



REPORT

GEOTECHNICAL DESIGN REPORT

**Route 189 Culvert Replacement
Lubec, Maine
Maine DOT WIN 21697.00**

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 6, 2018

Project No.: 1772215

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November 6, 2018

Project No.: 1772215

Adam Stockin, PE
Supervising Structural Engineer
WSP USA, Inc.
428 Dow Highway
Elliot, ME 03903

**RE: GEOTECHNICAL DESIGN REPORT
ROUTE 189 CULVERT REPLACEMENT
LUBEC, MAINE
MAINE DOT WIN 21697.00**

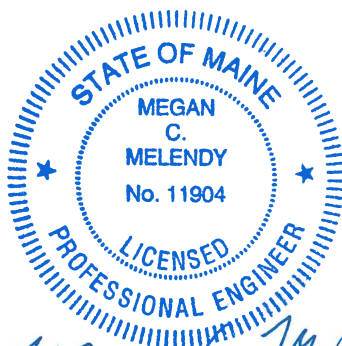
Dear Mr. Stockin:

Golder Associates Inc. (Golder) is pleased to submit this Preliminary Geotechnical Design Report to WSP USA, Inc. for the proposed Route 189 Culvert Replacement in Lubec, 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 2, 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) preliminary geotechnical investigation for replacement of the culvert carrying Mays Stream under State Route 189 in Lubec, 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 foundations; 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.

Background

The culvert replacement site is located about 1,100 feet (ft) west of the intersection of State Route 189/191 where State Route 189 crosses Mays Stream. The existing culvert has a span width of 12 ft and is a structural steel pipe arch culvert built in 1956. The culvert is supported on a layer of Granular Borrow as shown on Figure 3 according to notes on the 1956 design drawings¹. The roadway is 36 ft wide and is flanked by steel guardrail for the approaches.

The historical drawings indicate that the design overburden consists of approximately 11 ft of approach fill near the culvert overlying stream bed deposits. Golder understands that little historical information exists regarding the native soils or bedrock beneath the approach fills; however, the historical drawings note a monolithic concrete structure at the site prior to culvert construction (presumed to be the first generation stream crossing) that did not show "serious cracks or indication of settlement."

Based on discussions with WSP and our review of the PDR Plans prepared by WSP², we understand MaineDOT plans to replace the existing culvert with a 24-foot span, 73 ft long, precast concrete, four-sided, box culvert with an interior base layer of simulated streambed material (Special Fill) at least 2 ft thick to provide a natural stream bottom condition. The proposed box culvert will be about the same length and located along the same centerline as the existing culvert but has an invert elevation of 23.83 ft (NAVD 1988 datum) which is about 3.8 ft lower than the existing culvert. In addition, we have assumed that WSP USA, Inc. (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.

¹ State Highway Commission Bridge Division (1956), *Mays Bridge over Mays Stream*, Lubec, Washington County.

² WSP, October 5, 2018 PDR, State of Maine Department of Transportation Mays Bridge #2527 over Mays Stream, Lubec, Maine. STP-02169(700).



2.0 GEOLOGIC SETTING

Regional Surficial Geology

The proposed culvert replacement site is located in southeastern Maine within the Seaboard Lowlands Physiographic Province³. Regional surficial geologic mapping indicates a layer of glacial 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 consists of two varieties: a basal (or lodgement) till, fine grained and very dense; and an overlying ablation (or melt-out) till, coarser grained, stony and relatively loose. The till generally overlies bedrock.

Regional Bedrock Geology

Regional bedrock geologic mapping indicates the bedrock beneath the site consists of the Silurian-aged Quoddy Formation, pelite member. The lithology consists of pyrite-bearing and rusty-weathering, gray to black, siltstone and siliceous shale/argillite, and a few feldspathic ash tuff beds, metamorphosed to greenschist facies.^{4,5}. Four episodes of folding have deformed the sedimentary rocks into broad to tight anticlines and synclines, striking generally northeast-southwest. Five episodes of faulting are identified in the area, producing many fault-bounded lithologic blocks, with the faults trending mostly northeast-southwest.

³ 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.

⁴ Gates, O., 1977. Geologic Map and Cross Sections of the Eastport 15' Quadrangle, Washington County, Maine. Maine Geological Survey Geologic Map GM-3, scale 1:48,000, 23 p.

⁵ 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 June 6, 2017 New England Boring Contractors (NEB) of Hermon, Maine drilled two borings (BB-LUB-101, BB-LUB-102) at the locations shown on Figure 2 using a truck-mounted Mobile drill rig. Test borings were drilled along the road located on either side of the existing culvert to depths of approximately 24 to 27 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 an automatic hammer. 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-LUB-101 and -102, NEB obtained 10 ft of NQ sized bedrock core from the borings.

As-drilled locations and ground surface elevations for the borings were not surveyed following the field program. The boring locations shown on Figure 2 are approximate and are based on field measurements to existing site features made by Golder personnel. Table 1 includes a summary of the boring information including approximate Northings and Eastings, as-drilled elevations (based on 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 of 0.869 (based on a hammer calibration report provided by NEB⁶) was used for the automatic hammer method in determining the N_{60} corrections shown on the logs. 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 our rock core descriptions, rock mass rating, and rock quality assessments.

⁶ GZA Geo Environmental (2017). SPT Energy Testing report titled "Truck 83 – New Hampshire License Plate No.: 4368," prepared for New England Boring Contractors.



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-LUB-101 and BB-LUB-102 locations during the 2017 Golder Investigation.

Testing on the selected 2017 Golder Investigation 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/Rock Laboratory Test	Testing Procedure	Number of Tests Completed
Grain Size Analysis, sieve only	AASHTO T88, ASTM D422	3
Grain Size Analysis including Hydrometer	AASHTO T88, ASTM D422	2
Natural Moisture Content	AASHTO T265, ASTM D2216	5
Uniaxial Compressive Strength of Rock	ASTM D7012C	1

Selected soil and rock testing results are included on the boring logs in Appendix A and summarized on Table 3. 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 and fill materials placed during culvert installation and construction of the roadway, and naturally occurring alluvial and glacial till sediments. The underlying weathered bedrock surface is interpreted to range from about 12.0 to 15.0 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 5 inches thick was encountered in both of the borings.

Fill

Sand and gravel subgrade fill materials ranging in thickness from 9 to 10 ft. were encountered directly beneath the asphalt pavement at the boring locations. The fill materials generally consist of brown, loose to very dense, dry, fine to coarse sand, with some gravel and fractured rock and little silt. Corrected SPT N-values⁷ in the fill materials ranged from 6 to 74, with an average of 35, indicating a dense consistency. High (50+) N₆₀-values were observed in the first split spoon sample taken directly below the asphalt in both borings. This is likely influenced by gravel within the fill and is therefore likely artificially high, but also may be indicative of a higher compacted subbase layer directly below the pavement. A grain size analyses of this layer indicated an AASHTO classifications of A-1-b (0) and SM under the Unified Soil Classification System (USCS). The measured water content of the tested samples were roughly 3 percent.

Alluvium

A two foot thick layer of Alluvium was encountered below the fill layer in the eastern boring (BB-LUB-102). This layer consists of dark greyish-blue and maroon, wet, loose, gravel with some sand. An N₆₀-value of 10 was observed, indicating a generally loose consistency. Laboratory testing in this layer indicates an AASHTO classification of A-1-a (1), a USCS classification of GP, and a water content of 4.9 percent.

Organic Silts and Clays

A two foot thick layer of organic clayey silt to silty clay with trace fine sand was observed in the western boring (BB-LUB-101) below the fill layer. This material was damp with a very soft consistency and brown to gray in color. Field pocket penetrometer measurements indicated an unconfined compressive strength (q_u) of 1.25

⁷ All subsequent references to SPT N-values in this report pertain to the energy corrected N₆₀ values shown on the boring logs in Appendix A.



tons per square foot (tsf) within this layer. Laboratory testing of a sample within this layer suggests the soils is classified as A-4 and CL using the AASHTO and USCS criteria, respectively.

Glacial Till

Glacial till was encountered beneath the alluvial sediments in BB-LUB-102 with a thickness of 4 ft. This layer consists of gray, damp, medium dense to dense, clayey sand, with some gravel and fractured rock. N_{60} -values ranged from 22 to 52, with an average of 37, indicating a dense consistency. Based on field observations and a grain size analyses from layer indicated an AASHTO classification of A-4 (0) and a USCS classification of SC. The measured water content of the tested sample was 9.2 percent.

Weathered Bedrock

Approximately two ft of weathered bedrock consisting of fractured rock and gravel with little clayey silt was observed over more competent bedrock. The top of weathered bedrock was interpreted to be between about 12 and 15 ft bgs.

Bedrock

Bedrock was encountered in both borings as determined from rock core (BB-LUB-101 and -102). Competent bedrock surface depths are interpreted to be between about 14 and 17 ft bgs. Rock quality designation (RQD) of the core samples indicated bedrock that is very poor to fair (0%-68%) west of the culvert centerline and very poor to fair (0-58%) east of the culvert centerline.

Core samples collected showed bedrock consisting of light to dark gray chlorite-talc schist. This rock is strong (R4), slightly to moderately weathered (W2-W3), with extremely close to closely spaced discontinuities. Rock Mass Rating (RMR) of the rock core runs ranged from 36 to 57 with an average of (43.75) at BB-LUB-101 and from 32 to 51 with an average of 39 at BB-LUB-102. Laboratory testing indicated an unconfined compressive strength (UCS) of 6,380 psi. A detailed summary of the rock core is presented in Table 2.

Groundwater

Groundwater level measurements were measured upon completion of the boreholes and removal of the casing. Groundwater levels shown on the subsurface profile (Figure 3) were interpreted based on observed changes in saturation and water level meter measurements. Groundwater levels are interpreted to lie between approximately 8 and 11 ft below the roadway.



6.0 EVALUATIONS AND RECOMMENDATIONS

We understand that the MaineDOT plans to replace the existing culvert with a 24-foot span, precast concrete, four-sided, box culvert. The proposed box culvert will be about the same length and located in the same location as the existing plate pipe arch culvert but has an invert elevation of 23.83 ft which is lower than the current culvert. We understand there are no plans to raise the grade of the road or widen the approaches. Details from the WSP PDR indicate the proposed culvert will have a 1-foot tall headwall, 2-foot deep toe wall, and a 5-foot long Plain Riprap apron at the inlet and outlet. The slopes immediately adjacent to the proposed box culvert will be cut back to a 1.5H:1V slope and surfaced with a 3-foot layer of Plain Riprap. Infinite slope theory indicates that this slope configuration will provide a factor of safety greater than 1.3, provided the riprap bedding material is free draining. Based on the subsurface conditions encountered at the test borings and discussions with WSP, we conclude the proposed precast concrete box culvert can be satisfactorily supported on a layer of compacted bedding material (Granular Borrow Material for Underwater Backfill or $\frac{3}{4}$ inch crushed stone) directly overlying glacial till, weathered rock and/or bedrock. The proposed box culvert invert elevation may require a limited amount of bedrock removal on portions of the west side of the culvert alignment to allow for the 1 ft of bedding material beneath the box culvert structure.

Bearing Capacity and Subgrade Modulus

Boring BB-LUB-101 indicated a thin layer of organic silts and clays is present at the approximate bearing elevation of the proposed culvert. Depending on the extent this material may have been removed during the construction of the existing culvert, this layer may be encountered during excavation for the new, wider culvert. This thin, soft cohesive layer is not suitable for support of the proposed box culvert and, if encountered, will need to be removed in its entirety beneath the proposed box culvert and replaced with Granular Borrow Material for Underwater Backfill (MaineDOT 703.19) or other approved bearing material. We recommend that the proposed new box culvert be founded on a minimum 1-foot thick layer of Granular Borrow Material for Underwater Backfill or $\frac{3}{4}$ inch crushed stone (MaineDOT 703.13) placed on an erosion control geotextile overlying the native till, weathered bedrock and/or competent bedrock. For this bearing condition, we recommend a strength limit state factored bearing resistance of 32 kips per square foot (ksf) be used for design. A service limit state bearing resistance of 10 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. The factored bearing stress should not exceed the nominal resistance of the culvert concrete (0.3 f'_c). A modulus of subgrade reaction for a 1 ft x 1 ft steel plate (k₁) equal to 200 pounds per cubic inch (pci) should be used for structural design of the proposed culvert. Refer to the calculations included in Appendix D.

**Settlement**

The proposed box culvert is planned to be larger than the existing culvert. As stated above, we assume that the new box culvert will be founded on a layer of compacted granular material bearing on undisturbed dense native glacial till, weathered bedrock or competent bedrock. Golder assumes that the new culvert installation will result in a net unloading of the bearing surface and settlements are expected to be negligible.

Slope Stability

To maintain culvert replacement work within the existing right-of-way, the PDR plans show that an approximately 40 ft to 60 ft length of embankment sideslope adjacent to the proposed box culvert inlet and outlet, on the north and south sides of the road respectively, will be steepened to 1.5H:1V. Golder did not observe any signs of existing embankment stability issues during the field investigation. However, since the proposed design requires steepening the slope, Golder evaluated the global stability of the proposed embankment. Global stability was evaluated using infinite slope theory and assumes the riprap bedding material is free draining and head will not buildup within the riprap layer. As shown in the attached calculations included in Appendix D, the minimum calculated factor of safety for the proposed steepened embankment exceeds 1.3.

Culvert Bedding and Backfill

Construction and installation of the concrete box culvert should be in accordance with MaineDOT Standard Specification 534. The samples of glacial till collected from the test borings indicated >35% cohesive fines, which will be 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, the exposed subgrade should be covered with an erosion control geotextile, and the excavated materials should be replaced with compacted Granular Borrow Material for Underwater Backfill (MaineDOT 703.19) or $\frac{3}{4}$ inch crushed stone (MaineDOT 703.13). In addition, as discussed above, the 1956 design drawings note that the prior monolithic concrete structure (assumed to be the first generation stream crossing) was to be removed but the extent of removal is unknown. If this concrete structure is encountered during subgrade preparation for installation of the new box culvert, the older structure should be completely removed within the area of the new structure and the subgrade should be over-excavated to at least two feet below the bottom of the new box culvert and replaced with Granular Borrow or crushed stone.

The native layer of organic silts and clays (see Section 3) below the proposed culvert bearing surface should be removed in its entirety and replaced with Granular Borrow Material for Underwater Backfill or other approved bearing material. The culvert should be bedded on a minimum 1-foot thick layer of compacted



Granular Borrow Material for Underwater Backfill or $\frac{3}{4}$ inch crushed stone overlying an erosion control geotextile. The backfill placed against the sides of the culvert should consist of the same Granular Borrow Material for Underwater Backfill. 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 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.

Riprap and Scour

As shown in the PDR 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 2-feet thick by 5-feet long Plain Riprap Apron. We understand that MaineDOT has allowed for a shorter apron than the standard 10-feet 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 2-feet deep by 1-foot thick toe wall/cut off wall along the width of the culvert to prevent undermining.

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. However, construction activities will require soil excavation and may include earth support systems to support approach fills during construction if laying back the slopes is not feasible. 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 may be 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 189 Culvert Replacement crossing Mays Stream in Lubec, 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 189 Culvert Replacement
Lubec, Maine
MaineDOT WIN 21697.00

Test Boring Designation ^{1,2}	As-Drilled Locations ³		Existing Ground Surface Elevation ³ (feet)	Boring Depth ⁴ (feet)
	Northing	Easting		
BB-LUB-101	358475.0	2504442.0	35.9	24.0
BB-LUB-102	358508.5	2504468.5	36.2	27.0

Notes:

1. Test boring locations are shown in Figure 2 - "Boring Location Plan," and are approximate.
2. Borings were performed by New England Boring Contractors in May, 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
Preliminary Geotechnical Design Report
Route 189 Culvert Replacement
Lubec, Maine
MaineDOT WIN: 21697.00

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	%	Length	%	Designation	Weathering ⁴	Estimated Field Strength ⁴		Rock Mass Rating [RMR] ⁵
					[ft]												
	[in]	[ft]		[ft]	Start	End	Midpoint	[ft]	[ft]		[ft]						
BB-LUB-101	NQ [1.875"]	35.9	R1	1.0	14.0	16.0	15.0	2.0	1.7	83%	0.9	46%	Poor	Slightly Weathered (W2) to Moderately Weathered (W3)	Strong Rock (R4)	44	14.0' - 16.0': Light to dark gray, CHLORITE-TALC SCHIST, strong (R4), slightly to moderately weathered (W2 - W3), low angle fractures (5 to 35 degrees), very close to closely spaced (0" to 7"), minor (<1mm) clay infilling in fractures very rough to slightly rough, planar to irregular, thin (<2mm) quartz veins throughout [QUODDY FORMATION].
			R2	2.7	16.0	17.3	16.7	1.3	1.0	75%	0.0	0%	Very Poor	Slightly Weathered (W2) to Moderately Weathered (W3)	Strong Rock (R4)	38	16.0' - 17.3': Light to dark gray, CHLORITE-TALC SCHIST, strong (R4), slightly to moderately weathered (W2 - W3), vertically dipping fractures (85 to 90 degrees), very close to closely spaced (0" to 4"), minor (<1mm) red clay infilling in fractures, very rough to slightly rough, planar to curved, broken core [QUODDY FORMATION].
			R3	5.0	17.3	20.7	19.0	3.3	2.3	70%	0.3	10%	Very Poor	Slightly Weathered (W2) to Moderately Weathered (W3)	Strong Rock (R4)	36	17.3' - 20.7': Light to dark gray, CHLORITE-TALC SCHIST, strong (R4), slightly to moderately weathered (W2 - W3), vertically dipping fractures (85 to 90 degrees), very close to closely spaced (0" to 3"), very rough to smooth, planar to irregular, some (<2mm) red clay infilling in fractures, thin (<2mm) quartz veins throughout, highly fractured, [QUODDY FORMATION].
			R4	8.4	20.7	24.1	22.4	3.4	3.2	93%	2.3	68%	Fair	Slightly Weathered (W2)	Strong Rock (R4) to Very Strong Rock (R5)	57	20.7' - 24.1': Light to dark gray, CHLORITE-TALC SCHIST, strong to very strong (R4 - R5), slightly weathered (W2), moderately dipping fractures (35 to 55 degrees), very close to closely spaced (0" to 6"), very rough to smooth, planar to irregular, thin (<1mm) mineral (quartz and pyrite) infilling in joints, thin (<1cm) quartz veins throughout [QUODDY FORMATION].
BB-LUB-102	NQ [1.875"]	36.2	R1	1.0	17.0	18.9	18.0	1.9	1.2	61%	0.0	0%	Very Poor	Moderately Weathered (W3)	Medium Strong Rock (R3)	34	17.0' - 18.9': Light to dark gray, CHLORITE-TALC SCHIST, medium strong (R3), moderately weathered (W3), very close fracture spacing (0" to 2"), rough to very rough, planar to irregular, broken core [QUODDY FORMATION].
			R2	2.6	18.9	20.3	19.6	1.4	1.0	71%	0.0	0%	Very Poor	Moderately Weathered (W3)	Medium Strong Rock (R3)	34	18.9' - 20.3': Light to dark gray, CHLORITE-TALC SCHIST, medium strong (R3), moderately weathered (W3), horizontal to vertically dipping fractures (0 to 90 degrees), very close to closely spaced (0" to 4"), rough to very rough, planar to irregular [QUODDY FORMATION].
			R3	3.9	20.3	21.4	20.9	1.1	0.8	69%	0.0	0%	Very Poor	Moderately Weathered (W3)	Medium Strong Rock (R3)	33	20.3' - 21.4': Light to dark gray, CHLORITE-TALC SCHIST, medium strong (R3), moderately weathered (W3), very closely spaced fractures (0" to 2"), very rough, planar to irregular, broken core. [QUODDY FORMATION].
			R4	4.8	21.4	22.1	21.8	0.7	0.4	62%	0.0	0%	Very Poor	Moderately Weathered (W3)	Medium Strong Rock (R3)	32	21.4' - 22.1': Light to dark gray, CHLORITE-TALC SCHIST, medium strong (R3), moderately weathered (W3), very closely spaced fractures (0" to 2"), very rough to rough, planar to irregular, broken core. [QUODDY FORMATION].
			R5	5.8	22.1	23.6	22.8	1.5	1.1	72%	0.3	22%	Very Poor	Slightly Weathered (W2)	Medium Strong Rock (R3) to Strong Rock (R4)	44	22.1' - 23.6': Light to dark gray, CHLORITE-TALC SCHIST, medium strong (R3) to strong rock (R4), slightly weathered (W2), steep to vertically dipping fractures (80 to 90 degrees), closely spaced (4" to 5"), very rough to rough, planar [QUODDY FORMATION].
			R6	7.1	23.6	24.6	24.1	1.0	0.8	83%	0.6	58%	Fair	Slightly Weathered (W2) to Moderately Weathered (W3)	Medium Strong Rock (R3)	51	23.6' - 24.6': Light to dark gray, CHLORITE-TALC SCHIST, medium strong (R3), slightly weathered (W2) to moderately weathered (W3), stepp to vertically dipping fractures (80 to 90 degrees), very close to closely spaced (0" to 6"), very rough to slightly rough, planar [QUODDY FORMATION].
			R7	8.8	24.6	27.0	25.8	2.4	2.4	100%	1.2	48%	Poor	Slightly Weathered (W2)	Medium Strong Rock (R3)	49	24.6' - 27.0': Light to dark gray, CHLORITE-TALC SCHIST, slightly weathered (W2), medium strong (R3), horizontal to vertically dipping fractures (0 to 85 degrees), close;y spaced (2" to 7"), very rough to slightly rough, planar to irregular [QUODDY FORMATION].

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 189 Culvert Replacement
Lubec, Maine

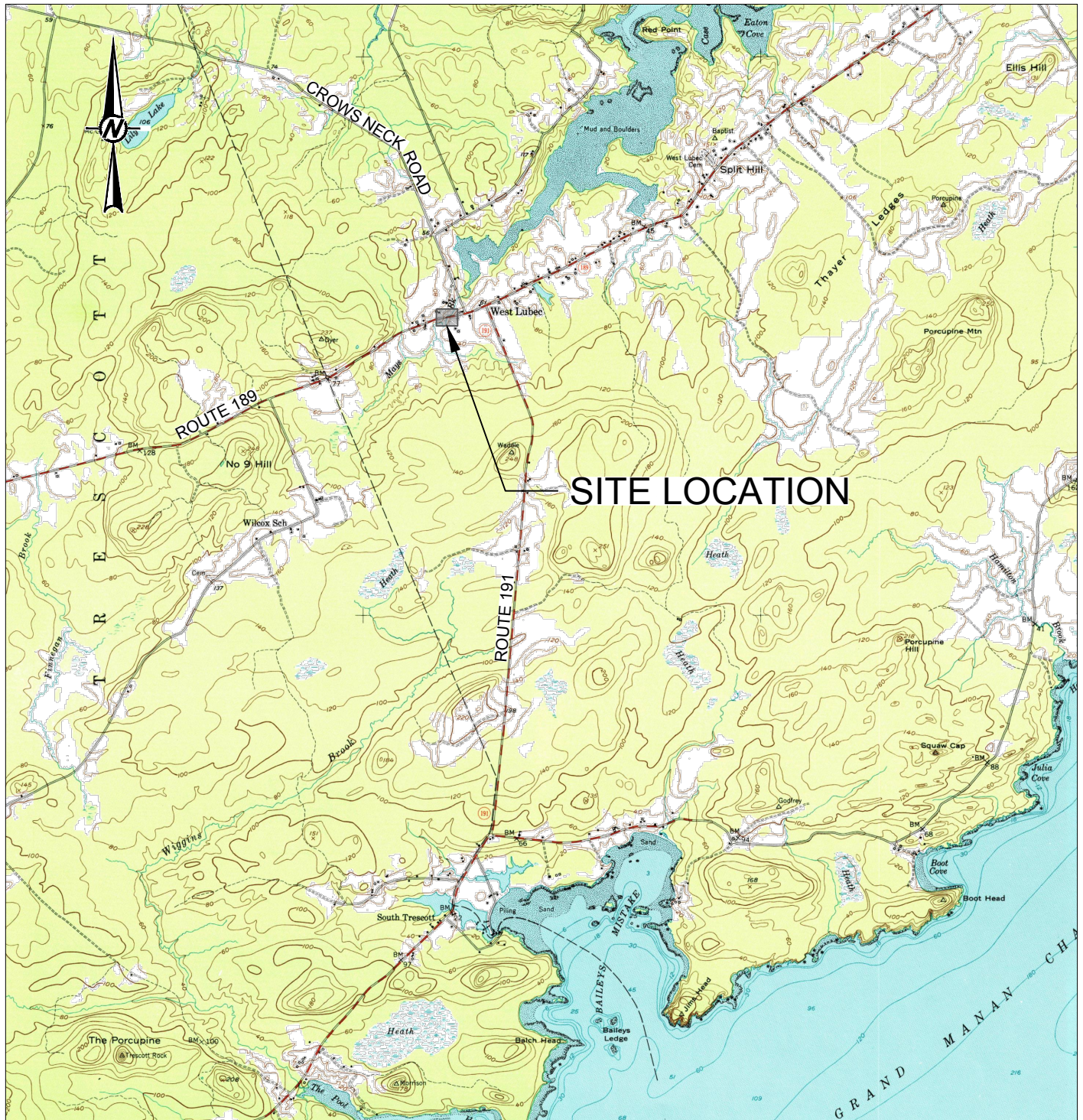
Test Boring Designation ¹	Existing Ground Surface Elevation ² (ft)	Sample Number	Sample Depth Below Ground Surface (ft)	Approximate Sample Elevation (ft)	Water Content (%)	Sieve Minus No. 200 (%)	AASHTO Soil Classification ³	USCS Soil Classification ³	Bulk Density (psf)	Compressive Strength (psi)
BB-LUB-101	35.9	1D	1.0 - 3.0	34.9 - 32.9	3.0	12.1	A-1-b (0)	SM	-	-
		3DB	10.0 - 12.0	25.9 - 23.9	26.0	94.7	A-4 (0)	OL	-	-
		R1	14.20 - 14.58	21.7 - 21.3	-	-	-	-	184	6,380
BB-LUB-102	36.2	1D	1.0 - 3.0	35.2 - 33.2	3.1	11.7	A-1-b (0)	SW-SM	-	-
		5D	9.0 - 11.0	27.2 - 25.2	4.9	0.0	A-1-a (1)	GP	-	-
		6D	11.0 - 13.0	25.2 - 23.2	9.2	37.6	A-4 (0)	SC	-	-

Notes:

1. Approximate test boring locations are shown in Figure 2 - "Boring Location Plan" and based on field measurements made by Golder personnel to existing site features.
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 USA, INC.
428 DOW HIGHWAY
ELIOT, MAINE 03903

CONSULTANT



YYYY-MM-DD 2018-11-06

DESIGNED TRM

PREPARED RWC

REVIEWED MCM

APPROVED MSP

PROJECT
ROUTE 189 CULVERT REPLACEMENT
LUBEC, MAINE
MAINEDOT WIN 21697.00 - MAYS BRIDGE

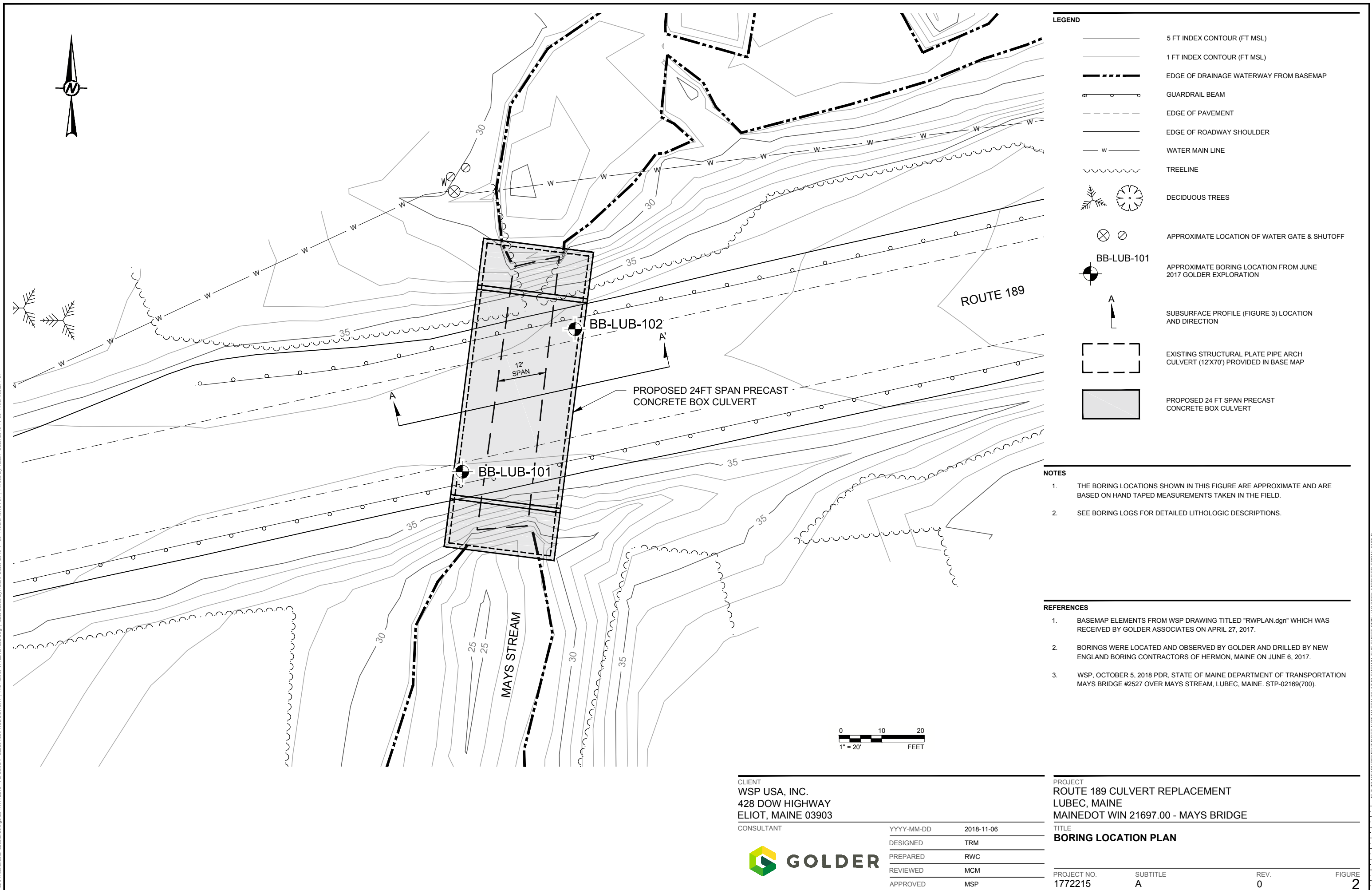
TITLE
SITE LOCATION PLAN

PROJECT NO.
1772215

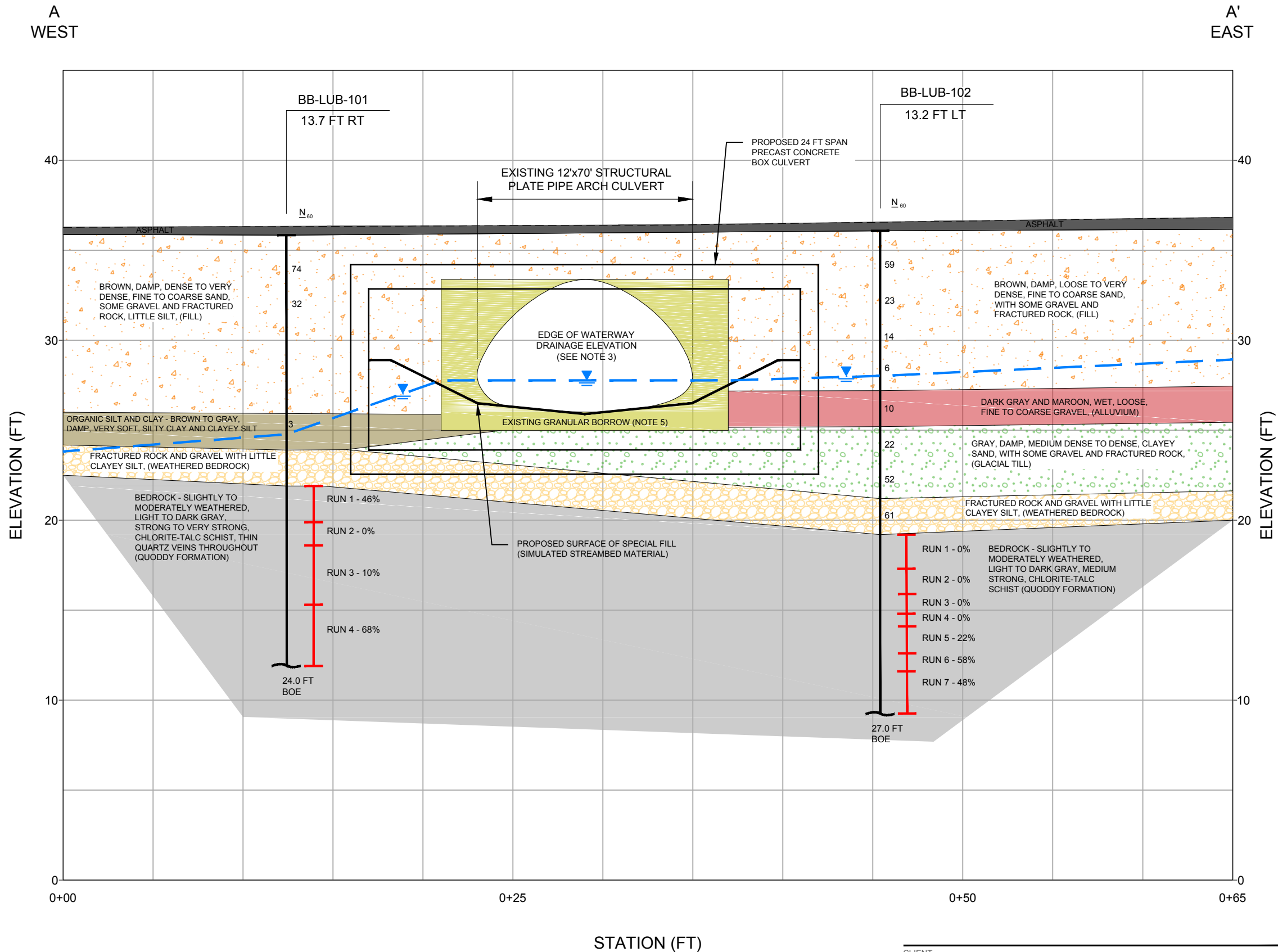
SUBTITLE
A

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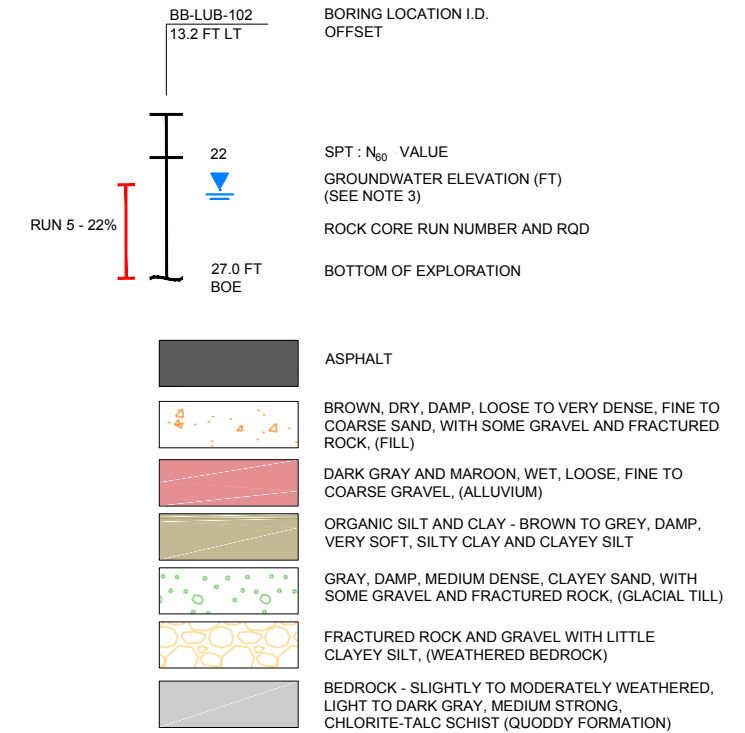
FIGURE
1



Path: \\manchester\cadd\Drawings\2017\1772215 - PB Culvert - Lubea.MEP\PRODUCTION | File Name: 1772215A003.dwg | Last Edited By: cslark Date: 2018-11-06 Time: 3:17:49 PM | Printed By: cslark Date: 2018-11-06 Time: 3:17:49 PM



LEGEND

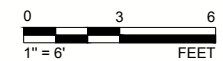


NOTES

- THE BORING LOCATIONS SHOWN IN THIS FIGURE ARE APPROXIMATE AND ARE BASED ON HAND TAPED MEASUREMENTS TAKEN IN THE FIELD.
- SEE BORING LOGS FOR DETAILED LITHOLOGIC DESCRIPTIONS.
- GROUNDWATER FLUCTUATIONS MAY OCCUR DUE TO CONDITIONS OTHER THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE. WATER LEVEL SHOWN IN THE RIVER CHANNEL IS BASED ON THE EDGE OF WATERWAY ELEVATION SHOWN ON FIGURE 2 AND TAKEN FROM WSP BASEMAP. GROUNDWATER LEVELS OUTSIDE OF THE RIVER CHANNEL ARE BASED ON MEASUREMENTS TAKEN IN THE BORINGS DURING THE JUNE 2017 FIELD EXPLORATION.
- THIS GENERALIZED SUBSURFACE PROFILE IS INTENDED TO CONVEY TRENDS IN SUBSURFACE CONDITIONS. THE BOUNDARIES BETWEEN STRATA ARE APPROXIMATE AND IDEALIZED, AND HAVE BEEN DEVELOPED BY INTERPRETATIONS OF WIDELY SPACED EXPLORATIONS AND SAMPLES. ACTUAL SOIL AND ROCK TRANSITIONS MAY VARY AND ARE PROBABLY MORE ERRATIC. FOR MORE SPECIFIC INFORMATION REFER TO EXPLORATION LOGS.
- EXISTING GRANULAR BORROW EXTENT DETAILED SURROUNDING THE EXISTING CULVERT IS BASED ON 1956 DRAWING NOTES.

REFERENCES

- BASEMAP ELEMENTS FROM WSP DRAWING TITLED "RWPLAN.dgn" WHICH WAS RECEIVED BY GOLDER ASSOCIATES ON APRIL 27, 2017.
- BORINGS WERE LOCATED AND OBSERVED BY GOLDER AND DRILLED BY NEW ENGLAND BORING CONTRACTORS OF HERMON, MAINE ON JUNE 6, 2017.
- LOCATION OF EXISTING CULVERT IS TAKEN FROM 1956 BRIDGE DRAWINGS TITLED "MAYS BRIDGE OVER MAYS STREAM" AND ARE APPROXIMATE.
- WSP, OCTOBER 5, 2018 PDR, STATE OF MAINE DEPARTMENT OF TRANSPORTATION MAYS BRIDGE #2527 OVER MAYS STREAM, LUBEC, MAINE. STP-02169(700).



CLIENT
WSP USA, INC.
428 DOW HIGHWAY
ELIOT, MAINE 03903

CONSULTANT

YYYY-MM-DD 2018-11-06

DESIGNED TRM

PREPARED RWC

REVIEWED MCM

APPROVED MSP



PROJECT
ROUTE 189 CULVERT REPLACEMENT
LUBEC, MAINE
MAINEDOT WIN 21697.00 - MAYS BRIDGE

TITLE
INTERPRETED SUBSURFACE PROFILE A-A'

PROJECT NO.
1772215

SUBTITLE
A

REV.
0

FIGURE
3

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)	GRAVEL WITH FINES (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixtures.	TERMS DESCRIBING DENSITY/CONSISTENCY			
		GC	Clayey gravels, gravel-sand-clay mixtures.	Coarse-grained soils (more than half of material is larger than No. 200 sieve): Includes (1) clean gravels; (2) silty or clayey gravels; and (3) silty, clayey or gravelly sands. Density is rated according to standard penetration resistance (N-value).				
FINE-GRAINED SOILS (more than half of material is smaller than No. 200 sieve size)	SILTS AND CLAYS (liquid limit less than 50)	CLEAN SANDS	SW	Well-graded sands, gravelly sands, little or no fines	Density of Cohesionless Soils		Standard Penetration Resistance N-Value (blows per foot)	
		(little or no fines)	SP	Poorly-graded sands, gravelly sand, little or no fines.	Very loose	0 - 4		
					Loose	5 - 10		
					Medium Dense	11 - 30		
					Dense	31 - 50		
					Very Dense	> 50		
					Fine-grained soils (more than half of material is smaller than No. 200 sieve): Includes (1) inorganic and organic silts and clays; (2) gravelly, sandy or silty clays; and (3) clayey silts. Consistency is rated according to undrained shear strength as indicated.			
	SILTS AND CLAYS (liquid limit greater than 50)	SANDS WITH FINES (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures	Approximate Undrained Shear Strength (psf)		Field Guidelines	
			SC	Clayey sands, sand-clay mixtures.	Consistency of Cohesive soils	SPT N-Value (blows per foot)		
					Very Soft	WOH, WOR, WOP, <2	0 - 250	Fist easily penetrates
				Soft	2 - 4	250 - 500	Thumb easily penetrates	
			Medium Stiff	5 - 8	500 - 1000	Thumb penetrates with moderate effort		
				Stiff	9 - 15	1000 - 2000	Indented by thumb with great effort	
				Very Stiff	16 - 30	2000 - 4000	Indented by thumbnail	
				Hard	>30	over 4000	Indented by thumbnail with difficulty	
Desired Soil Observations (in this order, if applicable):					Rock Quality Designation (RQD):			
Color (Munsell color chart)					RQD (%) = $\frac{\text{sum of the lengths of intact pieces of core} * > 4 \text{ inches}}{\text{length of core advance}}$			
Moisture (dry, damp, moist, wet)					*Minimum NQ rock core (1.88 in. OD of core)			
Density/Consistency (from above right hand side)					Correlation of RQD to Rock Mass Quality			
Texture (fine, medium, coarse, etc.)					Rock Mass Quality RQD (%)			
Name (sand, silty sand, clay, etc., including portions - trace, little, etc.)					Very Poor ≤ 25			
Gradation (well-graded, poorly-graded, uniform, etc.)					Poor 26 - 50			
Plasticity (non-plastic, slightly plastic, moderately plastic, highly plastic)					Fair 51 - 75			
Structure (layering, fractures, cracks, etc.)					Good 76 - 90			
Bonding (well, moderately, loosely, etc.,)					Excellent 91 - 100			
Cementation (weak, moderate, or strong)					Desired Rock Observations (in this order, if applicable):			
Geologic Origin (till, marine clay, alluvium, etc.)					Color (Munsell color chart)			
Groundwater level					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))			
Maine Department of Transportation Geotechnical Section Key to Soil and Rock Descriptions and Terms Field Identification Information					Sample Container Labeling Requirements:			
					WIN Blow Counts			
					Bridge Name / Town Sample Recovery			
					Boring Number Date			
					Sample Number Personnel Initials			
					Sample Depth			

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS				Project: Route 189 Culvert Replacement Location: Lubec, Maine				Boring No.: BB-LUB-101 WIN: 21697.00			
Driller: New England Boring Contractors				Elevation (ft.): 35.9 (See Remarks)				Auger ID/OD: 4"			
Operator: Mike Porter				Datum:				Sampler: Standard Split Spoon			
Logged By: TRM				Rig Type: Truck Mounted Mobile #83				Hammer Wt./Fall: 140 lbs./30"			
Date Start/Finish: 8:00/12:00 6/6/17				Drilling Method: SSA & D+W				Core Barrel: NQ			
Boring Location: West Side Approach				Casing ID/OD: 4"				Water Level*: 11.1' bgs @ 12:05 6/6/17			
Hammer Efficiency Factor: 0.869				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											
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	35.48		5" of pavement.	
	1D	24/19.2	1.00 - 3.00	20/24/27/18	51	74				1D (1.00'-3.00'): Dark brown, dry, very dense, fine to coarse SAND, some gravel and fractured rock, little silt (FILL).	#414644 A-1-b (0) SM WC: 3.0 %
	2D	24/15.6	3.00 - 5.00	18/11/11/12	22	32				2D (3.00'-5.00'): Dark brown, damp, medium dense, fine to coarse SAND, some gravel and fractured rock, little silt (FILL).	
5										Brown silty wash with gravel to 10'.	
10	3D	24/15.6	10.00 - 12.00	WOH/WOH/2/3	2	3	73	25.90		3D (10.00'-12.00'): Top 0.6': Brown, damp, very soft, organic clayey SILT, trace organics. Bottom 0.7': Gray, damp, very soft, silty CLAY, little fine to coarse sand, trace organics, moderate plasticity. PP: 1.25, 1.25, 1.25 TSF Grinding and chattering during wash to 12'.	#414647 A-4 (0) CL WC: 26.0%
	R1	24/20	14.00 - 16.00	RQD = 46%						Top of Rock Tricone roller bit through weathered bedrock from 12' to 14'. Run 1: Light to dark gray, CHLORITE-TALC SCHIST, strong (R4), slightly to moderately weathered (W2 - W3), low angle fractures (5 to 35 degrees), very close to closely spaced (0" to 7"), minor (<1mm) clay infilling in fractures very rough to slightly rough, planar to irregular, thin (<2mm) quartz veins throughout [QUODDY FORMATION]. Recovery: 83% R1 Core Times: (min:sec) 14.0' - 15.0': (3:03) 14.0' - 15.0': (2:48)	#414654 UCS: 6380 psi
	R2	16/12	16.00 - 17.33	RQD = 0%							
	R3	40/28	17.33 - 20.66	RQD = 10%							
20	R4	41/38	20.63 - 24.05	RQD = 68%						Run 2: Light to dark gray, CHLORITE-TALC SCHIST, strong (R4), slightly to moderately weathered (W2 - W3), vertically dipping fractures (85 to 90 degrees), very close to closely spaced (0" to 4"), minor (<1mm) red clay infilling in fractures, very rough to slightly rough, planar to curved, broken core [QUODDY FORMATION]. Recovery: 75% R2 Core Times: (min:sec) 16.0' - 17.0': (2:31) 17.0' - 17.3': (1:15)	
25										Run 3: Light to dark gray, CHLORITE-TALC SCHIST, strong (R4), slightly to moderately weathered (W2 - W3), vertically dipping fractures (85 to 90 degrees), very close to closely spaced (0" to 3"), very rough to smooth, planar to irregular, some (<2mm) red clay infilling in fractures, thin (<2mm) quartz veins throughout, highly fractured, [QUODDY FORMATION]. Recovery: 70% R3 Core Times: (min:sec)	
30											
Remarks: - Boring backfilled with cuttings and road side gravel, one bag of gravel, 10 lbs cold patch. - 300 lb hammer used for driving casing. - Elevation approximate. Based on map data provided by WSP. - Hammer efficiency factor averaged from GZA SPT Energy Testing Report for NEB Truck 83 Drill Rig, NH Plate No. 4368, dated July 12, 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 1 of 2 Boring No.: BB-LUB-101	

[illegible]

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS				Project: Route 189 Culvert Replacement Location: Lubec, Maine				Boring No.: BB-LUB-102 WIN: 21697.00			
Driller: New England Boring Contractors				Elevation (ft.): 36.2 (See Remarks)				Auger ID/OD: 4"			
Operator: Mike Porter				Datum:				Sampler: Standard Split Spoon			
Logged By: TRM				Rig Type: Truck Mounted Mobile #83				Hammer Wt./Fall: 140 lbs./30"			
Date Start/Finish: 12:45/18:15 6/6/17				Drilling Method: SSA & D+W				Core Barrel: NQ			
Boring Location: East Side Approach				Casing ID/OD: 4"				Water Level*: 8.2' bgs A 18:00 6/6/17			
Hammer Efficiency Factor: 0.869				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											
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	35.78		5" of pavement.	
	1D	24/18	1.00 - 3.00	17/21/20/14	41	59				1D (1.00'-3.00'): Brown, dry, dense, fine to coarse SAND, some gravel and fractured rock, little silt (FILL).	#414645 A-1-b (0) SW-SM WC: 3.1 %
	2D	24/18	3.00 - 5.00	11/7/9/8	16	23				2D (3.00'-5.00'): Dark brown, damp, medium dense, fine to coarse SAND, some gravel and fractured rock, little silt (FILL).	
	3D	24/19.2	5.00 - 7.00	8/5/5/5	10	14	35			3D (5.00'-7.00'): Dark brown, damp, loose, fine to coarse SAND, some gravel, little silt (FILL).	
5										4D (7.00'-9.00'): Dark brown, moist, very loose, fine to coarse SAND, some gravel, little silt (FILL).	
	4D	24/13.2	7.00 - 9.00	5/2/2/1	4	6	17				#414646 A-1-a (1) GP 4.9% #414648 A-4 (0) SC WC: 9.2%
	5D	24/6	9.00 - 11.00	6/3/4/3	7	10	10			5D (9.00'-11.00'): 3" spoon: dark grayish-blue and maroon, wet, loose, GRAVEL (ALLUVIUM). 2" spoon: fine to coarse GRAVEL; wash.	
	6D	24/8.4	11.00 - 13.00	23/7/8/12	15	22	82			6D (11.00'-13.00'): Gray, damp, medium dense, clayey SAND, some gravel and fractured rock, fines have moderate plasticity (GLACIAL TILL).	
10										7D (13.00'-15.00'): Gray, damp, dense, clayey SAND, some gravel and fractured rock, fines have moderate plasticity (GLACIAL TILL).	
	7D	24/6	13.00 - 15.00	22/14/22/18	36	52	95				#414646 A-1-a (1) GP 4.9% #414648 A-4 (0) SC WC: 9.2%
	8D	21/4.8	15.00 - 16.75	22/20/22/(53/3")	42	61	91			8D (15.00'-17.00'): dense, FRACTURED ROCK AND GRAVEL, little clayey silt (WEATHERED ROCK).	
	R1	23/14	17.00 - 18.92	RQD = 0%			NQ?			Run 1: Light to dark gray, CHLORITE-TALC SCHIST, medium strong (R3) , moderately weathered (W3), very close fracture spacing (0" to 2"), rough to very rough, planar to irregular, broken core [QUODDY FORMATION]. Recovery: 60% R1 Times: (min:sec) 17.0' - 18.0': (1:53) 18.0' - 18.9': (1:22)	
15										Run 2: Light to dark gray, CHLORITE-TALC SCHIST, medium strong (R3) , moderately weathered (W3), horizontal to vertically dipping fractures (0 to 90 degrees), very close to closely spaced (0" to 4"), rough to very rough, planar to irregular [QUODDY FORMATION]. Recovery: 70% R2 Core Times: (min:sec) 18.9' - 19.9': (1:53) 19.9' - 20.3': (1:22)	
	R2	17/12	18.90 - 20.32	RQD = 0%							#414646 A-1-a (1) GP 4.9% #414648 A-4 (0) SC WC: 9.2%
	R3	13/9	20.30 - 21.38	RQD = 0%						Run 3: Light to dark gray, CHLORITE-TALC SCHIST, medium strong (R3) , moderately weathered (W3), very closely spaced fractures (0" to 2"), very rough, planar to irregular, broken core. [QUODDY FORMATION]. Recovery: 69% R3 Core Times: (min:sec)	
	R4	8/5	21.38 - 22.05	RQD = 0%							
20											
	R5	18/13	22.07 - 23.57	RQD = 22%							#414646 A-1-a (1) GP 4.9% #414648 A-4 (0) SC WC: 9.2%
	R6	12/10	23.60 - 24.60	RQD = 58%							
	R7	29/29	24.60 - 27.02	RQD = 48%							
25											
											#414646 A-1-a (1) GP 4.9% #414648 A-4 (0) SC WC: 9.2%
30											
Remarks: - Borehole collapse to 8.2' - Boring backfilled with cuttings, 2 bags of gravel, and 10 lbs of cold patch. - Elevation approximate. Based on base map data provided by WSP. - Hammer efficiency factor averaged from GZA SPT Energy Testing Report for NEB Truck 83 Drill Rig, NH Plate No. 4368, dated July 12, 2017.											
Stratification lines represent approximate boundaries between soil types; transitions may be gradual.										Page 1 of 2 Boring No.: BB-LUB-102	

Maine Department of Transportation Soil/Rock Exploration Log US CUSTOMARY UNITS				Project: Route 189 Culvert Replacement Location: Lubec, Maine				Boring No.: BB-LUB-102 WIN: 21697.00				
Driller: New England Boring Contractors				Elevation (ft.): 36.2 (See Remarks)				Auger ID/OD: 4"				
Operator: Mike Porter				Datum:				Sampler: Standard Split Spoon				
Logged By: TRM				Rig Type: Truck Mounted Mobile #83				Hammer Wt./Fall: 140 lbs./30"				
Date Start/Finish: 12:45/18:15 6/6/17				Drilling Method: SSA & D+W				Core Barrel: NQ				
Boring Location: East Side Approach				Casing ID/OD: 4"				Water Level*: 8.2' bgs A 18:00 6/6/17				
Hammer Efficiency Factor: 0.869				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 _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					
30										20.3' - 21.3': (1:50) 21.3' - 21.4': (0:50) Run 4: Light to dark gray, CHLORITE-TALC SCHIST, medium strong (R3) , moderately weathered (W3), very closely spaced fractures (0" to 2"), very rough to rough, planar to irregular, broken core. [QUODDY FORMATION] Recovery: 63% R4 Core Time: (min:sec) 21.4' - 22.1': (1:50) Run 5: Light to dark gray, CHLORITE-TALC SCHIST, medium strong (R3) to strong rock (R4), slightly weathered (W2), steep to vertically dipping fractures (80 to 90 degrees), closely spaced (4" to 5"), very rough to rough, planar [QUODDY FORMATION]. Recovery: 72% Core Times: (min:sec) 22.1' - 23.1': (1:37) 23.1' - 23.6': (0:50) Run 6: Light to dark gray, CHLORITE-TALC SCHIST, medium strong (R3) , slightly weathered (W2) to moderately weathered (W3), steep to vertically dipping fractures (80 to 90 degrees), very close to closely spaced (0" to 6"), very rough to slightly rough, planar [QUODDY FORMATION]. Recovery: 83% Core Times: (min:sec) 23.6' - 24.6': (1:20) Run 7: Light to dark gray, CHLORITE-TALC SCHIST, slightly weathered (W2), medium strong (R3), horizontal to vertically dipping fractures (0 to 85 degrees), closey spaced (2" to 7"), very rough to slightly rough, planar to irregular [QUODDY FORMATION]. Recovery: 100% Core Times: (min:sec) 24.6' - 25.6': (1:20) 25.6' - 26.6': (1:50) 26.6' - 27.0': (0:19)		
35												
40												
45												
50												
55												
60												
Remarks: - Borehole collapse to 8.2' - Boring backfilled with cuttings, 2 bags of gravel, and 10 lbs of cold patch. - Elevation approximate. Based on base map data provided by WSP. - Hammer efficiency factor averaged from GZA SPT Energy Testing Report for NEB Truck 83 Drill Rig, NH Plate No. 4368, dated July 12, 2017.												
Stratification lines represent approximate boundaries between soil types; transitions may be gradual.										Page 2 of 2		
* Water level readings have been made at times and under conditions stated. Groundwater fluctuations may occur due to conditions other than those present at the time measurements were made.										Boring No.: BB-LUB-102		

APPENDIX B
ROCK CORE PHOTOS

APPENDIX B
Rock Core Photos
Route 189 Culvert Replacement
Lubec, Maine
MaineDOT WIN: 21697.00

Boring	Run	Depth	Recovery		RQD	
			inches	%	inches	%
BB-LUB-101	R1	14.0' – 16.0'	20/24	83%	11/24	46%
	R2	16.0' – 17.3'	12/16	75%	0/16	0%
	R3	17.3' – 20.6'	28/40	70%	4/40	10%
	R4	20.6' – 24.0'	38/41	93%	28/41	68%
BB-LUB-102	R1	17.0' – 18.9'	14/23	61%	0/23	0%
	R2	18.9' – 20.3'	12/17	71%	0/17	0%
	R3	20.3' – 21.4'	9/13	69%	0/13	0%



From Top to Bottom of Photo:

Row 1 = BB-LUB-101 Run 1: 14.0 - 16.0 ft-bgs./BB-LUB-101 Run 2: 16.0 - 17.3 ft-bgs./BB-LUB-101 Run 3: 17.3 - 20.6 ft-bgs.

Row 2 = BB-LUB-101 Run 3: 17.3 - 20.6 ft-bgs./BB-LUB-101 Run 4: 20.6 - 24.0 ft-bgs.

Row 3 = BB-LUB-102 Run 1: 17.0 - 18.9 ft-bgs./BB-LUB-102 Run 2: 18.9 - 20.3 ft-bgs./BB-LUB-102 Run 3: 20.3 - 21.4 ft-bgs.

APPENDIX B
Rock Core Photos
Route 189 Culvert Replacement
Lubec, Maine
MaineDOT WIN: 21697.00

<u>Boring</u>	<u>Run</u>	<u>Depth</u>	<u>Recovery</u>		<u>RQD</u>	
			<u>inches</u>	<u>%</u>	<u>inches</u>	<u>%</u>
BB-LUB-102	R4	21.4' – 22.1'	5/8	62%	0/8	0%
	R5	22.1' – 23.6'	13/18	72%	4/18	22%
	R6	23.6' – 24.6'	10/12	83%	7/12	58%
	R7	24.6' – 27.0'	29/29	100%	14/29	48%



From Top to Bottom of Photo:

Row 3 = BB-LUB-102 Run 4: 21.4 - 22.1 ft-bgs.

Row 4 = BB-LUB-102 Run 5: 22.1 - 23.6 ft-bgs./BB-LUB-102 Run 6: 23.6 - 24.6 ft-bgs./BB-LUB-102 Run 7: 24.6 - 27.0 ft-bgs.

APPENDIX C
LABORATORY TEST RESULTS



Client:	Golder Associates		Project No:	GTX-306600
Project:	Route 189 Culvert Replacement			
Location:	Lubec, ME			
Boring ID:	---	Sample Type:	---	Tested By: jbr
Sample ID:	---	Test Date:	06/27/17	Checked By: emm
Depth :	---	Test Id:	414653	

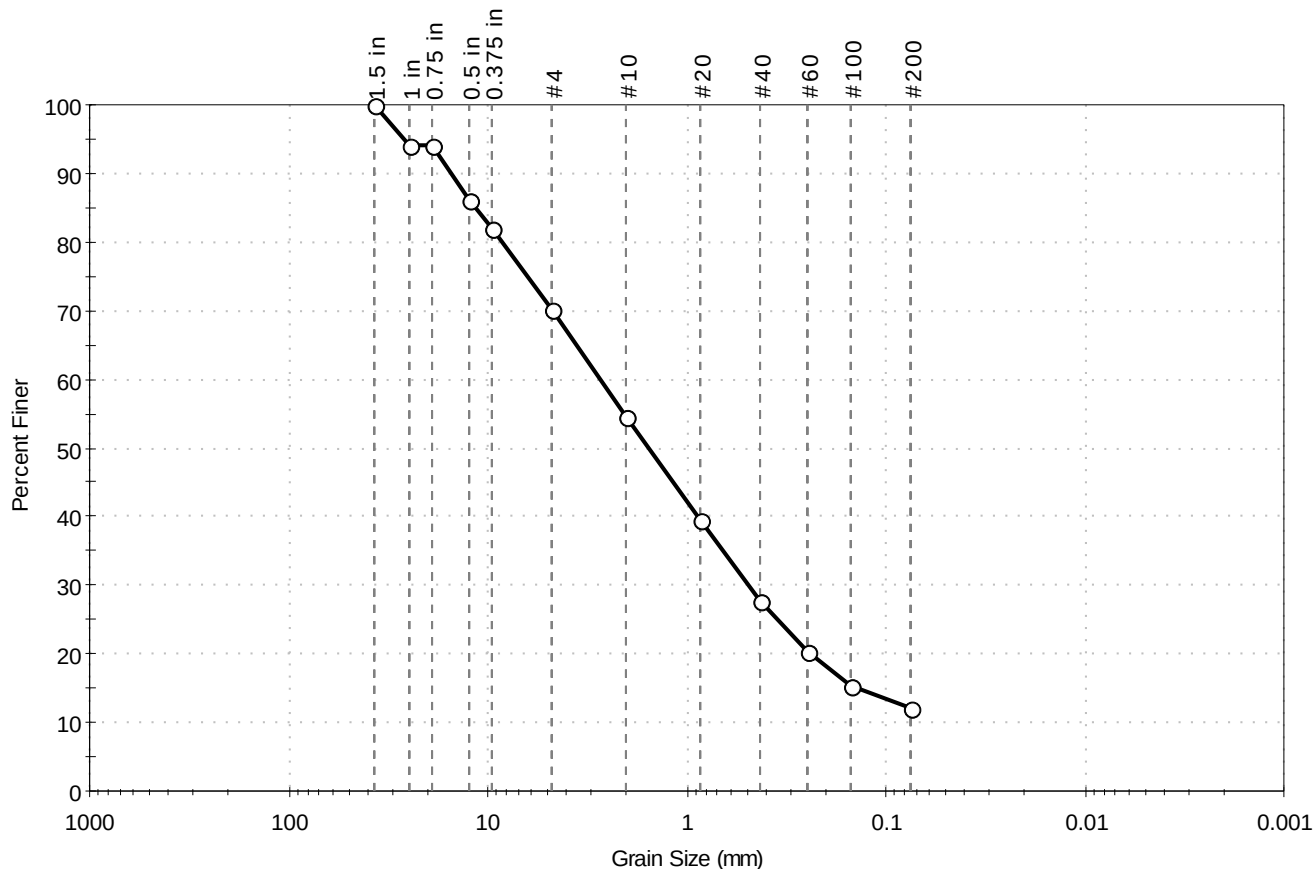
Moisture Content of Soil and Rock - ASTM D2216

Boring ID	Sample ID	Depth	Description	Moisture Content, %
BB-LUB-101	1D	1-3 ft	Moist, grayish brown silty sand with gravel	3.0
BB-LUB-101	3DB	10-12 ft	Moist, dark gray clay	26.0
BB-LUB-102	1D	1-3 ft	Moist, brownish gray sand with silt and gravel	3.1
BB-LUB-102	5D	9-11 ft	Moist, gray gravel with sand	4.9
BB-LUB-102	6D	11-13 ft	Moist, olive clayey sand with gravel	9.2

Notes: Temperature of Drying : 110° Celsius

Client: Golder Associates	Project No: GTX-306600
Project: Route 189 Culvert Replacement	
Location: Lubec, ME	
Boring ID: BB-LUB-101	Sample Type: jar
Sample ID: 1D	Test Date: 06/23/17
Depth: 1-3 ft	Test Id: 414644
Test Comment: ---	Tested By: jbr
Visual Description: Moist, grayish brown silty sand with gravel	Checked By: emm
Sample Comment: ---	

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	29.9	58.0	12.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1.5 in	37.50	100		
1 in	25.00	94		
0.75 in	19.00	94		
0.5 in	12.50	86		
0.375 in	9.50	82		
#4	4.75	70		
#10	2.00	55		
#20	0.85	39		
#40	0.42	28		
#60	0.25	20		
#100	0.15	15		
#200	0.075	12		

Coefficients

D ₈₅ = 11.5483 mm	D ₃₀ = 0.4838 mm
D ₆₀ = 2.6989 mm	D ₁₅ = 0.1360 mm
D ₅₀ = 1.5406 mm	D ₁₀ = N/A
C _u = N/A	C _c = N/A

Classification

ASTM N/A

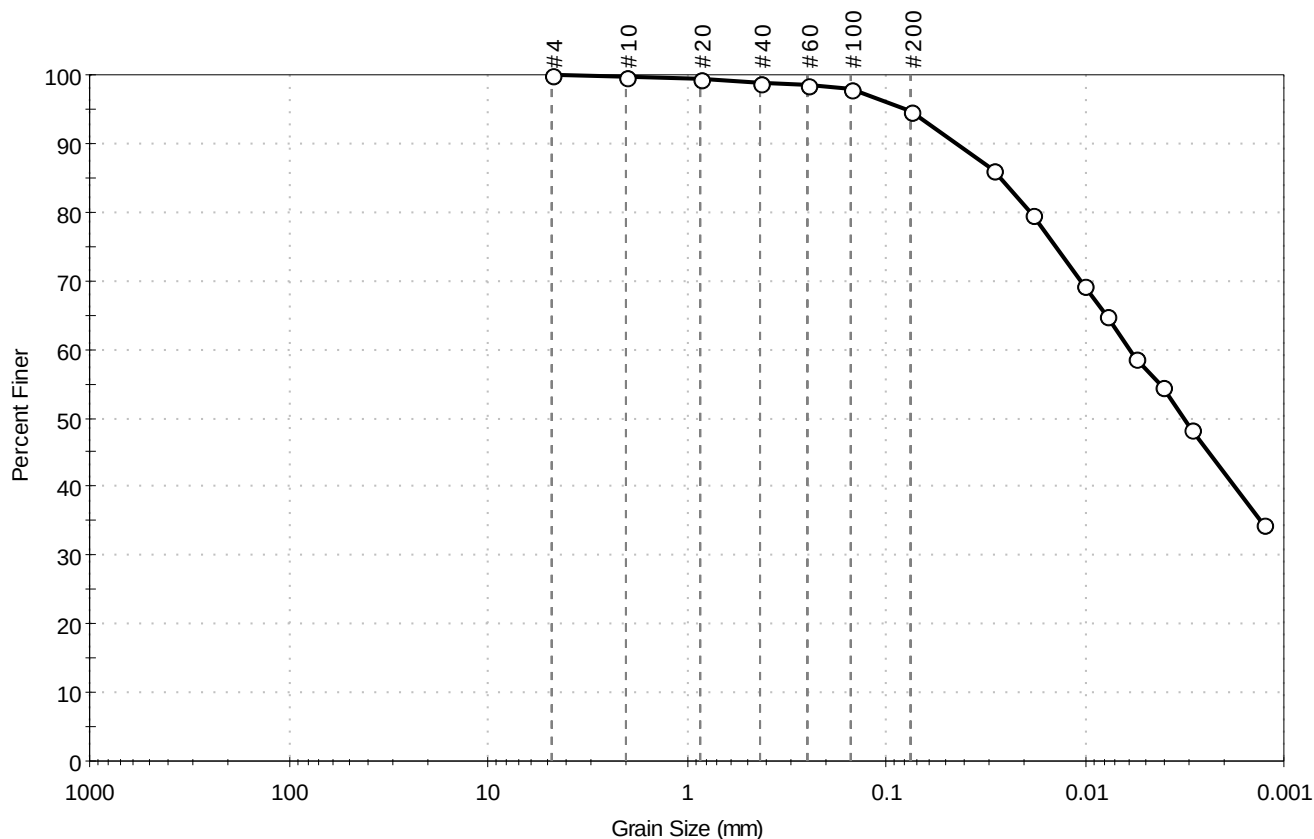
AASHTO Stone Fragments, Gravel and Sand (A-1-b (0))

Sample / Test Description

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

Client: Golder Associates	Project No: GTX-306600	
Project: Route 189 Culvert Replacement		
Location: Lubec, ME		
Boring ID: BB-LUB-101	Sample Type: jar	Tested By: jbr
Sample ID: 3DB	Test Date: 06/27/17	Checked By: emm
Depth: 10-12 ft	Test Id: 414647	
Test Comment: ---		
Visual Description: Moist, dark gray clay		
Sample Comment: ---		

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	5.3	94.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.85	99		
#40	0.42	99		
#60	0.25	98		
#100	0.15	98		
#200	0.075	95		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0291	86		
---	0.0184	80		
---	0.0102	69		
---	0.0078	65		
---	0.0055	59		
---	0.0041	55		
---	0.0029	48		
---	0.0013	35		

Coefficients

$D_{85} = 0.0270$ mm $D_{30} = \text{N/A}$
 $D_{60} = 0.0059$ mm $D_{15} = \text{N/A}$
 $D_{50} = 0.0032$ mm $D_{10} = \text{N/A}$
 $C_u = \text{N/A}$ $C_c = \text{N/A}$

Classification

ASTM N/A

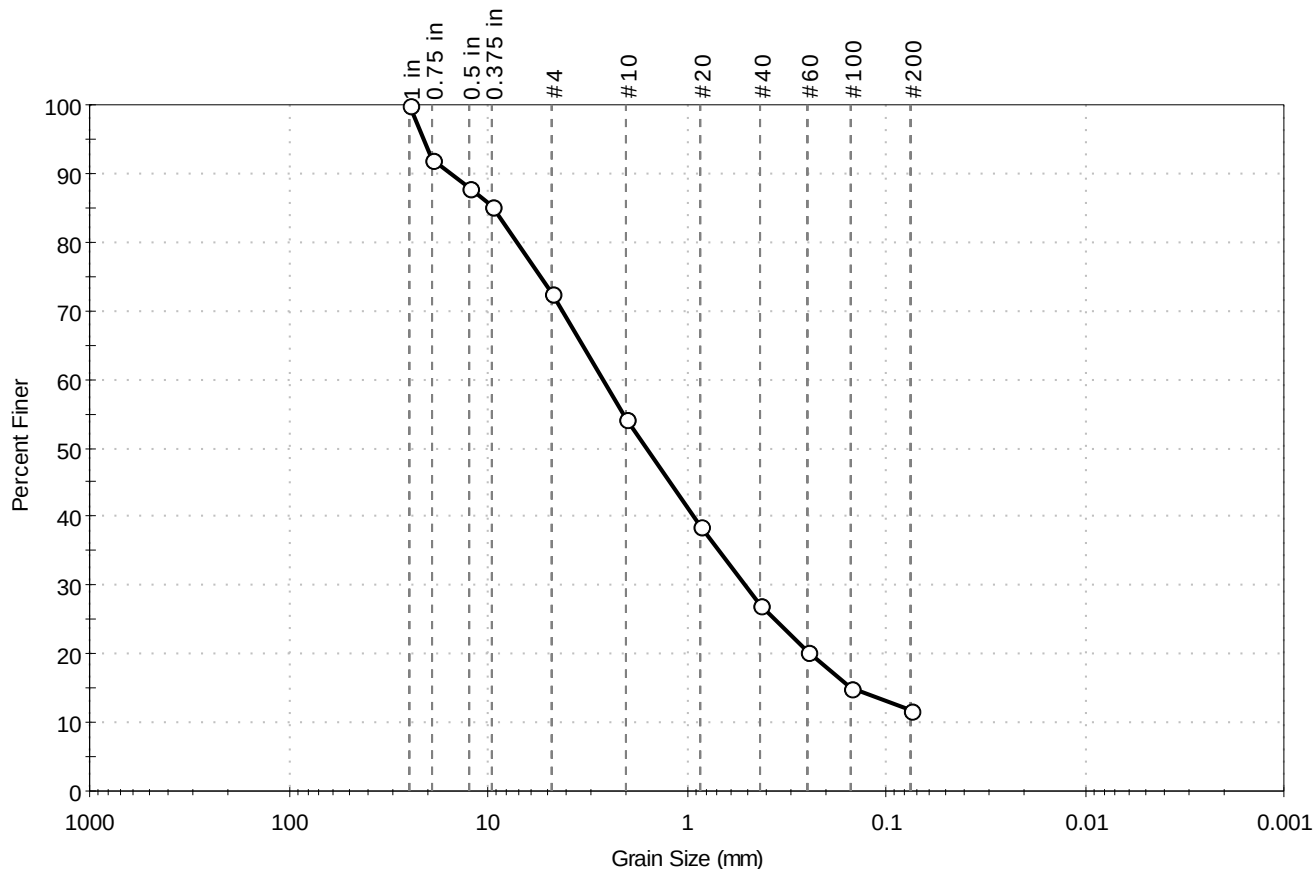
AASHTO Silty Soils (A-4 (0))

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 No:	GTX-306600
Project:	Route 189 Culvert Replacement		
Location:	Lubec, ME		
Boring ID:	BB-LUB-102	Sample Type:	jar
Sample ID:	1D	Test Date:	06/23/17
Depth :	1-3 ft	Test Id:	414645
Test Comment:	---		
Visual Description:	Moist, brownish gray sand with silt and gravel		
Sample Comment:	---		

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	27.4	60.9	11.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1 in	25.00	100		
0.75 in	19.00	92		
0.5 in	12.50	88		
0.375 in	9.50	85		
#4	4.75	73		
#10	2.00	54		
#20	0.85	39		
#40	0.42	27		
#60	0.25	20		
#100	0.15	15		
#200	0.075	12		

Coefficients

D ₈₅ = 9.4403 mm	D ₃₀ = 0.5057 mm
D ₆₀ = 2.6210 mm	D ₁₅ = 0.1481 mm
D ₅₀ = 1.5791 mm	D ₁₀ = N/A
C _u = N/A	C _c = N/A

Classification

ASTM N/A

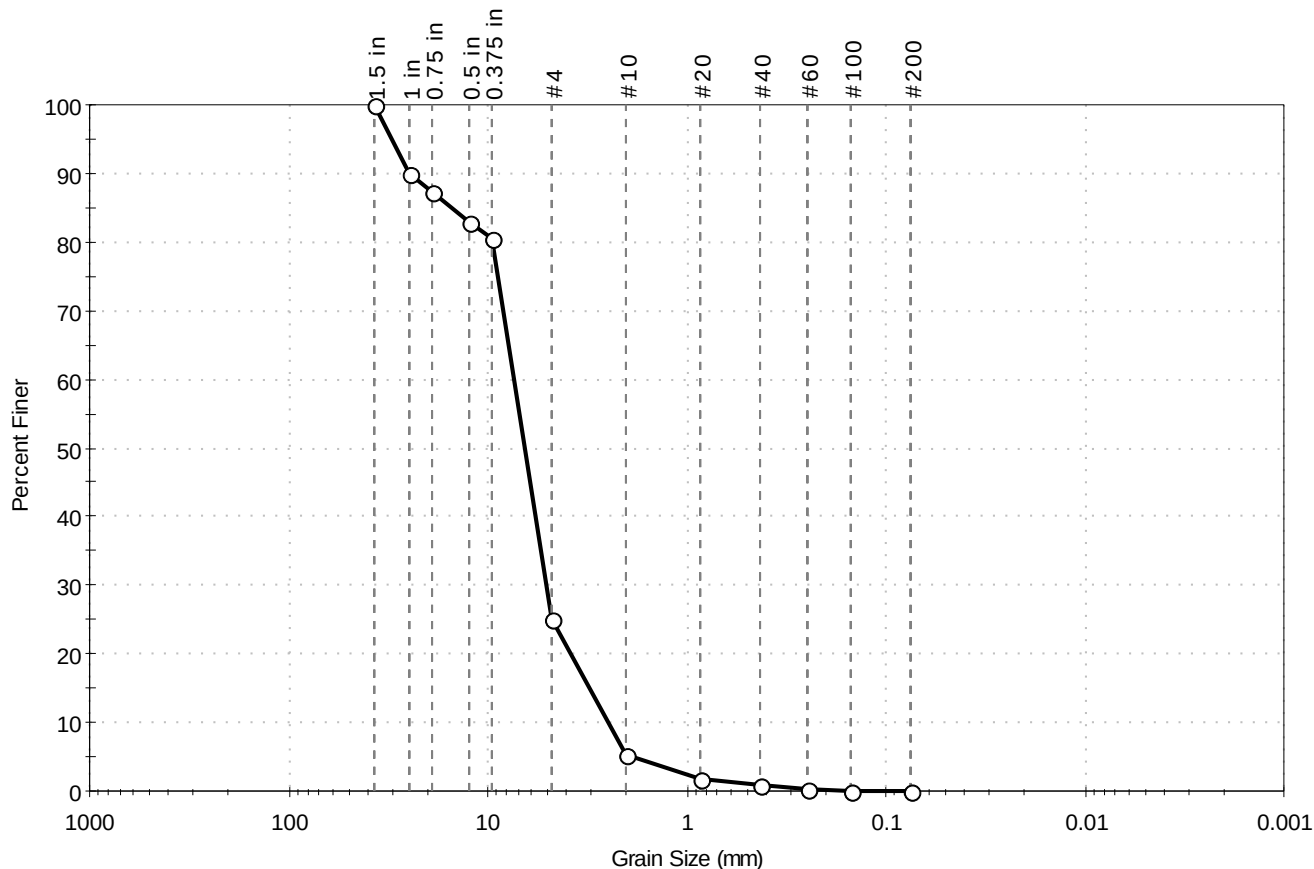
AASHTO Stone Fragments, Gravel and Sand (A-1-b (0))

Sample / Test Description

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

Client:	Golder Associates		
Project:	Route 189 Culvert Replacement		
Location:	Lubec, ME	Project No:	GTX-306600
Boring ID:	BB-LUB-102	Sample Type:	jar
Sample ID:	5D	Test Date:	06/23/17
Depth :	9-11 ft	Test Id:	414646
Test Comment:	---		
Visual Description:	Moist, gray gravel with sand		
Sample Comment:	---		

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	75.1	24.9	0.0

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1.5 in	37.50	100		
1 in	25.00	90		
0.75 in	19.00	87		
0.5 in	12.50	83		
0.375 in	9.50	80		
#4	4.75	25		
#10	2.00	5		
#20	0.85	2		
#40	0.42	1		
#60	0.25	0		
#100	0.15	0		
#200	0.075	0.0		

Coefficients

D ₈₅ = 15.1183 mm	D ₃₀ = 5.0593 mm
D ₆₀ = 7.3563 mm	D ₁₅ = 3.0593 mm
D ₅₀ = 6.4933 mm	D ₁₀ = 2.4522 mm
C _u = 3.000	C _c = 1.419

Classification

ASTM Poorly graded gravel with sand (GP)

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

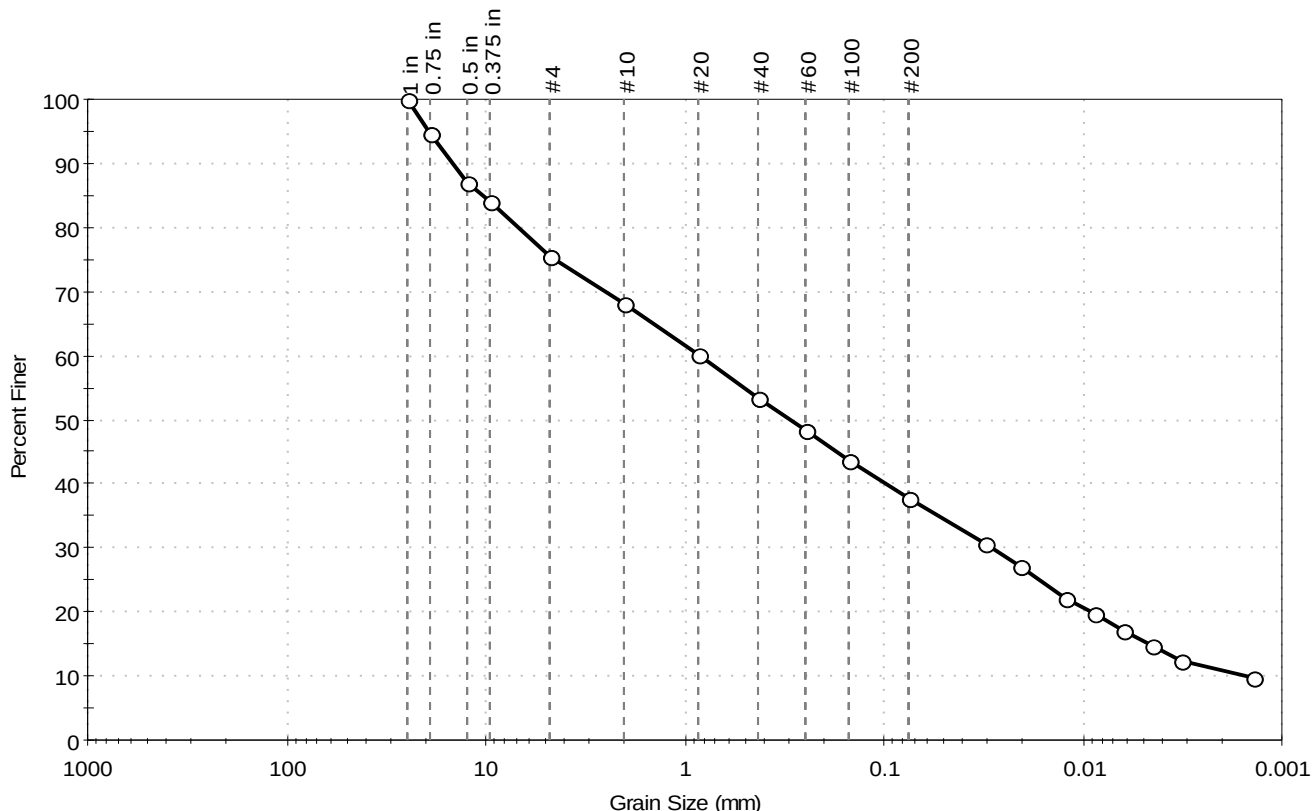
Sample / Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Client:	Golder Associates		
Project:	Route 189 Culvert Replacement		
Location:	Lubec, ME	Project No:	GTX-306600
Boring ID:	BB-LUB-102	Sample Type:	jar
Sample ID:	6D	Test Date:	06/27/17
Depth :	11-13 ft	Test Id:	414648
Test Comment:	---		
Visual Description:	Moist, olive clayey sand with gravel		
Sample Comment:	---		

Particle Size Analysis - ASTM D422



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	24.6	37.8	37.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1 in	25.00	100		
0.75 in	19.00	95		
0.5 in	12.50	87		
0.375 in	9.50	84		
#4	4.75	75		
#10	2.00	68		
#20	0.85	60		
#40	0.42	53		
#60	0.25	48		
#100	0.15	44		
#200	0.075	38		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0311	31		
---	0.0207	27		
---	0.0123	22		
---	0.0088	20		
---	0.0063	17		
---	0.0045	15		
---	0.0032	12		
---	0.0014	10		

Coefficients

$D_{85} = 10.3811$ mm $D_{30} = 0.0285$ mm
 $D_{60} = 0.8351$ mm $D_{15} = 0.0046$ mm
 $D_{50} = 0.2956$ mm $D_{10} = 0.0015$ mm
 $C_u = 556.733$ $C_c = 0.648$

Classification

ASTM N/A

AASHTO Silty Soils (A-4 (0))

Sample / Test Description

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



Client:	Golder Associates		
Project:	Route 189 Culvert Replacement		
Location:	Lubec, ME	Project No:	GTX-306600
Boring ID:	BB-LUB-101	Sample Type:	cylinder
Sample ID:	Run 1	Test Date:	06/27/17
Depth :	14.15-14.70 ft	Test Id:	414654
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-LUB-101	Run 1	14.2-14.58 ft	184	6380	3	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)

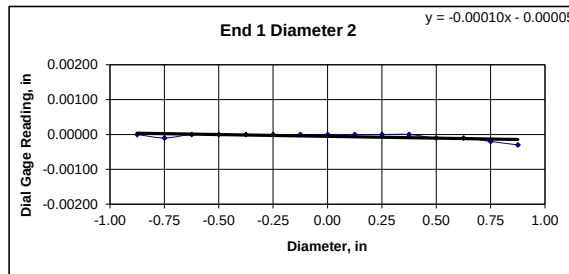
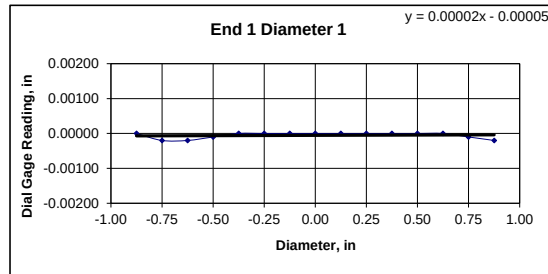


Client:	Golder Associates	Test Date:	6/27/2017
Project Name:	Route 189 Culvert Replacement	Tested By:	rlc
Project Location:	Lubec, ME	Checked By:	jsc
GTX #:	306600		
Boring ID:	BB-LUB-101		
Sample ID:	Run 1		
Depth:	14.2-14.58 ft		
Visual Description:	See photographs		

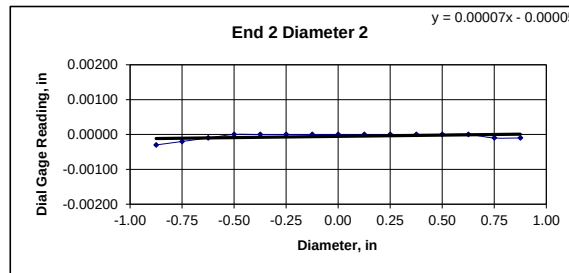
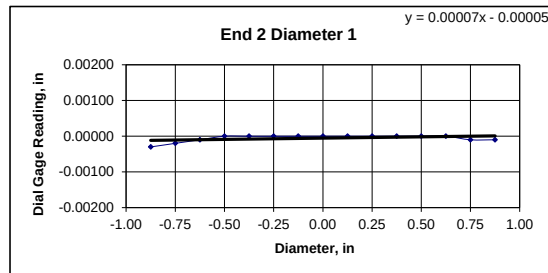
UNIT WEIGHT DETERMINATION AND DIMENSIONAL AND SHAPE TOLERANCES OF ROCK CORE SPECIMENS BY ASTM D4543

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:	4.45	4.45	4.45	Maximum difference must be $<$ 0.020 in.	
Specimen Diameter, in:	1.99	1.99	1.99	Straightness Tolerance Met? YES	
Specimen Mass, g:	670.02				
Bulk Density, lb/ft ³ :	184				
Length to Diameter Ratio:	2.2	Minimum Diameter Tolerance Met? YES			
		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	0.00000	-0.00020	-0.00020	-0.00010	0.00000	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	0.00000	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° = 0.00020 90° = 0.00030															
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	-0.00030	-0.00020	-0.00010	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	-0.00010	-0.00010
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	0.00000	0.00000	-0.00010	-0.00010
Difference between max and min readings, in: 0° = 0.0003 90° = 0.0003 Maximum difference must be < 0.0020 in. Difference = ± 0.00015															
Flatness Tolerance Met? YES															



DIAMETER 1	
End 1:	
Slope of Best Fit Line	0.00002
Angle of Best Fit Line:	0.00115
End 2:	
Slope of Best Fit Line	0.00007
Angle of Best Fit Line:	0.00401
Maximum Angular Difference:	0.00286
Parallelism Tolerance Met? Spherically Seated	YES



DIAMETER 2	
End 1:	
Slope of Best Fit Line	0.00010
Angle of Best Fit Line:	0.00573
End 2:	
Slope of Best Fit Line	0.00007
Angle of Best Fit Line:	0.00401
Maximum Angular Difference:	0.00172
Parallelism Tolerance Met? Spherically Seated	YES

PERPENDICULARITY (Procedure P1)						Maximum angle of departure must be $\leq$ 0.25°	
END 1	Difference, Maximum and Minimum (in.)	Diameter (in.)	Slope	Angle°	Perpendicularity Tolerance Met?		
Diameter 1, in	0.00020	1.990	0.00010	0.006	YES		
Diameter 2, in (rotated 90°)	0.00030	1.990	0.00015	0.009	YES	Perpendicularity Tolerance Met? YES	
END 2							
Diameter 1, in	0.00030	1.990	0.00015	0.009	YES		
Diameter 2, in (rotated 90°)	0.00030	1.990	0.00015	0.009	YES		

Client:	Golder Associates
Project Name:	Route 189 Culvert Replacement
Project Location:	Lubec, ME
GTX #:	306600
Test Date:	6/27/2017
Tested By:	rlc
Checked By:	jsc
Boring ID:	BB-LUB-101
Sample ID:	Run 1
Depth, ft:	14.2-14.58



After cutting and grinding



After break

APPENDIX D
CALCULATIONS



SUBJECT: Subgrade Modulus
Project Number: 1772215
Project Name: Route 189 Culvert Replacement - Lubec, ME
Prepared by: CJS
Date: 6/20/2017
Checked by: MCM
Reviewed by: MSP

Objective:

Determine the subgrade modulus.

Method:

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-LUB-101, BB-LUB-102.

Assumptions:

1. Assume the new culvert bottom slab (~El. 26.0, per WSP) sits atop 2ft of compacted structural fill. This 2ft of structural fill is assumed to replace all organic material near the culvert bearing surface. Assume box culvert will be placed on a minimum 2ft thick layer of compacted structural fill (i.e. underwater backfill). Bedrock is estimated to be about 5 ft below the bottom of the proposed box culvert. Therefore, there will be about 3ft of native till and weathered bedrock beneath the structural fill. The subgrade modulus value provided in this calculation will be for the till/weathered bedrock beneath this structural fill layer.
2. The west side of the new culvert is assumed to rest on roughly 2.5ft of "weathered rock - fractured rock and gravel with little clayey silt." The east side of the new culvert culvert is assumed to rest on roughly 2ft of "Till - clayey sand with some gravel and fracture rock," overlying 1.5ft of weathered rock. For the purposes of this calculation, conservatively assume that the entire subsurface is composed of Clayey Sand (Till) that will be saturated below the river elevation.

Calculations:

A.) Determine the subgrade modulus.

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 Table 6.2. This table coupled with the assumption of a medium dense to dense saturated sand yields k_1 values ranging from 125-550pci.

Based on FHWA Figure 8-3 and medium dense to dense glacial till, the selected k_1 value for a coarse-grained material is 180 tcf = 208 pci.

Table 7.1 from the Canadian Geotechnical Society give a range of 220 to 592 pci for granular soils.

Conclusion:

Use a k_1 value of 200 pci for the proposed culvert replacement in Lubec.



SUBJECT: Bearing Capacity & Settlement Proposed Culvert
Project Number: 1772215
Project Name: Route 189 Culvert Replacement, Lubec, ME
Prepared by: CJS
Date: 11/6/2018
Checked by: MCM
Reviewed by: MSP

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 the Hough Method.

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. 31.96 (i.e. 100 year flood)
2. Ground surface (i.e. depth = 0ft) is at ~ El. 36.4.
3. Approximate bottom of culvert box elevation is at ~ El. 22.5'.
4. Proposed culvert will be a 4-sided box culvert - 24ft span and 73ft long (from WSP).
5. Assume compacted fill below footing is one foot thick to removal all organic material observed near the bearing elevation during the field exploration.
6. Assume box culvert will be placed on a minimum 1ft thick layer of compacted structural fill (i.e. underwater backfill). Bedrock is estimated to be within 3 ft of the bottom of the proposed box culvert. Therefore, there will be about 2ft of native till and weathered bedrock beneath the structural fill. This calculation assumes a 2-layer system for estimating bearing of compacted structural fill over till. This approach is conservative since the bearing capacity influence zone for this case (2B, i.e. 48ft) will consist primarily of bedrock. Refer to the interpreted subsurface profile A-A' in the geotechnical report.

$$D_w = 4.44 \text{ ft}$$

Calculations:

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

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 composed of till and weathered bedrock. Selected values are summarized below:

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

	Internal Friction Angle, ϕ_f (°)	Cohesion (ksf)	Unit weight, γ (kcf)
Compacted Fill Below Footing	34	0	0.125
Till and Weathered Rock	36	0	0.135

$$H = \text{thickness of upper soil layer below footing (compacted fill), ft} \quad H = 1.0 \text{ ft.}$$

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 =	24 ft
γ_1 =	0.125 kcf
ϕ_{f1}^* =	34 °
D_f =	13.9 ft
L_f =	73 ft

$$N_{qm1} = 36.0$$

$$N_{q1} = 29.4$$

$$s_q = 1.22$$

$$d_q = 1.00$$

$$35.7$$

$$N_{\gamma1} = 41.1$$

$$s_\gamma = 0.87$$

$$D_w = 4.44$$

$$C_{wq} = 0.66$$

$$C_{w\gamma} = 0.54$$

$$q_1 = 70.4 \text{ ksf}$$

Layer 2 - Till & Weathered Bedrock

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

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

d_q = depth correction factor, Table 10.6.3.1.2a-4

Presumpscot	
B_f =	24 ft - Based on PDR
γ_1 =	0.135 kcf
ϕ_{f1}^* =	36 °
c^* =	0.000 ksf
D_f =	14.9 ft
L_f =	73 ft

$$N_{qm2} = 46.8$$

$$N_{q2} = 37.8$$

$$s_q = 1.24$$

$$d_q = 1.00$$

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

$$N_{\gamma m 2} = \boxed{48.9}$$

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

$$N_{\gamma 2} = \boxed{56.3}$$

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

$$s_{\gamma} = \boxed{0.87}$$

D_w = depth to water, ft

$$D_w = \boxed{4.44} \text{ ft}$$

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

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

$$C_{wq} = \boxed{0.65}$$

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

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

$$C_{w\gamma} = \boxed{0.54}$$

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

$$N_{c m 2} = \boxed{53.9}$$

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

$$N_{c2} = \boxed{50.6}$$

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

$$s_c = \boxed{1.07}$$

$$q_2 = \boxed{104.1} \text{ ksf}$$

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

$$H_{crit} = \boxed{-10.6} \text{ ft}$$

Is H_{crit} less than H?

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

$$K = \boxed{0.5}$$

$$q_n = \boxed{N/A} \text{ ksf}$$

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.

$$q_n = \boxed{70.4} \text{ ksf}$$

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)

$$\phi_b = \boxed{0.45}$$

$$Q_{R-2} (\text{ksf}) = \boxed{31.66}$$

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: Glacial Till and Weathered Rock

In Situ Consistency: Medium Dense to Dense

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

Bearing Resistance: Range 8 - 14 ksf, Use 10ksf

Factored bearing Resistance = $10\text{ksf} * 1.0 = \mathbf{10\text{ksf}}$

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

Conclusions:

For the proposed 24ftx73ft four sided box culvert:

- the bearing capacity for the strength limit state is 31.7 ksf
- the presumptive bearing capacity for the service limit state is 10.0 ksf (at 1inch of settlement)
- The proposed box culvert will be larger than the existing culvert. Therefore it is assumed that the installation of the new culvert will result in a net negative loading. As such, settlement is assumed to be negligible.



GOLDER

PROJECT	Route 189 Culvert Replacement	PROJECT #	1772215
DESCRIPTION	Infinite Slope Stability Check		
PREPARED BY	CJS	DATE	11/2/2018
Checked:		DATE	11/6/18
REVIEWED BY	JDL (11/2/16) MCM	SHEET	1 OF 1
REF/DWGS			

Purpose: Verify Stability of proposed riprap slope treatment

Reference: 1) WSP, "Preliminary Design Report - Mays Bridge #2527 over Mays Stream
Lubec, Maine STP-02169(700), Win 21697.00," dated October 5, 2018

2) Terzaghi, Karl, Peck, Ralph B. and Mesri Gholamreza, (1996). "Soil Mechanics
in Engineering Practice," 3rd ed, pc

Assumptions: 1) Riprap has $\phi = 42^\circ$ and is placed at a 3ft thickness

2) Bedding material beneath riprap is free draining (i.e. riprap is dry)

3) Riprap is placed at 1.5H:1V slope (i.e $\beta = 33.7^\circ$)

Calculation:

Calculate factor of safety of riprap slope using infinite slope theory:

$$F = \frac{\tan \phi}{\tan \beta} = \frac{\tan(42^\circ)}{\tan(33.7^\circ)} = \underline{1.35}$$

Conclusion:

The proposed 1.5H:1V riprap slope has factor of safety greater than required 1.3, provide riprap remains drained.