.
2. TCR = total core recovery. Total core recovery is the length of core recovered divided by the length of the run.
3. RQD = rock quality designation. RQD is the total length of intact, full diameter core pieces recovered with a length greater than or equal to twice the core diameter (i.e., length of 4 inches) measured along the core axis. The percent RQD is the total length of RQD measured versus the run length. Note that vertical discontinuities are not included in determination of RQD.
4. Weathering and Estimated Field Strength based on Tables II.4 and II.3 (respectively) in Willey, 2004 (based on ISRM, 1981).
5. Rock Mass Rating System (RMR; Bieniawski, 1989) assigns numerical ratings to six parameters, including the strength of the intact rock, the RQD, the discontinuity spacing, discontinuity conditions, groundwater conditions, and orientation of discontinuities. These ratings are summed to give the RMR value. As proposed foundations or tie-back designs are not complete, the rating adjustment for joint orientation was assigned a value of 0.
6. ft = feet, in = inches

Prepared by: LLM
Checked by: JRS
Reviewed by: MCM



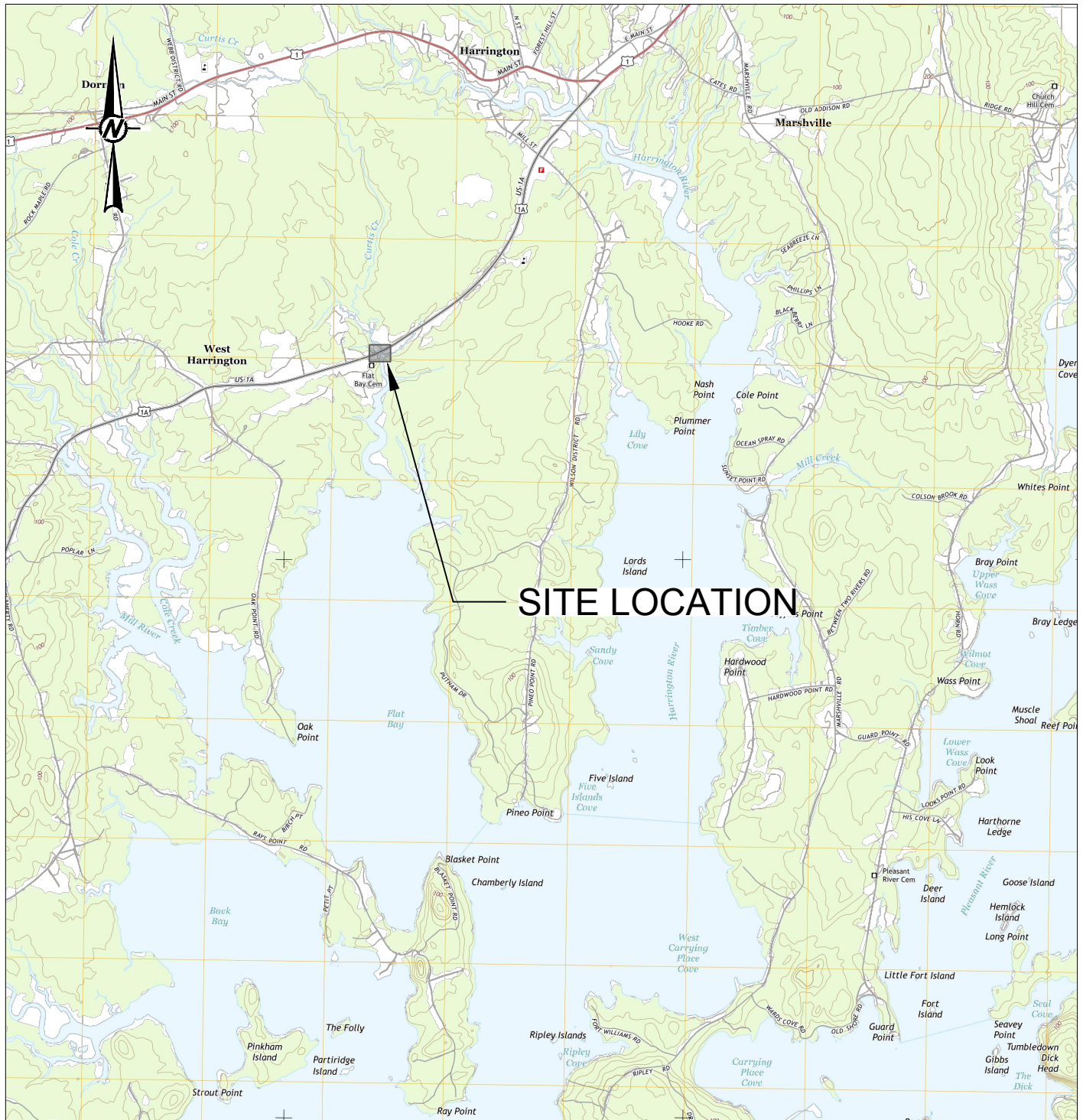
Table 3: Summary of Laboratory Testing Results
Geotechnical Design Recommendation Report
Route 1A Culvert Replacement
Harrington, Maine
MAINEDOT WIN 21693.00

Test Boring Designation ¹	Existing Ground Surface Elevation ² (ft)	Sample Number	Sample Depth Below Ground Surface (ft)	Approximate Sample Elevation (ft)	Water Content (%)	Sieve Minus No. 200 (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Liquidity Index	AASHTO Soil Classification ^{3,4}	USCS Soil Classification ^{3,4}	Bulk Density ⁴ (psf)	Compressive Strength ⁴ (psi)
BB-HAR-101	23.0	2D	3.0 - 5.0	20.0 - 18.0	3.7	6.1	-	-	-	-	A-1-b (1)	SP - SM	-	-
		6D	25.0 - 27.0	-2.0 - -4.0	13.1	3.8	-	-	-	-	A-1-b (1)	SP	-	-
		9D	31.0 - 33.0	-8.0 - -10.0	24.8	80.6	32	18	14	0.5	A-6 (10)	CL	-	-
		R1	50.45 - 50.82	-27.5 - -27.8	-	-	-	-	-	-	-	-	165	27,124
BB-HAR-102	21.0	3D	10.0 - 12.0	11.0 - 9.0	18.6	83.8	-	-	-	-	A-4 (0)	CL	-	-
		4D	15.0 - 17.0	6.0 - 4.0	8.8	10.5	-	-	-	-	A-1-b (0)	SW - SM	-	-
		6D	25.0 - 27.0	-4.0 - -6.0	28.9	99.2	-	-	-	-	A-4 (0)	CL	-	-
		9D	31.0 - 33.0	-10.0 - -12.0	31.0	-	36	19	17	0.7	A-6 (10)	CL	-	-
		10D	33.0 - 35.0	-12.0 - -14.0	25.6	91.0	-	-	-	-	A-4 (0)	CL	-	-
		12D	40.0 - 42.0	-19.0 - -21.0	10.8	16.6	-	-	-	-	A-1-b (0)	SM	-	-

- Notes:
1. Test boring locations are shown in Figure 2 - "Boring Location Plan."
 2. As-drilled locations and elevations are approximate and are based on field taped measurements and the basemap provided by WSP.
 3. AASHTO and USCS symbols assigned based on interpretation of laboratory test results.
 4. Laboratory testing was performed by GeoTesting Express, Inc. Complete laboratory test results are provided in Appendix C.

Prepared By: TRM
 Checked By: CJS
 Reviewed By: MCM

FIGURES



REFERENCE

- 1.) BASEMAP TAKEN FROM U.S.G.S. 7.5 MINUTE QUADRANGLE OF LUBEC, ME DATED 1949.



CLIENT
WSP
428 DOW HIGHWAY
ELIOT, MAINE 03903

CONSULTANT



YYYY-MM-DD 2018-10-25

DESIGNED LLM

PREPARED RWC

REVIEWED MCM

APPROVED MSP

PROJECT
ROUTE 1A CULVERT REPLACEMENT
HARRINGTON, MAINE
MAINEDOT WIN 21693.00 - JOHNSON BRIDGE NO. 3275

TITLE
SITE LOCATION PLAN

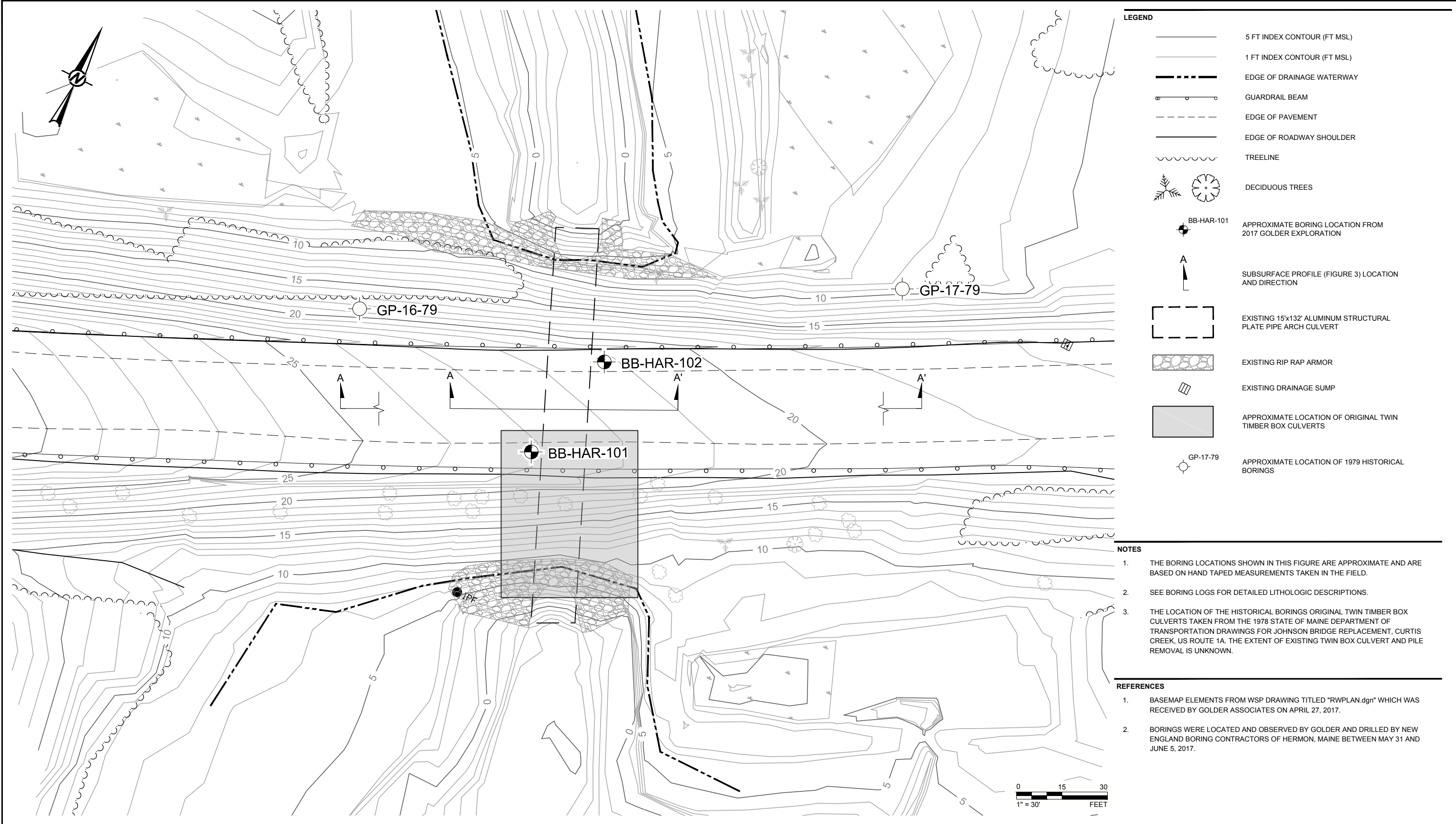
PROJECT NO.
1772220

SUBTITLE
B

REV.
1

FIGURE
1

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CLIENT
WSP
428 DOW HIGHWAY
ELIOT, MAINE 03903

CONSULTANT



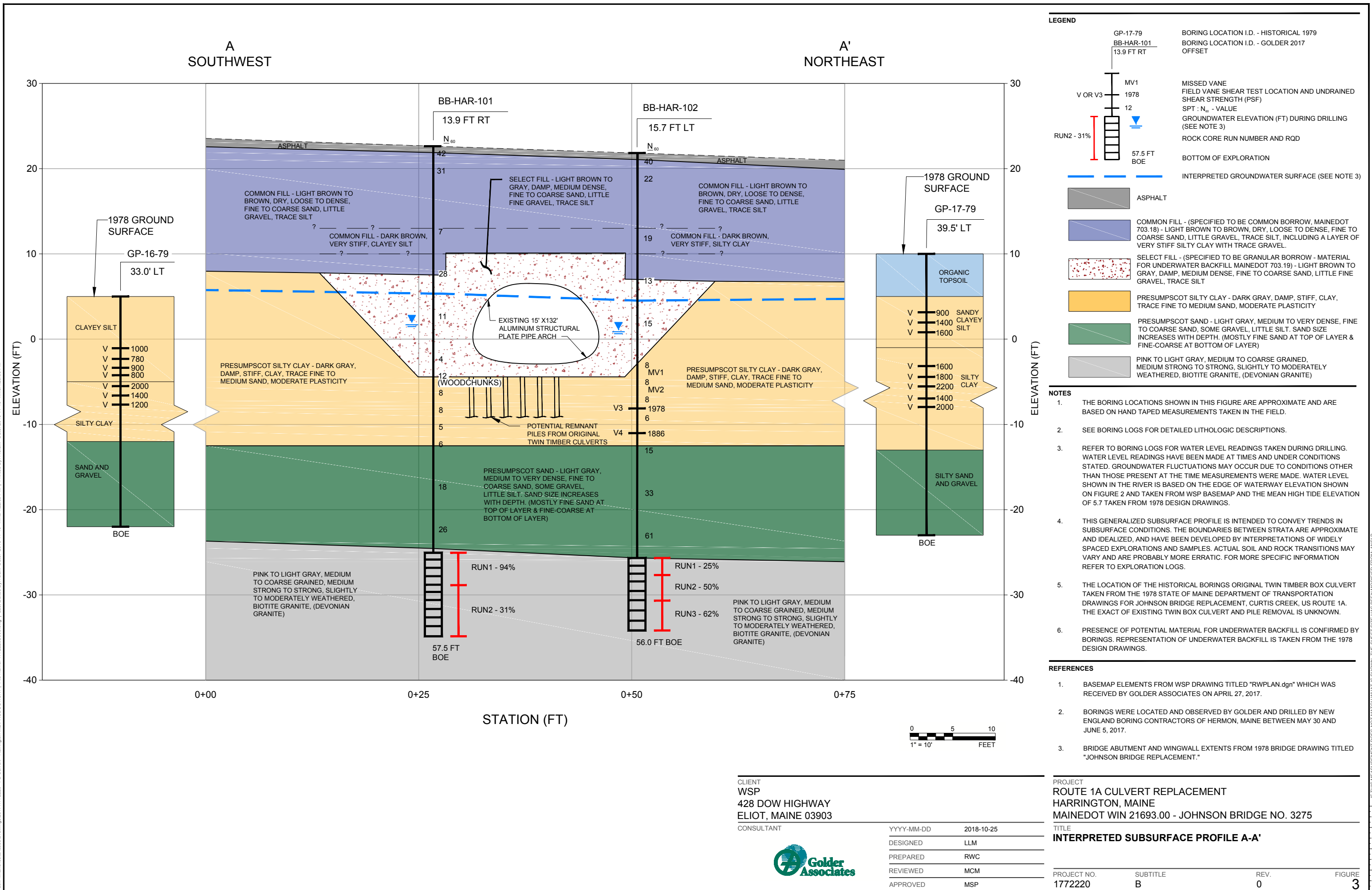
YYYY-MM-DD	2018-10-25
DESIGNED	LLM
PREPARED	RWC
REVIEWED	MCM
APPROVED	MSP

PROJECT
ROUTE 1A CULVERT REPLACEMENT
HARRINGTON, MAINE
MAINEDOT WIN 21693.00 - JOHNSON BRIDGE NO. 3275

TITLE
BORING LOCATION PLAN

PROJECT NO. 1772220	SUBTITLE B	REV. 0	FIGURE 2
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1 in IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI B



APPENDIX A
BORING LOGS

UNIFIED SOIL CLASSIFICATION SYSTEM					MODIFIED BURMISTER SYSTEM								
MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES									
COARSE-GRAINED SOILS (more than half of material is larger than No. 200 sieve size)	GRAVELS (more than half of coarse fraction is larger than No. 4 sieve size)	CLEAN GRAVELS	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.	Descriptive Term		Portion of Total (%)						
		(little or no fines)	GP	Poorly-graded gravels, gravel sand mixtures, little or no fines.	trace	0 - 10							
					little	11 - 20							
					some	21 - 35							
				adjective (e.g. sandy, clayey)	36 - 50								
	SANDS (more than half of coarse fraction is smaller than No. 4 sieve size)	CLEAN SANDS	SW	Well-graded sands, gravelly sands, little or no fines	TERMS DESCRIBING DENSITY/CONSISTENCY								
SP			Poorly-graded sands, gravelly sand, little or no fines.										
SANDS WITH FINES (Appreciable amount of fines)		GM	Silty gravels, gravel-sand-silt mixtures.	<u>Coarse-grained soils</u> (more than half of material is larger than No. 200 sieve): Includes (1) clean gravels; (2) silty or clayey gravels; and (3) silty, clayey or gravelly sands. Density is rated according to standard penetration resistance (N-value).									
		GC	Clayey gravels, gravel-sand-clay mixtures.										
		FINE-GRAINED SOILS (more than half of material is smaller than No. 200 sieve size)	SILTS AND CLAYS (liquid limit less than 50)					ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity.	Density of Cohesionless Soils		Standard Penetration Resistance N-Value (blows per foot)	
								CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Very loose	0 - 4		
OL	Organic silts and organic silty clays of low plasticity.	Loose		5 - 10									
SILTS AND CLAYS (liquid limit greater than 50)	MH	CH		OH	Medium Dense	11 - 30							
					Dense	31 - 50							
					Very Dense	> 50							
			<u>Fine-grained soils</u> (more than half of material is smaller than No. 200 sieve): Includes (1) inorganic and organic silts and clays; (2) gravelly, sandy or silty clays; and (3) clayey silts. Consistency is rated according to undrained shear strength as indicated.										
HIGHLY ORGANIC SOILS	Pt	Peat and other highly organic soils.	Approximate Undrained Shear Strength (psf)		Field Guidelines								
					<u>Consistency of Cohesive soils</u>								
					<u>SPT N-Value (blows per foot)</u>								
					WOH, WOR, WOP, <2								
					0 - 250								
					Fist easily penetrates								
					Soft								
					2 - 4								
					250 - 500								
					Thumb easily penetrates								
					Medium Stiff								
					5 - 8								
					500 - 1000								
					Thumb penetrates with moderate effort								
					Stiff								
					9 - 15								
					1000 - 2000								
					Indented by thumb with great effort								
					Very Stiff								
					16 - 30								
					2000 - 4000								
					Indented by thumbnail								
					Hard								
					>30								
					over 4000								
					Indented by thumbnail with difficulty								
					<u>Rock Quality Designation (RQD):</u>								
					RQD (%) = $\frac{\text{sum of the lengths of intact pieces of core} * > 4 \text{ inches}}{\text{length of core advance}}$								
					*Minimum NQ rock core (1.88 in. OD of core)								
					Correlation of RQD to Rock Mass Quality								
					<u>Rock Mass Quality</u>		<u>RQD (%)</u>						
					Very Poor		≤25						
					Poor		26 - 50						
					Fair		51 - 75						
					Good		76 - 90						
					Excellent		91 - 100						
					<u>Desired Rock Observations (in this order, if applicable):</u>								
					Color (Munsell color chart)								
					Texture (aphanitic, fine-grained, etc.)								
					Rock Type (granite, schist, sandstone, etc.)								
					Hardness (very hard, hard, mod. hard, etc.)								
					Weathering (fresh, very slight, slight, moderate, mod. severe, severe, etc.)								
					Geologic discontinuities/jointing:								
					-dip (horiz - 0-5 deg., low angle - 5-35 deg., mod. dipping - 35-55 deg., steep - 55-85 deg., vertical - 85-90 deg.)								
					-spacing (very close - <2 inch, close - 2-12 inch, mod. close - 1-3 feet, wide - 3-10 feet, very wide >10 feet)								
					-tightness (tight, open, or healed)								
					-infilling (grain size, color, etc.)								
					Formation (Waterville, Ellsworth, Cape Elizabeth, etc.)								
					RQD and correlation to rock mass quality (very poor, poor, etc.)								
					ref: ASTM D6032 and AASHTO Standard Specification for Highway Bridges, 17th Ed. Table 4.4.8.1.2A								
					Recovery (inch/inch and percentage)								
					Rock Core Rate (X.X ft - Y.Y ft (min:sec))								
					<u>Sample Container Labeling Requirements:</u>								
					WIN		Blow Counts						
					Bridge Name / Town		Sample Recovery						
					Boring Number		Date						
					Sample Number		Personnel Initials						
					Sample Depth								
Maine Department of Transportation Geotechnical Section Key to Soil and Rock Descriptions and Terms Field Identification Information													

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS				Project: Harrington Culvert Replacement Location: Harrington, Maine				Boring No.: BB-HAR-101 WIN: 21693.00																																																																																																																																																																																																																																																																																							
Driller: New England Boring Contractors				Elevation (ft.): 23.0 (See Remarks)				Auger ID/OD: 4"																																																																																																																																																																																																																																																																																							
Operator: Tom Schaefer				Datum:				Sampler: Standard Split Spoon																																																																																																																																																																																																																																																																																							
Logged By: TRM				Rig Type: Mobile B53				Hammer Wt./Fall: 140 lbs./30"																																																																																																																																																																																																																																																																																							
Date Start/Finish: 7:15 AM 06/02/2017				Drilling Method: SSA & D+W				Core Barrel:																																																																																																																																																																																																																																																																																							
Boring Location: Southwest Side Approach				Casing ID/OD: 4"				Water Level*: See Remarks																																																																																																																																																																																																																																																																																							
Hammer Efficiency Factor: 0.6				Hammer Type: Automatic ☐ Hydraulic ☐ Rope & Cathead ☒																																																																																																																																																																																																																																																																																											
Definitions: D = Split Spoon Sample MD = Unsuccessful Split Spoon Sample Attempt U = Thin Wall Tube Sample MU = Unsuccessful Thin Wall Tube Sample Attempt V = Field Vane Shear Test, PP = Pocket Penetrometer MV = Unsuccessful Field Vane Shear Test Attempt																																																																																																																																																																																																																																																																																															
R = Rock Core Sample SSA = Solid Stem Auger HSA = Hollow Stem Auger RC = Roller Cone WOH = Weight of 140lb. Hammer WOR/C = Weight of Rods or Casing WO1P = Weight of One Person																																																																																																																																																																																																																																																																																															
S _u = Peak/Remolded Field Vane Undrained Shear Strength (psf) S _u (lab) = Lab Vane Undrained Shear Strength (psf) q _p = Unconfined Compressive Strength (ksf) N-uncorrected = Raw Field SPT N-value Hammer Efficiency Factor = Rig Specific Annual Calibration Value N ₆₀ = SPT N-uncorrected Corrected for Hammer Efficiency N ₆₀ = (Hammer Efficiency Factor/60%)*N-uncorrected																																																																																																																																																																																																																																																																																															
T _v = Pocket Torvane Shear Strength (psf) WC = Water Content, percent LL = Liquid Limit PL = Plastic Limit PI = Plasticity Index G = Grain Size Analysis C = Consolidation Test																																																																																																																																																																																																																																																																																															
<table border="1"> <thead> <tr> <th rowspan="2">Depth (ft.)</th> <th colspan="8">Sample Information</th> <th rowspan="2">Elevation (ft.)</th> <th rowspan="2">Graphic Log</th> <th rowspan="2">Visual Description and Remarks</th> <th rowspan="2">Laboratory Testing Results/ AASHTO and Unified Class.</th> </tr> <tr> <th>Sample No.</th> <th>Pen./Rec. (in.)</th> <th>Sample Depth (ft.)</th> <th>Blows (6 in.) Shear Strength (psf) or RQD (%)</th> <th>N-uncorrected</th> <th>N₆₀</th> <th>Casing</th> <th>Blows</th> </tr> </thead> <tbody> <tr> <td>0</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>SSA</td> <td>22.3</td> <td rowspan="20"> </td> <td>9" of asphalt.</td> <td rowspan="20"> #414679 A-1-b (1) SP-SM WC: 3.7% </td> </tr> <tr> <td></td> <td>1D</td> <td>24/15.6</td> <td>1.00 - 3.00</td> <td>19/24/18/17</td> <td>42</td> <td>42</td> <td></td> <td></td> <td></td> <td>1D (1.00'-3.00'): Light brown, dry, dense, fine to medium SAND, little gravel, trace silt (COMMON BORROW).</td> </tr> <tr> <td></td> <td>2D</td> <td>24/15.6</td> <td>3.00 - 5.00</td> <td>11/16/15/19</td> <td>31</td> <td>31</td> <td></td> <td></td> <td></td> <td>2D (3.00'-5.00'): Light brown, dry, dense, fine to coarse SAND, some gravel, trace silt (COMMON BORROW).</td> </tr> <tr> <td>5</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>52</td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>80</td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>59</td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>35</td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>27</td> <td></td> <td></td> </tr> <tr> <td>10</td> <td>3D</td> <td>24/9.6</td> <td>10.00 - 12.00</td> <td>2/4/3/5</td> <td>7</td> <td>7</td> <td></td> <td>22</td> <td></td> <td>3D (10.00'-12.00'): Brown with some occasional orange staining, damp, medium stiff, clayey SILT, trace fine gravel, moderate plasticity (COMMON BORROW).</td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>12</td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>16</td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>36</td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>41</td> <td></td> <td></td> </tr> <tr> <td>15</td> <td>4D</td> <td>24/8.4</td> <td>15.00 - 17.00</td> <td>8/14/14/15</td> <td>28</td> <td>28</td> <td></td> <td>33</td> <td>8.0</td> <td>4D (15.00'-17.00'): Light brown to gray, damp, medium dense, fine to coarse SAND, little fine gravel, trace silt [FILL - POSSIBLE 703.19 MATERIAL FOR UNDERWATER BACKFILL].</td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>33</td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>52</td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>59</td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>46</td> <td></td> <td></td> </tr> <tr> <td>20</td> <td>5D</td> <td>24/6</td> <td>20.00 - 22.00</td> <td>7/6/5/7</td> <td>11</td> <td>11</td> <td></td> <td>44</td> <td></td> <td>5D (20.00'-22.00'): Light brown to gray, damp, medium dense, fine to coarse SAND, trace fine gravel, trace silt [FILL - POSSIBLE 703.19 MATERIAL FOR UNDERWATER BACKFILL].</td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>40</td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>48</td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>65</td> <td></td> <td></td> </tr> <tr> <td>25</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>71</td> <td></td> <td>Fine gravel to wash to 25'.</td> </tr> </tbody> </table>												Depth (ft.)	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Shear Strength (psf) or RQD (%)	N-uncorrected	N ₆₀	Casing	Blows	0								SSA	22.3		9" of asphalt.	#414679 A-1-b (1) SP-SM WC: 3.7%		1D	24/15.6	1.00 - 3.00	19/24/18/17	42	42				1D (1.00'-3.00'): Light brown, dry, dense, fine to medium SAND, little gravel, trace silt (COMMON BORROW).		2D	24/15.6	3.00 - 5.00	11/16/15/19	31	31				2D (3.00'-5.00'): Light brown, dry, dense, fine to coarse SAND, some gravel, trace silt (COMMON BORROW).	5								52											80											59											35											27			10	3D	24/9.6	10.00 - 12.00	2/4/3/5	7	7		22		3D (10.00'-12.00'): Brown with some occasional orange staining, damp, medium stiff, clayey SILT, trace fine gravel, moderate plasticity (COMMON BORROW).									12											16											36											41			15	4D	24/8.4	15.00 - 17.00	8/14/14/15	28	28		33	8.0	4D (15.00'-17.00'): Light brown to gray, damp, medium dense, fine to coarse SAND, little fine gravel, trace silt [FILL - POSSIBLE 703.19 MATERIAL FOR UNDERWATER BACKFILL].									33											52											59											46			20	5D	24/6	20.00 - 22.00	7/6/5/7	11	11		44		5D (20.00'-22.00'): Light brown to gray, damp, medium dense, fine to coarse SAND, trace fine gravel, trace silt [FILL - POSSIBLE 703.19 MATERIAL FOR UNDERWATER BACKFILL].									40											48											65			25								71		Fine gravel to wash to 25'.
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	1D	24/15.6	1.00 - 3.00	19/24/18/17	42	42					1D (1.00'-3.00'): Light brown, dry, dense, fine to medium SAND, little gravel, trace silt (COMMON BORROW).																																																																																																																																																																																																																																																																																				
	2D	24/15.6	3.00 - 5.00	11/16/15/19	31	31					2D (3.00'-5.00'): Light brown, dry, dense, fine to coarse SAND, some gravel, trace silt (COMMON BORROW).																																																																																																																																																																																																																																																																																				
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Maine Department of Transportation <u>Soil/Rock Exploration LOG</u> <u>US CUSTOMARY UNITS</u>				Project: Harrington Culvert Replacement Location: Harrington, Maine				Boring No.: BB-HAR-101 WIN: 21693.00																																																																																																																																																																																														
Driller: New England Boring Contractors				Elevation (ft.): 23.0 (See Remarks)				Auger ID/OD: 4"																																																																																																																																																																																														
Operator: Tom Schaefer				Datum:				Sampler: Standard Split Spoon																																																																																																																																																																																														
Logged By: TRM				Rig Type: Mobile B53				Hammer Wt./Fall: 140 lbs./30"																																																																																																																																																																																														
Date Start/Finish: 7:15 AM 06/02/2017				Drilling Method: SSA & D+W				Core Barrel:																																																																																																																																																																																														
Boring Location: Southwest Side Approach				Casing ID/OD: 4"				Water Level*: See Remarks																																																																																																																																																																																														
Hammer Efficiency Factor: 0.6				Hammer Type: Automatic ☐ Hydraulic ☐ Rope & Cathead ☒																																																																																																																																																																																																		
Definitions: D = Split Spoon Sample MD = Unsuccessful Split Spoon Sample Attempt U = Thin Wall Tube Sample MU = Unsuccessful Thin Wall Tube Sample Attempt V = Field Vane Shear Test, PP = Pocket Penetrometer MV = Unsuccessful Field Vane Shear Test Attempt R = Rock Core Sample SSA = Solid Stem Auger HSA = Hollow Stem Auger RC = Roller Cone WOH = Weight of 140 lb. Hammer WOR/C = Weight of Rods or Casing WO1P = Weight of One Person S_u = Peak/Remolded Field Vane Undrained Shear Strength (psf) S_u(lab) = Lab Vane Undrained Shear Strength (psf) q_p = Unconfined Compressive Strength (ksf) N-uncorrected = Raw Field SPT N-value Hammer Efficiency Factor = Rig Specific Annual Calibration Value N₆₀ = SPT N-uncorrected Corrected for Hammer Efficiency N₆₀ = (Hammer Efficiency Factor/60%)*N-uncorrected T_v = Pocket Torvane Shear Strength (psf) WC = Water Content, percent LL = Liquid Limit PL = Plastic Limit PI = Plasticity Index G = Grain Size Analysis C = Consolidation Test																																																																																																																																																																																																						
<table><tr><th rowspan="2">Depth (ft.)</th><th colspan="7">Sample Information</th><th rowspan="2">Elevation (ft.)</th><th rowspan="2">Graphic Log</th><th rowspan="2">Visual Description and Remarks</th><th rowspan="2">Laboratory Testing Results/ AASHTO and Unified Class.</th></tr><tr><th>Sample No.</th><th>Pen./Rec. (in.)</th><th>Sample Depth (ft.)</th><th>Blows (6 in.) Shear Strength (psf) or RQD (%)</th><th>N-uncorrected</th><th>N₆₀</th><th>Casing Blows</th></tr><tr><td rowspan="3">25</td><td>6D</td><td>24/7.2</td><td>25.00 - 27.00</td><td>5/2/2/3</td><td>4</td><td>4</td><td>44</td><td rowspan="12">-4.0</td><td rowspan="12"></td><td>6D (25.00'-27.00'): Light brown to gray, damp, very loose, fine to coarse SAND, little fine gravel, trace silt [FILL - POSSIBLE 703.19 MATERIAL FOR UNDERWATER BACKFILL].</td><td rowspan="3">#414680 A-1-b (1) SP WC: 13.1 %</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>25</td><td>7D (27.00'-29.00'): Dark gray, damp, stiff, CLAY, trace fine to medium sand, moderate plasticity, wood chunks in top 2" of sample (PRESUMPCOT).</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>35</td><td>8D (29.00'-31.00'): Dark gray with black staining, damp, medium stiff, clayey SILT, some fine sand, trace fine gravel, moderate plasticity (PRESUMPCOT).</td></tr><tr><td rowspan="3">30</td><td>8D</td><td>24/22.8</td><td>29.00 - 31.00</td><td>3/4/4/5</td><td>8</td><td>8</td><td>33</td><td></td><td></td><td>9D (31.00'-33.00'): Dark grey with black staining, damp, medium stiff, silty CLAY, little fine sand, trace fine gravel, moderate plasticity (PRESUMPCOT).</td><td rowspan="3">#414681 A-6 (10) CL WC: 24.8 %</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>32</td><td></td><td></td><td>10D (33.00'-35.00'): Top 1.2': Dark gray with dark staining, silty CLAY.</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>39</td><td></td><td></td><td>Bottom 0.8': Dark gray, damp, loose, fine SAND, some clay, trace silt (PRESUMPCOT).</td></tr><tr><td rowspan="3">35</td><td>9D</td><td>24/24</td><td>31.00 - 33.00</td><td>4/3/5/4</td><td>8</td><td>8</td><td>29</td><td></td><td></td><td>PP: 1.5, 1.25 TSF; TV: 0.450, 0.425 kg/cm² Fine gravel and wood in wash to 30'. 11D (35.00'-37.00'): Top 1': dark gray, silty CLAY, some fine sand, moderate plasticity.</td><td rowspan="3"></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>36</td><td></td><td></td><td>Bottom 1': Alternating layers of gray with black staining, clayey fine SAND and fine sandy CLAY, with some silt (PRESUMPCOT).</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>51</td><td></td><td></td><td>PP: 0.0 ; TV: 0.400, 0.350 (clay) Seam of fine sand from 34' to 35.4'. 35.8' to 37' is alternating layers of fine sand and fine sandy clay. 1" to 2" thick layers.</td></tr><tr><td rowspan="3">40</td><td>10D</td><td>24/24</td><td>33.00 - 35.00</td><td>WOH/2/3/3</td><td>5</td><td>5</td><td>44</td><td></td><td></td><td>12D (40.00'-42.00'): Light gray, damp, medium dense, fine SAND, interbedded with clayey fine sand and silt.</td><td rowspan="3"></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>43</td><td></td><td></td><td>40' to 41' is alternating layers of fine sand to clayey fine sand.</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>41</td><td></td><td></td><td>13D (45.00'-47.00'): Light gray, damp, medium dense, fine to coarse SAND, little silt, trace fine gravel (PRESUMPCOT).</td></tr><tr><td rowspan="3">45</td><td>11D</td><td>24/24</td><td>35.00 - 37.00</td><td>WOH/2/4/6</td><td>6</td><td>6</td><td>38</td><td></td><td></td><td>Top of Bedrock</td><td rowspan="3">#414690 UCS: 27124 psi</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>50</td><td></td><td></td><td>Run 1: Pink, medium to coarse grained BIOTITE-GRANITE, medium strong (R3), slightly weathered (W2), fractures are closely spaced (5" to 12"), horizontal to moderately dipping (0 to 60 degrees),</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td>81/2"</td><td></td><td></td><td></td></tr><tr><td>50</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr></table>												Depth (ft.)	Sample Information							Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N ₆₀	Casing Blows	25	6D	24/7.2	25.00 - 27.00	5/2/2/3	4	4	44	-4.0		6D (25.00'-27.00'): Light brown to gray, damp, very loose, fine to coarse SAND, little fine gravel, trace silt [FILL - POSSIBLE 703.19 MATERIAL FOR UNDERWATER BACKFILL].	#414680 A-1-b (1) SP WC: 13.1 %							25	7D (27.00'-29.00'): Dark gray, damp, stiff, CLAY, trace fine to medium sand, moderate plasticity, wood chunks in top 2" of sample (PRESUMPCOT).							35	8D (29.00'-31.00'): Dark gray with black staining, damp, medium stiff, clayey SILT, some fine sand, trace fine gravel, moderate plasticity (PRESUMPCOT).	30	8D	24/22.8	29.00 - 31.00	3/4/4/5	8	8	33			9D (31.00'-33.00'): Dark grey with black staining, damp, medium stiff, silty CLAY, little fine sand, trace fine gravel, moderate plasticity (PRESUMPCOT).	#414681 A-6 (10) CL WC: 24.8 %							32			10D (33.00'-35.00'): Top 1.2': Dark gray with dark staining, silty CLAY.							39			Bottom 0.8': Dark gray, damp, loose, fine SAND, some clay, trace silt (PRESUMPCOT).	35	9D	24/24	31.00 - 33.00	4/3/5/4	8	8	29			PP: 1.5, 1.25 TSF; TV: 0.450, 0.425 kg/cm ² Fine gravel and wood in wash to 30'. 11D (35.00'-37.00'): Top 1': dark gray, silty CLAY, some fine sand, moderate plasticity.								36			Bottom 1': Alternating layers of gray with black staining, clayey fine SAND and fine sandy CLAY, with some silt (PRESUMPCOT).							51			PP: 0.0 ; TV: 0.400, 0.350 (clay) Seam of fine sand from 34' to 35.4'. 35.8' to 37' is alternating layers of fine sand and fine sandy clay. 1" to 2" thick layers.	40	10D	24/24	33.00 - 35.00	WOH/2/3/3	5	5	44			12D (40.00'-42.00'): Light gray, damp, medium dense, fine SAND, interbedded with clayey fine sand and silt.								43			40' to 41' is alternating layers of fine sand to clayey fine sand.							41			13D (45.00'-47.00'): Light gray, damp, medium dense, fine to coarse SAND, little silt, trace fine gravel (PRESUMPCOT).	45	11D	24/24	35.00 - 37.00	WOH/2/4/6	6	6	38			Top of Bedrock	#414690 UCS: 27124 psi							50			Run 1: Pink, medium to coarse grained BIOTITE-GRANITE, medium strong (R3), slightly weathered (W2), fractures are closely spaced (5" to 12"), horizontal to moderately dipping (0 to 60 degrees),							81/2"				50											
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[illegible]

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS				Project: Harrington Culvert Replacement Location: Harrington, Maine				Boring No.: BB-HAR-102 WIN: 21693.00			
Driller: New England Boring Contractors				Elevation (ft.): 21 (See Remarks)				Auger ID/OD: 4"			
Operator:				Datum:				Sampler: Standard Split Spoon			
Logged By: TRM				Rig Type: Mobile B53				Hammer Wt./Fall: 140 lbs./30"			
Date Start/Finish: 7:15 AM 05/31/2017				Drilling Method: SSA & D+W				Core Barrel:			
Boring Location: Northeast Side Approach				Casing ID/OD: 4"				Water Level*: See Remarks			
Hammer Efficiency Factor: 0.6				Hammer Type: Automatic ☐ Hydraulic ☐ Rope & Cathead ☒							
Definitions: D = Split Spoon Sample MD = Unsuccessful Split Spoon Sample Attempt U = Thin Wall Tube Sample MU = Unsuccessful Thin Wall Tube Sample Attempt V = Field Vane Shear Test, PP = Pocket Penetrometer MV = Unsuccessful Field Vane Shear Test Attempt R = Rock Core Sample SSA = Solid Stem Auger HSA = Hollow Stem Auger RC = Roller Cone WOH = Weight of 140lb. Hammer WOR/C = Weight of Rods or Casing WO1P = Weight of One Person S_u = Peak/Remolded Field Vane Undrained Shear Strength (psf) S_{u(lab)} = Lab Vane Undrained Shear Strength (psf) q_p = Unconfined Compressive Strength (ksf) N-uncorrected = Raw Field SPT N-value Hammer Efficiency Factor = Rig Specific Annual Calibration Value N₆₀ = SPT N-uncorrected Corrected for Hammer Efficiency N₆₀ = (Hammer Efficiency Factor/60%)*N-uncorrected T_v = Pocket Torvane Shear Strength (psf) WC = Water Content, percent LL = Liquid Limit PL = Plastic Limit PI = Plasticity Index G = Grain Size Analysis C = Consolidation Test											
Depth (ft.)	Sample Information							Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/ AASHTO and Unified Class.
	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N ₆₀	Casing Blows				
0							SSA	20.3		1D (1.00'-3.00'): Brown, dry, dense, fine to medium SAND, little gravel, trace silt (COMMON BORROW). 2D (3.00'-5.00'): Light brown, dry, medium dense, fine to coarse SAND, little gravel, trace silt. Bottom 0.2' was asphalt and shoe plug was brown silty clay (COMMON BORROW). Light brown, gravelly wash from 0' to 10', gravel content decreasing with depth. 3D (10.00'-12.00'): Dark brown to gray with orange staining, dry, very stiff, silty CLAY, trace gravel, trace sand, moderately plastic; gravelly seam about 1" thick (COMMON BORROW). PP: >4.5, >4.5, >4.5 TSF Grinding/chattering down to 15'. Light brown sandy/gravelly wash to 15'. 4D (15.00'-17.00'): Light brown, damp, medium dense, fine to coarse SAND, little gravel, little silt, trace gravel [FILL - POSSIBLE 703.19 MATERIAL FOR UNDERWATER BACKFILL]. Light brown sandy wash to 20'. 5D (20.00'-22.00'): Dark brown, damp, medium dense, fine to coarse SAND, some fine gravel, trace silt [FILL - POSSIBLE 703.19 MATERIAL FOR UNDERWATER BACKFILL]. Gravelly wash to 25'.	#414682 A-4 (0) CL WC: 18.6 % #414683 A-1-b (0) SW-SM WC: 8.8 %
1	1D	24/6	1.00 - 3.00	11/22/18/16	40	40					
2	2D	24/21.6	3.00 - 5.00	14/12/10/7	22	22					
3							64				
4							65				
5							53				
6							48				
7	3D	24/10.8	10.00 - 12.00	9/9/10/16	19	19	67				
8							48				
9							92				
10							82				
11							46				
12	4D	24/7.2	15.00 - 17.00	9/7/6/15	13	13	35				
13							30				
14							59				
15							65				
16							51				
17	5D	24/3.6	20.00 - 22.00	10/6/9/(26/3")	15	15	47				
18							31				
19							37				
20							43				
21							43				
Remarks: 1. Elevation approximate. Taken from base map data provided by WSP. 2. Sample remolded by vane, N-value not valid. 3. Water level is influenced by tidal fluctuations. Water Levels: 8.9' bgs @ 15:00 05/31/2017; 13.9' bgs @ 10:30 06/01/2017; 19.6' bgs in casing at @ 13:20 06/01/2017; 20.8' bgs when casing removed @ 13:50 06/01/2017. 4. Boring collapse to 21' bgs when casing removed.											
Stratification lines represent approximate boundaries between soil types; transitions may be gradual.										Page 1 of 3 Boring No.: BB-HAR-102	

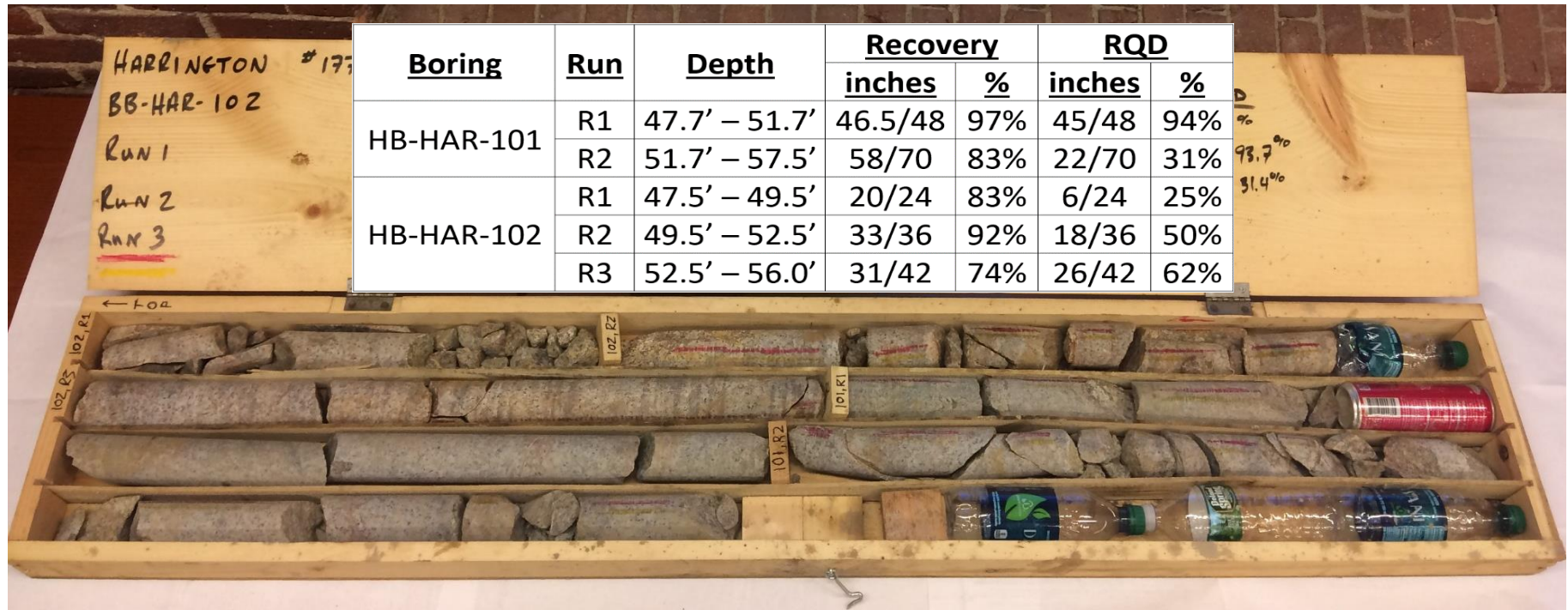
* Water level readings have been made at times and under conditions stated. Groundwater fluctuations may occur due to conditions other than those present at the time measurements were made.

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS				Project: Harrington Culvert Replacement Location: Harrington, Maine				Boring No.: BB-HAR-102 WIN: 21693.00			
Driller: New England Boring Contractors				Elevation (ft.): 21 (See Remarks)				Auger ID/OD: 4"			
Operator:				Datum:				Sampler: Standard Split Spoon			
Logged By: TRM				Rig Type: Mobile B53				Hammer Wt./Fall: 140 lbs./30"			
Date Start/Finish: 7:15 AM 05/31/2017				Drilling Method: SSA & D+W				Core Barrel:			
Boring Location: Northeast Side Approach				Casing ID/OD: 4"				Water Level*: See Remarks			
Hammer Efficiency Factor: 0.6				Hammer Type: Automatic ☐ Hydraulic ☐ Rope & Cathead ☒							
Definitions: D = Split Spoon Sample MD = Unsuccessful Split Spoon Sample Attempt U = Thin Wall Tube Sample MU = Unsuccessful Thin Wall Tube Sample Attempt V = Field Vane Shear Test, PP = Pocket Penetrometer MV = Unsuccessful Field Vane Shear Test Attempt R = Rock Core Sample SSA = Solid Stem Auger HSA = Hollow Stem Auger RC = Roller Cone WOH = Weight of 140 lb. Hammer WOR/C = Weight of Rods or Casing WO1P = Weight of One Person S _u = Peak/Remolded Field Vane Undrained Shear Strength (psf) S _u (lab) = Lab Vane Undrained Shear Strength (psf) q _u = Unconfined Compressive Strength (ksf) N-uncorrected = Raw Field SPT N-value Hammer Efficiency Factor = Rig Specific Annual Calibration Value N ₆₀ = SPT N-uncorrected Corrected for Hammer Efficiency N ₆₀ = (Hammer Efficiency Factor/60%)*N-uncorrected T _v = Pocket Torvane Shear Strength (psf) WC = Water Content, percent LL = Liquid Limit PL = Plastic Limit PI = Plasticity Index G = Grain Size Analysis C = Consolidation Test											
Depth (ft.)	Sample Information							Elevation (ft.)	Graphic Log	Visual Description and Remarks	Laboratory Testing Results/AASHTO and Unified Class.
	Sample No.	Pen./Rec. (in.)	Sample Depth (ft.)	Blows (6 in.) Shear Strength (psf) or RQD (%)	N-uncorrected	N ₆₀	Casing Blows				
25	6D	24/21.6	25.00 - 27.00	5/3/5/7	8	8	50	-4.0		25.00-27.00': Gray, dry, medium stiff, silty CLAY, little brown/orange staining, moderate plasticity. Wood chunks from 25.5' to 25.8', grain is horizontal, possibly downed tree (PRESUMPCOT). PP: 1.5, 1.5, 0.75 TSF; TV: 0.375, 0.400, 0.275 kg/cm ² Failed (65X130) vane attempt. Would not push. 27.00-29.00': Gray, damp, medium stiff, silty CLAY, little black staining, moderate plasticity (PRESUMPCOT). PP: 1.25, 1.5, 0.75 TSF; TV: 0.3, 0.325 kg/cm ² Wood chunks from 27.0' to 27.3'. A lot of wood in cuttings, possibly piles. Failed (55X110) vane attempt. Would only push 0.5'. 29.00-31.00': Grey with black staining, moist, medium stiff, silty CLAY (PRESUMPCOT). PP: 0; TV: 0; Sample too soft and moist Maxed out torque wrench (>44.3 ft.lb) on 55X110 vane. Could not advance vane any further. 31.00-33.00': Gray with black staining, damp, medium stiff, silty CLAY, moderately plastic (PRESUMPCOT). PP: 1.0, 1.0, 1.0 TSF; TV: 0.425, 0.375, 0.275 kg/cm ² 33.00-35.00': Gray, damp, soft, silty CLAY, trace sand (PRESUMPCOT). PP: 1.0, 1.0, 1.0 TSF; TV: 0.250, 0.250 kg/cm ² Vane (Bigger of the small vanes? (25.4 X 50.8)) 12 in.lbs./11 in.lbs. Could not advance any further. 35.00-37.00': No recovery with 2" spoon, followed with 3" spoon. 3" spoon sample: Gray, moist, medium dense, silty fine SAND, trace clay, 1.5" piece of rounded gravel (PRESUMPCOT). Fine sand and gravel in wash to 40'. 40.00-42.00': Gray, moist, dense, fine to coarse SAND, some gravel, little silt, little clay (PRESUMPCOT). Switched to 3" casing at 40'. 45.00-47.00': Gray, moist, very dense, fine to coarse SAND, some gravel, trace silt, trace clay, weathered pink granite fragments for bottom 0.3' (PRESUMPCOT). Trace fine gravel in stained wash/cuttings 25' to 47'. Top of Rock at 47.5' bgs. Run 1: Pink to light gray, medium to coarse grained BIOTITE-GRANITE, medium strong (R3), moderately weathered (W3),	#414686 A-4 (0) CL WC: 28.9 % #414689 CL WC: 31% #414687 A-4 (0) CL WC: 25.6 % #414685 A-1-b (0) SM WC: 10.8 %
	MV1						30				
	7D	24/13.2	27.00 - 29.00	3/4/4/6	8	8	42				
	MV2						40				
30	8D	24/7.2	29.00 - 31.00	2/4/4/5	8	8	40				
	V3		30.60 - 30.63	Su = >1978 psf			50				
	9D	24/24	31.00 - 33.00	WOH/3/3/4	6	6	43				
							40				
	10D	24/24	33.00 - 35.00	1/WOH/2/4	Note 2		40				
	V4		33.30 - 33.33	Su=1886/1729psf			40				
							40				
35	11D	24/14.4	35.00 - 37.00	3/8/7/8	15	15	43	-14.0			
							50				
							49				
							50				
							50				
40	12D	24/8.4	40.00 - 42.00	9/20/13/10	33	33	45				
							7				
							23				
							28				
45	13D	24/8.4	45.00 - 47.00	15/23/38/(53/10)	61	61	27	-26.5			
	R1	24/20	47.50 - 49.50	RQD = 25%							
50	R2	36/33	49.50 - 52.50	RQD = 50%							
Remarks: 1. Elevation approximate. Taken from base map data provided by WSP. 2. Sample remolded by vane, N-value not valid. 3. Water level is influenced by tidal fluctuations. Water Levels: 8.9' bgs @ 15:00 05/31/2017; 13.9' bgs @ 10:30 06/01/2017; 19.6' bgs in casing at @ 13:20 06/01/2017; 20.8' bgs when casing removed @ 13:50 06/01/2017. 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 2 of 3 Boring No.: BB-HAR-102	

Maine Department of Transportation <u>Soil/Rock Exploration Log</u> <u>US CUSTOMARY UNITS</u>				Project: Harrington Culvert Replacement Location: Harrington, Maine				Boring No.: BB-HAR-102 WIN: 21693.00																																																																																																																																																																																																																																																																																																														
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Recovery: 83% R1 Core Times: (min:sec) 47.5' - 48.5': (1:50) 48.5' - 49.5': (2:11) Run 2: Pink to light gray, medium to coarse grained BIOTITE-GRANITE, strong (R4), slightlyly weathered (W2), low angle to vertical fractures (30 to 90 degrees), moderaley close spacing (3" to 9"), minor clay infilling (<1mm), fracture surfaces are planar to undulating to stepped and rough [DEVONIAN GRANITE]. Recovery: 92% R2 Core Times: (min:sec) 49.5' - 50.5': (2:27) 50.5' - 51.5': (1:50) 51.5' - 52.5': (1:29) Run 3: Pink to light gray, medium to coarse grained BIOTITE-GRANITE, strong (R4), slightlyly weathered (W2), fractures are low angle to mederately dipping (20 to 45 degrees), with close to moderately close spacing (2" to 14"), minor clay infilling (<1mm), fracture surfaces are planar to undulating and rough [DEVONIAN GRANITE]. 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Recovery: 92% R2 Core Times: (min:sec) 49.5' - 50.5': (2:27) 50.5' - 51.5': (1:50) 51.5' - 52.5': (1:29) Run 3: Pink to light gray, medium to coarse grained BIOTITE-GRANITE, strong (R4), slightlyly weathered (W2), fractures are low angle to mederately dipping (20 to 45 degrees), with close to moderately close spacing (2" to 14"), minor clay infilling (<1mm), fracture surfaces are planar to undulating and rough [DEVONIAN GRANITE]. Recovery: 74% R3 Core Times: (min:sec) 52.5' - 54.0': (2:50) 54.0' - 55.0': (2:17) 55.0' - 56.0': (1:05) Stopped coring because of water problems, must be good permeability above discontinuities.	-56.0																								R3	42/31	52.50 - 56.00	RQD = 62%																													55																																												60																																												65																																																							70																																																							75										
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APPENDIX B
ROCK CORE PHOTOS

APPENDIX B
Rock Core Photos
Route 1A Culvert Replacement
Harrington, Maine
MaineDOT WIN: 21693.00



From Top to Bottom of Photo:

Row 1 = BB-HAR-102 Run 1: 47.5 - 49.5 ft-bgs./BB-HAR-102 Run 2: 49.5 - 52.5 ft-bgs.

Row 2 = BB-HAR-102 Run 3: 52.5 - 56.0 ft-bgs./BB-HAR-101 Run 1: 47.7 - 49.7 ft-bgs.

Row 3 = BB-HAR-101 Run 1: 49.7 - 51.7 ft-bgs./BB-HAR-101 Run 2: 51.7 - 57.5 ft-bgs.

APPENDIX C
LABORATORY TEST RESULTS



Client:	Golder Associates		
Project:	Route 1A Culvert Replacement		
Location:	Harrington, ME	Project No:	GTX-306602
Boring ID:	---	Sample Type:	---
Sample ID:	---	Test Date:	06/26/17
Depth :	---	Test Id:	414677
		Tested By:	jbr
		Checked By:	emm

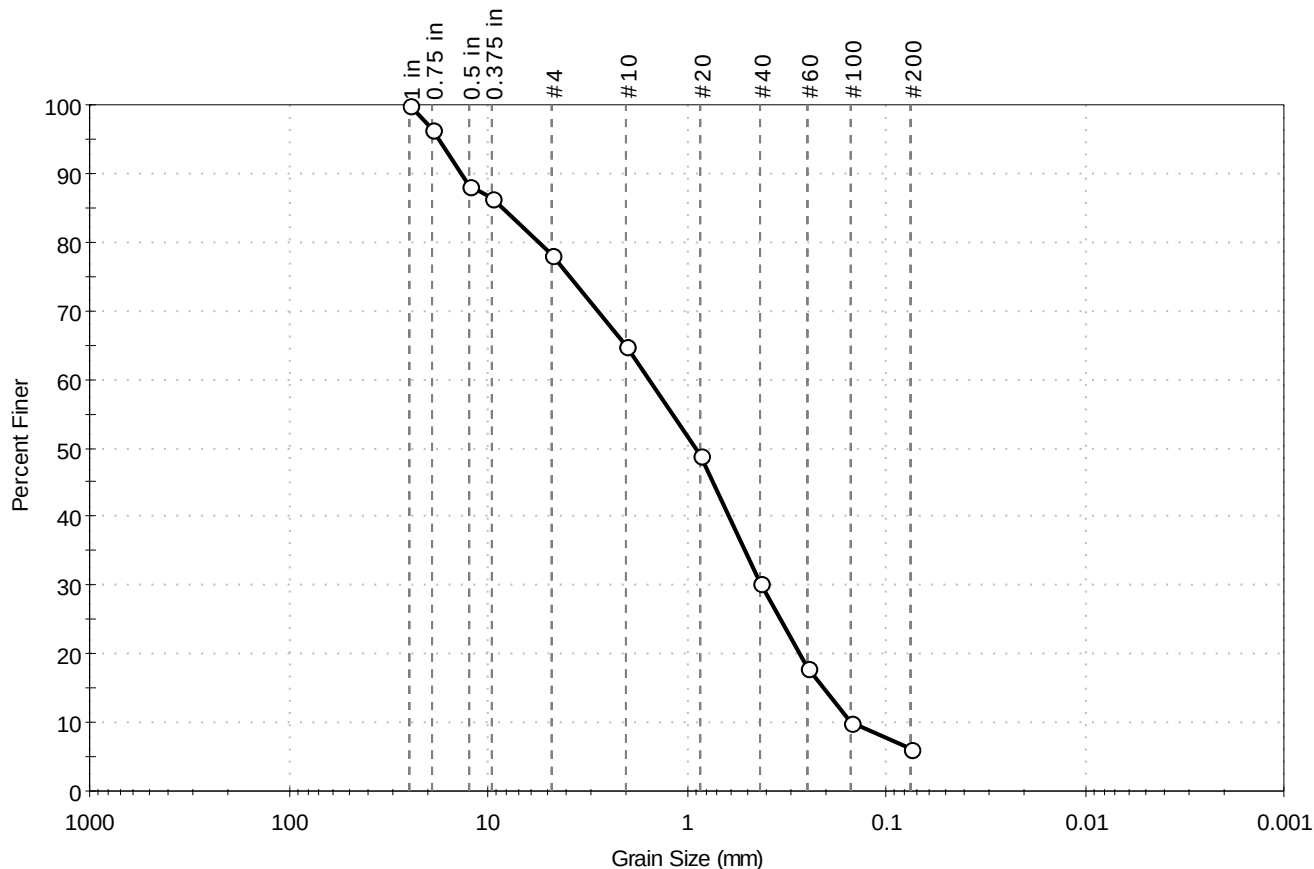
Moisture Content of Soil and Rock - ASTM D2216

Boring ID	Sample ID	Depth	Description	Moisture Content, %
BB-HAR-101	2D	3-5 ft	Moist, light yellowish brown sand with silt and gravel	3.7
BB-HAR-101	6D	25-27 ft	Moit, dark gray sand with gravel	13.1
BB-HAR-101	9D	31-33 ft	Moist, olive clay with sand	24.8
BB-HAR-102	3D	10-12 ft	Moist, grayish brown clay with sand	18.6
BB-HAR-102	4D	15-17 ft	Moist, dark grayish brown sand with silt	8.8
BB-HAR-102	6D	25-27 ft	Moist, olive clay	28.9
BB-HAR-102	10D	33-35 ft	Moist, olive clay	25.6
BB-HAR-102	12D	40-42 ft	Moist, light gray silty sand with gravel	10.8

Notes: Temperature of Drying : 110° Celsius

Client:	Golder Associates	Project No:	GTX-306602
Project:	Route 1A Culvert Replacement		
Location:	Harrington, ME		
Boring ID:	BB-HAR-101	Sample Type:	jar
Sample ID:	2D	Test Date:	06/27/17
Depth :	3-5 ft	Test Id:	414679
Test Comment:	---		
Visual Description:	Moist, light yellowish brown sand with silt and gravel		
Sample Comment:	---		

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	21.9	72.0	6.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1 in	25.00	100		
0.75 in	19.00	96		
0.5 in	12.50	88		
0.375 in	9.50	87		
#4	4.75	78		
#10	2.00	65		
#20	0.85	49		
#40	0.42	30		
#60	0.25	18		
#100	0.15	10		
#200	0.075	6.1		

Coefficients

D ₈₅ = 8.3802 mm	D ₃₀ = 0.4196 mm
D ₆₀ = 1.5382 mm	D ₁₅ = 0.2052 mm
D ₅₀ = 0.9006 mm	D ₁₀ = 0.1484 mm
C _u = 10.365	C _c = 0.771

Classification

ASTM N/A

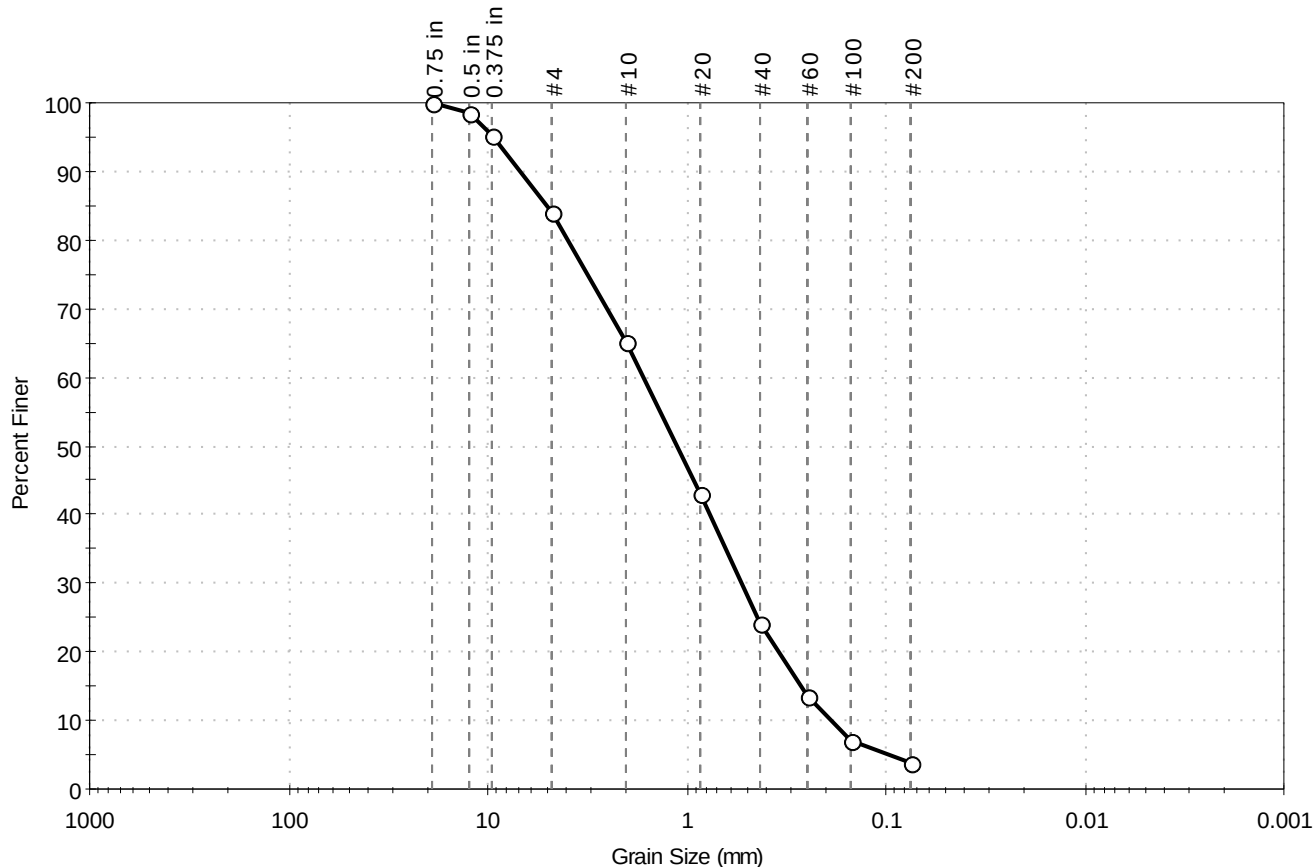
AASHTO Stone Fragments, Gravel and Sand (A-1-b (1))

Sample / Test Description

Sand/Gravel Particle Shape : ANGULAR
Sand/Gravel Hardness : HARD

Client:	Golder Associates		
Project:	Route 1A Culvert Replacement		
Location:	Harrington, ME	Project No:	GTX-306602
Boring ID:	BB-HAR-101	Sample Type:	jar
Sample ID:	6D	Test Date:	06/27/17
Depth :	25-27 ft	Test Id:	414680
Test Comment:	---		
Visual Description:	Moist, dark gray sand with gravel		
Sample Comment:	---		

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	16.1	80.1	3.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.75 in	19.00	100		
0.5 in	12.50	99		
0.375 in	9.50	95		
#4	4.75	84		
#10	2.00	65		
#20	0.85	43		
#40	0.42	24		
#60	0.25	14		
#100	0.15	7		
#200	0.075	3.8		

Coefficients

D ₈₅ = 5.0699 mm	D ₃₀ = 0.5258 mm
D ₆₀ = 1.6321 mm	D ₁₅ = 0.2678 mm
D ₅₀ = 1.1099 mm	D ₁₀ = 0.1879 mm
C _u = 8.686	C _c = 0.902

Classification

ASTM Poorly graded sand with gravel (SP)

AASHTO Stone Fragments, Gravel and Sand (A-1-b (1))

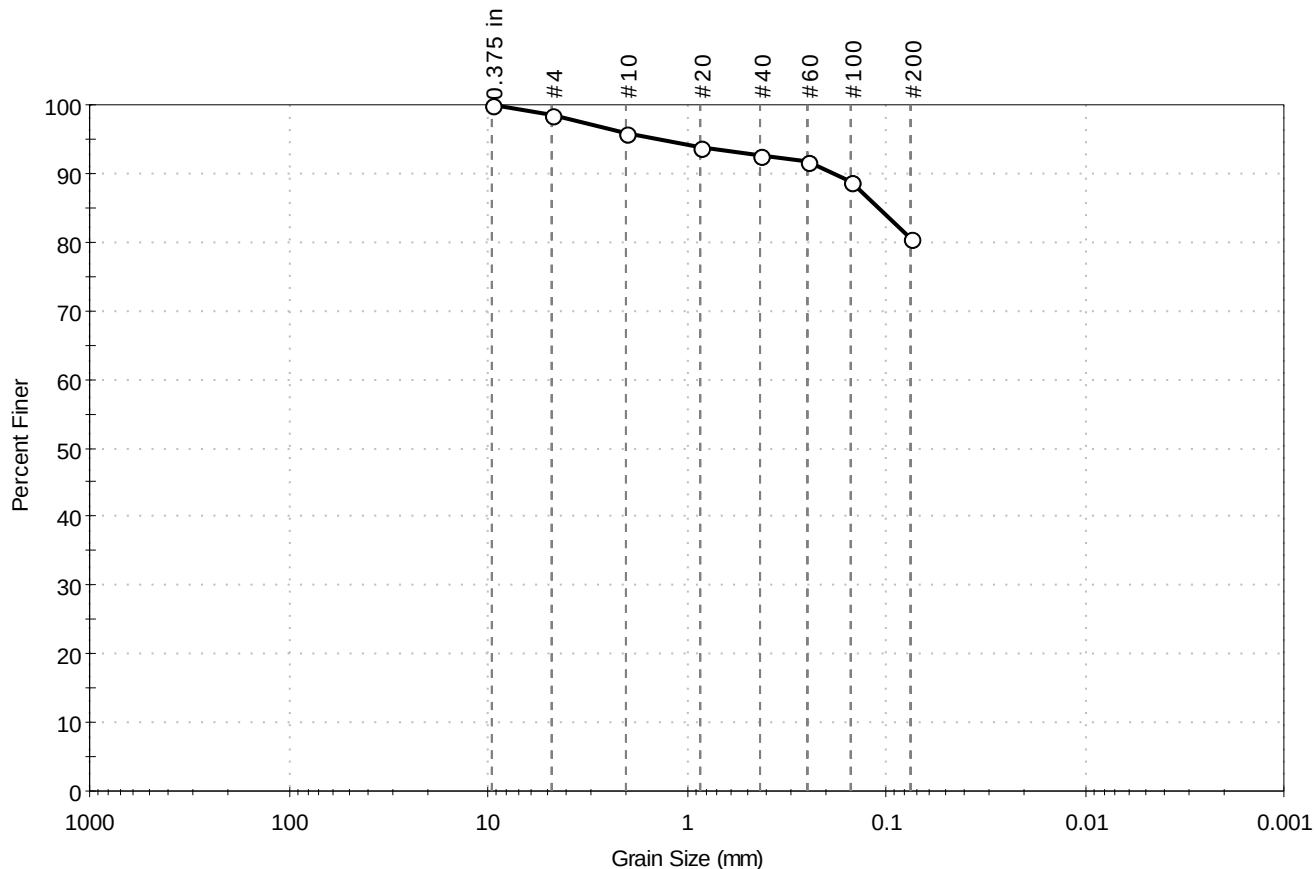
Sample / Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Client:	Golder Associates		
Project:	Route 1A Culvert Replacement		
Location:	Harrington, ME	Project No:	GTX-306602
Boring ID:	BB-HAR-101	Sample Type:	jar
Sample ID:	9D	Test Date:	06/27/17
Depth :	31-33 ft	Test Id:	414681
Test Comment:	---		
Visual Description:	Moist, olive clay with sand		
Sample Comment:	---		

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	1.5	17.9	80.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	99		
#10	2.00	96		
#20	0.85	94		
#40	0.42	93		
#60	0.25	92		
#100	0.15	89		
#200	0.075	81		

Coefficients

$D_{85} = 0.1091$ mm $D_{30} = \text{N/A}$
 $D_{60} = \text{N/A}$ $D_{15} = \text{N/A}$
 $D_{50} = \text{N/A}$ $D_{10} = \text{N/A}$
 $C_u = \text{N/A}$ $C_c = \text{N/A}$

Classification

ASTM Lean clay with sand (CL)

AASHTO Clayey Soils (A-6 (10))

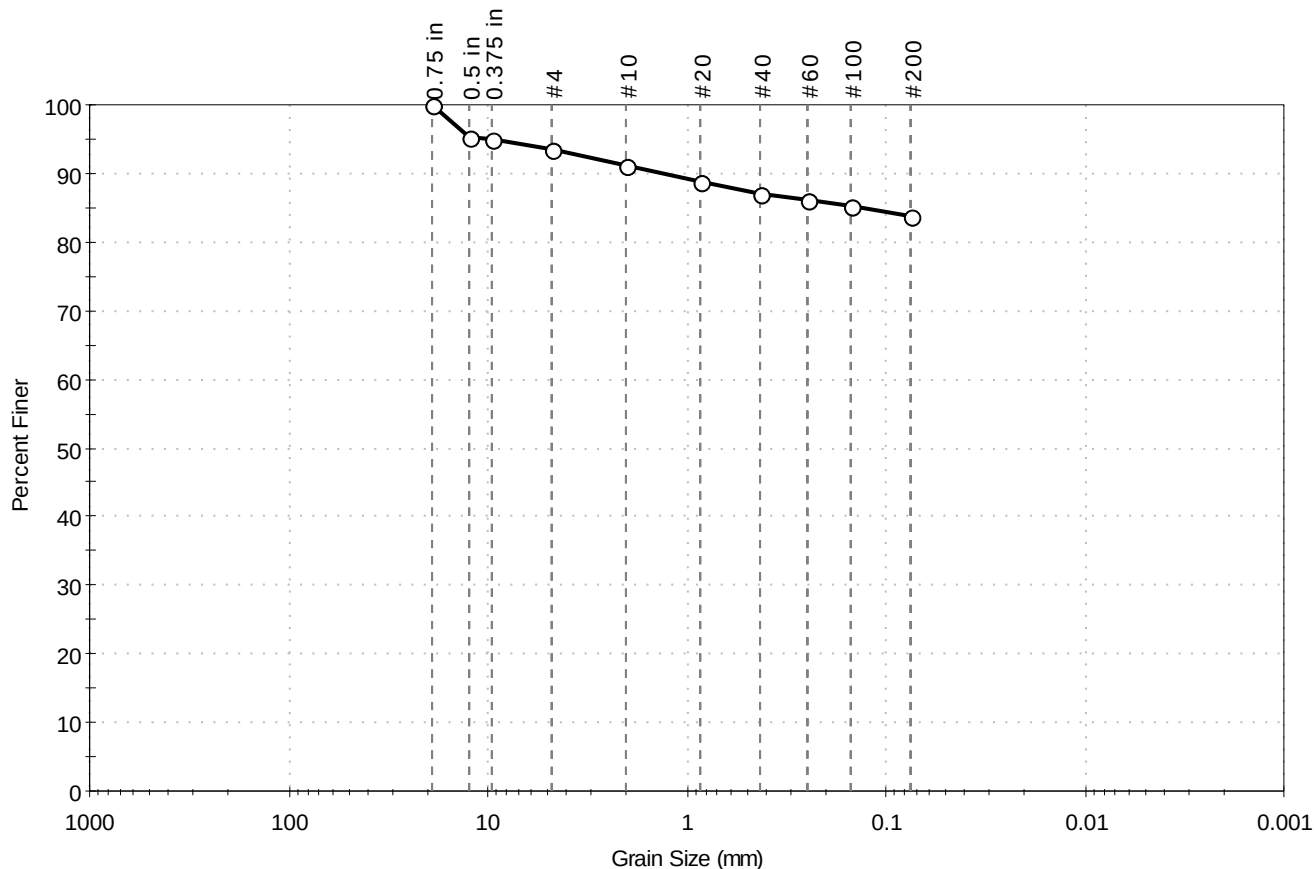
Sample / Test Description

Sand/Gravel Particle Shape : ---

Sand/Gravel Hardness : ---

Client:	Golder Associates		
Project:	Route 1A Culvert Replacement		
Location:	Harrington, ME	Project No:	GTX-306602
Boring ID:	BB-HAR-102	Sample Type:	jar
Sample ID:	3D	Test Date:	06/27/17
Depth :	10-12 ft	Test Id:	414682
Test Comment:	---		
Visual Description:	Moist, grayish brown clay with sand		
Sample Comment:	---		

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	6.5	9.7	83.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.75 in	19.00	100		
0.5 in	12.50	95		
0.375 in	9.50	95		
#4	4.75	93		
#10	2.00	91		
#20	0.85	89		
#40	0.42	87		
#60	0.25	86		
#100	0.15	85		
#200	0.075	84		

Coefficients

D ₈₅ = 0.1408 mm	D ₃₀ = N/A
D ₆₀ = N/A	D ₁₅ = N/A
D ₅₀ = N/A	D ₁₀ = N/A
C _u = N/A	C _c = N/A

Classification

ASTM N/A

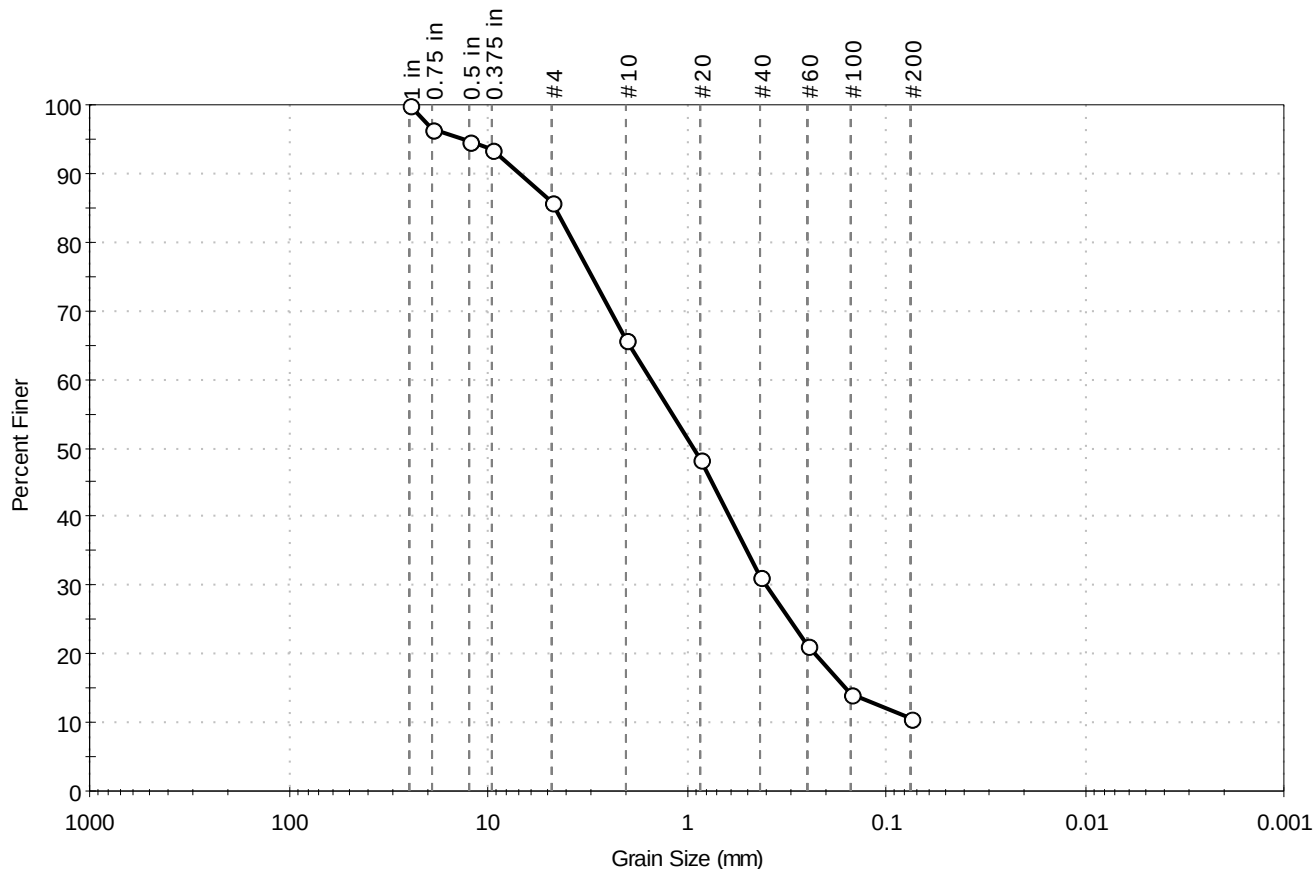
AASHTO Silty Soils (A-4 (0))

Sample / Test Description

Sand/Gravel Particle Shape : ANGULAR
Sand/Gravel Hardness : HARD

Client:	Golder Associates		
Project:	Route 1A Culvert Replacement		
Location:	Harrington, ME	Project No:	GTX-306602
Boring ID:	BB-HAR-102	Sample Type:	jar
Sample ID:	4D	Test Date:	06/27/17
Depth :	15-17 ft	Test Id:	414683
Test Comment:	---		
Visual Description:	Moist, dark grayish brown sand with silt		
Sample Comment:	---		

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	14.1	75.4	10.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1 in	25.00	100		
0.75 in	19.00	96		
0.5 in	12.50	95		
0.375 in	9.50	94		
#4	4.75	86		
#10	2.00	66		
#20	0.85	48		
#40	0.42	31		
#60	0.25	21		
#100	0.15	14		
#200	0.075	10		

Coefficients

D ₈₅ = 4.5721 mm	D ₃₀ = 0.3965 mm
D ₆₀ = 1.5019 mm	D ₁₅ = 0.1583 mm
D ₅₀ = 0.9189 mm	D ₁₀ = N/A
C _u = N/A	C _c = N/A

Classification

ASTM N/A

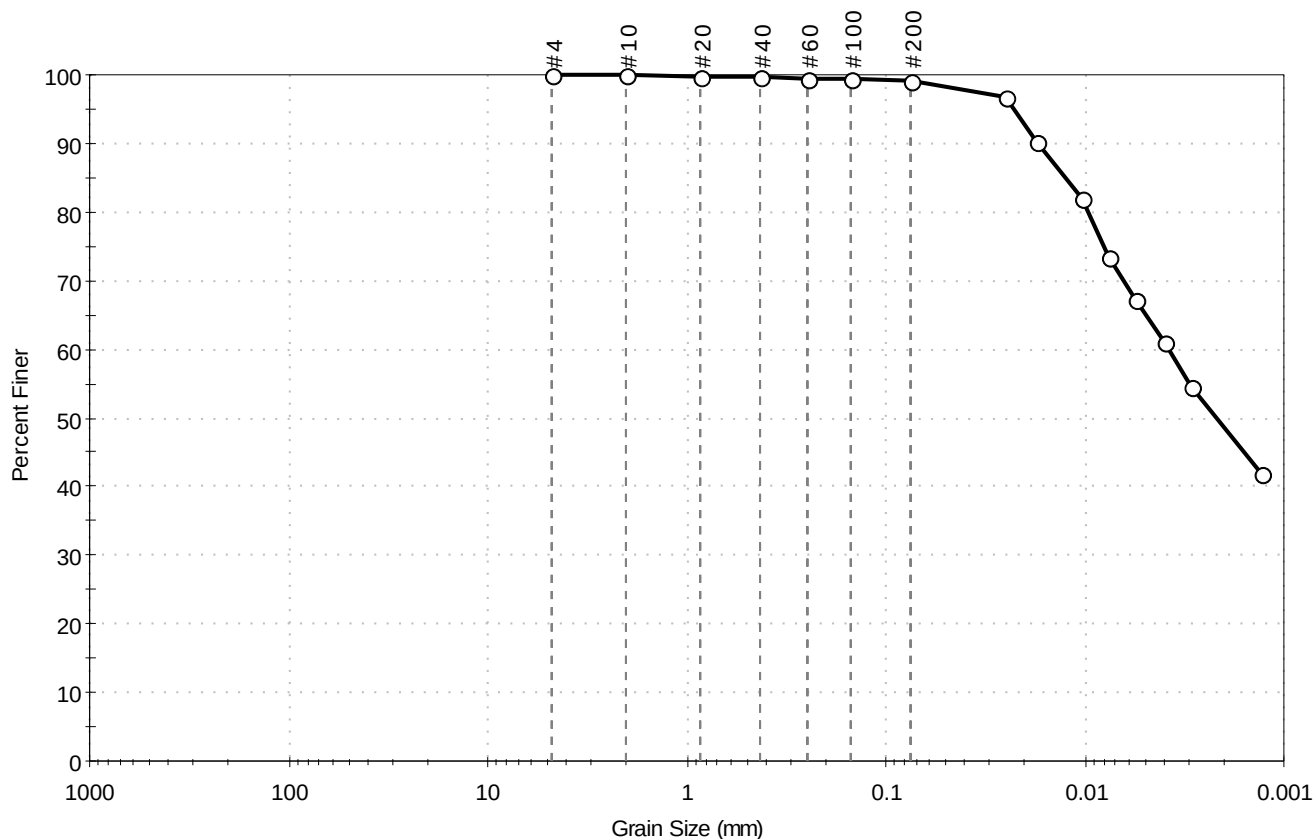
AASHTO Stone Fragments, Gravel and Sand (A-1-b (0))

Sample / Test Description

Sand/Gravel Particle Shape : ANGULAR
Sand/Gravel Hardness : HARD

Client:	Golder Associates	Project No:	GTX-306602
Project:	Route 1A Culvert Replacement		
Location:	Harrington, ME		
Boring ID:	BB-HAR-102	Sample Type:	jar
Sample ID:	6D	Test Date:	06/28/17
Depth :	25-27 ft	Test Id:	414686
Test Comment:	---	Tested By:	jbr
Visual Description:	Moist, olive clay	Checked By:	emm
Sample Comment:	---		

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	0.8	99.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	100		
#60	0.25	99		
#100	0.15	99		
#200	0.075	99		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0251	97		
---	0.0174	90		
---	0.0105	82		
---	0.0076	74		
---	0.0055	67		
---	0.0040	61		
---	0.0029	55		
---	0.0013	42		

Coefficients

D ₈₅ = 0.0126 mm	D ₃₀ = N/A
D ₆₀ = 0.0038 mm	D ₁₅ = N/A
D ₅₀ = 0.0022 mm	D ₁₀ = N/A
C _u = N/A	C _c = N/A

Classification

ASTM N/A

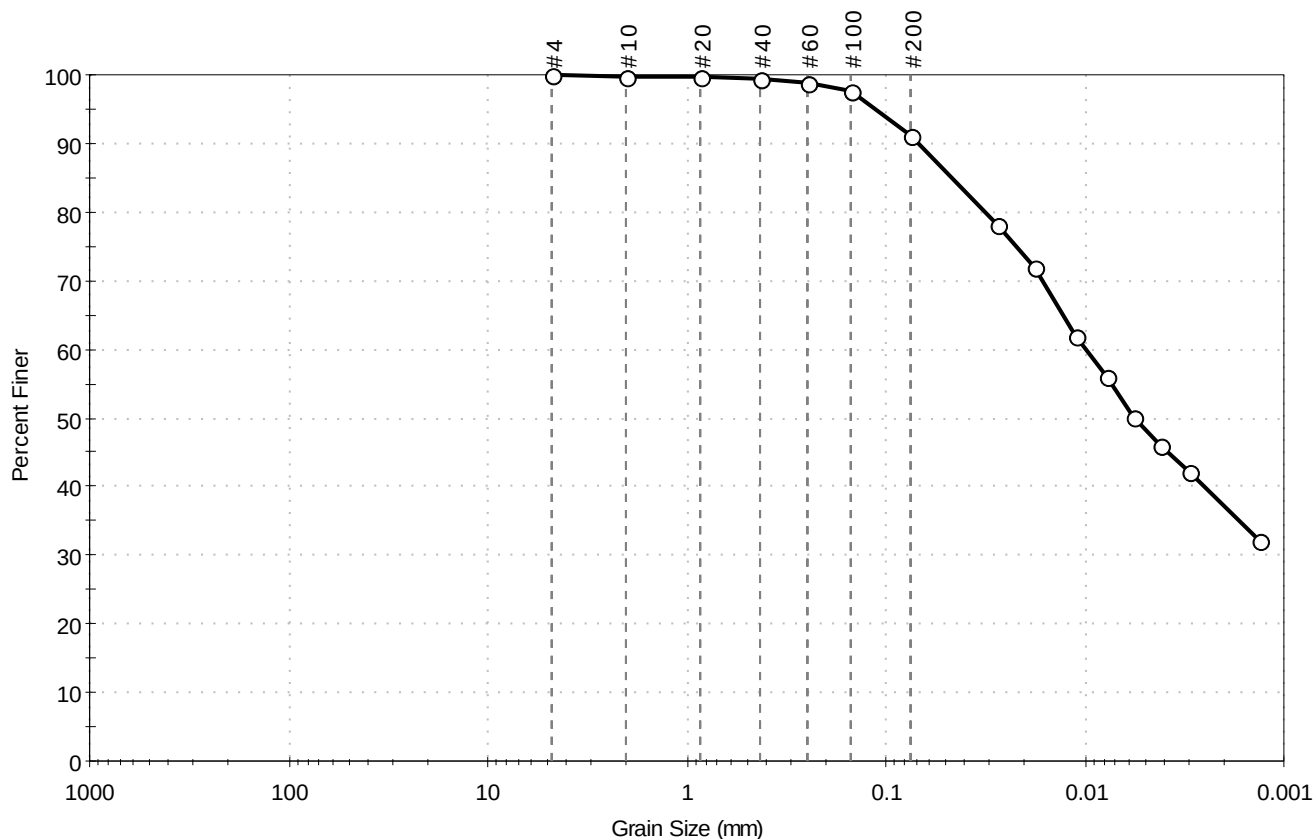
AASHTO Silty Soils (A-4 (0))

Sample / Test Description

Sand/Gravel Particle Shape : ---
 Sand/Gravel Hardness : ---
 Dispersion Device : Apparatus A - Mech Mixer
 Dispersion Period : 1 minute
 Specific Gravity : 2.65
 Separation of Sample: #200 Sieve

Client:	Golder Associates		
Project:	Route 1A Culvert Replacement		
Location:	Harrington, ME	Project No:	GTX-306602
Boring ID:	BB-HAR-102	Sample Type:	jar
Sample ID:	10D	Test Date:	06/28/17
Depth :	33-35 ft	Test Id:	414687
Test Comment:	---		
Visual Description:	Moist, olive clay		
Sample Comment:	---		

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	9.0	91.0

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	100		
#40	0.42	99		
#60	0.25	99		
#100	0.15	98		
#200	0.075	91		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0273	78		
---	0.0179	72		
---	0.0111	62		
---	0.0079	56		
---	0.0058	50		
---	0.0042	46		
---	0.0030	42		
---	0.0013	32		

Coefficients

$D_{85} = 0.0468 \text{ mm}$ $D_{30} = \text{N/A}$
 $D_{60} = 0.0098 \text{ mm}$ $D_{15} = \text{N/A}$
 $D_{50} = 0.0057 \text{ mm}$ $D_{10} = \text{N/A}$
 $C_u = \text{N/A}$ $C_c = \text{N/A}$

Classification

ASTM N/A

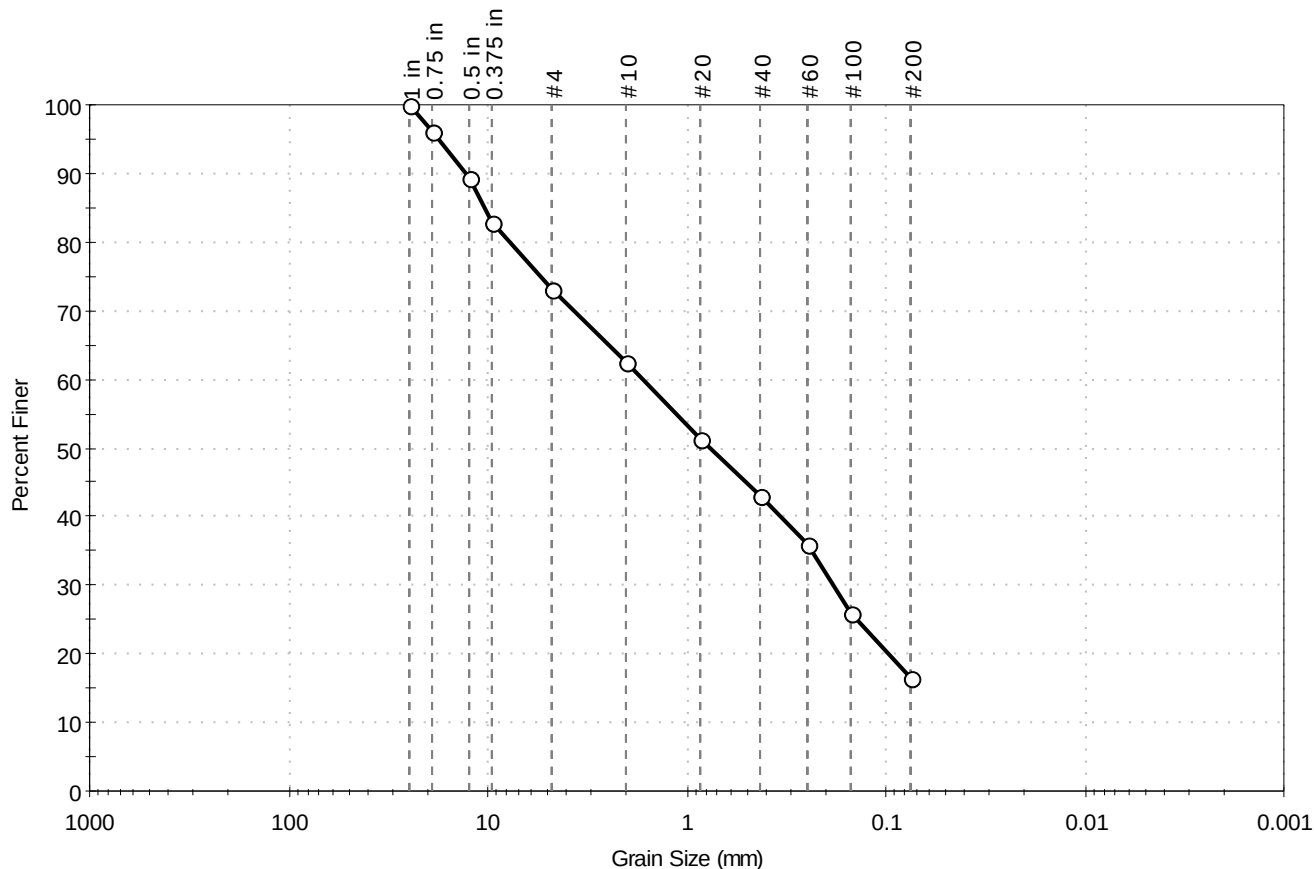
AASHTO Silty Soils (A-4 (0))

Sample / Test Description

Sand/Gravel Particle Shape : ---
 Sand/Gravel Hardness : ---
 Dispersion Device : Apparatus A - Mech Mixer
 Dispersion Period : 1 minute
 Specific Gravity : 2.65
 Separation of Sample: #200 Sieve

Client:	Golder Associates		
Project:	Route 1A Culvert Replacement		
Location:	Harrington, ME	Project No:	GTX-306602
Boring ID:	BB-HAR-102	Sample Type:	jar
Sample ID:	12D	Test Date:	06/27/17
Depth :	40-42 ft	Test Id:	414685
Test Comment:	---		
Visual Description:	Moist, light gray silty sand with gravel		
Sample Comment:	---		

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	26.9	56.5	16.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1 in	25.00	100		
0.75 in	19.00	96		
0.5 in	12.50	89		
0.375 in	9.50	83		
#4	4.75	73		
#10	2.00	63		
#20	0.85	51		
#40	0.42	43		
#60	0.25	36		
#100	0.15	26		
#200	0.075	17		

Coefficients

D ₈₅ = 10.3608 mm	D ₃₀ = 0.1837 mm
D ₆₀ = 1.6521 mm	D ₁₅ = N/A
D ₅₀ = 0.7656 mm	D ₁₀ = N/A
C _u = N/A	C _c = N/A

Classification

ASTM N/A

AASHTO Stone Fragments, Gravel and Sand (A-1-b (0))

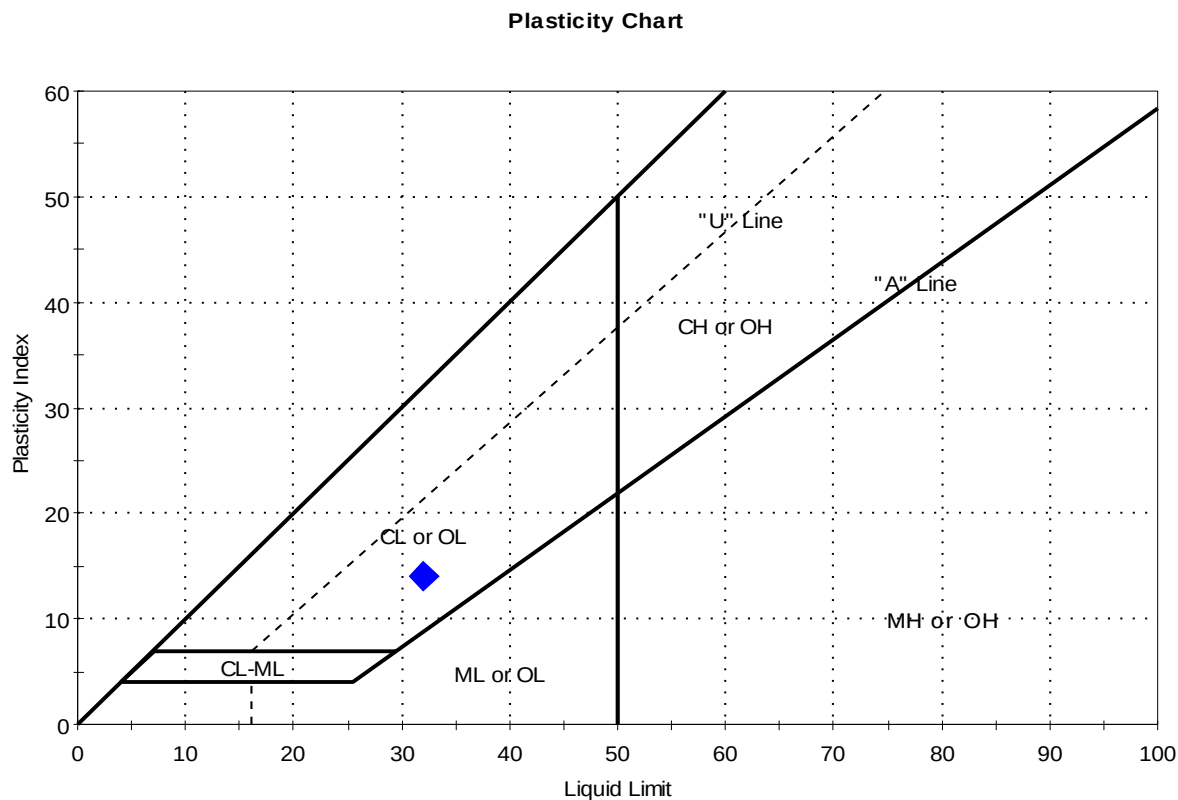
Sample / Test Description

Sand/Gravel Particle Shape : ANGULAR
Sand/Gravel Hardness : HARD



Client:	Golder Associates	Project No:	GTX-306602
Project:	Route 1A Culvert Replacement		
Location:	Harrington, ME		
Boring ID:	BB-HAR-101	Sample Type:	jar
Sample ID:	9D	Test Date:	06/28/17
Depth :	31-33 ft	Test Id:	414688
Test Comment:	---	Tested By:	cam
Visual Description:	Moist, olive clay with sand	Checked By:	emm
Sample Comment:	---		

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content, %	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	9D	B-HAR-10	31-33 ft	25	32	18	14	0.5	Lean clay with sand (CL)

Sample Prepared using the WET method

7% Retained on #40 Sieve

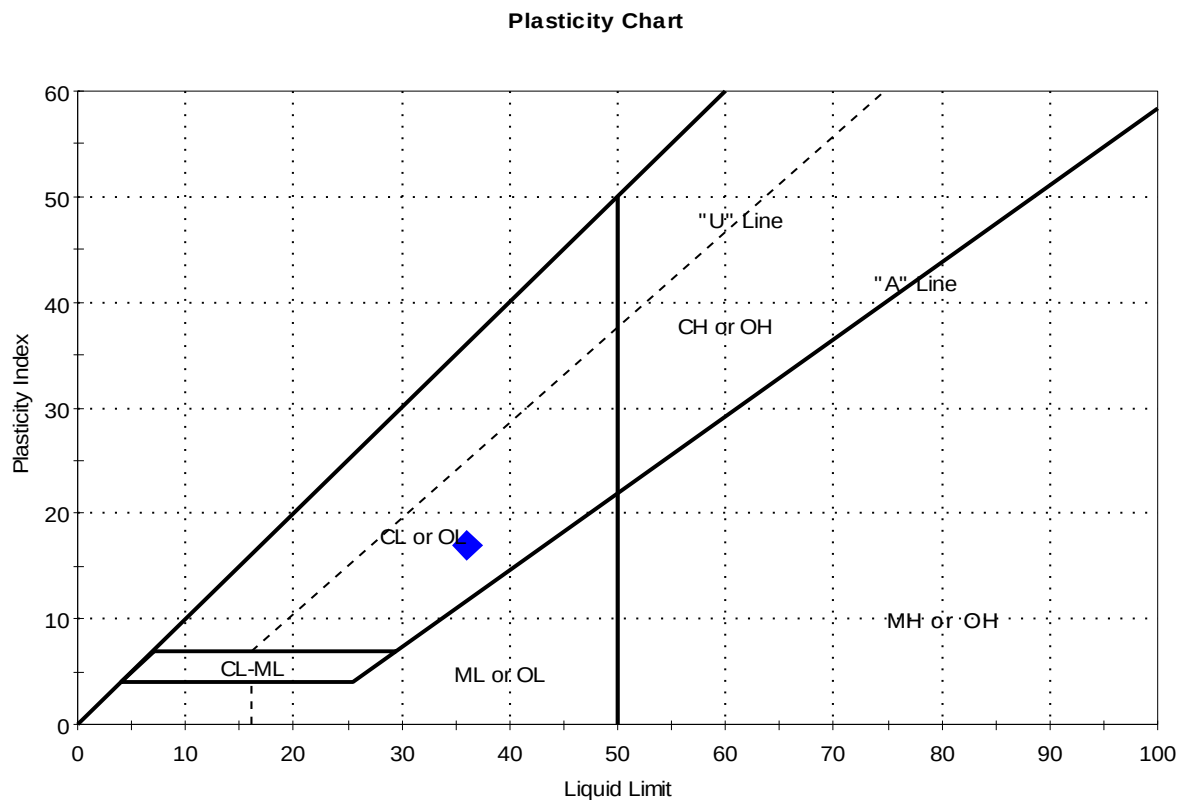
Dry Strength: VERY HIGH

Dilatancy: SLOW

Toughness: LOW

Client:	Golder Associates	Project No:	GTX-306602
Project:	Route 1A Culvert Replacement		
Location:	Harrington, ME		
Boring ID:	BB-HAR-102	Sample Type:	jar
Sample ID:	9D	Test Date:	06/28/17
Depth:	31-33 ft	Test Id:	414689
Test Comment:	---	Tested By:	cam
Visual Description:	Moist, olive clay	Checked By:	emm
Sample Comment:	---		

Atterberg Limits - ASTM D4318



Symbol	Sample ID	Boring	Depth	Natural Moisture Content, %	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Soil Classification
◆	9D	B-HAR-10	31-33 ft	31	36	19	17	0.7	

Sample Prepared using the WET method

Dry Strength: VERY HIGH

Dilatancy: SLOW

Toughness: LOW



Client:	Golder Associates		
Project:	Route 1A Culvert Replacement		
Location:	Harrington, ME	Project No:	GTX-306602
Boring ID:	BB-HAR-101	Sample Type:	jar
Sample ID:	Run 1	Test Date:	06/27/17
Depth :	50.3-51.3 ft	Test Id:	414690
Test Comment:	---		
Visual Description:	See photograph(s)		
Sample Comment:	---		

Bulk Density and Compressive Strength of Rock Core Specimens by ASTM D7012 Method C

Boring ID	Sample Number	Depth	Bulk Density, pcf	Compressive strength, psi	Failure Type	Meets ASTM D4543	Note(s)
BB-HAR-101	Run 1	50.45-50.82 ft	165	27124	1	Yes	---

Notes: Density determined on core samples by measuring dimensions and weight and then calculating.
All specimens tested at the approximate as-received moisture content and at standard laboratory temperature.
The axial load was applied continuously at a stress rate that produced failure in a test time between 2 and 15 minutes.
Failure Type: 1 = Intact Material Failure; 2 = Discontinuity Failure; 3 = Intact Material and Discontinuity Failure
(See attached photographs)

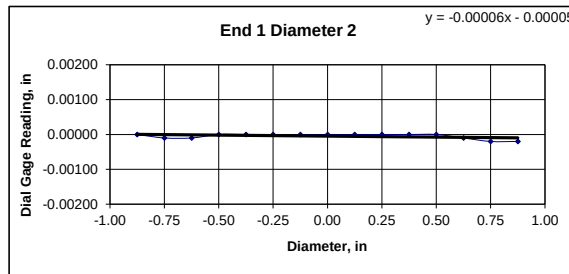
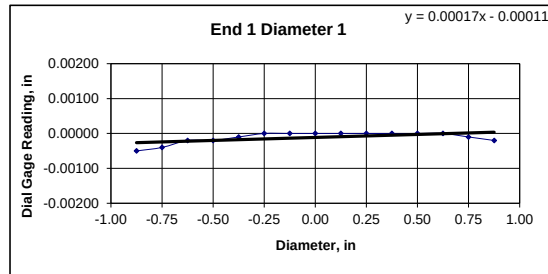


Client:	Golder Associates	Test Date:	6/27/2017
Project Name:	Route 1A Culvert Replacement	Tested By:	rlc
Project Location:	Harrington, ME	Checked By:	jsc
GTX #:	306602		
Boring ID:	BB-HAR-101		
Sample ID:	Run 1		
Depth:	50.45-50.82 ft		
Visual Description:	See photographs		

UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

BULK DENSITY				DEVIATION FROM STRAIGHTNESS (Procedure S1)	
	1	2	Average	Maximum gap between side of core and reference surface plate: Is the maximum gap $\leq$ 0.02 in.? YES	
Specimen Length, in:	4.47	4.48	4.48	Maximum difference must be $<$ 0.020 in. Straightness Tolerance Met? YES	
Specimen Diameter, in:	1.99	1.99	1.99		
Specimen Mass, g:	603.58				
Bulk Density, lb/ft ³ :	165	Minimum Diameter Tolerance Met? YES			
Length to Diameter Ratio:	2.2	Length to Diameter Ratio Tolerance Met? YES			

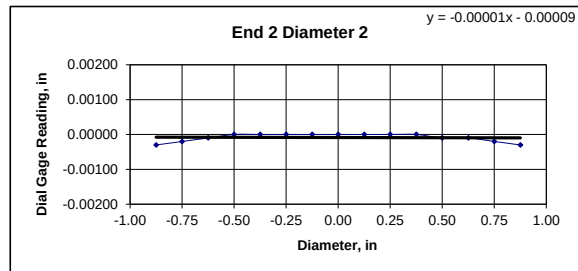
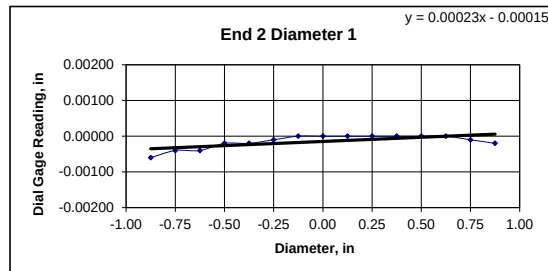
END FLATNESS AND PARALLELISM (Procedure FP1)															
END 1	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00050	-0.00040	-0.00020	-0.00020	-0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	-0.00010	-0.00020
Diameter 2, in (rotated 90°)	0.00000	-0.00010	-0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	-0.00020	-0.00020
Difference between max and min readings, in: 0° = 0.00050 90° = 0.00020															
END 2	-0.875	-0.750	-0.625	-0.500	-0.375	-0.250	-0.125	0.000	0.125	0.250	0.375	0.500	0.625	0.750	0.875
Diameter 1, in	-0.00060	-0.00040	-0.00040	-0.00020	-0.00020	-0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	-0.00010	-0.00020
Diameter 2, in (rotated 90°)	-0.00030	-0.00020	-0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	-0.00010	-0.00010	-0.00020	-0.00030
Difference between max and min readings, in: 0° = 0.0006 90° = 0.0003 Maximum difference must be < 0.0020 in. Difference = ± 0.00030															
Flatness Tolerance Met? YES															



DIAMETER 1

End 1:		
Slope of Best Fit Line	0.00017	
Angle of Best Fit Line:	0.00974	
End 2:		
Slope of Best Fit Line	0.00023	
Angle of Best Fit Line:	0.01318	
Maximum Angular Difference:	0.00344	

Parallelism Tolerance Met? YES
Spherically Seated



DIAMETER 2

End 1:		
Slope of Best Fit Line	0.00006	
Angle of Best Fit Line:	0.00344	
End 2:		
Slope of Best Fit Line	0.00001	
Angle of Best Fit Line:	0.00057	
Maximum Angular Difference:	0.00286	

Parallelism Tolerance Met? YES
Spherically Seated

PERPENDICULARITY (Procedure P1)						(Calculated from End Flatness and Parallelism measurements above)	
END 1		Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?	Maximum angle of departure must be $\leq$ 0.25°
Diameter 1, in	0.00050	1.990	0.00025	0.014	YES		
Diameter 2, in (rotated 90°)	0.00020	1.990	0.00010	0.006	YES		Perpendicularity Tolerance Met? YES
END 2							
Diameter 1, in	0.00060	1.990	0.00030	0.017	YES		
Diameter 2, in (rotated 90°)	0.00030	1.990	0.00015	0.009	YES		

Client:	Golder Associates
Project Name:	Route 1A Culvert Replacement
Project Location:	Harrington, ME
GTX #:	306602
Test Date:	6/27/2017
Tested By:	rlc
Checked By:	jsc
Boring ID:	BB-HAR-101
Sample ID:	Run 1
Depth, ft:	50.45-50.82



After cutting and grinding



After break

APPENDIX D
CALCULATIONS



SUBJECT: Settlement of Existing Culvert
Project Number: 1772220
Project Name: Route 1A Culvert Replacement, Harrington, ME
Prepared by: CJS/TRM
Date: 8/2/2017
Checked by: CJS
Reviewed by: MCM

Objective:

To calculate the bearing resistance of the proposed culvert for the strength limit state and the service limit state and settlement at the service limit state.

Method:

Use the method described in the AASHTO LRFD Bridge Design Specifications, 7th Ed, 2014. Calculate the factored bearing resistance for both the strength limit state and the service limit state. Estimate settlement at the service state using Hough Method and consolidation theory.

References:

1. AASHTO LRFD Bridge Design Specifications, 7th Ed, 2014 (LRFD)
2. GEOTECHNICAL ENGINEERING CIRCULAR NO. 6: Shallow Foundations. FHWA: September 2002 (FHWA).
3. MEDOT. (2003). "Bridge Design Guide", includes updates through (2014).

Assumptions:

1. Ground water table is at ~ El. 5. $D_w = 17.5$ ft
2. Assume that the consolidation is from recompression with in the clay layer due to low loading from the culvert replacement. Clay consolidation parameter, $C_{re} = 0.02$. Value based on published data and internal database of consolidation parameters for similar medium stiff Presumpscot Formation clay.
3. Ground surface (i.e. depth = 0ft) is at ~ El. 22.5.
4. Approximate bottom of culvert box elevation is at ~ El. -5'.
5. Use the soil properties and thicknesses shown in the attached sketch.
6. Loading ($\Delta\sigma_v$) is taken from PB calculation titled, "Comparison of DL (Existing vs. Proposed)," dated 8/1/2017 as Proposed pressure = 2.017ksf minus Existing pressure 1.889ksf - $\Delta\sigma_v = 0.128$ ksf.
7. Proposed culvert will be a 4-sided box culvert - 16ft span, 13ft rise, and 132ft long.

Calculations:

- A. Determine the bearing resistance at the strength limit state. Use Article 10.6.3, Strength Limit Design, from the AASHTO LRFD Bridge

Assume fill below footing will be compacted Underdrain Backfill Material Type C (703.22). Use properties from MEDOT Bridge Design Guide. Assume second layer is presumpscot clay with strength parameters obtained from historical and 2017 in situ vane shear testing. Selected values are summarized below:

ϕ_f = internal friction angle, deg
 c = cohesion for Presumpscot material, psf

	Internal Friction Angle, ϕ_f (°)	Cohesion (ksf)	Unit weight, γ (kcf)
Compacted Fill Below Footing	36	0	0.135
Presumpscot Clay	0	1.200	0.120

H = thickness of upper soil layer below footing (compacted fill), ft $H = 1.0$ ft.

According to LRFD Article 10.6.3.1.2d, when the soil profile contains a second soil layer of different properties within a distance below the footing less than H_{crit} , then the bearing resistance needs to be calculated for a two-layered soil system.

$$H_{crit} = \frac{(3 * B_f) \ln \left(\frac{q_1}{q_2} \right)}{2 \left(1 + \frac{B_f}{L_f} \right)} \quad \text{Eq 10.6.3.1.2d-1}$$

where:

- q_1 = nominal bearing resistance of a footing supported by the upper soil assuming the layer is infinitely thick
 q_2 = nominal bearing resistance of a fictitious footing supported on the surface of the second layer

Layer 1 - Structural Fill Below Footing

Calculate q_1 :

$$q_1 = \gamma_1 D_{f1} N_{qm1} C_{wq1} + \frac{1}{2} \gamma_1 B_f N_{\gamma m1} C_{w\gamma}$$

where:

B_f = footing width, ft

γ_1 = total unit weight, kcf

ϕ_{f1}^* = effective friction angle (reduced for failure mode)

D_f = footing embedment depth, ft

L_f = footing length, ft

$$N_{qm1} = N_{q1} s_q d_q$$

N_{q1} = surcharge factor, Table 10.6.3.1.2a-1

$$s_q = 1 + \left(\frac{B_f}{L_f} \tan \phi_{f1} \right)$$

d_q = depth correction factor, Table 10.6.3.1.2a-4

$$N_{\gamma m1} = N_{\gamma q1} s_\gamma$$

$N_{\gamma1}$ = unit weight factor, Figure 10.6.3.1.2a-1

$$s_\gamma = 1 - 0.4 \left(\frac{B_f}{L_f} \right)$$

D_w = depth to water, ft

C_{wq} = coefficient of groundwater, FHWA eq 5-9

$$C_{wq} = 0.5 + 0.5 \left(\frac{D_w}{D_f} \right) \leq 1.0$$

$C_{w\gamma}$ = coefficient of groundwater, FHWA eq 5-10

$$C_{w\gamma} = 0.5 + 0.5 \left(\frac{D_w}{1.5B_f + D_f} \right) \leq 1.0$$

Fill	
B_f =	16 ft
γ_1 =	0.135 kcf
ϕ_{f1}^* =	36 °
D_f =	27.7 ft
L_f =	132 ft

$$N_{qm1} = 50.9$$

$$N_{q1} = 37.8$$

$$s_q = 1.09$$

$$d_q = 1.24$$

$$53.6$$

$$N_{\gamma1} = 56.3$$

$$s_\gamma = 0.95$$

$$D_w = 17.5$$

$$C_{wq} = 0.82$$

$$C_{w\gamma} = 0.67$$

$$q_1 = 194.1 \text{ ksf}$$

Layer 2 - Presumpscot Clay

Calculate q_2 :

$$q_2 = c N_{cm2} + \gamma_2 D_{f2} N_{qm2} C_{wq2} + \frac{1}{2} \gamma_2 B_f N_{\gamma m2} C_{w\gamma}$$

where:

B_f = footing width, ft

γ_2 = total unit weight, kcf

ϕ_{f2}^* = effective friction angle (reduced for failure mode)

c^* = effective cohesion (reduced for failure mode), ksf

D_f = footing embedment depth = $D_{f(1)} + H$, ft

L_f = footing length, ft

$$N_{qm2} = N_{q2} s_q d_q$$

N_{q2} = surcharge factor, Table 10.6.3.1.2a-1

$$s_q = 1 + \left(\frac{B_f}{L_f} \tan \phi_{f2} \right)$$

Presumpscot	
B_f =	16 ft - Based on drawing
γ_1 =	0.120 kcf
ϕ_{f1}^* =	0 °
c^* =	1.200 ksf
D_f =	28.7 ft
L_f =	132 ft

$$N_{qm2} = 1.2$$

$$N_{q2} = 1.0$$

$$s_q = 1.00$$

d_q = depth correction factor, Table 10.6.3.1.2a-4

$$d_q = 1.24$$

$$N_{\gamma m 2} = N_{\gamma 2} s_{\gamma}$$

$$N_{\gamma m 2} = 0.0$$

$N_{\gamma 2}$ = unit weight factor, Figure 10.6.3.1.2a-1

$$N_{\gamma 2} = 0.0$$

$$s_{\gamma} = 1 - 0.4 \left(\frac{B_f}{L_f} \right)$$

$$s_{\gamma} = 1.00$$

D_w = depth to water, ft

$$D_w = 17.5 \text{ ft}$$

C_{wq} = coefficient of groundwater, FHWA eq 5-9

$$C_{wq} = 0.5 + 0.5 \left(\frac{D_w}{D_f} \right) \leq 1.0$$

$$C_{wq} = 0.81$$

$C_{w\gamma}$ = coefficient of groundwater, FHWA eq 5-10

$$C_{w\gamma} = 0.5 + 0.5 \left(\frac{D_w}{1.5B_f + D_f} \right) \leq 1.0$$

$$C_{w\gamma} = 0.67$$

$$N_{c m 2} = N_c s_c$$

$$N_{c m 2} = 5.3$$

N_{c2} = cohesion factor, Table 10.6.3.1.2a-1

$$N_{c2} = 5.1$$

$$s_c = 1 + \left(\frac{B}{5L} \right)$$

$$s_c = 1.02$$

$$q_2 = 9.8 \text{ ksf}$$

Calculate H_{crit}

$$H_{crit} = \frac{(3 * B_f) \ln \left(\frac{q_1}{q_2} \right)}{2 \left(1 + \frac{B_f}{L_f} \right)}$$

Eq 10.6.3.1.2d-1

$$H_{crit} = 64.0 \text{ ft}$$

Is H_{crit} less than H? No

If H_{crit} is less than H, then a two-layer system does not apply.

Calculate q_n for a two layer system

$$q_n = q_2 e^{2 \left[1 + \left(\frac{B_f}{L_f} \right) \right] K \tan \phi_{f1} \left(\frac{H}{B} \right)}$$

Eq 10.6.3.1.2f-1

where:

$$K = \frac{1 - \sin^2 \phi_{f1}}{1 + \sin^2 \phi_{f1}}$$

Eq 10.6.3.1.2f-2

$$K = 0.5$$

$$q_n = 10.2 \text{ ksf}$$

q_n for two-layer system: use $q_n = q_1$ if H_{crit} is less than H, otherwise use q_n calculated for two-layers.

$$q_n = 10.2 \text{ ksf}$$

Apply resistance factor:

$$q_R = \phi_b q_n$$

ϕ_b = resistance factor specified in Article 10.5.5.2.2 =
(Table 10.5.5.2.2-1: Semi-empirical methods, all soils)

$$\phi_b = 0.45$$

$$q_{R-2} (\text{ksf}) = 4.61$$

B. Estimate Bearing Capacity at Service Limit

Presumptive Bearing Resistance for Service Limit State (LRFD Table C10.6.2.6.1-1):

Type of bearing material: Silty Clay with trace Sand

In Situ Consistency: Medium Stiff (N = 5-8, in situ vane data: 800-2000psf)

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

Bearing Resistance: Range 2-6 ksf, Use 4ksf

Factored bearing Resistance = 4ksf * 1.0 = **4ksf**

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

C. Estimate Settlement

Use consolidation theory to estimate settlement of the Presumpscot clay layer (Layer 1). Use the Hough method to estimate settlement of the Presumpscot Sand layer beneath the clay (Layer 2).

*Assume clay is in recompression. Use $C_{re} = 0.02$ as indicated above.

Determine C' and σ'_{v0} for in situ existing soil. Use FHWA Figure 5-19 . Assume a C' for Layer 2 based on the "well graded silty SAND and GRAVEL." (N=15-61, N_{ave} =31. Use N=15, very conservative)

	Upper fill Thickness (ft)	Unit Weight Upper Fill (ksf)	Water Table Thickness Above Culvert Bottom (ft)	Unit Weight of Water (ksf)	σ'_{v0} (ksf)
Stress due to existing soil above proposed culvert bottom	27.68	0.125	10.18	0.0624	2.82

Layer	Depth Below Culvert: (ft)	Layer Thickness (ft)	Z (ft)	$(N_1)_{60}$ avg	C'	Unit Weight of Layer (ksf)	σ'_{v0} (ksf)
Presumpscot Clay 1	0.0-7.0	7	3.5	Not required for clay consolidation analysis		0.12	3.03
Presumpscot Sand 2	7.0-21.0	14	14	15	65	0.12	3.63

Calculate the total settlement of the clays (Layer1) using the consolidation theory:

General Equation (Holtz & Kovacs, 1981)

$$\Delta H_i = C_{re} H_c \log \frac{\sigma'_p}{\sigma'_{v0}} + C_{ce} H_c \log \frac{\sigma'_{v0} + \Delta \sigma_v}{\sigma'_p} \quad \text{for overconsolidated clay, } \sigma'_{v0} + \Delta \sigma_v > \sigma'_p$$

$$\Delta H_i = C_{re} H_c \log \frac{\sigma'_{v0} + \Delta \sigma_v}{\sigma'_{v0}} \quad \text{for overconsolidated clay, } \sigma'_{v0} + \Delta \sigma_v \leq \sigma'_p$$

**use this case for Layer 1.*

$$\Delta H_i = C_{ce} H_c \log \frac{\sigma'_{v0} + \Delta \sigma_v}{\sigma'_{v0}} \quad \text{for normally consolidated clay}$$

$$\Delta \sigma_v = (\Delta \sigma_v) / q \times q$$

where:

H_c = initial height of layer i, ft

$\Delta \sigma_v$ = surcharge load, psf

σ'_{v0} = in situ vertical effective stress, psf

$\sigma'_{v0} + \Delta \sigma_v$ = (check against σ'_p to select equation)

σ'_p = preconsolidated stress, psf

C_{re} = modified recompression index

C_{ce} = modified compression index

Layer 1 - Presumpscot Clay	
H _c	7
Δσ _v	0.128
σ' _{v0}	3.03
σ' _{v0} + Δσ _v	3.15
C _{TE}	0.02
H ₁	0.003
	0.03

ft
ksf
ksf
ksf
ft
in

Calculate the total settlement of the Presumpscot Sand (Layer 2) using the Hough method:

General Equation (FHWA Eq. 5-24)

$$\Delta H_i = H_c \frac{1}{C'} \log\left(\frac{\sigma'_{v0} + \Delta\sigma_v}{\sigma'_{v0}}\right)$$

where:

ΔH_i = settlement in each layer, ft

H_c = initial height of layer i, ft

C' = bearing capacity index, FHWA Figure 5-19

Δσ_v = (Δσ_v)/q x q (conservatively assume this factor = 1.0 for this calculation)

Layer 2 - Presumpscot Sand	
H _c	14
Δσ _v	0.128
σ' _{v0}	3.63
σ' _{v0} + Δσ _v	3.76
C'	65
H ₂	0.003
	0.04

ft
ksf
ksf
ksf
ft
in

Estimated Settlement	
Layer	ΔH _i (in)
1	0.03
2	0.04
Total Settlement: (in)	0.07

Conclusions:

For the proposed 16ftx132ft four sided box culvert:

the bearing capacity for the strength limit state is 4.61 ksf

the presumptive bearing capacity for the service limit state is 4.0 ksf (at 1inch of settlement)

the estimated settlement for the provided culvert loads is less than 0.1 inch.



SUBJECT: Subgrade Modulus
Project Number: 1772220
Project Name: Route 1A Culvert Replacement - Harrington, ME
Prepared by: TRM
Date: 8/3/2017
Checked by: CJS
Reviewed by: 

Objective:

Determine the subgrade modulus.

Method:

1) Use Figure 8-3 from FHWA, Table 6.2 from Das, and Table 7.1 from Canadian Geotechnical Society.

References:

1. GEOTECHNICAL ENGINEERING CIRCULAR NO. 6: Shallow Foundations. FHWA: September 2002 (FHWA).
2. Das, Braja M. Principles of Foundation Engineering, 7th ed. Thomson Brooks/Cole, 2003.
3. Foundation Engineering Manual, 4th Edition. (2006). Canadian Geotechnical Society
4. Golder Associates Inc., (2017). Geotechnical Boring Logs BB-HAR-101, BB-HAR-102.

Assumptions:

1. Assume slab design section bears on medium stiff clay (Presumpscot) for upper 7 feet and Silty Sand and Gravel for the next 14 feet above bedrock.

Calculations: **A.) Determine the subgrade modulus for Layer 1 Presumpscot Clay.**

According to Das, the value of the subgrade modulus, k , also known as the coefficient of subgrade reaction, is not a constant for a given soil type and depends on several factors, including the size of the foundation and the depth of embedment. The subgrade modulus of a 1 square ft bearing plate at the ground surface, k_1 , can be estimated from FHWA Figure 8-3 (Ref 1, Attachment 1).

Based on FHWA Figure 8-3, and the corrected N_{60} blowcounts from Reference 6, the N_{60} values are in the range of 5-12, with an average of 8 for the clay, corresponding to a medium stiff consistency. Field vane data ranges from ~800-2000psf with an average of 1460psf indicating a stiff clay. The suggested k_1 value for a fine grained material with a medium stiff to stiff consistency is therefore 25 tcf = 29 pci.

Table 6.2 from Das includes k_1 values of 40 to 90 lb/in³ for stiff clay.

Table 7.1 from the Canadian Geotechnical Society gives a range of 37 pci to 110 pci for stiff cohesive soils

Based on the values presented above use an average k_1 value of 56 pci for medium stiff to stiff clay.

B) Determine the subgrade modulus for Layer 2 Silty Sand and Gravel.

According to Das, the value of the subgrade modulus, k , also known as the coefficient of subgrade reaction, is not a constant for a given soil type and depends on several factors, including the size of the foundation and the depth of embedment. The subgrade modulus of a 1 square ft bearing plate at the ground surface, k_1 , can be estimated from FHWA Figure 8-3 (Ref 1, Attachment 1).



SUBJECT: Subgrade Modulus

Project Number: 1772220

Project Name: Route 1A Culvert Replacement - Harrington, ME

Prepared by: TRM

Checked by: CJS

Date: 8/3/2017

Reviewed by: *Mum*

Based on FHWA Figure 8-3, and the corrected N_{60} blowcounts from Reference 6, the N_{60} values are in the range of 15-61, with an average of 30 for the silty sand and gravel, corresponding to a medium dense to dense consistency. The suggested k_1 value for a coarse grained material with a medium dense to dense consistency is therefore 175 tcf = 203 pci.

Table 6.2 from Das includes k_1 values of 125 to 145 pci for medium saturated sand and 475 to 550 pci for dense saturated sand. Use higher end of medium dense range due to the inclusion of gravel within the layer and borderline dense consistency.

Table 7.1 from the Canadian Geotechnical Society gives a range of 74 pci to 220 pci for compact sand and 220 to 592 pci for dense sand. Use the higher end of the compact values.

Based on the values presented above use an average k_1 value of 140 pci for medium dense to dense silty sand and gravel.

C) Determine a representative k_1 value for the two layer system.

	k_1 (pci)	Layer thickness (L, ft)
Layer 1: Presumpscot Formation:	56	7
Layer 2: Silty Sand and Gravel:	140	14

Take a weighted arithmetic mean:

$$k_{1ave} = \frac{(k_{1_{layer1}} \times L_{layer1}) + (k_{1_{layer2}} \times L_{layer2})}{L_{layer1} + L_{layer2}}$$

$k_{1ave} =$	112	pci
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Conclusion:

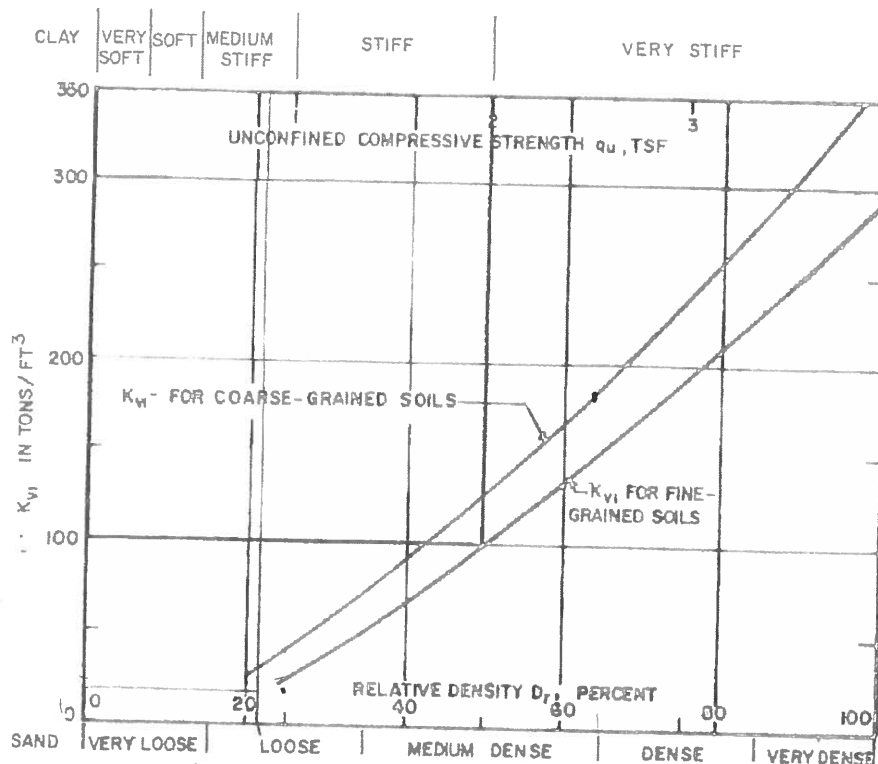
Use an k_1 value of 112 pci for the proposed culvert replacement in Harrington.

Ref. 1

Technical Report Documentation Page

1. Report No. FHWA-SA-02-054	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle GEOTECHNICAL ENGINEERING CIRCULAR NO. 6 Shallow Foundations		5. Report Date September 2002	
		6. Performing Organization Code	
7. Author(s) Robert E. Kimmerling		8. Performing Organization Report No.	
9. Performing Organization Name and Address PanGEO, Inc. 3414 N.E. 55 th Street Seattle, Washington 98105		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No. DTFH61-00-C-00031	
12. Sponsoring Agency Name and Address Office of Bridge Technology Federal Highway Administration HIBT, Room 3203 400 Seventh Street, S.W. Washington, D.C. 20590		13. Type of Report and Period Covered Technical Manual	
		14. Sponsoring Agency Code	
15. Supplementary Notes Contracting Officer's Technical Representative: Chien-Tan Chang (HIBT) FHWA Technical Consultant: Jerry DiMaggio (HIBT)			
16. Abstract This document is FHWA's primary reference of recommended design and procurement procedures for shallow foundations. The Circular presents state-of-the-practice guidance on the design of shallow foundation support of highway bridges. The information is intended to be practical in nature, and to especially encourage the cost-effective use of shallow foundations bearing on structural fills. To the greatest extent possible, the document coalesces the research, development and application of shallow foundation support for transportation structures over the last several decades. Detailed design examples are provided for shallow foundations in several bridge support applications according to both Service Load Design (Appendix B) and Load and Resistance Factor Design (Appendix C) methodologies. Guidance is also provided for shallow foundation applications for minor structures and buildings associated with transportation projects.			
17. Key Words Shallow foundation, spread footing, abutment, mat foundation, bearing capacity, settlement, eccentricity, overturning, sliding, global stability, LRFD		18. Distribution Statement No Restrictions. This document is available to the public from the National Technical Information Service, Springfield, Virginia 22161	
19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages 310	22. Price

Ref 1



DEFINITIONS

ΔH_i = IMMEDIATE SETTLEMENT OF FOOTING
 q = FOOTING UNIT LOAD IN tsf
 B = FOOTING WIDTH

D = DEPTH OF FOOTING BELOW GROUND SURFACE
 K_{vi} = MODULUS OF VERTICAL SUBGRADE REACTION

COARSE-GRAINED SOILS

(MODULUS OF ELASTICITY INCREASING LINEARLY WITH DEPTH)
 SHALLOW FOOTINGS $D \leq B$

FOR $B \leq 20 \text{ FT}$:

$$\Delta H_i = \frac{4 q B^2}{K_{vi} (B+1)^2}$$

FOR $B \geq 40 \text{ FT}$:

$$\Delta H_i = \frac{2 q B^2}{K_{vi} (B+1)^2}$$

INTERPOLATE FOR INTERMEDIATE VALUES OF B

DEEP FOUNDATION $D \geq 5B$

FOR $B \leq 20 \text{ FT}$:

$$\Delta H_i = \frac{2 q B^2}{K_{vi} (B+1)^2}$$

- NOTES: 1. NONPLASTIC SILT IS ANALYZED AS COARSE-GRAINED SOIL WITH MODULUS OF ELASTICITY INCREASING LINEARLY WITH DEPTH.
 2. VALUES OF K_{vi} SHOWN FOR COARSE-GRAINED SOILS APPLY TO DRY OR MOIST MATERIAL WITH THE GROUNDWATER LEVEL AT A DEPTH OF AT LEAST $1.5B$ BELOW BASE OF FOOTING. IF GROUNDWATER IS AT BASE OF FOOTING, USE $K_{vi}/2$ IN COMPUTING SETTLEMENT

Figure 8-3: Modulus of Subgrade Reaction (NAVFAC, 1986a)

Ref 2

where

k = coefficient of subgrade modulus of the rectangular foundation ($L \times B$)
 $k_{(B \times B)}$ = coefficient of subgrade modulus of a square foundation having dimension of $B \times B$

Equation (6.45) indicates that the value of k for a very long foundation with a width B is approximately $0.67k_{(B \times B)}$.

The modulus of elasticity of granular soils increases with depth. Because the settlement of a foundation depends on the modulus of elasticity, the value of k increases with the depth of the foundation.

Table 6.2 provides typical ranges of values for the coefficient of subgrade reaction, $k_{0.3}(k_1)$, for sandy and clayey soils.

For long beams, Vesic (1961) proposed an equation for estimating subgrade reaction, namely,

$$k' = Bk = 0.65 \sqrt[12]{\frac{E_s B^4}{E_F I_F}} \frac{E_s}{1 - \mu_s^2}$$

or

$$k = 0.65 \sqrt[12]{\frac{E_s B^4}{E_F I_F}} \frac{E_s}{B(1 - \mu_s^2)} \quad (6.46)$$

where

E_s = modulus of elasticity of soil

B = foundation width

E_F = modulus of elasticity of foundation material

I_F = moment of inertia of the cross section of the foundation

μ_s = Poisson's ratio of soil

Table 6.2 Typical Subgrade Reaction Values, $k_{0.3}(k_1)$

Soil type	$k_{0.3}(k_1)$	
	MN/m ³	lb/in. ³
Dry or moist sand:		
Loose	8–25	30–90
Medium	25–125	90–450
Dense	125–375	450–1350
Saturated sand:		
Loose	10–15	35–55
Medium	35–40	125–145
Dense	130–150	475–550
Clay:		
Stiff	10–25	40–90
Very stiff	25–50	90–185
Hard	>50	>185

Ref. 3

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place during excavation and placement of steel reinforcing, and limitations of the theory, only approximate indications of the magnitude of the coefficient of subgrade reaction can be given. In addition, because the stresses from the raft affect the soil to considerable depth below bearing level, longer-term consolidation settlements may develop; these settlements also may vary, depending on the differences in soil compressibility existing at different points under the raft. Such considerations need to be taken into account by the geotechnical engineer when assessing appropriate values for subgrade reaction.

Unlike strength and compressibility, the modulus of subgrade reaction is not a fundamental soil property. Rather, it is a common design approach used by structural engineers to model the interface between the foundation soil and concrete footing (i.e., soil-structure interaction). The modulus of subgrade reaction is a number required by structural engineers to model the deformation and stiffness response of a footing (raft) on soil. The modulus of subgrade reaction is defined as:

$$k = q/\delta \quad (7.1)$$

where

- k = modulus of subgrade reaction
- q = applied bearing or contact pressure on footing
- δ = settlement of footing under applied pressure q

The modulus of subgrade reaction, though simple in its definition, is a very difficult parameter to evaluate properly because it is not a unique fundamental property that is readily measured. Its value depends on many factors, including size and shape of footing (raft), type of soil, relative stiffness of footing and soil, duration of loading relative to the hydraulic conductivity of the loaded soil, and others. The value of modulus of subgrade reaction can also vary from one point to another beneath a footing or raft (e.g., centre, edge or corner) and can change with time, in particular for soils with low hydraulic conductivity such as clays.

Field plate load tests are commonly used to determine numerical values for the modulus of subgrade reaction. A database of numerical values and types of soil has been developed. Because the modulus value can change with size of footing, a one foot (300 mm) square footing has been adopted as the standard basis for comparison purposes, and frequently serves as the starting point for design. The technical literature cites typical values for the modulus of subgrade reaction, k_{v1} , (for a one-foot square plate) for a variety of soil types. Typical ranges in k_{v1} are summarized in Table 7.1. Appropriate design values for modulus of subgrade reaction generally decrease if the size of the loaded plate (or footing) is larger than one foot (300 mm) by one foot (300 mm). The manner in which the value of modulus of subgrade reaction decreases with increasing footing size varies with the type of foundation soil. Additional information is provided below, as well as by Terzaghi (1955), NavFac (1982) and Winterkorn and Fang (1975).

TABLE 7.1 Typical Ranges In Vertical Modulus Of Subgrade Reaction

Soil Type	k_{v1} (MPa/m) ⁽¹⁾
Granular Soils (Moist or Dry) ⁽²⁾	
Loose	5 - 20 74 pci
Compact Sand	20 - 60 220 pci
Dense	60 - 160 592 pci
Very Dense	160 - 300 ⁽³⁾
Cohesive Soils	
Soft	< 5 = 16 lb/in ²
Firm	5 - 10 = 37 lb/in ²
Stiff	10 - 30 = 110 lb/in ²
Very Stiff	30 - 80 = 295 lb/in ²
Hard	80 - 200 ⁽³⁾ = 737 lb/in ²



CALCULATIONS

Date: 11/19/2018

Made by: CJS / KAR

Project No.: 1772220

Checked by: CJS

Subject: Global Stability Analysis

Reviewed by: MCM

Project Short Title: Johnson Bridge over Flat Bay River - Harrington Maine

1.0 Purpose

Calculate global factor of safety for the proposed box culvert replacement slope armoring.

2.0 Method

Use Slide slope stability analysis software to analyze global stability.

3.0 References

- 1) Golder Associates boring logs, Report Appendix A.
- 2) WSP, November 7, 2018, Draft PS&E Plans, titled, "State of Maine Department of Transportation Harrington Washington County Johnson Bridge Over Flat Bay River US Route 1A," Federal Aid Project No. STP-02169(300). Sheets 9 and 16.
- 3) WSP hydraulic analysis included in the Preliminary Design Report, Johnson Bridge #3275 over Flat Bay River, STP-02169(300) WIN 21693.00.
- 4) Rocscience, Inc. 2018. "SLIDE – 2D Limit Equilibrium Slope Stability Analysis", Version 2018 8.016, build date July 23, 2018, Toronto, Ontario, Canada.

4.0 Attachments

- 1) Slide Output Figures

5.0 Assumptions

- 1) The load applied by the road and traffic for final design conditions is modeled at 250 psf.
- 2) Groundwater conditions are based on results of H&H analysis (Reference 3) for two design cases described below.
- 3) A $FS \geq 1.3$ was required for final design conditions under 500-yr flood elevations. A $FS \geq 1.1$ was required for simulated rapid drawdown event following a 500-yr flood.
- 4) Circular surfaces were analyzed using the Bishop simplified method and auto refine search. Non-circular surfaces were analyzed using the Spencer method and simulated annealing search with optimization.

6.0 Calculation

Determine input parameters to build the soil model in Slide. Use field N values and local engineering experience to develop these parameters. The field N values are shown on the boring logs (Reference 1). The material parameters selected for use in the Slide models are shown in Figures D-1 to D-4.

Use the soil layer parameters summarized in Figures D-1 to D-4 to analyze the following scenarios:

1. Final design conditions with 500-year flood upstream and downstream tailwater water surface elevations. (H&H analysis, Reference 3)
2. Final design conditions with rapid drawdown following a 500-yr flood event tailwater water surface elevation based on 1.1-yr return period downstream tailwater elevation. (H&H analysis, Reference 3)

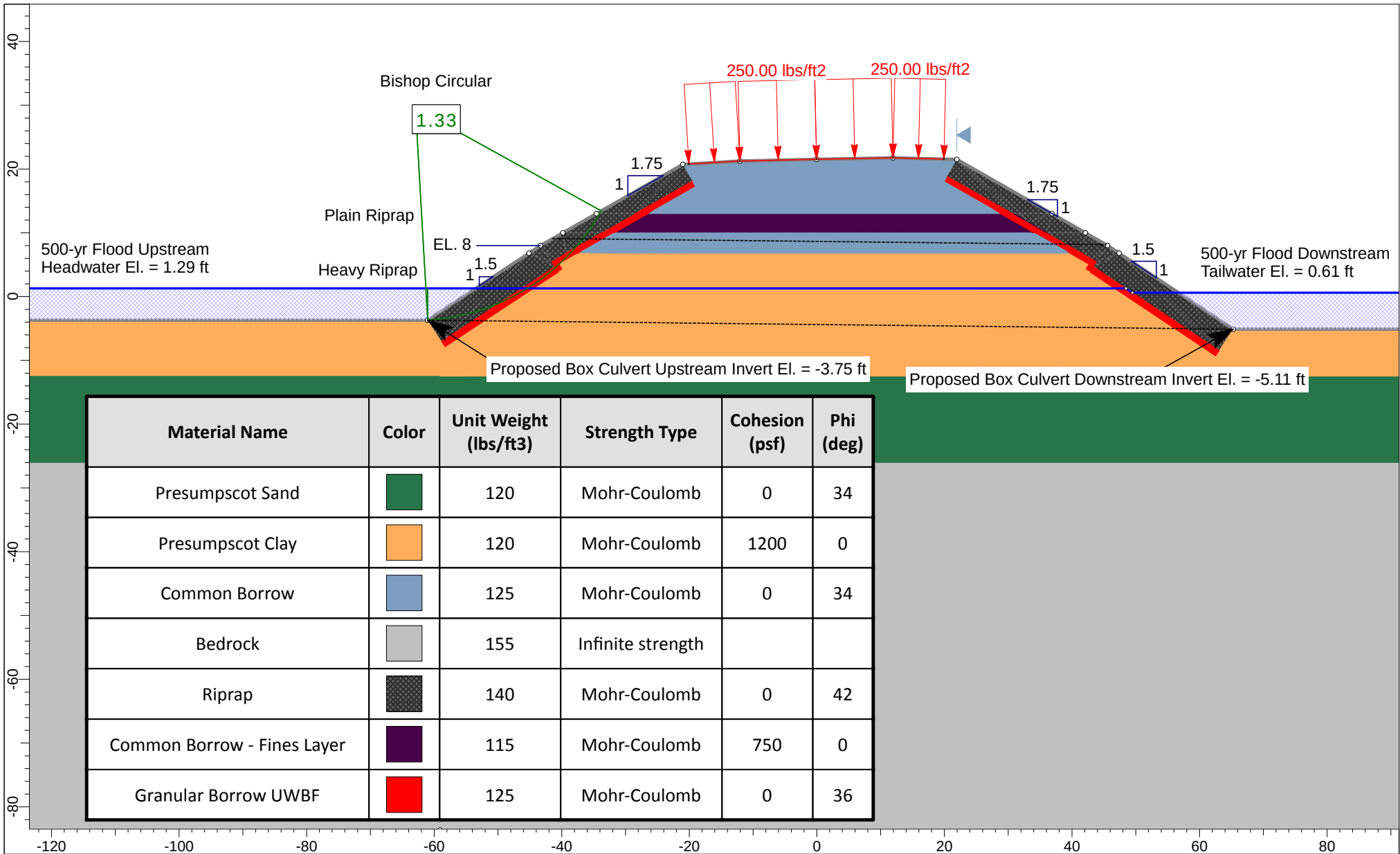
7.0 Results & Conclusions

Table 7.1: Proposed Conditions Slope Stability Results

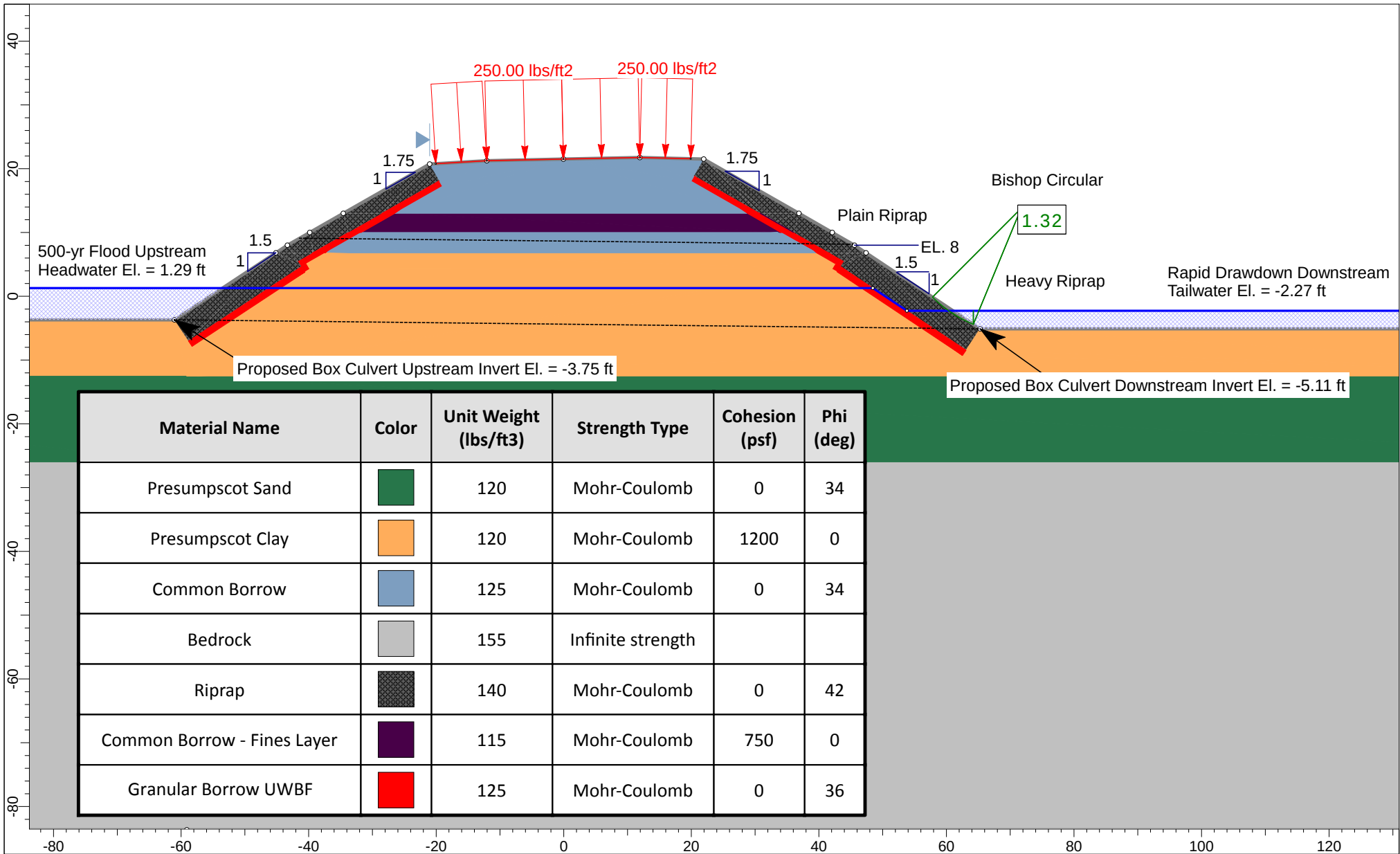
Run Description	Figure Nos.	Global Factor of Safety	
		Circular Failure: Bishop	Non-Circular Failure: Spencer
CASE 1: Final Design Conditions - 500-year Flood ($FS \geq 1.3$)	D-1	1.33	
	D-2		1.31
CASE 2: Final Design Conditions - Rapid Drawdown ($FS \geq 1.1$)	D-3	1.32	
	D-4		1.30

Conclusion:

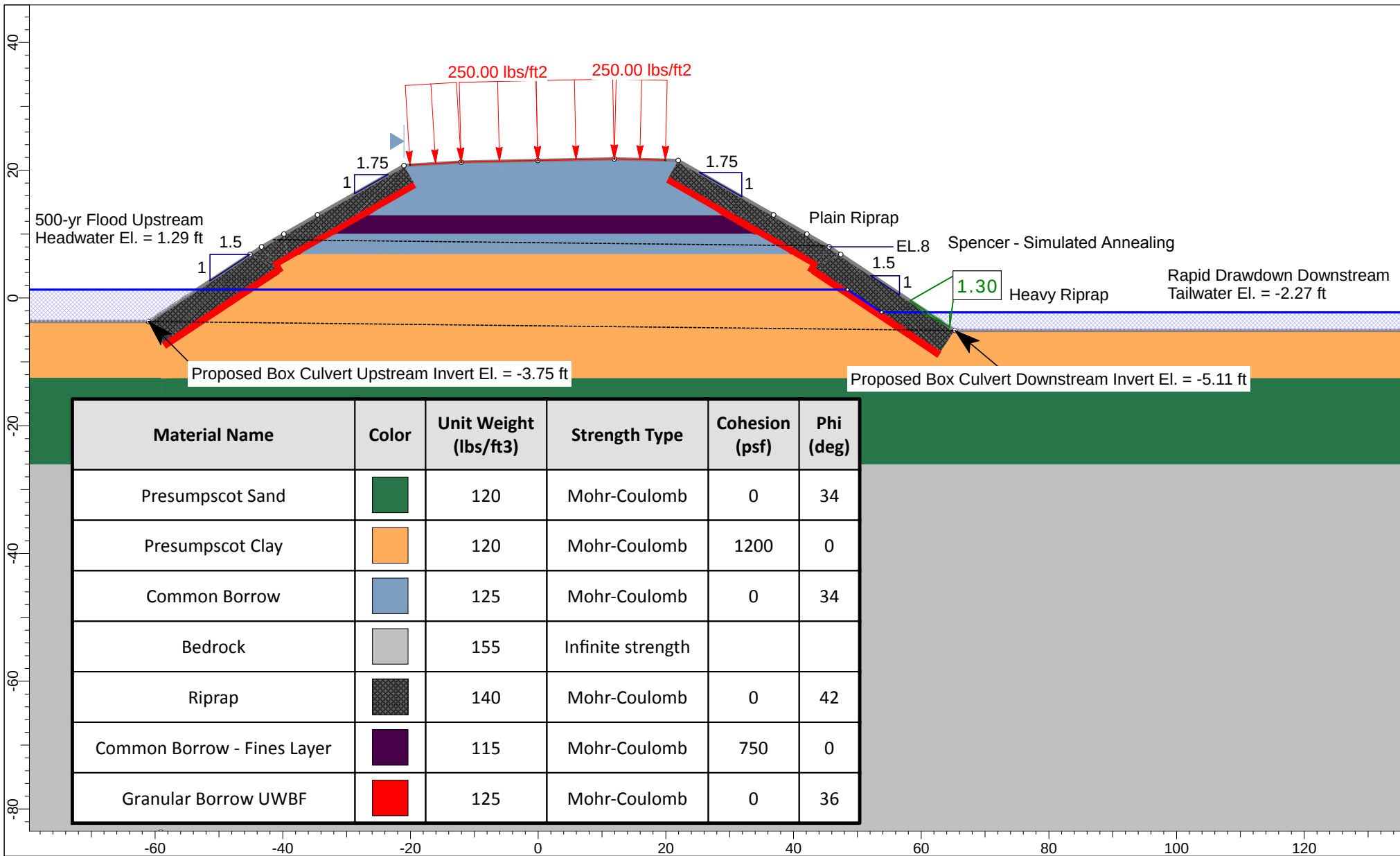
- The proposed slope armoring system maintains acceptable factors of safety.



 GOLDER	Project					Johnson Bridge over Flat Bay River - Harrington Maine	
	Analysis Description					Box Culvert Replacement - Slope Armoring - CIRCULAR	
	Drawn By	CJS	Checked by:	KAR	Reviewed by:	MCM	Scale
	Date	11/16/2018					Figure D-1



 GOLDER SLIDEINTERPRET 8.014	Project				
	Johnson Bridge over Flat Bay River - Harrington Maine				
	Analysis Description				
	Box Culvert Replacement - Slope Armoring - CIRCULAR				
	Drawn By	CJS	Checked by:	KAR	Reviewed by:
				MCM	Scale
Date	11/16/2018				
Figure D-3					



 SLIDEINTERPRET 8.014	Project					Johnson Bridge over Flat Bay River - Harrington Maine	
	Analysis Description					Box Culvert Replacement - Slope Armoring - BLOCK	
	Drawn By	CJS	Checked by:	KAR	Reviewed by:	MCM	Scale
	Date	11/16/2018					Figure D-4