



**THURBER** ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
REPLACEMENT OF STRUCTURAL CULVERT No. 29-249/C1  
LOCHA CREEK CULVERT CROSSING OF HIGHWAY 17  
TOWNSHIP OF McNAB/BRAESIDE, ON  
G.W.P. 4061-17-00  
AGREEMENT NUMBER: 4016-E-0014**

**GEOCRES NUMBER: 31F-205**

**SUBMITTED TO  
McINTOSH PERRY CONSULTING ENGINEERS**

**LOCATION:  
LATITUDE: 45.44406°  
LONGITUDE: -76.53489°**

**March 2019  
20482**

## TABLE OF CONTENTS

### PART 1: FACTUAL INFORMATION

1	INTRODUCTION .....	1
2	SITE DESCRIPTION .....	1
3	SITE INVESTIGATION AND FIELD TESTING .....	2
4	LABORATORY TESTING .....	4
5	DESCRIPTION OF SUBSURFACE CONDITIONS .....	4
5.1	Overview / General .....	4
5.2	Surface Cover .....	4
5.3	Embankment Fill .....	4
5.4	Silty Sand (SM) to Sandy Silt (ML) .....	5
5.5	Organic Silt (OL) with Sand .....	5
5.6	Sandy Clay (CL/CI) to Silty Clayey Sand (SC-SM) .....	6
5.7	Clay (CL to CH) .....	6
5.8	Silty Clayey Sand (SC-SM) with Gravel to Sandy Silty Clay: Till .....	7
5.9	Marble Bedrock .....	7
5.10	Groundwater Conditions .....	8
5.11	Analytical Test Results .....	9
6	MISCELLANEOUS .....	10

### PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7	GENERAL .....	11
7.1	Existing Foundations .....	11
7.2	Proposed Structure .....	12
7.3	Design Code Considerations .....	12
7.4	Frost Penetration Depth .....	12
8	SEISMIC CONSIDERATIONS .....	13
8.1	Spectral and Peak Acceleration Hazard Values .....	13
8.2	CHBDC Seismic Site Classification .....	13
8.3	Seismic Liquefaction .....	13
9	GEOTECHNICAL ASSESSMENT/CONSIDERATIONS .....	13

10	EVALUATION OF DESIGN OPTIONS .....	15
10.1	Culvert Type/Foundation Alternatives .....	15
10.2	Construction Staging Alternatives .....	16
10.3	Recommended Approach for the Culvert Replacement .....	16
11	FOUNDATION DESIGN RECOMMENDATIONS .....	17
11.1	Axial Compression.....	17
11.2	Downdrag and Lateral Loading due to Clay Settlement .....	17
11.3	Foundation Lateral Response .....	18
11.4	Pile Installation .....	19
11.5	Frost Protection .....	19
11.6	Lateral Earth Pressures and Culvert Backfill .....	19
11.6.1	Static Lateral Earth Pressure Coefficients.....	19
11.6.2	Combined Static and Seismic Lateral Earth Pressure Parameters .....	20
11.7	Embankment Design and Reinstatement .....	21
11.7.1	Embankment Reinstatement .....	21
11.7.2	Embankment for Future Highway Twinning .....	21
11.7.3	Temporary Widening Construction.....	22
11.8	Cement Type and Corrosion Potential .....	22
12	INSTRUMENTATION AND MONITORING .....	23
13	CONSTRUCTION CONSIDERATIONS .....	23
13.1	Excavations .....	23
13.2	Dewatering .....	24
13.3	Temporary Protection Systems .....	25
13.4	Erosion Protection .....	26
14	CONSTRUCTION CONCERNS .....	26
15	CLOSURE .....	27

## **APPENDICES**

Appendix A	Borehole Locations and Soil Strata Drawings
Appendix B	Record of Borehole Sheets
Appendix C	Laboratory Test Results
Appendix D	Site Photographs
Appendix E	Comparison of Culvert Type/Foundation Alternatives
Appendix F	Clay Property Summary Figures
	Pile Analysis P–Y Data Output
	Soil Lateral Displacement Profile
Appendix G	2015 NBC Seismic Hazard Calculation
	Slope Stability Analysis Results
Appendix H	List of Referenced Specifications
	Non-Standard Special Provisions



**FOUNDATION INVESTIGATION AND DESIGN REPORT  
REPLACEMENT OF STRUCTURAL CULVERT No. 29-249/C1  
LOCHA CREEK CULVERT CROSSING OF HIGHWAY 17  
TOWNSHIP OF McNAB/BRAESIDE, ON  
G.W.P. 4061-17-00  
AGREEMENT NUMBER: 4016-E-0014**

**GEOCRES NUMBER: 31F-205**

**PART 1: FACTUAL INFORMATION**

**1 INTRODUCTION**

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) at the Locha Creek Culvert site located on Highway 17, within the Township of McNab/Breaside, in Renfrew County Ontario. Thurber carried out the investigation as a subconsultant to McIntosh Perry Consulting Engineers (MPCE) as part of Agreement No. 4016-E-0014.

A base plan, Preliminary General Arrangement (GA) and construction staging drawings were provided by MPCE for the preparation of this report. A copy of the GA Drawing is provided in Appendix A.

No previous foundation reports were available for this site.

The purpose of this investigation was to explore the subsurface conditions at the Locha Creek Culvert site and based on this data, provide a borehole location plan, record of boreholes, a stratigraphic profile, laboratory test results and a written description of the subsurface conditions.

**2 SITE DESCRIPTION**

Culvert 29-249/C1 is located at approximately Station 15+692 on Highway 17, approximately 170 m west of the intersection with Miller Road (northbound) / Anderson Road (southbound), in Renfrew County, Ontario. The location of the culvert is shown on the Key Plan on Drawing No. 1 in Appendix A.

It is noted that for project orientation purposes, Highway 17 within the project limits, will be assumed to run east-west. Flow through the culvert is from south to north.

In the vicinity of the culvert site, Highway 17 is an undivided highway with one through lane in each direction. An eastbound righthand turn taper is also present at the culvert crossing. Based on the drawing provided, the driving lanes are 3.7 m wide and the turn taper has a maximum width of 3.5 m. A steel cable guide rail is present along the south side of the highway.

The existing 48 m long corrugated steel sectional plate arch culvert is 4.8 m wide and 3.0 m high. The existing Highway 17 embankment slopes are graded at 2H:1V (Horizontal:Vertical) and 3H:1V at the inlet and outlet respectively. The slopes are covered with grass and brush. The June 2018 GA drawing indicates that the top of pavement at the centreline of Highway 17 above the culvert alignment is at elevation 138.9 m. The cover over the existing culvert from shoulder to the top of the culvert is approximately 4.5 m. Rip-rap is present on the side slopes surrounding both

the inlet and outlet. No signs of settlement or erosion of the existing embankment slopes were noted at the time of the investigation. Storm water drainage in the area is to ditches and Locha Creek.

The site is located within a physiographic region known as the Ottawa Valley Clay Plains which is characterized by clay plains interrupted by ridges of rock or sand.

The lands surrounding the project limits are gently rolling with a mixture of wooded areas and open fields. There is a strip of flat land, covered with grass and brush, that curves out from Highway 17 toward Miller Road to the northwest, suggesting a possible former road alignment. A buried Enbridge natural gas pipeline is present to the north and east of the existing culvert running parallel to Miller Road.

Site photographs showing the general conditions at the site, along the existing highway embankment and at the inlet and outlet and along the proposed culvert alignment are presented in Appendix D.

### 3 SITE INVESTIGATION AND FIELD TESTING

A field investigation was carried out between September 11<sup>th</sup> and 25<sup>th</sup>, 2017, based on the initial plans for the replacement of the culvert on the same alignment with a culvert of similar length. The investigation included advancing seven boreholes (Boreholes 17-1 through 17-7). Borehole 17-4 was advanced beyond the planned drilling/sampling depth by advancing a dynamic cone penetration test.

Based on the design development and results of the initial (2017) investigation, a supplemental investigation was carried out in 2018 for a potentially longer culvert that would extend beneath the future 4-laning of Highway 17 (to be constructed to the north of the existing Highway 17 alignment).

The 2018 field investigation was carried out between June 11<sup>th</sup> and June 15<sup>th</sup>, 2018, and included advancing three additional boreholes (18-101 through 18-103).

The approximate MTM Zone 9 locations and ground surface elevations of the boreholes are indicated on Drawing No. 1, provided in Appendix A and are summarized in Table 3-1. The borehole elevations were surveyed relative to HPC 152 which was identified on the base plans as having a geodetic elevation of 139.100 m. The survey was completed with a Nikon-AP-8 automatic level with an instrument accuracy of +/-1.5 mm. The reported elevations are considered accurate within 0.1 m.

**Table 3-1: Borehole Summary**

Borehole	Location	Northing (m)	Easting (m)	Ground Surface Elevation (m)	Borehole Termination Elevation (m)
17-1	Existing Inlet/Cofferdam	5033771.3	302079.3	131.9	121.2
17-2	Existing Inlet/Cofferdam	5033773.2	302072.3	131.9	119.8
17-3	Highway 17 Eastbound	5033789.1	302072.6	138.9	120.0
17-4	Highway 17 Westbound	5033794.5	302085.7	138.8	119.9* 107.7**
17-5	Existing Outlet/Cofferdam	5033825.9	302077.5	133.8	122.5

<b>Borehole</b>	<b>Location</b>	<b>Northing (m)</b>	<b>Easting (m)</b>	<b>Ground Surface Elevation (m)</b>	<b>Borehole Termination Elevation (m)</b>
17-6	Existing Outlet/Cofferdam	5033825.8	302089.1	132.7	119.9
17-7	Embankment Widening	5033821.8	302109.2	134.3	121.5
18-101	Proposed Outlet	5033858.0	302096.9	132.5	100.3
18-102	Culvert	5033812.3	302076.5	137.7	104.7
18-103	Proposed Inlet	5033766.1	302084.0	133.9	105.5

NOTES: \* – Termination of Sampled Borehole  
\*\* – DCPT refusal

As a component of our standard procedures and due diligence, Thurber contacted Ontario One Call to provide utility locates/clearances for the borehole locations.

The boreholes completed during the 2017 field investigation were advanced using a CME75 truck mounted drill rig for the roadway embankment boreholes, and portable drilling equipment using a full weight hammer and tripod for the inlet and outlet boreholes. The boreholes completed during the 2018 field investigation were advanced using a CME45C track mounted drill rig equipped with NQ size coring equipment.

The subsurface stratigraphy encountered in the boreholes was recorded in the field by Thurber personnel. Split spoon samples were collected at regular depth intervals in all boreholes during the completion of Standard Penetration Tests (SPT), following the methods described in ASTM Standard D1586-11. Thin-walled tube samples (Shelby tube samples) were collected in the cohesive deposits in Boreholes 17-2, 17-3, and 18-101 through 18-103. In-situ shear vane testing was carried out within the cohesive strata. All soil samples recovered from the boreholes were placed in moisture-proof containers and the samples were transported to Thurber's Ottawa geotechnical laboratory for further examination and testing. Bedrock was cored with NQ size coring equipment, following ASTM Standard D6032-08, in Boreholes 18-101 through 18-103. Bedrock core samples were stored in wooden core boxes for transport.

A 25 mm inside diameter PVC piezometer was installed in Boreholes 17-5 and 18-102 to allow for measurement of the groundwater level at the site. Piezometer construction details are illustrated on the Record of Borehole sheets for Boreholes 17-5 and 18-102, provided in Appendix B. The piezometers were decommissioned in accordance with Ontario MOE Regulation 903, as amended, after taking the final groundwater measurement.

The boreholes without a piezometer were backfilled with a low-permeability combination of auger cuttings and bentonite pellets in accordance with Ontario MOE Regulation 903, as amended. Boreholes advanced within paved areas were capped with 150 mm of cold patch asphalt.

The as-drilled locations of the boreholes and ground surface elevations at the borehole locations were surveyed by Thurber. The vertical datum used was Horizontal Control Point (HCP) 152, located in the westbound shoulder to the west of the culvert at approximate Station 15+555. Data provided by MPCE indicated that HCP 152 has a geodetic elevation of 139.100 m.

## **4 LABORATORY TESTING**

Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all soil samples. Grain size distribution analyses and Atterberg Limits testing were carried out on selected samples to MTO and ASTM standards. One dimensional consolidation tests were carried out on four thin-walled tube samples. All recovered bedrock core was logged and core recoveries and Rock Quality Designation (RQD) values were determined. Unconfined compressive strength testing was carried out on select samples of the recovered bedrock.

The geotechnical laboratory test results are presented on the Record of Borehole sheets in Appendix B and are illustrated on the figures in Appendix C.

Chemical analysis for determination of pH, resistivity, soluble sulphate, sulphides, conductivity, and chloride concentrations was carried out on three samples of the soil recovered during the field investigations. Copies of the chemical analysis results are provided in Appendix C.

## **5 DESCRIPTION OF SUBSURFACE CONDITIONS**

### **5.1 Overview / General**

Reference is made to the Record of Borehole sheets in Appendix B for details of the soil stratigraphy encountered in the boreholes. A stratigraphic profile for the proposed culvert alignment is presented on Drawing No. 1 in Appendix A for illustrative purposes. An overall description of the stratigraphy is given in the following paragraphs; however, the factual data presented in the Record of Boreholes governs any interpretation of the site conditions.

For reference, the stratigraphy in the area of the boreholes is characterized by embankment fill, overlying a deep clay deposit, over a thin glacial till deposit over marble bedrock. Relatively thin deposits of silty sand, sandy silt, organic silt with sand, sandy clay and silty clayey sand were encountered above the clay or between the fill and clay deposits at some borehole locations.

More detailed descriptions of the individual strata are presented below.

### **5.2 Surface Cover**

Boreholes 17-3 and 17-4 were advanced through the Highway 17 lane or shoulder pavement structure. The thickness of the asphalt at the borehole locations was 170 mm and 290 mm.

A 50 mm thick layer of rootmat/topsoil was observed at the surface of Borehole 18-103.

### **5.3 Embankment Fill**

#### **Sand with Gravel to Silty Sand: FILL**

A fill layer consisting predominantly of sand with varying amounts of gravel and silt was encountered below the asphalt layer of Boreholes 17-3 and 17-4. The top of this layer was encountered at elevations 138.7 m and 138.5 m, and the layer had a thickness 1.2 m in both Boreholes 17-3 and 17-4 respectively. The SPT N values ranged from 6 to 49, indicating a loose to dense condition; but typically compact.

The moisture content of the samples tested ranged from 4% to 20%. The results of a grain size analysis test conducted on a sample of this material indicated a gravel content of 6%, a sand content of 80%, and a fines content (combined silt and clay size particles) of 14%. Grain size analysis results are illustrated on Figure 1 in Appendix C.

### **Sand /Silty Sand: FILL**

A fill layer was encountered beneath the pavement structure in Boreholes 17-3 and 17-4, below the surface cover in Borehole 18-103, and at the ground surface in Boreholes 17-5, 17-6, 17-7, and 18-102. The fill layer consisted mainly of sand to silty sand, however, the deposit also contained layers or pockets of sandy silt, sandy clay and silty clay, as well as trace amounts of organic material. Cobbles and boulders were encountered within the fill in Borehole 17-4 and may be present at other locations. The top of this fill deposit ranges from elevation 132.7 m to 137.7 m. The thickness of the layer ranged from 0.8 m to 5.5 m. The SPT N values ranged from 2 to 54, indicating a very loose to very dense condition; but typically loose to compact.

The moisture content of the samples tested ranged from 3% to 54%. The results of grain size analysis tests conducted on samples of this material indicated a gravel content ranging from 1% to 25%, a sand content ranging from 69% to 87%, and a fines content ranging from 3% to 12%. Grain size analysis results are illustrated on Figure 2 in Appendix C.

### **5.4 Silty Sand (SM) to Sandy Silt (ML)**

A stratum of silt and sand was encountered at the ground surface of Boreholes 17-1, and 17-2, beneath the sandy clay in Boreholes 17-3 and 18-101, and beneath the fill in Borehole 17-5. Organic material was noted in this stratum. The top of this layer was encountered at elevations ranging from 131.3 m to 131.9 m. The thickness of the layer ranged from 0.5 m to 2.2 m. The SPT N values ranged from 2 to 8; indicating a very loose to loose condition.

The moisture content of the samples tested ranged from 32% to 51%. The results of grain size analysis tests conducted on samples of this material indicated a gravel content of 0% and 10%, a sand content ranging from 19% to 91% and a fines content ranging from 9% to 81%. Grain size analysis results are illustrated on Figure 3 in Appendix C.

The results of Atterberg Limits testing completed on a sample of the fines of this material indicated a non-plastic silt.

### **5.5 Organic Silt (OL) with Sand**

A layer of organic silt with sand was encountered below the sand with silt layer in Boreholes 17-1, and 17-2. The top of this layer was encountered at elevations 130.7 m and 131.1 m, and the layer had a thickness of 0.8 m and 1.0 m in Boreholes 17-1 and 17-2 respectively. The SPT N value was 1, indicating a very loose condition.

The moisture content of the samples tested were 98% and 133%. The results of a grain size analysis test conducted on a sample of this material indicated a gravel content of 0%, a sand content of 39% and a silt content of 30% and a clay content of 31%. Grain size analysis results are illustrated on Figure 4 in Appendix C.

The results of Atterberg Limits testing completed on a sample of this material indicated a non-plastic silt.

## **5.6 Sandy Clay (CL/CI) to Silty Clayey Sand (SC-SM)**

A deposit that ranged from sandy clay to silty clayey sand was encountered in Boreholes 17-2, 17-3, 17-4, 18-101, 18-102 and 18-103. Occasional sand seams and organic matter were noted within this deposit at some borehole locations. The top of this layer ranges from elevation 130.1 m to 132.7 m. The thickness of the layer ranges from 0.5 m to 2.1 m. The SPT N values ranged from 1 to 14 indicating a very soft to very stiff consistency.

The moisture content of the samples tested ranged from 18% to 62%. The results of grain size analysis tests conducted on samples of this material indicated a gravel content ranging from 0% to 3%, a sand content ranging from 33% to 57%, a silt content ranging from 18% to 34% and a clay content ranging from 22% to 33%. Grain size analysis results are illustrated on Figure 5 in Appendix C.

The results of Atterberg Limits testing completed on samples of this material indicated a liquid limit ranging from 19 to 37, a plastic limit ranging from 13 to 22, and a plasticity index ranging from 6 to 17. Atterberg Limits analysis results are illustrated on Figure 6 in Appendix C and indicate a clay of low to intermediate plasticity (CL to CI). The results of the Atterberg Limits testing on the fines of the material with 40% fines indicated that the fines consisted of silty clay (CL-ML) resulting in an overall description of silty clayey sand (SC-SM).

## **5.7 Clay (CL to CH)**

Underneath the above soil layers, a clay deposit was encountered in all boreholes. The top of clay layer ranges from elevation 129.1 m to 133.5 m. The thickness of this layer, where fully penetrated, ranged from 18.6 m to 23.6 m. Borehole 17-4, was extended beyond sampling limits by DCPT with refusal encountered at elevation 107.7 m, suggesting a clay thickness of approximately 23.5 m. All boreholes from the 2017 investigation were terminated in this layer. In-situ shear vane test results indicated undrained shear strengths ranging from 25 kPa to greater than 100 kPa; indicating a firm to very stiff consistency, but typically firm to stiff. The measured sensitivity of the deposit ranged from 1.5 to 32; indicating a low sensitivity to quick clay deposit, but typically low sensitive to sensitive.

The moisture content of the samples tested ranged from 24% to 55%. The results of grain size analysis tests conducted on samples of this material indicated a gravel content ranging from 0% to 7%, a sand content ranging from 0% to 22%, a silt content ranging from 35% to 57% and a clay content ranging from 30% to 65%. Grain size analysis results are illustrated on Figures 7 to 10 in Appendix C.

The results of Atterberg Limits testing completed on samples of this material indicated a liquid limit ranging from 22 to 56, a plastic limit ranging from 13 to 27, and a plasticity index ranging from 8 to 33. The liquidity index ranged from 0.4 to 35; typically between 1.0 and 2.3. Atterberg Limits analysis results are illustrated on Figures 11 to 14 in Appendix C, and indicate a clay of low to high plasticity (CL to CH); but typically low to intermediate plasticity (CL to CI).

The results of laboratory oedometer (one-dimensional consolidation) tests carried out on four undisturbed clay sample are summarized in Table 5-1.



**Table 5-1: Consolidation Test Results**

Parameter	Value			
	17-2	17-3	18-101	18-101
Borehole	17-2	17-3	18-101	18-101
Sample	ST9	ST17	ST5	ST9
Sample Depth, (m)	10.2	15.6	4.9	11
Sample Elevation, (m)	121.7	123.3	127.7	121.5
Estimated Existing Effective Stress, ( $P_0$ ), (kPa)	83	193	37	85
Moisture Content, (%)	45	49	43	45
Unit Weight, ( $\gamma$ ) (kN/m <sup>3</sup> )	17.5	16.8	17.5	17.6
Specific Gravity ( $G_s$ )	2.746	2.746	2.750	2.750
Initial Void Ratio ( $e_0$ )	1.229	1.383	1.197	1.211
Pre-consolidation Pressure ( $P'_c$ ), (kPa)	210	200	285	185
Compression Index ( $C_c$ )	0.654	0.746	0.475	0.648
Recompression Index ( $C_r$ )	0.054	0.080	0.023	0.017
Overconsolidation Ratio (OCR)	2.5	1.0	7.7	2.2

It is noted that Borehole 17-3 was drilled through the existing Highway 17 embankment, resulting in the higher existing effective stress and lower OCR. A summary of the clay properties with depth are presented in Appendix F.

## 5.8 Silty Clayey Sand (SC-SM) with Gravel to Sandy Silty Clay: Till

A glacial till deposit ranging from silty clayey sand with gravel to sandy silty clay was encountered beneath the clay in Boreholes 18-101 through 18-103. The top of this layer ranges from elevation 107.8 m to 111.2 m. The thickness of the layer ranges from 1.4 m to 3.8 m. The SPT N values ranged from 7 to 45; indicating a loose to dense condition. It should be noted that artesian conditions were noted in this layer which may have decreased these values.

Occasional cobbles and boulders were noted within the glacial till, particularly within the lower portion of this layer and coring techniques were required to penetrate the layer.

The moisture content of the samples tested ranged from 17% to 36%. The results of grain size analysis tests conducted on two samples of this material indicated a gravel content of 3% and 11%, a sand content of 37% and 75% and a fines content of 14% and 60%. Grain size analysis results are illustrated on Figure 15 in Appendix C.

The results of Atterberg Limits testing completed on the material with 60% fines indicated that the fines consisted of silty clay (CL-ML). Atterberg Limits analysis results are illustrated on Figures 16 in Appendix C.

## 5.9 Marble Bedrock

The overburden materials were underlain by a grey to white marble bedrock. All three boreholes from the 2018 investigation were advanced into bedrock by coring with NQ-size coring equipment.

A summary of the bedrock surface elevation is provided in Table 5-2.

**Table 5-2: Bedrock Summary**

Borehole	Location	Ground Surface Elevation (m)	Top of Bedrock Elevation (m)
18-101	Proposed culvert outlet (North end)	132.5	104.0
18-102	Mid-point of proposed culvert alignment	137.7	107.9
18-103	Proposed Inlet (South end)	133.9	109.3

The total core recovery ranged from 92% to 100%, the solid core recovery ranged from 30% to 100% and the RQD ranged from 20% to 100%. Unconfined compressive strength testing was carried out on three samples of the bedrock; (see results in Appendix C). The results ranged from 127 MPa to 165 MPa. Photographs of the bedrock core are presented in Appendix C.

Based on the RQD value the bedrock is classified as very poor to excellent quality; but typically fair. Based on unconfined compressive strength testing the bedrock is very strong.

### 5.10 Groundwater Conditions

The water level in Locha Creek was measured at an approximate elevation of 132.1 m on June 16, 2018. The groundwater level in the area of the culvert is expected to reflect the creek water level.

Piezometers were installed at the site in Boreholes 17-5 and 18-102. A summary of the measured water levels are provided in Table 5-3 below.

**Table 5-3: Summary of Groundwater Conditions**

Borehole	Screened Material	Depth (mbgs)	Groundwater Elevation (m)	Date of Measurement
17-5	Fill	1.1	132.7	October 6, 2017
18-102	Clay	5.9	131.8	June 15, 2018

Artesian conditions were noted at the site upon completion of drilling in Boreholes 18-101, 18-102 and 18-103. It is suspected that the artesian condition originates from the glacial till layer which is overlain by between 18.6 m (Borehole 18-103) and 23.6 m (Borehole 18-101) of clay. The non-stabilized artesian levels were measured in the drill casing and are presented in Table 5-4. The artesian flow was sealed at the source with a combination of bentonite and clay spoils while decommissioning the boreholes.

**Table 5-4: Summary of Artesian Groundwater Conditions**

Borehole	Screened Material	Depth (mbgs)	Groundwater Elevation (m)	Date of Measurement
18-101	Till	-3.0*	135.5	June 12, 2018
18-102	Till	-0.5*	138.2	June 13, 2018
18-103	Till	-2.4*	138.2	June 15, 2018

\* Negative values denote measurements above the ground surface

All observations are considered short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.



## 5.11 Analytical Test Results

Samples of the native soils were submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate, sulphides, chloride concentrations, resistivity and electrical conductivity. The analysis results are summarized in Table 5-3. Copies of the test results are provided in Appendix C.

**Table 5-5: Results of Chemical Analysis**

Sample	Depth (m)	pH	Resistivity (Ohm-cm)	Chloride (µg/g)	Sulphate (µg/g)	Sulphide (%)	Conductivity uS/cm
17-1 SS5	3.5	7.72	1730	174	69	-	-
17-6 SS4	2.6	7.90	849	741	16	-	-
18-101 SS2B	1.2	7.32	7280	18	20	< 0.02	137

## 6 MISCELLANEOUS

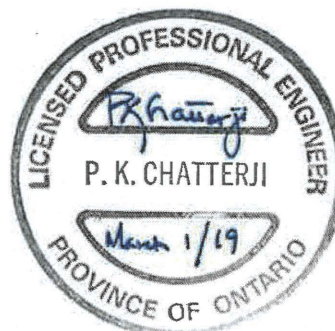
Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. Thurber surveyed the borehole locations and determined the ground surface elevations based on construction drawings provided by McIntosh Perry Consulting Engineers. George Downing Estate Drilling Ltd. and Forage M3 Drilling Services Inc., both of Hawkesbury, Ontario supplied and operated the drilling equipment to carry out the drilling, sampling, and in-situ testing. The drilling, and sampling operations in the field were supervised on a full-time basis by Katya Edney, P.Eng. and Christopher Murray, P.Eng. of Thurber. Laboratory testing was carried out by Thurber in its MTO-approved laboratory in Ottawa. Unconfined Compressive Strength Testing of the bedrock and oedometer testing was carried out by Stantec Consulting Ltd. in its MTO-approved laboratory in Ottawa.

Overall project management and direction of the field program was provided by Paul Carnaffan, P.Eng. Interpretation of the field data and preparation of this report was completed by Kenton Power, P.Eng. The report was reviewed by Paul Carnaffan, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.  
Report Prepared By:



Paul Carnaffan, P.Eng.  
Principal, Senior Geotechnical Engineer



P.K. Chatterji, P.Eng.  
Review Principal, Designated MTO Contact

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
REPLACEMENT OF STRUCTURAL CULVERT No. 29-249/C1  
LOCHA CREEK CULVERT CROSSING OF HIGHWAY 17  
TOWNSHIP OF McNAB/BRAESIDE, ON  
G.W.P. 4061-17-00  
AGREEMENT NUMBER: 4016-E-0014**

**GEOCRES NUMBER: 31F-205**

**PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**7 GENERAL**

This report presents the interpretation of the factual data obtained from a foundation investigation conducted by Thurber at the Locha Creek Culvert located on Highway 17, in the Township of McNab/Braeside, within Renfrew County, Ontario.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. Contractors must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

The following sections provide geotechnical recommendations for the replacement of the existing Locha Creek Culvert. The discussions and recommendations presented in this report are based on the information provided by McIntosh Perry Consulting Engineers (MPCE) and on the factual data obtained during the course of this investigation.

**7.1 Existing Foundations**

The existing culvert consists of a 48.0 m x 4.8 m x 3.0 m corrugated steel plate arch (CSPA). No wingwalls or headwalls are present. Photographs 1, 3 and 5 in Appendix D show the existing condition of the road platform, and the inlet and outlet respectively

The top of pavement above the culvert at the existing Highway 17 centreline is shown at elevation 138.92 m. The existing highway embankment is approximately 13.5 m wide across the top, up to 6.2 m high and the embankment slopes are graded at 2H:1V and 3H:1V at the inlet and outlet respectively.

No evidence of excessive settlement, erosion or embankment instability was observed during the site work, however, the asphalt thickness of 270 mm identified in Borehole 17-4 is relatively thick for the traffic on this highway and may be indicative of past settlement that has been corrected by asphalt padding.

## 7.2 Proposed Structure

Based on information provided by MPCE, the existing culvert is to be replaced along the existing alignment with an 85.5 m long pre-cast, concrete open footed culvert with an internal span of 7.3 m and an internal height of 3.0 m. The additional length would all be on the north side, extending beneath the future 4-laning of Highway 17. The GA indicates a culvert invert elevation of 131.27 m at the inlet and 131.25 m at the outlet.

A preliminary plan and cross section for the future Highway 17 WBL indicates the embankment will be approximately 12.3 m wide and will have an approximate top of pavement elevation at the centreline of 139.0 m; representing a fill height of up to 6.5 m. The timeline for twining of Highway 17 has not been confirmed.

No retaining walls or headwalls are proposed for the replacement culvert.

The Construction Staging drawings indicate that two lanes of traffic will operate through the construction zone during all stages of the culvert replacement. It is understood that temporary widening of the highway platform to the north in conjunction with a temporary protection system (up to 9 m in height) is being considered as part of construction staging for this project.

It is understood that the preliminary flow diversion plan for this site is to install a pipe, or a series of pipes, through the existing culvert to maintain creek flow through the construction zone during construction of the new wider culvert. Cofferdams and temporary protection systems are also anticipated to be required. See Section 13.2 for further details on dewatering.

## 7.3 Design Code Considerations

The geotechnical assessment presented below has been prepared based on the available data regarding the proposed foundations and existing ground conditions and in accordance with the Canadian Highway Bridge Design Code, version CSA S6-14, (CHBDC).

In accordance with CHBDC, the analysis and design of the structure takes into consideration the importance of the structure and the consequence associated with exceeding limit states. The importance category and consequence classification are defined by the Regulatory Authority, which in this case is the Ministry of Transportation, Ontario (MTO).

It is understood that the replacement of the Locha Creek culvert is being designed to the Major Route importance category.

This project has been assigned Typical Consequence Classification, in accordance with Section 6.5.1 of the CHBDC. Accordingly, a consequence factor ( $\Psi$ ) of 1.0, as per Table 6.1 of the CHBDC, has been used in assessing the factored geotechnical resistances.

## 7.4 Frost Penetration Depth

The frost penetration depth at this site is 1.9 m as per OPSD 3090.101.

## **8 SEISMIC CONSIDERATIONS**

### **8.1 Spectral and Peak Acceleration Hazard Values**

The seismic hazard data for the CHBDC is based on the fifth-generation seismic model developed by the Geological Survey of Canada (GSC). Seismic hazard data for this site has been obtained from the GSC's seismic hazard calculator. The data includes peak ground acceleration (PGA), peak ground velocity (PGV), and the 5% damped spectral response acceleration values ( $S_a(T)$ ) for the reference ground condition (Site Class C) for a range of periods ( $T$ ) and for a range of return periods including the 475-year, 975-year and 2475-year events. The GSC seismic hazard calculation data sheet for this site is presented in Appendix G.

The site coefficients used to determine the design spectral acceleration and displacement values are a function of the Site Class and the peak ground acceleration (PGA) for this location for a reference Site Class C with a 2% probability of exceedance in 50 years is 0.228g. This value is to be scaled by the  $F(PGA)$  based on the site-specific Site Class as per Section 4.4.3.3 (Table 4.8) of the CHBDC (See Section 8.2).

### **8.2 CHBDC Seismic Site Classification**

In accordance with the CHBDC, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy.

Based on the average undrained shear strengths measured below the anticipated culvert foundation elevation, the site is classified as a Seismic Site Class E in accordance with Table 4.1 of the CHBDC. As per Table 4.8 of the CHBDC, Site Class E yields a  $PGA_{ref}$  of 0.182 and  $F(PGA)$  of 1.332 for the site. These values give a factored PGA of 0.304 g.

### **8.3 Seismic Liquefaction**

A liquefaction triggering analysis for the non-cohesive soils at the site was completed using the Idriss and Boulanger simplified procedure outlined in Section C4.6 of the CHBDC Commentary. Based on the factored PGA (Section 8.2), the non-cohesive foundation soils encountered at the drilled locations are not considered susceptible to liquefaction during a 1 in 2,475 year seismic event.

The susceptibility of the cohesive soils at the site to experience cyclic mobility or cyclic softening was initially assessed using the Bray et al. (2004) criteria and the results of index property testing. Soils that were considered potentially susceptible were subsequently assessed based on in-situ shear strength measurements using the simplified procedure outlined in Boulanger and Idriss (2007). Based on the results of both analyses, the cohesive material at this site below elevation 125 m is classified as susceptible to cyclic mobility or cyclic softening. A residual shear strength equal to 85% of the undrained shear strength was applied to this cohesive layer (see Sections 11.3 and 11.7 for further discussion).

## **9 GEOTECHNICAL ASSESSMENT/CONSIDERATIONS**

The design of the culvert needs to consider both the replacement beneath the existing Highway 17 embankment and the extension to the north beneath the future Highway 17 WBL embankment. Based on the results of the field and laboratory investigation and the information

provided by MPCE with regards to the proposed project requirements, the geotechnical foundation design considerations include the following:

### Bearing Resistance

- The near surface overburden soils at this site will not provide sufficient geotechnical resistance for an open footed culvert supported on spread footings.
- The clay deposit at this site would provide sufficient bearing resistance to allow for the installation of a closed bottom culvert, provided, other measures are taken to mitigate settlement associated with the proposed embankment for the future twinning of Highway 17 (see below).
- Deep foundations could be used to support an open footed culvert or short single span bridge. The deep foundations should extend to bedrock, however, the relatively thin glacial till layer overlying the bedrock does contain occasional cobbles and boulders and there is the possibility that some piles may not reach the bedrock surface.

### Settlement

The future twinning will result in a fill height of about 6.5 m across the north end of the new culvert. Settlement of the future highway embankment needs to be considered not only in terms of pavement performance on the approaches but also in selection and design of the culvert foundations. It is noted that no future grade raise anticipated along the existing alignment.

The clay deposit beyond the existing embankment is over-consolidated, however, based on the height of the proposed embankment, construction with conventional granular fill will result in exceedance of the pre-consolidation pressure within the lower part of the clay deposit. It was noted that the pre-consolidation pressure of a sample of clay tested under the existing embankment from Borehole 17-3 at a depth of 15.6 m below top of pavement was only 7 kPa greater than the estimated current effective stress (200 kPa versus 193 kPa). Other consolidation tests were completed where the new alignment is proposed. In those areas, the difference between the pre-consolidation stress and existing stress is larger. However, after construction of the embankment, the condition will be similar to that under the existing embankment.

An assessment of the time dependent settlement that would result from construction of the proposed Highway 17 WBL embankment using conventional granular fill with 2H:1V side slopes was carried out using Rocscience's Settle<sup>3D</sup> modelling software with a Boussinesq stress distribution. The design pre-consolidation pressure profile has been derived from the oedometer tests carried out on the native clay material, supplemented by correlations with undrained shear strength and index properties.

The following has been assumed for the embankment geometry:

- Height = 6.5 m
- Length = 33 m
- Platform Width = 12.5 m
- Side slopes = 2H:1V

The geotechnical parameters used in the settlement analysis were based on the consolidation test results from Borehole 18-101.

The clay stratum was separated into three sub-layers; crust, upper and lower. Table 9-1 presents the properties used in the Settle<sup>3D</sup> analysis for the various sub-layers.

**Table 9-1: Settle<sup>3D</sup> Inputs**

Clay Layer	Elevation (m)	C <sub>c</sub>	C <sub>r</sub>	P' <sub>c</sub> (kPa)	e <sub>o</sub>
Crust	132.5 to 130.0	0.5	0.0149	300	1.197
Upper	130.0 to 125.0	0.5	0.0149	300 – 180	1.197
Lower	125.0 to 108.0	0.648	0.0166	180 – 250	1.211

The results of the settlement analysis for the proposed embankment are summarized as follows:

- The magnitude of total settlement beneath the proposed embankment has been estimated to be about 155 mm (5 mm immediate settlement, 150 mm primary consolidation).
- It is anticipated that it will take approximately 3 years to achieve 90% of the settlement due to the proposed grade raise.
- Secondary consolidation of approximately 20 to 25 mm is expected between years 3 and 20.
- It is noted that construction of the grade raise using conventional granular fill will result in exceedance of the pre-consolidation stress in the lower portion of the clay deposit.

### Construction

Excavations will extend below the water level in the creek. An adequate and effective dewatering plan including surface water management, cofferdams, creek diversion and excavation dewatering will be required to enable excavation to the required founding elevation and construction of the foundations in the dry (See Section 13.2).

The bedrock surface elevation decreases approximately 5 m from north to south along the length of the culvert (elevation 109.3 m to 104.0 m). Suggested wording for a Notice to Contractor alerting the Contractor to the variable pile length is provided in Appendix H.

## **10 EVALUATION OF DESIGN OPTIONS**

### **10.1 Culvert Type/Foundation Alternatives**

A detailed assessment of culvert types and foundation options was carried out following the 2017 field investigation for replacement of the existing culvert beneath the current Highway 17. Options evaluated included circular pipes, and both closed box and open footed culverts. The key findings and conclusion of the assessment are summarized as follows:

- An open footed culvert on spread footings was determined to be not feasible due to insufficient bearing resistance available from the underlying clay and the potential settlement in the foundation clay.



- Although circular pipes installed with appropriate granular bedding over the clay subgrade were considered feasible, numerous circular pipes would be required to provide the required hydraulic capacity.
- A closed box culvert supported on the clay was determined to be feasible and was recommended as the preferred alternative.

It is understood that the creek contains sensitive fish habitat and that a closed bottom culvert is not permissible at this site from a fisheries perspective. In addition, the intention to install the culvert to the full length that extends beneath the future twinned Highway 17 configuration was identified. The longer culvert means that the design needs to address the potential for large differential settlement between the south end of the culvert (beneath the existing Highway 17 embankment) and the north end of the culvert (beneath the future Highway 17 WBL embankment). As a result, an open footed culvert supported on deep foundations (steel H-piles driven to bedrock) was identified as the preferred alternative and a supplemental field and laboratory investigation was carried out in 2018 to provide the data for evaluation and design of the deep foundations and settlement mitigation measures (if required). An updated evaluation of the culvert/foundation alternatives including the advantages, disadvantages, risk/consequences and relative cost from a foundation's perspective is provided in Appendix E.

## 10.2 Construction Staging Alternatives

For the proposed culvert replacement, the following construction staging methods were considered.

- Open Cut with Full Road Closure and Detour  
Installation of a new culvert using open cut techniques and a full road closure would allow for an expedited construction schedule and could reduce costs associated with requiring roadway protection and traffic staging. However, it is understood that an acceptable detour route is not available and therefore this option is not feasible.
- Open Cut with Staged Temporary Widening  
This option seems like a natural choice given that the culvert will be constructed to extend beneath the future twinned highway configuration. Therefore, if the north end (beneath the future twinning) was constructed first, traffic could then be diverted to the north while the south end beneath the existing highway is replaced. It is noted however, that the proximity of the culvert to the intersection with Miller/Anderson Road may not allow for a full shift to allow for staged open cut without temporary protection systems. A review of the requirement for property acquisition and highway geometry would also need to be completed to assess this option.
- Open Cut with Staged Construction and Temporary Protection System  
The use of open cut techniques in conjunction with staged culvert replacement and temporary protection systems, either with or without embankment widening, is a feasible construction option from a geotechnical perspective.

## 10.3 Recommended Approach for the Culvert Replacement

From a foundation engineering perspective, replacing the existing culvert with a new longer open bottom culvert supported on piles using staged construction is recommended. The staged



construction is expected to include embankment widening and may also require temporary protection systems, depending on property and highway design constraints.

## 11 FOUNDATION DESIGN RECOMMENDATIONS

The culvert may be supported on steel H-piles driven to bedrock or to practical refusal within the glacial till.

Approximate key elevations are as follows:

- Proposed top of pavement 139.0 m
- Proposed top of pile 130.0 m
- Locha Creek water level on June 16, 2018 132.1 m
- Glacial till surface (Boreholes 18-101 through 18-103) 107.8 to 110.7 m
- Bedrock surface (Boreholes 18-101 through 18-103) 104.0 to 109.3 m

The length of the piles is expected to range from approximately 21 m at the south end to 26 m at the north end. Suggested wording for a Notice to Contractor to alert the Contractor to the expected variation in pile length is provided in Appendix H.

### 11.1 Axial Compression

The factored geotechnical resistance of steel piles driven to bedrock at this site are as follows:

**Table 11-1: Factored Geotechnical Resistances at ULS and SLS**

Pile Section	Factored Geotechnical Resistance at ULS (kN)*	Factored Geotechnical Resistance at SLS (kN)
HP 310x110	2,650	N/A
HP 310x132	3,150	N/A

\* The factored axial structural resistance of the piles will likely govern the design.

The SLS condition will not govern for piles driven to bedrock.

It is anticipated that the factored geotechnical resistance at ULS exceeds the factored axial structural capacity of the pile (typically 2,000 kN for HP 301x110 and 2,400 kN for HP 310x132). Therefore, the factored axial structural capacity at ULS shall be used for design.

The factored geotechnical resistances include the following factors as per Table 6.2 of the CHBDC:

- $\phi_{gu} = 0.4$  (ULS; static analysis; typical degree of understanding)
- $\phi_{gs} = 0.8$  (SLS; static analysis; typical degree of understanding)

### 11.2 Downdrag and Lateral Loading due to Clay Settlement

It is understood that no grade raise is proposed for the segment of culvert beneath the existing highway embankment but that the grade to the north is to be raised by up to 6.5 m for the future

highway twinning embankment. Piles within the southern portion of the culvert alignment, outside of the influence of the proposed new embankment, will not be subjected to downdrag loads.

Although the greatest settlement will occur directly beneath the new embankment, due to the height of the new fill and thickness of the clay deposit, the new fill will also result in consolidation of some of the clay beneath the existing highway alignment. All piles located more than 10 m north of the centreline of the existing highway alignment will be subject to an unfactored downdrag load of approximately 1000 kN/pile due to the placement of the fill to construct the new highway embankment. It is noted that this contract will include instrumentation of the culvert and instrumentation of the piles to measure actual downdrag loads.

A load factor shall be added to the downdrag value provided as per Table 3.3 of the CHBDC to obtain the factored downdrag load. In accordance with Section C6.11.4.10 of the Commentary to the CHBDC for the structural design of a pile, the factored downdrag load shall be added to the factored permanent loads to assess the effects of downdrag. Also, in geotechnical analysis of downdrag, transient and live loads shall not be considered. The factored dead and downdrag loads shall not exceed the factored structural capacity of the piles.

In addition to vertical settlement of the clay deposit resulting in downdrag loads, lateral deformation of the clay is expected during the settlement process. The estimated lateral displacement profile is provided in tabular format in Appendix F. The resulting loading on the piles can be evaluated in a structural model using the p-y curves (see Section 11.3) for the static load case and imposing the displacement profile. The deep foundations will need to be designed to resist this loading.

If the HP 310x110 pile sections provide adequate resistance to the downdrag loads or lateral loads, a heavier pile section could be considered (e.g. HP 310x132). Alternatively, consideration could be given to constructing the embankments with lightweight fill or to pre-loading the area prior to installation of the piles. Pre-loading would likely require installation of a temporary culvert such as a CSP arch culvert.

### 11.3 Foundation Lateral Response

The lateral soil response of HP 310x110 and HP 310x132 piles was evaluated using the software program LPILE 2018 published by Ensoft Inc. The lateral soil response for a single pile, for static and seismic conditions, is presented as p-y data in the tables provided in Appendix F for soils below the top of pile/underside of footing elevation indicated on the June 2018 GA Drawing. For the seismic conditions, a residual clay strength equal to 85% of the undrained shear strength was applied to the cohesive layers below elevation 125 m. The response of the pile foundation under inertial loading shall be checked using both static and “seismically reduced” lateral load transfer (p-y) curves. The values of P(kN/m) represent soil reaction per metre of pile length while the y(m) values represent soil/pile deflection. The values are applicable for both HP 310x110 and HP 310x132 piles.

The p-y data provided is unfactored. Lateral resistance or deflection calculated based on these parameters shall be factored using the geotechnical resistance factors ( $\phi_{gu}$  and  $\phi_{gs}$ ) provided in Table 6.2 of the CHBDC.

If lateral spacing between an adjacent pile or another structural element is less than four equivalent pile diameters, suitable reduction factors based on the center to center spacing shall

be applied as per Section C6.11.3 and Figures C6.11.3(r), C.6.11.3(s) and C6.11.3(t) of the Commentary to the CHBDC.

#### 11.4 Pile Installation

Driven piles must be installed in accordance with OPSS.PROV 903 and SSP 109F57.

As the piles are to be driven through glacial till that contains cobbles and boulders, the pile tips of new piles driven at the site shall be protected from damage during driving with pile tip protection from an approved manufacturer such as Titus Steel (standard H-Point) or approved equivalent.

The appropriate pile driving note is "Piles to be driven to bedrock."

#### 11.5 Frost Protection

The frost penetration depth at this site is 1.9 m as per OPSD 3090.101. Accordingly, a minimum of 1.9 m of earth cover, or equivalent insulation, must be provided above the base of the pile foundations to serve as frost protection. Frost tapers, if required will be addressed as part of the pavement design report under a separate cover by MPCE.

#### 11.6 Lateral Earth Pressures and Culvert Backfill

Backfilling and monitoring of backfilling operations for the installation of the culvert shall be carried out in accordance OPSS 902 and MTO Special Provision (SP) No. 109S12.

Backfill for the culvert must consist of free draining granular material conforming to OPSS.PROV 1010 Granular A or B material specifications placed and compacted in accordance with OPSS.PROV 501. The minimum granular backfill requirements shall be similar to those shown on OPSD 3101.150 for abutment walls.

The lateral earth pressure parameters provided in Table 11-2 and Table 11-3 are based on the assumption that the backfill is fully drained so that there are no unbalanced hydrostatic pressures. If adequate drainage cannot be confirmed, the potential for buildup of hydrostatic pressures should be considered in the design.

##### 11.6.1 Static Lateral Earth Pressure Coefficients

Lateral earth pressures acting on structures shall be computed in accordance with the CHBDC but generally are given by the expression:

$$P_h = K^*(\gamma h + q)$$

where:

- $P_h$  = horizontal pressure on the wall (kPa)
- $K$  = earth pressure coefficient
- $\gamma$  = unit weight of retained soil (kN/m<sup>3</sup>); use submerged unit weight for soils below the groundwater level
- $h$  = depth below top of fill where pressure is computed (m)
- $q$  = value of any surcharge (kPa)

The recommended lateral earth pressure parameters for use in the design of vertical walls with a horizontal backslope are provided in Table 11-2.

If lateral movement is not permissible and/or the wall is retained from lateral yielding, it is recommended that the at-rest horizontal lateral earth pressures be used for design. Active pressures shall be used for the design of unrestrained walls. For static analysis of permanent structures, passive earth resistance should be ignored, and therefore has not been provided.

**Table 11-2: Static Lateral Earth Pressure Coefficient**

Parameter	OPSS Granular A & B Type II	OPSS Granular B Type I and III
Soil Unit Weight, $\text{kN/m}^3$ , $\gamma$	22.0	21.2
Angle of Internal Friction, $\phi$	35°	32°
Coefficient of at Rest Earth Pressure, $K_o$ (Restrained Wall)	0.43	0.47
Coefficient of Active Earth Pressure, $K_a$ (Unrestrained Wall)	0.27	0.31

A lateral pressure due to backfill compaction shall be added to the calculated lateral earth pressure in accordance with Section 6.12.3 of the CHBDC. A live load surcharge shall be considered as per Section 6.12.5 of the CHBDC.

#### 11.6.2 Combined Static and Seismic Lateral Earth Pressure Parameters

The following recommendations are per Section C4.6.5 of the Commentary of the CHBDC which states that seismically induced lateral soil pressures may be calculated using the Mononobe-Okabe Method with:

- $k_h = \frac{1}{2} F(\text{PGA}) \cdot \text{PGA}$  for structures that allow 25 mm to 50 mm of movement, and
- $k_h = F(\text{PGA}) \cdot \text{PGA}$  for non-yielding walls

The ratio of wall movement to wall height required to mobilize the active condition would be approximately 0.002 for a yielding structure with respect to the assessment of seismically induced lateral earth pressures.

The recommended seismic lateral earth pressure parameters for use in the design of vertical walls that are provided in Table 11-3 assume the following:

- Seismic Site Class of E,
- Site Coefficient  $F(\text{PGA})$  of 1.33 as per Table 4.8 of the CHBDC, and
- Site adjusted PGA value with a 2% probability of exceedance in 50 years of 0.304g as outlined in Section 8.2.

**Table 11-3: Lateral Earth Pressure (Under Seismic Loads)**

Parameter	OPSS Granular A & B Type II	OPSS Granular B Type I and III
Soil Unit Weight, kN/m <sup>3</sup> , $\gamma$	22.0	21.2
Angle of Internal Friction, $\phi$	35°	32°
Coefficient of Active Earth Pressure, $K_{AE}$ (Restrained Wall)	0.48	0.53
Coefficient of Active Earth Pressure, $K_{AE}$ (Unrestrained Wall)	0.36	0.40

The total pressure due to combined static and seismic loads acting at a specific depth below the top of the wall may be determined using the following equation that includes consideration of material properties and the soil profile:

$$\sigma_h = K\gamma d + (K_{AE} - K_a) \gamma (H - d)$$

where:

- $\sigma_h$  = lateral earth pressure at depth, d (kPa)
- d = depth below the top of the wall (m)
- K = static earth pressure coefficient  
( $K_o$  for non-yielding and  $K_a$  for yielding walls)
- $\gamma$  = unit weight of retained soil (kN/m<sup>3</sup>); use submerged unit weight for soils below the groundwater level
- $K_{AE}$  = combined static and seismic earth pressure coefficient
- H = total height of the wall (m)

## 11.7 Embankment Design and Reinstatement

### 11.7.1 Embankment Reinstatement

The existing Highway 17 embankment slopes are graded at approximately 2H:1V on the inlet side and 3H:1V on the outlet side. No evidence of slope instability, settlement or erosion concerns were noted. Provided that the embankment is reconstructed to its original geometry with embankment slopes of 2H:1V or flatter, settlement is anticipated to be negligible and stability should not be compromised.

Embankment reinstatement is generally expected to be limited to the culvert backfill and pavement reinstatement (i.e. all granular fill).

### 11.7.2 Embankment for Future Highway Twinning

As discussed in Section 9, the increased length of the culvert on the north end is intended for the culvert to extend beneath the future twinned highway configuration. The anticipated new highway embankment is expected to result in approximately 155 mm of settlement, with approximately 90% of the settlement occurring over the first 3 years.

The anticipated settlement exceeds the MTO embankment settlement criteria. However, it is understood that construction of the highway twinning is likely to start at least 3 years after construction of the culvert. Therefore, the embankment post construction settlement criteria could be met by constructing the embankment within 30 m east and west of the culvert now in

conjunction with the culvert backfill. This would reduce post-construction settlement following construction of the future highway twinning.

In order to meet the lateral earth pressures requirements outlined above the culvert backfill and cover material shall consist of Granular B Type II. The embankment material between the bottom of the pavement subbase elevation and the top of the cover material could consist of either OPSS Select Subgrade, Granular A or Granular B Type II materials. All backfill, and embankment material shall be placed and compacted in accordance with the OPSS.PROV 501.

The global stability for the new embankment for Highway 17 widening constructed using conventional granular fill with 2H:1V side slopes was evaluated using GeoStudio 2012 Slope/W software for limit equilibrium analysis. Input parameters for the analysis are based on the in-situ shear vane measurements, SPT N values and the results of laboratory testing.

The following additional parameters were used in the analysis:

- A traffic surcharge load as per Section 6.12.5 of the CHBDC
- Seismic Site Class of E
- Residual clay strength ( $S_u$ ) equal to 85% of the undrained shear strength of the cohesive layers (for post seismic analysis)
- Site Coefficient  $F(PGA)$  of 1.33 as per Table 4.8 of the CHBDC
- Site adjusted PGA value of 0.152 g, equal to  $\frac{1}{2}$  of the site adjusted PGA value (0.304 g) was used for seismic analysis, as per Section 4.4.3.3, of the CHBDC and outlined in Section 8.2.

The global stability analysis results indicate the following factor of safety values for each analysis:

- Short Term (Undrained): 2.0
- Long Term (Drained): 1.5
- Flow Side (Undrained, Reduced  $S_u$ ): 1.9
- Displacement (Undrained, Reduced  $S_u$ , Seismic Coefficient): 1.2

The slope is considered stable under both static and seismic conditions. Copies of the output from the global stability analyses for all analyses are provided in Appendix G.

### 11.7.3 Temporary Widening Construction

It is understood that a 12.5 m wide temporary platform widening for construction staging is proposed to the north of the existing westbound lane (measured from existing edge of pavement to proposed edge of slope). Cross-section drawings of the platform widening indicated the maximum height of the new temporary platform above the existing grade is 1.0 m. It is understood that further details on the platform/pavement widening will be provided in the pavement design report.

## 11.8 Cement Type and Corrosion Potential

Chemical analysis for determination of pH, water soluble sulphate, sulphides, chloride concentrations, resistivity and electrical conductivity was carried out on samples of the native

materials. The analysis results are summarized in Table 5-3 and a copy of the test results is provided in Appendix C.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The test results provided in Table 5-3 were compared with Table 3.2 of the MTO Gravity Pipe Design Guideline and generally indicate a severe corrosive environment. One of the three test results did indicate a very low corrosive environment. The test results provided in Table 5-3 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with the soil and groundwater at the site. The sulphate results in Table 5-3 were compared with Table 3 of Canadian Standards Association Standards A23.1-14 (CSA A23.1) and generally indicate a low degree of sulphate attack potential on concrete structures at this site.

## **12 INSTRUMENTATION AND MONITORING**

This structure has been selected for instrumentation and monitoring. The purpose of the instrumentation monitoring is to:

1. Enhance the knowledge on the behavior of three sided culverts and the factors that affect their behavior, e.g. span, culvert stiffness, embedment depth and soil conditions.
2. Introduce modified arching factors that best represent the actual state of stresses applied on three sided culverts.
3. Develop special design guidelines for three sided culverts based on full scale field measurements.
4. Reveal the influence of seasonal temperature variation on the structure and the appropriate approach to be considered in design if found to be significant.
5. Evaluate the time effects on culvert-soil structure interaction (e.g. soil creep and consolidation).
6. Establish a robust, yet simplified design method for three sided culverts.
7. Examine the applicability and limitations of the current standard of practice design methods of three sided culverts.
8. Provide recommendations for appropriate numerical modeling approach of three sided culverts.

In addition, instrumentation and monitoring is to be carried out to assess the downdrag loads on the piles.

The instrumentation plan and specifications are under development and will be submitted under separate cover.

## **13 CONSTRUCTION CONSIDERATIONS**

### **13.1 Excavations**

It is anticipated that temporary excavations in the order of 9 m below the existing top of pavement will be required to allow access for the removal of the existing culvert and installation of the new



foundations. Shallower excavations of up to 3.0 m below existing grade are anticipated north of the existing culvert outlet to construct the northern portion of the culvert.

Artesian conditions originating from the glacial till layer were noted at the site, with water pressures extending to at least 0.5 m to 3.0 m above the ground surface in Boreholes 18-101 through 18-103. Based on the design bottom of footing elevation of 130.0 m the glacial till surface would be overlain by between 18.8 m (Borehole 18-102) and 22.2 m (Borehole 18-101) of clay. As such base instability issues due to the artesian condition encountered in the glacial till layer is not considered a design issue at the site.

Excavation for the installation of the culvert shall be carried out in accordance OPSS 902 and MTO SP No. 109S12.

All excavations must be conducted in accordance with the requirements of the Occupational Health & Safety Act & Regulations (OHSA) for Construction Projects. The fills and native soils at the site shall be classified as Type 3 in accordance with OHSA. Unsupported excavations made in Type 3 soils must have side slopes no steeper than 1H:1V from the base of the excavation.

The management and disposal of excess material shall be in accordance with OPSS.PROV 180.

Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor. In addition, the Contractor must plan the work appropriately to ensure stable work platforms for equipment including pile driving cranes.

The base of excavation for removal of the existing culvert and construction of the new pile caps is expected to consist primarily of clay, with the possibility of some areas with saturated silt and sand. These subgrade materials will be easily disturbed by construction activities and should be protected with a concrete working slab or granular pad. The tender documents should include FOUN 0001, requiring the provision of a concrete working slab.

### **13.2 Dewatering**

The depth of excavations required to replace the existing culvert will extend below the creek level observed at the time of the investigation. Furthermore, groundwater and surface runoff will tend to seep into and accumulate into the excavations. The Contractor must control groundwater and creek/surface water flow at the site to permit the replacement of the culvert in a dry and stable excavation.

Excavation for construction of the culvert must be carried out with a properly designed dewatering system to control groundwater and creek/surface water and may include cofferdams, creek diversion, pumping, etc. The dewatering system will be required to remain operational and effective until the temporary excavations are backfilled and then shall be decommissioned and removed.

The design of dewatering systems is the responsibility of the Contractor. The Contract Documents must alert the Contractor to this responsibility and to design the system in accordance with SP FOUN0003 which amends OPSS 902. A preconstruction survey is not recommended, thus Designer Fill-In \*\* in this SP should be "NA". Recommended wording for an NSSP amending SP FOUN0003 to include the requirement that the design Engineer and design-checking Engineer of the dewatering system have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work has been provided in Appendix H.



The groundwater level will fluctuate and the minimum groundwater elevation at the time of the proposed work shall be taken as the creek water level of the design storm return period defined by the contract documents for the temporary dewatering system.

It is anticipated that the water course diversion will be carried out with a cofferdam redirecting creek water through a pipe or series of pipes installed through the existing culvert. During periods of high creek levels, a watertight braced enclosure system shall be considered. Sheet pile cofferdams can be designed following the recommendations provided in Section 13.3.

The comments on the installation and extraction of temporary protection systems are also relevant for sheet pile cofferdams.

### 13.3 Temporary Protection Systems

The proposed methodology is to replace the existing culvert in stages with a temporary protection system running east-west near the centerline of the highway. Temporary protection systems shall be provided in accordance with OPSS.PROV 539 and designed for Performance Level 2. All protection systems shall be designed by a Professional Engineer experienced in such designs.

Typical lateral earth pressure coefficients are provided in Table 13-1 for the design of vertical temporary protection systems. The values provided are for a horizontal backslope behind, and a horizontal surface in front of the protection system.

If the backslope behind or if the ground surface in front of the temporary protection systems are not horizontal, the lateral earth pressure parameters provided in Table 13-1 do not apply and recalculation of the earth pressure parameters will be required.

**Table 13-1: Lateral Earth Pressure Coefficients for Temporary Protection System Design**

Parameter	OPSS Granular A & B Type II	Existing Fill/SSM	Native Clay
Soil Unit Weight, $\text{kN/m}^3$ , $\gamma$	22.0	20.0	17.3
Angle of Internal Friction, $\phi$	35°	32°	27°
Coefficient of at Rest Earth Pressure, $K_o$	0.43	0.47	0.55
Coefficient of Active Earth Pressure, $K_a$	0.27	0.31	0.38
Coefficient of Passive Earth Pressure, $K_p$	3.69	3.25	2.66

The design of protection systems is the responsibility of the Contractor. The designer of the temporary protection system must ensure the penetration depth is sufficient to provide base fixity and incorporate traffic loading and surcharge loading due to construction equipment and their operations and shall consider the slope of temporary embankments above the top of the protection system and location of existing utilities and trenches.

The use of sheet piles driven sufficiently deep into the underlying clay soil to provide lateral stability is considered feasible. In view of the high lateral earth pressures associated with the existing embankment slope (retained heights of up to 9 m), tie back anchors consisting of soil anchors installed within the clay may be required to maintain stability. The use of deadman anchor blocks or internal bracing could also be considered.

### **13.4 Erosion Protection**

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the embankment slopes. The Contractor shall provide silt fences and erosion control blankets, as required, throughout the duration of the construction to prevent silt/sediments from running off the site as per OPSS 805.

Particle size analysis on samples of the embankment materials indicated that the soils have a low to moderate potential for soil erodibility (Wischmeier Nomograph factor, K of 0.10).

Erosion protection shall be provided at the culvert inlet and outlet areas. Design of the erosion protection measures must consider hydrologic and hydraulic factors and shall be carried out by specialists experienced in this field. It is recommended that the design by the specialist or Drainage Engineer be reviewed by the Foundation Engineer.

Typically, rock protection should be provided over all surfaces with which creek water is likely to be in contact. Treatment at the inlet and outlet shall be in accordance with OPSS 810.010. A vegetation cover shall be established on all other exposed earth surfaces as soon as practical to protect against surficial erosion in accordance with OPSS.PROV 804.

It is recommended that a clay seal be used to minimize the potential for erosion near the inlet and outlet areas. The clay seal shall extend a minimum of 0.3 m above the high-water level and laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements shall be in accordance with OPSS.PROV 1205. A geosynthetic clay liner may also be considered.

## **14 CONSTRUCTION CONCERNS**

The planned construction methodology includes an open cut excavation for the installation of a new culvert.

Potential construction concerns include, but are not necessarily limited to, the following:

- Construction will extend below the water level in the creek. An adequate and effective surface water management and dewatering plan must be implemented to construct the replacement culvert foundations in the dry.
- The glacial till layer is relatively thin (1.4 to 3.8 m) but contains cobbles and may contain boulders. Although most piles will likely penetrate the till and reach refusal on the bedrock, some of the piles may reach refusal on boulders. The tips of the piles shall be protected.
- Artesian conditions were encountered in the glacial till layer beneath the thick clay unit. Due to the shallow excavations depths and thickness of the clay layer, base instability issues due to the artesian condition encountered are not consider a design issue at the site.
- A suitable anchoring or bracing system may need to be incorporated into the temporary protection system design. Tie-back anchors would likely consist of soil anchors installed within the clay. The use of deadman anchor blocks or internal bracing could also be considered.

The successful performance of this structure will depend largely upon good workmanship and quality control during construction. Observation of the excavation and backfilling operations will be required as per MTO SP 109S12 during construction to confirm that the foundation recommendations are correctly implemented, and material specifications are met.

## 15 CLOSURE

Overall project management and direction of the field program was provided by Paul Carnaffan, P.Eng. Interpretation of the field data, geotechnical analysis and preparation of this report was completed by Kenton Power, P.Eng. and Deanna Pizycki, E.I.T. The report was reviewed by Paul Carnaffan, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations.

Thurber Engineering Ltd.  
Report Prepared By:



Paul Carnaffan, P.Eng.  
Principal, Senior Geotechnical Engineer

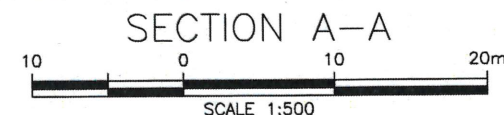
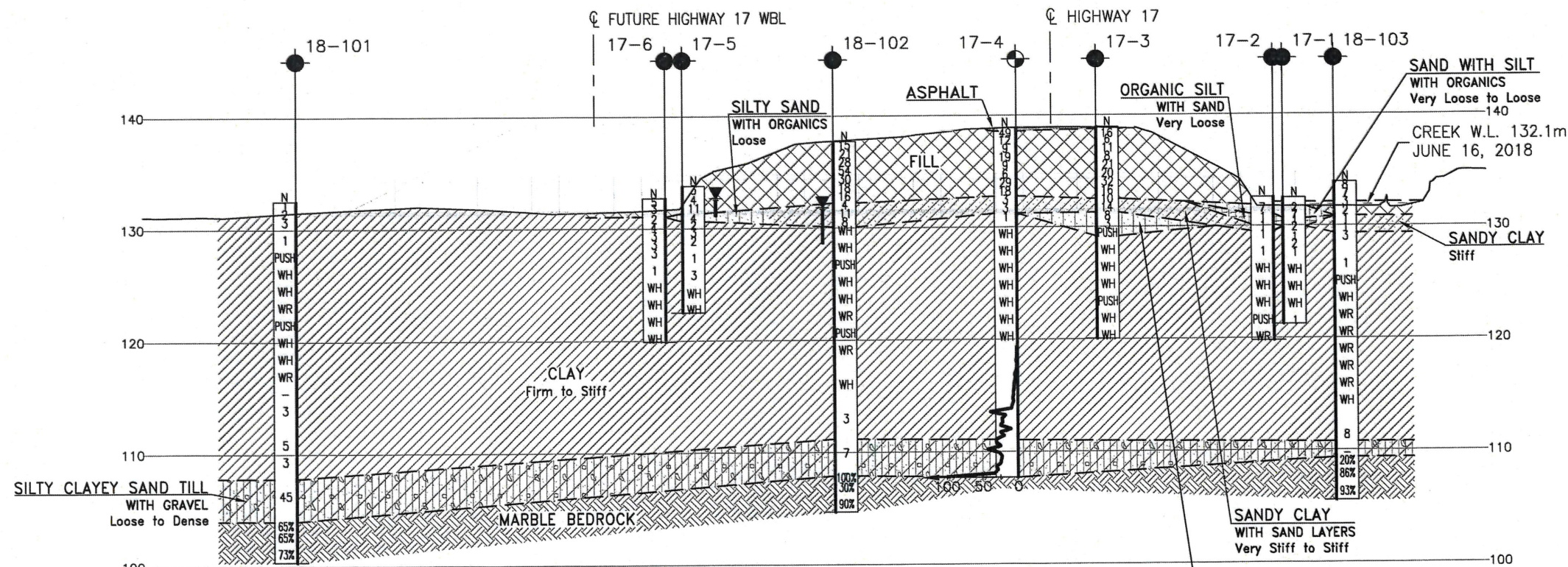
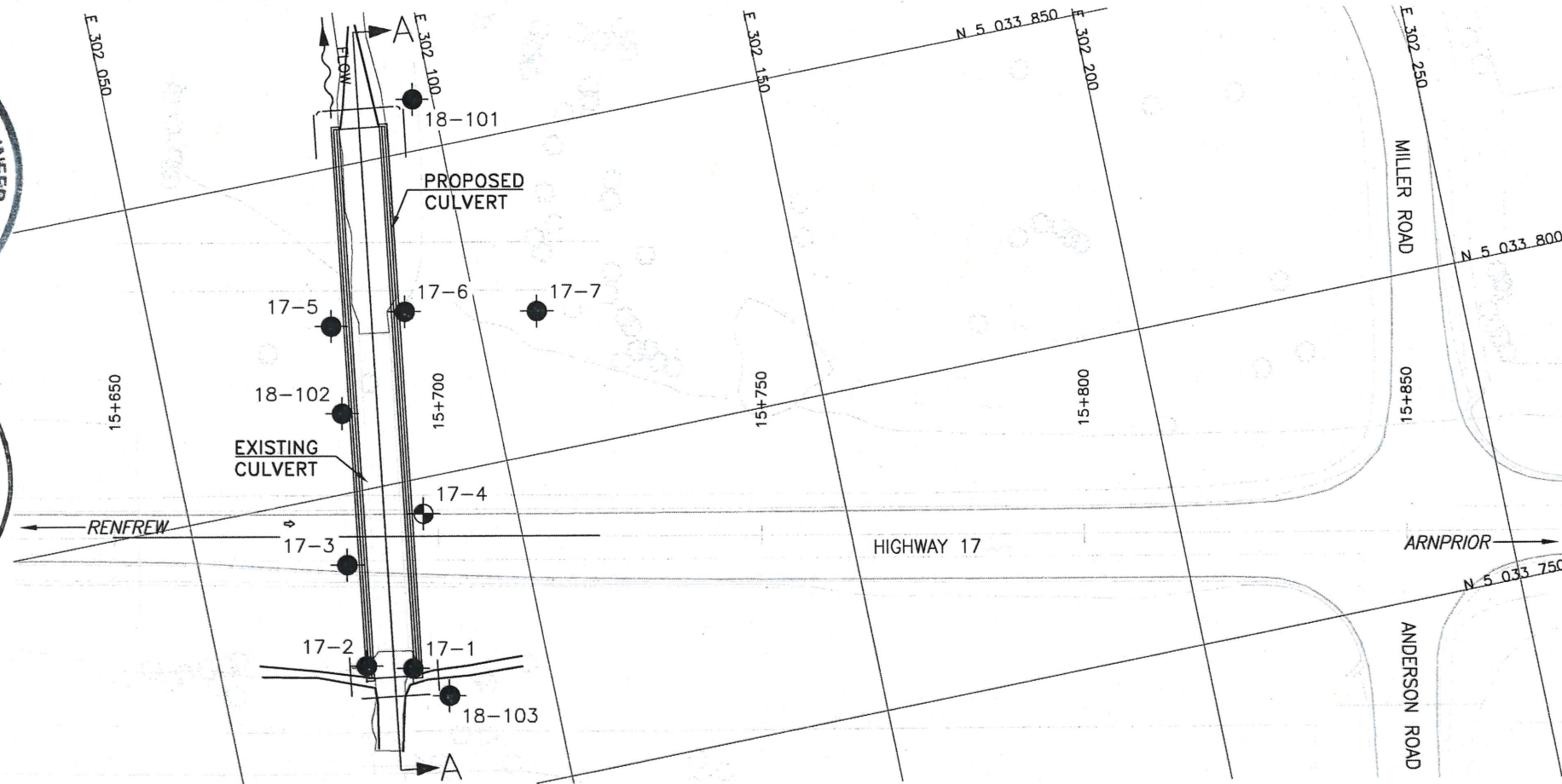
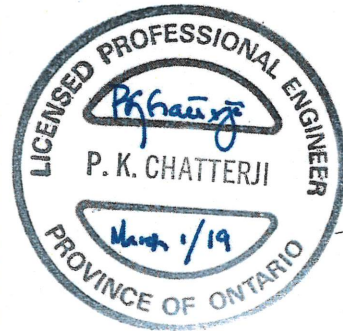


P.K. Chatterji, P.Eng.  
Review Principal, Designated MTO Contact

## **APPENDIX A**

### **BOREHOLE LOCATIONS AND SOIL STRATA DRAWINGS**





METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

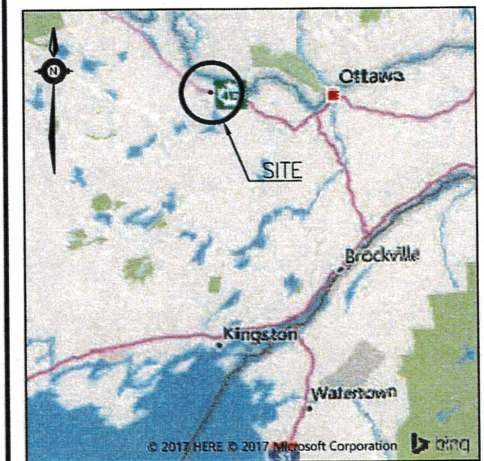
CONT No  
GWP No 4232-15-00

HIGHWAY 17  
LOCHA CREEK CULVERT  
REPLACEMENT  
BOREHOLE LOCATIONS AND SOIL STRATA

McINTOSH PERRY



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

- Borehole
- ⊕ Borehole and Cone
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60' Cone, 475J/blow)
- PH Pressure, Hydraulic
- W Water Level
- ⊕ Head Artesian Water
- ⊕ Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
17-1	132.5	5 033 771.3	302 079.3
17-2	132.6	5 033 773.2	302 072.3
17-3	138.9	5 033 789.1	302 072.6
17-4	138.8	5 033 794.5	302 085.7
17-5	133.8	5 033 825.9	302 077.5
17-6	132.7	5 033 825.8	302 089.1
17-7	134.3	5 033 821.8	302 109.2
18-101	132.5	5 033 858.0	302 096.9
18-102	137.7	5 033 812.3	302 076.5
18-103	133.9	5 033 766.1	302 084.0

-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Borehole locations are shown in MTM Zone 9 coordinates.

GEOCRETS No.

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	KP	CHK -	CODE
DRAWN	MFA	CHK KP	SITE
			LOAD
			STRUCT
			DWG 1
			DATE AUG 2018



**APPENDIX B**  
**RECORD OF BOREHOLE SHEETS**



## SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

### TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

Topsoil	mixture of soil and humus capable of supporting vegetative growth
Peat	mixture of fragments of decayed organic matter
Till	unstratified glacial deposit which may include particles ranging in sizes from clay to boulder
Fill	material below the surface identified as placed by humans (excluding buried services)

### TERMINOLOGY DESCRIBING SOIL STRUCTURE:

Desiccated	having visible signs of weathering by oxidization of clay materials, shrinkage cracks, etc.
Fissured	having cracks, and hence a blocky structure
Varved	composed of alternating layers of silt and clay
Stratified	composed of alternating successions of different soil types, e.g. silt and sand
Layer	> 75 mm in thickness
Seam	2 mm to 75 mm in thickness
Parting	< 2 mm in thickness

### RECOVERY:

For soil samples, the recovery is recorded as the length of the soil sample recovered.

### N-VALUE:

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 63.5 kg hammer falling 0.76 m, required to drive a 50 mm O.D. split spoon sampler 0.3 m into undisturbed soil. For samples where insufficient penetration was achieved and N-value cannot be presented, the number of blows are reported over the sampler penetration in millimetres (e.g. 50/75).

### DYNAMIC CONE PENETRATION TEST (DCPT):

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to an "A" size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone 0.3 m into the soil. The DCPT is used as a probe to assess soil variability.



### STRATA PLOT:

Strata plots symbolize the soil and bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



Boulders  
Cobbles  
Gravel      Sand      Silt      Clay      Organics      Asphalt      Concrete      Fill      Bedrock

### TEXTURING CLASSIFICATION OF SOILS

Classification	Particle Size
Boulders	Greater than 200 mm
Cobbles	75 – 200 mm
Gravel	4.75 – 75 mm
Sand	0.075 – 4.75 mm
Silt	0.002 – 0.075 mm
Clay	Less than 0.002 mm

### TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

Descriptive Term	Undrained Shear Strength (kPa)
Very Soft	12 or less
Soft	12 – 25
Firm	25 – 50
Stiff	50 – 100
Very Stiff	100 – 200
Hard	Greater than 200

NOTE: Clay sensitivity is defined as the ratio of the undisturbed strength over the remolded strength.

### SAMPLE TYPES

SS	Split spoon samples
ST	Shelby tube or thin wall tube
DP	Direct push sample
PS	Piston sample
BS	Bulk sample
WS	Wash sample
HQ, NQ, BQ etc.	Rock core sample obtained with the use of standard size diamond coring equipment

### TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

Descriptive Term	SPT “N” Value
Very Loose	Less than 4
Loose	4 – 10
Compact	10 – 30
Dense	30 – 50
Very Dense	Greater than 50



### MODIFIED UNIFIED SOIL CLASSIFICATION

Major Divisions		Group Symbol	Typical Description
COARSE GRAINED SOIL	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILT AND CLAY SOILS $W_L < 35\%$	ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		OL	Organic silts and organic silty-clays of low plasticity.
	SILT AND CLAY SOILS $35\% < W_L < 50\%$	MI	Inorganic compressible fine sandy silt with clay of medium plasticity, clayey silts.
		CI	Inorganic clays of medium plasticity, silty clays.
		OI	Organic silty clays of medium plasticity.
	SILT AND CLAY SOILS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy of silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other organic soils.

Note -  $W_L$  = Liquid Limit



## EXPLANATION OF ROCK LOGGING TERMS

### ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock materials.
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structures are preserved.

### TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.
Solid Core Recovery: (SCR)	Percent ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1 m in length or larger, as a percentage of total core length
Unconfined Compressive Strength: (UCS)	Axial stress required to break the specimen.
Fracture Index: (FI)	Frequency of natural fractures per 0.3 m of core run.

### DISCONTINUITY SPACING

Bedding	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 to 2 m
Medium bedded	0.2 to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 to 60 mm
Laminated	6 to 20 mm
Thinly laminated	Less than 6 mm

### STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)
Extremely Strong	Greater than 250
Very Strong	100 – 250
Strong	50 – 100
Medium Strong	25 – 50
Weak	5 – 25
Very Weak	1 – 5
Extremely Weak	0.25 – 1

## METRIC

[illegible]

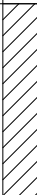
+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No 17-1

2 OF 2

METRIC

GWP# 4061-17-00 LOCATION Lat: 45.443868°, Long: -76.5347792° MTO Zone 9: N 5 033 771.3 E 302 079.3 ORIGINATED BY KE  
 HWY 17 BOREHOLE TYPE Portable / NW Casing COMPILED BY DJP  
 DATUM Geodetic DATE 2017.09.22 - 2017.09.22 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT  W P	NATURAL MOISTURE CONTENT  W	LIQUID LIMIT  W L	UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE								
	Continued From Previous Page						20	40	60	80	100					
	CLAY (Cl) Firm Grey							2.4								
										3.3						
121.2			11	SS	1		122									0 0 50 50
11.3	End of Borehole															

DOUBLE LINE LOCHA CREEK REPLACEMENT.GPJ 2012TEMPLATE(MTO).GDT 5/2/19

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
 15  
 10  
 5  
 0  
 (%) STRAIN AT FAILURE

## METRIC

[illegible]

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

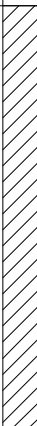
DOUBLE LINE LOCHA CREEK REPLACEMENT.GPJ 2012TEMPLATE(MTO).GDT 5/2/19

# RECORD OF BOREHOLE No 17-2

2 OF 2

METRIC

GWP# 4061-17-00 LOCATION Lat: 45.443885°, Long: -76.5348687° MTO Zone 9: N 5 033 773.2 E 302 072.3 ORIGINATED BY KE  
 HWY 17 BOREHOLE TYPE Portable / NW Casing COMPILED BY DJP  
 DATUM Geodetic DATE 2017.09.25 - 2017.09.25 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT  W P	NATURAL MOISTURE CONTENT  W	LIQUID LIMIT  W L	UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE									
	Continued From Previous Page						20	40	60	80	100	20	40	60			
119.8    12.8	CLAY (Cl) Stiff Grey								2.9 +								
										2.6 +							
			9	ST	PUSH												
											2.9 +						
									3.0 +								
			10	SS	WR												

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
15  
10  
5  
0  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 17-3

1 OF 2

METRIC

GWP# 4061-17-00 LOCATION Lat: 45.4440281° Long: -76.5348649° MTO Zone 9: N 5 033 789.1 E 302 072.6 ORIGINATED BY CAM  
 HWY 17 BOREHOLE TYPE HSA COMPILED BY KP  
 DATUM Geodetic DATE 2017.09.11 - 2017.09.12 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
138.9													
0.0	170 mm ASPHALT												
0.2	Silty sand with gravel to silty sand trace gravel Compact to loose Brown FILL		1	SS	16		138						6 80 14 (SH+CL)
			2	SS	6								
137.5													
1.4	Silty clay Stiff Grey FILL		3	SS	11		137						
136.6													
2.3	Silty sand Loose Brown FILL		4	SS	8		136						
136.2													
2.7													
135.9	Silty clay Stiff Grey FILL		5	SS	21		135						
3.0													
	Silty sand, with clay seams Compact to dense Brown FILL		6	SS	20		134						1 87 12 (SH+CL)
			7	SS	32								
			8	SS	16		133						
132.5			9	SS	10								
6.4	SANDY CLAY (CI) - occasional sand seams Very Stiff Grey		10	SS	14		132						0 33 34 33
131.3													
7.6	SAND with silt to SILT with sand Very loose to loose Grey		11	SS	8		131						0 90 10 (SH+CL)
			12	SS	3		130						0 19 50 31 non-plastic
			13	ST	PUSH								
129.1													
9.8	CLAY (CI to CL)						129						

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
 15  
 10  
 (%) STRAIN AT FAILURE



# RECORD OF BOREHOLE No 17-3

2 OF 2

METRIC

GWP# 4061-17-00 LOCATION Lat: 45.4440281°, Long: -76.5348649° MTO Zone 9: N 5 033 789.1 E 302 072.6 ORIGINATED BY CAM  
 HWY 17 BOREHOLE TYPE HSA COMPILED BY KP  
 DATUM Geodetic DATE 2017.09.11 - 2017.09.12 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								○ UNCONFINED + FIELD VANE								
								● QUICK TRIAXIAL × LAB VANE								
Continued From Previous Page							20 40 60 80 100				20 40 60					
120.0  																

DOUBLE LINE LOCHA CREEK REPLACEMENT.GPJ 2012TEMPLATE(MTO).GDT 5/2/19

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
 15  
 10  
 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 17-4

1 OF 4

METRIC

GWP# 4061-17-00 LOCATION Lat: 45.4440768°, Long: -76.5346975° MTO Zone 9: N 5 033 794.5 E 302 085.7 ORIGINATED BY KE  
 HWY 17 BOREHOLE TYPE HSA COMPILED BY KP  
 DATUM Geodetic DATE 2017.09.11 - 2017.09.11 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa												
138.8								20	40	60	80	100								
0.0	290 mm ASPHALT																			
138.5																				
0.3	Sand with gravel Dense Brown		1	SS	49															
138.0																				
0.8	FILL																			
	Silty sand Compact Brown		2	SS	12															
137.3																				
1.5	FILL																			
	Sandy silt Loose Brown		3	SS	9															
136.7																				
2.1	FILL																			
	Silty clay Stiff Grey		4	SS	19															
136.2																				
2.6	FILL																			
	Sand with silt, some gravel Loose to compact Brown		5	SS	9															
			6	SS	6															
	- cobbles and boulders from 4.5 m to 6.1 m		7	SS	29															
			8	SS	18															
132.7																				
6.1	SANDY CLAY (CI) - frequent sand layers Stiff Grey		9	SS	3															
			10	SS	3															
131.2																				
7.6	CLAY (CI to CL) Stiff Grey		11	SS	1															
			13	SS	WH															
	- vane attempted $S_u > 106$ kPa																			

DOUBLE LINE LOCHA CREEK REPLACEMENT.GPJ 2012TEMPLATE(MTO).GDT 5/2/19

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
 15  
 10  
 (%) STRAIN AT FAILURE

## METRIC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)									
								○ UNCONFINED + FIELD VANE			w <sub>p</sub> w w <sub>L</sub>									
								● QUICK TRIAXIAL × LAB VANE												
								20 40 60 80 100			20 40 60									
	Continued From Previous Page																			
	- vane attempted S <sub>u</sub> > 106 kPa CLAY (Cl to CL) Very stiff to firm Grey		13	SS	WH		128													
							127			13.6										
			14	SS	WH		126					H H			0 1 55 44					
										18.0										
										12.5										
			15	SS	WH		125													
	- becomes firm below 14.5 m						124			7.3										
										6.6										
			16	SS	WH		123													
										6.3										
										5.3										
			17	SS	WH		122								0 0 50 50					
							121			5.8										
										12.0										
119.9			18	SS	WH		120													
18.9	End of Borehole DCPT carried out from 18.9 m to 31.1 m																			
							119													

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

DOUBLE LINE LOCHA CREEK REPLACEMENT.GPJ 2012TEMPLATE(MTO).GDT 5/2/19

# RECORD OF BOREHOLE No 17-4

3 OF 4

METRIC

GWP# 4061-17-00 LOCATION Lat: 45.4440768°, Long: -76.5346975° MTO Zone 9: N 5 033 794.5 E 302 085.7 ORIGINATED BY KE  
 HWY 17 BOREHOLE TYPE HSA COMPILED BY KP  
 DATUM Geodetic DATE 2017.09.11 - 2017.09.11 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100					
	Continued From Previous Page DCPT continued						118							
							117							
							116							
							115							
							114							
							113							
							112							
							111							
							110							
							109							

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE


# RECORD OF BOREHOLE No 17-4

4 OF 4

METRIC

GWP# 4061-17-00 LOCATION Lat: 45.4440768°, Long: -76.5346975°  
MTO Zone 9: N 5 033 794.5 E 302 085.7  
 HWY 17 BOREHOLE TYPE HSA  
 DATUM Geodetic DATE 2017.09.11 - 2017.09.11

ORIGINATED BY KE  
 COMPILED BY KP  
 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT  γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES								
	Continued From Previous Page												
107.7	DCPT continued						108						
31.1	DCPT refusal												

DOUBLE LINE LOCHA CREEK REPLACEMENT.GPJ 2012TEMPLATE(MTO).GDT 5/2/19

## METRIC

Lat: 45.4443593°, Long: -76.5348025°  
MTO Zone 9: N 5 033 825.9 E 302 077.5

DOUBLE LINE LOCHA CREEK REPLACEMENT.GPJ 2012TEMPLATE(MTO).GDT 5/2/19

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No 17-5

2 OF 2

METRIC

GWP# 4061-17-00 LOCATION Lat: 45.4443593° Long: -76.5348025° MTO Zone 9: N 5 033 825.9 E 302 077.5 ORIGINATED BY KE  
 HWY 17 BOREHOLE TYPE Portable / NW Casing COMPILED BY DJP  
 DATUM Geodetic DATE 2017.09.18 - 2017.09.19 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)		
								20 40 60 80 100									W P W W L		
	Continued From Previous Page																		
122.5	CLAY (C) Firm Grey																		
11.3	End of Borehole WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) 2017.10.06 1.1 132.7																		



## METRIC

[illegible]

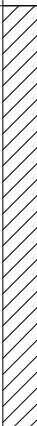
+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No 17-6

2 OF 2

METRIC

GWP# 4061-17-00 LOCATION Lat: 45.4443584° Long: -76.5346542° MTO Zone 9: N 5 033 825.8 E 302 089.1 ORIGINATED BY KE  
 HWY 17 BOREHOLE TYPE Portable / NW Casing COMPILED BY DJP  
 DATUM Geodetic DATE 2017.09.19 - 2017.09.20 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT  W P	NATURAL MOISTURE CONTENT  W	LIQUID LIMIT  W L	UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE								
	Continued From Previous Page							20 40 60 80 100								
119.9 12.8	CLAY (CL) Firm Grey															
			11	SS	WH		122									0 0 49 51
							121									
			12	SS	WH		120									
	End of Borehole															

DOUBLE LINE LOCHA CREEK REPLACEMENT.GPJ 2012TEMPLATE(MTO).GDT 5/2/19

# RECORD OF BOREHOLE No 17-7

1 OF 2

METRIC

GWP# 4061-17-00 LOCATION Lat: 45.4443225° Long: -76.5343972° MTO Zone 9: N 5 033 821.8 E 302 109.2 ORIGINATED BY KE  
 HWY 17 BOREHOLE TYPE Portable / NW Casing COMPILED BY DJP  
 DATUM Geodetic DATE 2017.09.20 - 2017.09.21 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	
134.3								SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	WATER CONTENT (%) 20 40 60			GR SA SI CL
0.0	Silty sand with organics trace gravel Very loose Brown FILL		1	SS	2		134					
133.5			2	SS	5		133					
0.8	CLAY (CH to CI) Very stiff to stiff Grey		3	SS	11		132					3 1 35 61
			4	SS	7		131					
			5	SS	5		130					0 0 36 64
			6	SS	5		129					
			7	SS	4		128					0 0 40 60
			8	SS	1		127					
			9	SS	WH		126					
			10	SS	WH		125					

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 17-7

2 OF 2

METRIC

GWP# 4061-17-00 LOCATION Lat: 45.4443225° Long: -76.5343972° MTO Zone 9: N 5 033 821.8 E 302 109.2 ORIGINATED BY KE  
 HWY 17 BOREHOLE TYPE Portable / NW Casing COMPILED BY DJP  
 DATUM Geodetic DATE 2017.09.20 - 2017.09.21 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE							
	Continued From Previous Page							20 40 60 80 100							
121.5   															

DOUBLE LINE LOCHA CREEK REPLACEMENT.GPJ 2012TEMPLATE(MTO).GDT 5/2/19

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
15  
10  
5  
0  
(%) STRAIN AT FAILURE

## METRIC

SOIL PROFILE					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES	GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT
			NUMBER  TYPE  "N" VALUES		<div>20406080100</div> <div>○ UNCONFINED     + FIELD VANE</div> <div>● QUICK TRIAXIAL    × LAB VANE</div> <div>20406080100</div>
					<div>PLASTIC LIMIT</div> <div>NATURAL MOISTURE CONTENT</div> <div>LQUID LIMIT</div> <div>w p                  w                  w L</div> <div>WATER CONTENT (%)</div> <div>204060</div>
					<div>UNIT WEIGHT</div> <div>γ</div> <div>kN/m<sup>3</sup></div>
					<div>REMARKS &amp; GRAIN SIZE DISTRIBUTION (%)</div> <div>GR SA SI CL</div>
132.5 0.0	SANDY CLAY (CL) with organics - rootlets, grass and wood pieces Very soft Brown	[Pattern]	1 BS 1		
131.9 0.6	SILTY SAND (SM) - occasional clay seams Very loose Grey Wet	[Pattern]	2 SS 2		
131.4 1.1	CLAY (CH) Very stiff Grey	[Pattern]	3 SS 3		
	- vane attempted S <sub>u</sub> > 106 kPa				
129.5 3.0	CLAY (CI to CL) Stiff to firm Grey	[Pattern]	4 SS 1		
			5 ST PUSH		
			6 SS WH		
	- becomes firm below 7 m				
			7 SS WH		
			8 SS WR		

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

## METRIC

Continued Next Page




+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No 18-101

3 OF 4

METRIC

GWP# 4061-17-00 LOCATION Lat: 45.4446478° Long: -76.5345541° MTO Zone 9: N 5 033 858.0 E 302 096.9 ORIGINATED BY CM  
 HWY 17 BOREHOLE TYPE HSA / NW / NQ COMPILED BY KP  
 DATUM Geodetic DATE 2018.06.11 - 2018.06.12 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
								20   40   60   80   100	W P                      W                      W L					
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE						
Continued From Previous Page														GR   SA   SI   CL
107.8 24.7	CLAY (CL) Stiff to very stiff   - frequent silt to fine sand seams below 21 m   - vane attempted S <sub>u</sub> > 106 kPa   - vane attempted S <sub>u</sub> > 106 kPa						112							11   75   14 (SH+CL)
			15	SS	5		111							
							110							
			16	SS	3		109							
							108							
104.0 28.5	Silty Clayey SAND (SC-SM) TILL Dense Grey Wet   - gravel and cobbles below 27 m   - cored 75 mm cobble at 28 m						107							
			17	SS	45		106							
							105							
							104							
							103							
	MARBLE BEDROCK Freshly weathered Very strong Close joint spacing Fair to good quality Coarse grained White		1	RUN									FI 3 2	RUN #1 TCR=100% SCR=100% RQD=65%
			2	RUN									5 2	RUN #2 TCR=93% SCR=80% RQD=65%

Continued Next Page

+ <sup>3</sup> × <sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE



## METRIC

[illegible]

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No 18-102

1 OF 4

METRIC

GWP# 4061-17-00 LOCATION Lat: 45.4442368° Long: -76.5348154° MTO Zone 9: N 5 033 812.3 E 302 076.5 ORIGINATED BY CM  
 HWY 17 BOREHOLE TYPE HSA / NW / NQ COMPILED BY KP  
 DATUM Geodetic DATE 2018.06.12 - 2018.06.13 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								20   40   60   80   100				W <sub>P</sub> W                      W <sub>L</sub>				
								○ UNCONFINED                      + FIELD VANE ● QUICK TRIAXIAL                      × LAB VANE								
137.7																
0.0	Silty sand some gravel Compact Brown Dry FILL		1	SS	15											
			2	SS	21											7   84   9 (SH+CL)
			3	SS	28											
135.6																
2.1	Sand with silt and gravel Very dense to compact Grey to brown FILL		4	SS	54											
			5	SS	30											
			6	SS	18											
			7	SS	16											24   69   7 (SH+CL)
132.2			8	SS	4											
5.5	SANDY CLAY (CL) to SILTY CLAYEY SAND - frequent sand layers Stiff Grey Moist - sand layer from 6.2 m to 6.5 m		9	SS	11											
			10	SS	8											3   57   18   22
	- sand layer from 7.2 m to 7.5 m															
130.1			11	SS	WH											
7.6	CLAY (CL) Very stiff to firm Grey															
	- vane attempted S <sub>u</sub> > 106 kPa		12	SS	WH											

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
 15  
 10  
 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 18-102

2 OF 4

METRIC

GWP# 4061-17-00 LOCATION Lat: 45.4442368°, Long: -76.5348154°  
MTO Zone 9: N 5 033 812.3 E 302 076.5 ORIGINATED BY CM  
HWY 17 BOREHOLE TYPE HSA / NW / NQ COMPILED BY KP  
DATUM Geodetic DATE 2018.06.12 - 2018.06.13 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	
	Continued From Previous Page							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	WATER CONTENT (%) 20 40 60			
	CLAY (CL) Stiff to firm							16.0 17.0 +				
			13	ST	PUSH		127					
							126	9.7 +				
			14	SS	WH		125				○	0 0 50 50
	- becomes firm below 13 m						124	+				
			15	SS	WH		123	5.1 7.0 +				
			16	SS	WR		122				○	
							121	+				
			17	ST	PUSH		120	+				
							119	8.7 +			○	
			18	SS	WR		118					

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
20  
15  
10  
(%) STRAIN AT FAILURE

## METRIC

[illegible]

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

DOUBLE LINE LOCHA CREEK REPLACEMENT.GPJ 2012TEMPLATE(MTO).GDT 5/2/19

# RECORD OF BOREHOLE No 18-102

4 OF 4

METRIC

GWP# 4061-17-00 LOCATION Lat: 45.4442368°, Long: -76.5348154°  
MTO Zone 9: N 5 033 812.3 E 302 076.5 ORIGINATED BY CM  
HWY 17 BOREHOLE TYPE HSA / NW / NQ COMPILED BY KP  
DATUM Geodetic DATE 2018.06.12 - 2018.06.13 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20 40 60 80 100									
	Continued From Previous Page																
	<b>MARBLE BEDROCK</b> Freshly weathered White Very strong Close joint spacing Poor to excellent quality Coarse grained		3	RUN		107								0	TCR=100% SCR=100% RQD=100%  RUN #3 TCR=100% SCR=98% RQD=30%  RUN #4 TCR=100% SCR=100% RQD=90% UCS=165MPa		
																4	
														5			
						4	RUN	106									2
																	2
104.7						105								0			
33.0														0			
	End of Borehole WATER LEVEL READINGS: DATE      DEPTH (m)    ELEV. (m) 2018.06.15      5.9      131.8 Note: Groundwater rose to at least 0.5 m above ground surface upon completion of drilling. The bottom 20 m of the borehole was backfilled with a bentonite and clay seal prior to installing a monitoring well screened within the clay.													3			
														1			

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity 20  
15 10 5  
(%) STRAIN AT FAILURE

## METRIC

[illegible]

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity



# RECORD OF BOREHOLE No 18-103

2 OF 3

METRIC

GWP# 4061-17-00 LOCATION Lat: 45.4438208° Long: -76.5347193° MTO Zone 9: N 5 033 766.1 E 302 084.0 ORIGINATED BY CM  
 HWY 17 BOREHOLE TYPE HSA / NW / NQ COMPILED BY KP  
 DATUM Geodetic DATE 2018.06.14 - 2018.06.15 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)	
								○ UNCONFINED    + FIELD VANE	● QUICK TRIAXIAL    × LAB VANE							
	Continued From Previous Page							20 40 60 80 100	20 40 60							
	CLAY (CL) Firm to stiff  															

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
 15  
 10  
 (%) STRAIN AT FAILURE

## METRIC

[illegible]

DOUBLE LINE LOCHA CREEK REPLACEMENT.GPJ 2012TEMPLATE(MTO).GDT 5/2/19

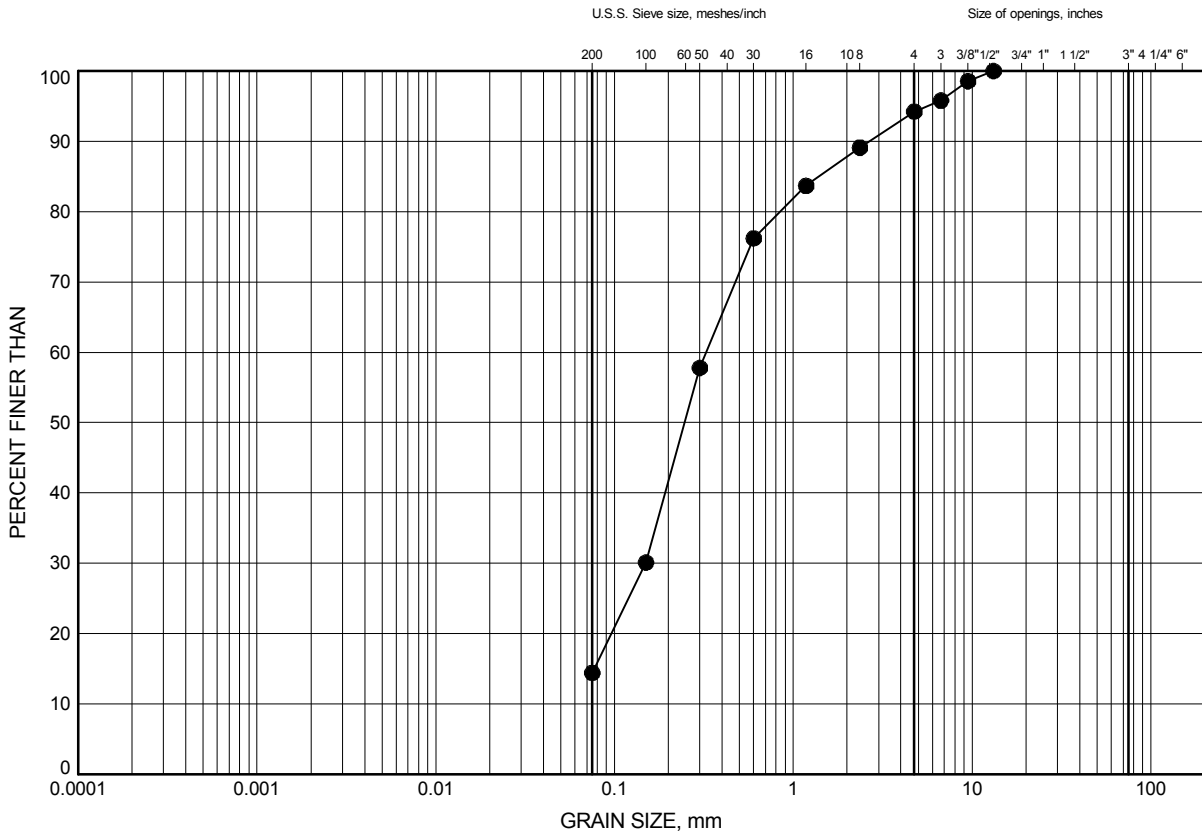
+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

**APPENDIX C**  
**LABORATORY TEST RESULTS**

Site 29-249/C1 Locha Creek Culvert  
**GRAIN SIZE DISTRIBUTION**

FIGURE 1

**Sand Fill**



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-3	1.07	137.83

Date February 2019  
 GWP# 4061-17-00

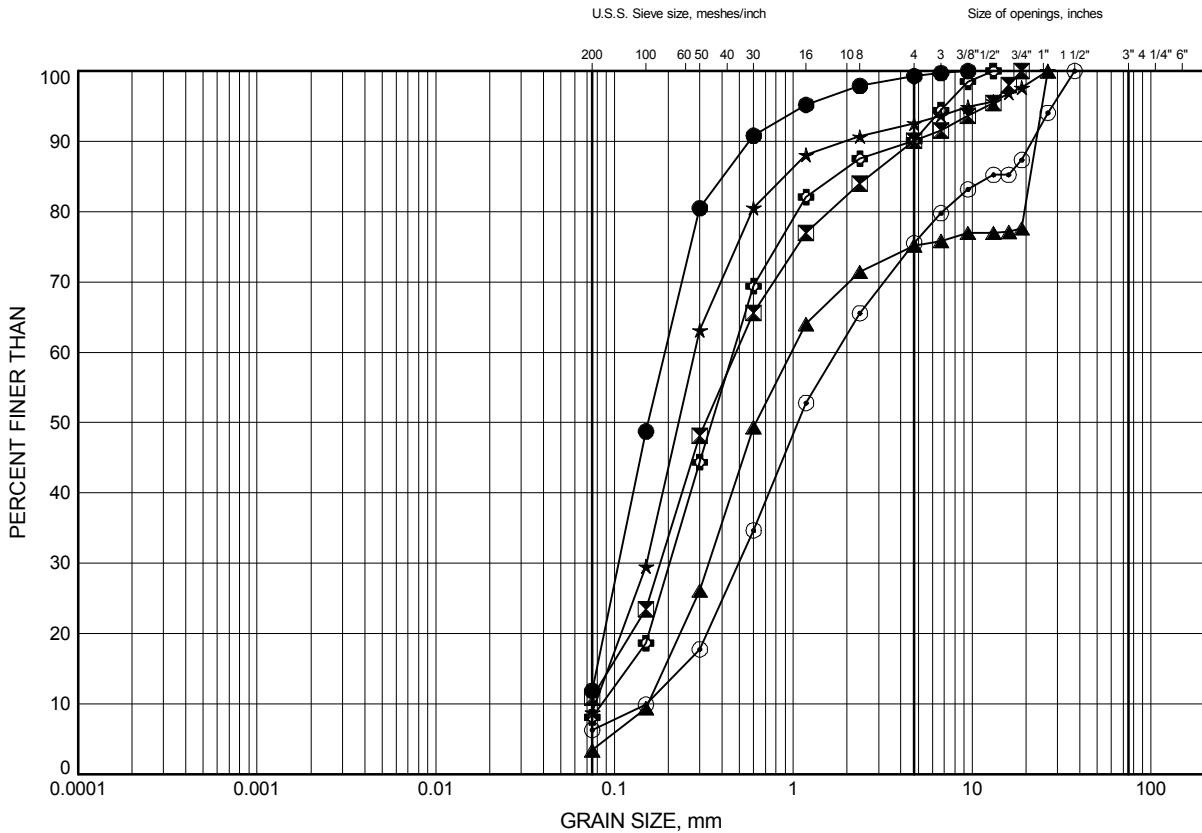


Prep'd DJP  
 Chkd. PC

Site 29-249/C1 Locha Creek Culvert  
GRAIN SIZE DISTRIBUTION

FIGURE 2

Sand Fill



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-3	4.88	134.02
⊠	17-4	4.11	134.69
▲	17-6	0.30	132.40
★	18-102	1.07	136.63
⊙	18-102	4.88	132.82
⊞	18-103	0.33	133.57

Date July 2018  
GWP# 4061-17-00

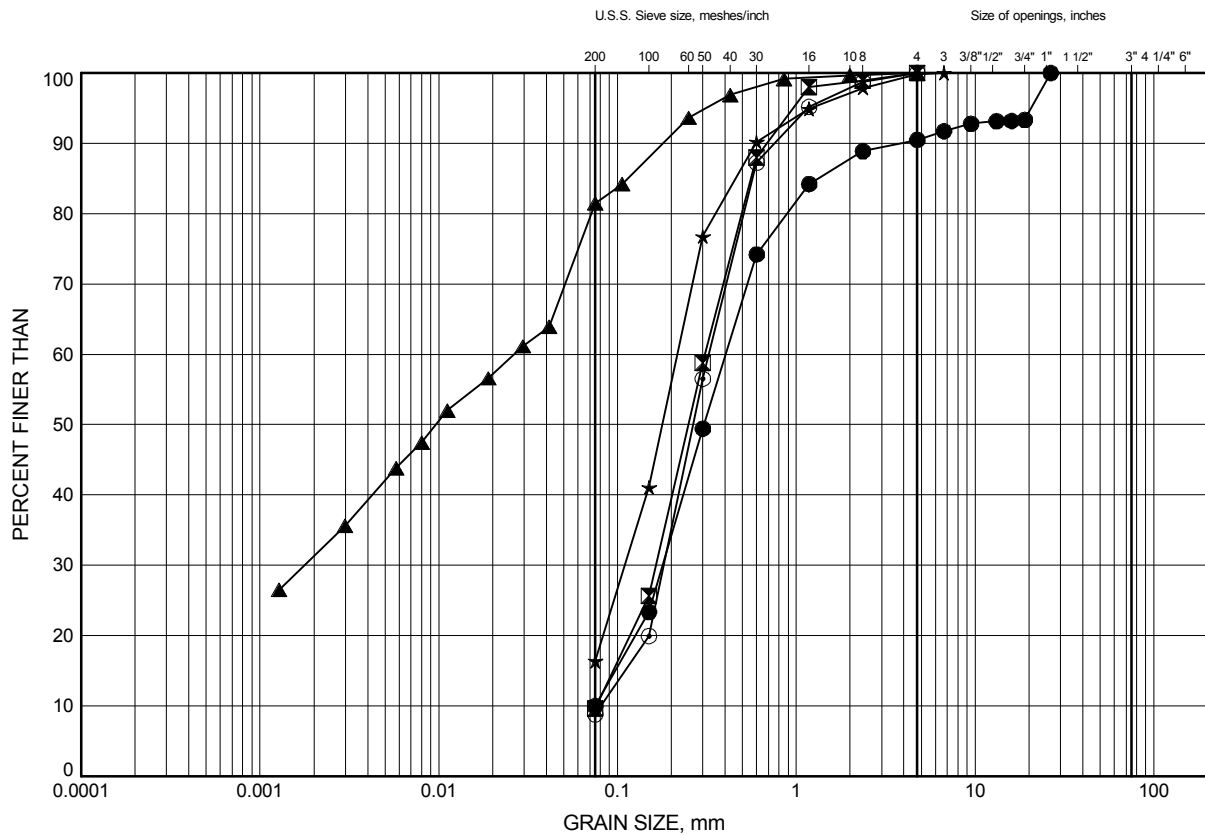


Prep'd KCP  
Chkd. PC

Site 29-249/C1 Locha Creek Culvert  
**GRAIN SIZE DISTRIBUTION**

FIGURE 3

**Silty Sand (SM) to Sandy Silt (ML)**



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-1	0.91	131.59
⊠	17-3	7.92	130.98
▲	17-3	8.69	130.21
★	17-5	2.86	130.94
⊙	18-101	0.91	131.59

Date July 2018

GWP# 4061-17-00



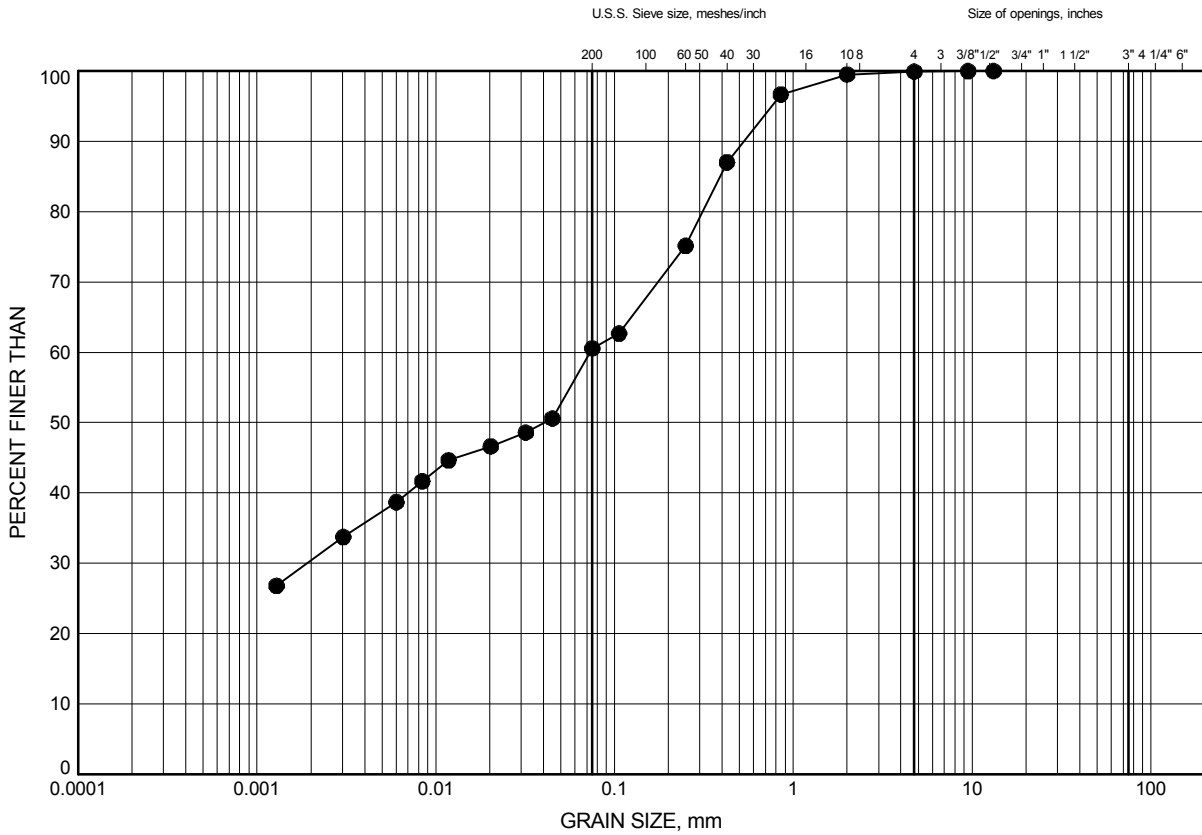
Prep'd KCP

Chkd. PC

Site 29-249/C1 Locha Creek Culvert  
**GRAIN SIZE DISTRIBUTION**

FIGURE 4

**Organic Silt (OL) with Sand**



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-2	1.83	130.77

Date July 2018  
 GWP# 4061-17-00

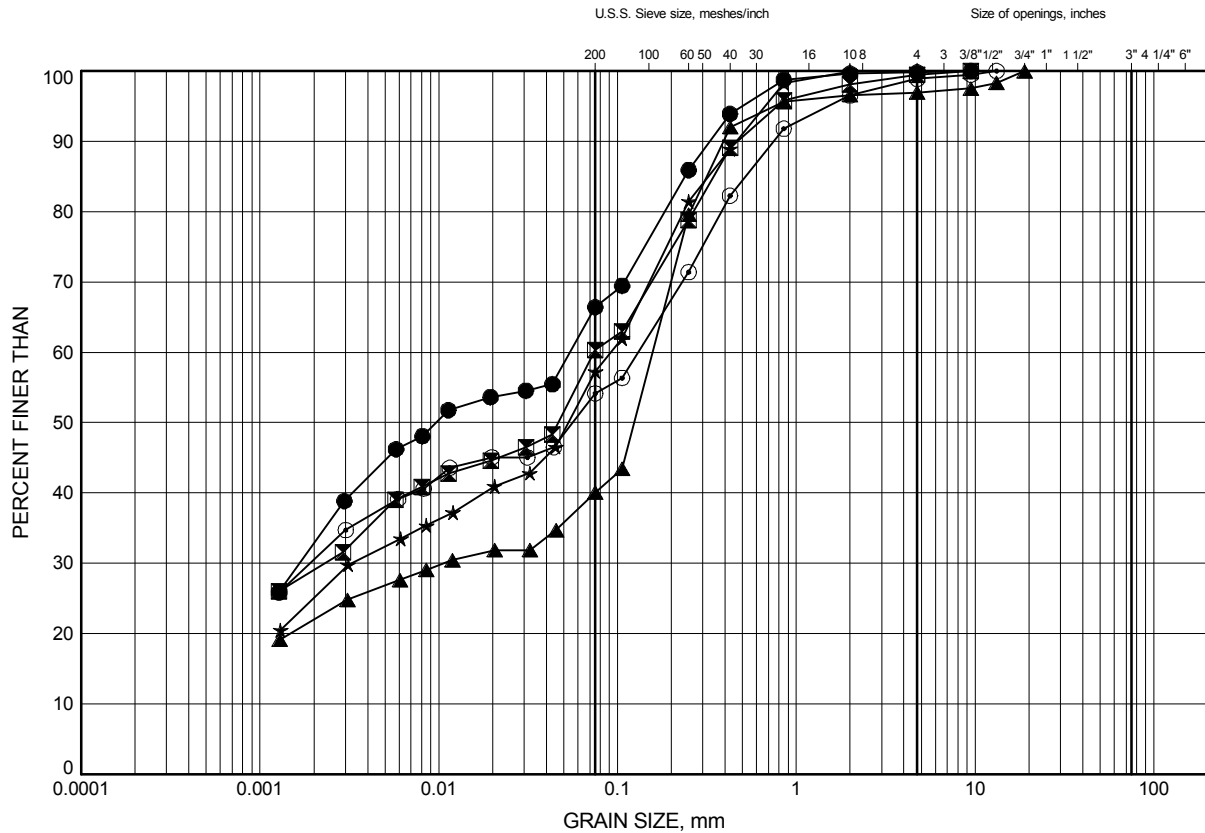


Prep'd KCP  
 Chkd. PC

Site 29-249/C1 Locha Creek Culvert  
**GRAIN SIZE DISTRIBUTION**

FIGURE 5

**Sandy Clay to Silty Clayey Sand**



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-3	7.16	131.74
⊠	17-4	7.16	131.64
▲	18-102	7.32	130.38
★	18-103	3.35	130.55
⊙	18-103	4.11	129.79

Date August 2018  
 GWP# 4061-17-00



Prep'd KCP  
 Chkd. PC

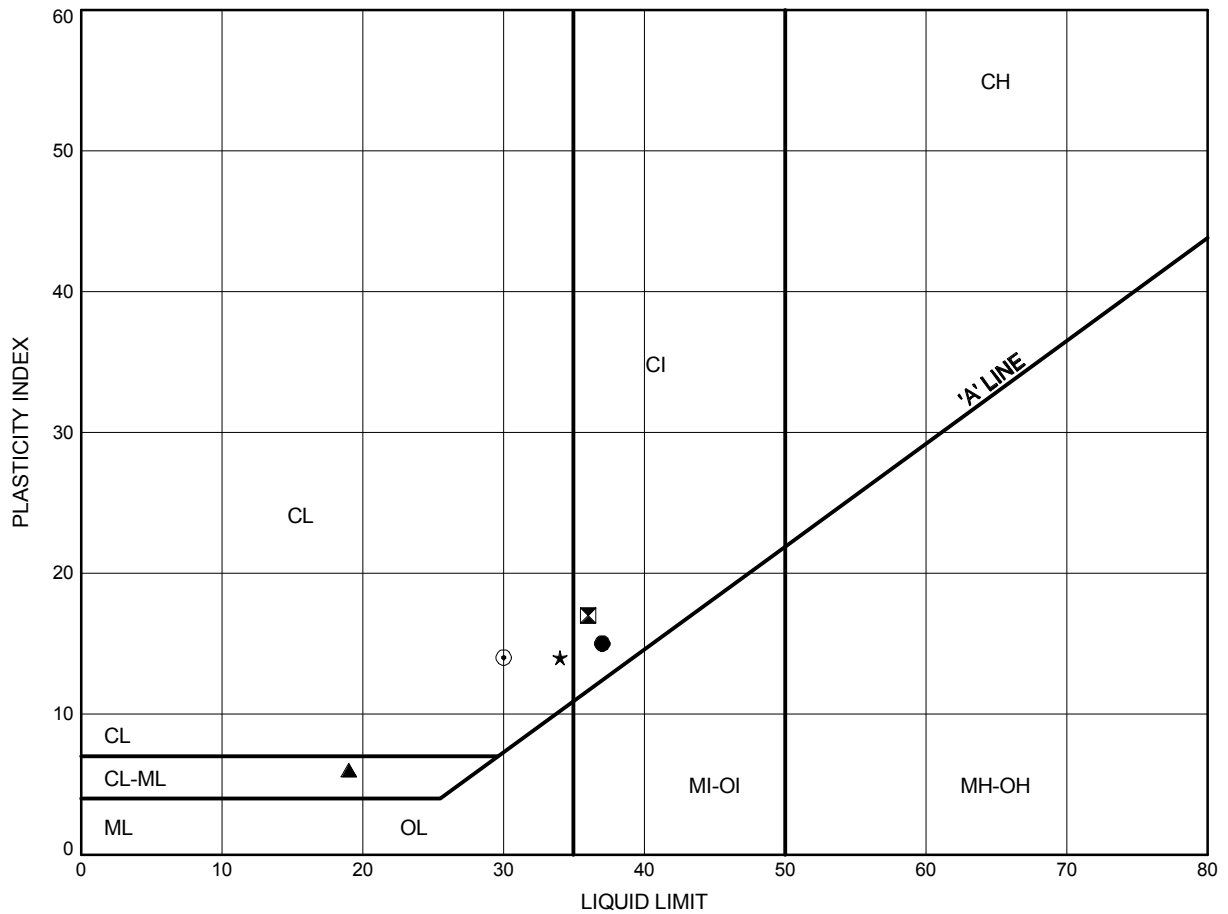


Site 29-249/C1 Locha Creek Culvert

# ATTERBERG LIMITS TEST RESULTS

FIGURE 6

Sandy Clay to Silty Clayey Sand



## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-3	7.16	131.74
⊠	17-4	7.16	131.64
▲	18-102	7.32	130.38
★	18-103	3.35	130.55
⊙	18-103	4.11	129.79

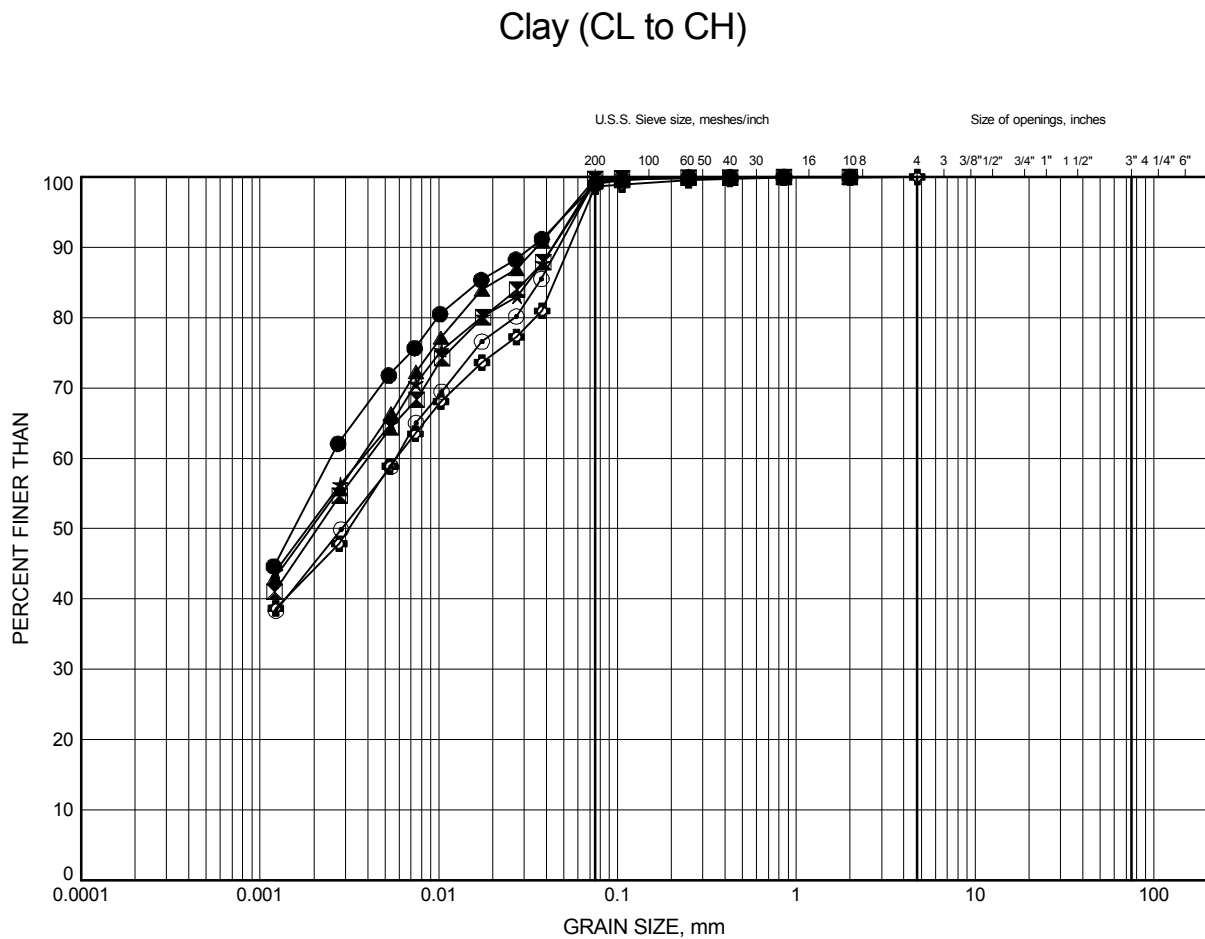
Date August 2018  
GWP# 4061-17-00



Prep'd KCP  
Chkd. PC

Site 29-249/C1 Locha Creek Culvert  
GRAIN SIZE DISTRIBUTION

FIGURE 7



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-1	4.11	128.39
⊠	17-1	10.97	121.53
▲	17-2	7.92	124.68
★	17-3	12.50	126.40
⊙	17-3	18.59	120.31
⊕	17-4	12.50	126.30

Date July 2018

GWP# 4061-17-00

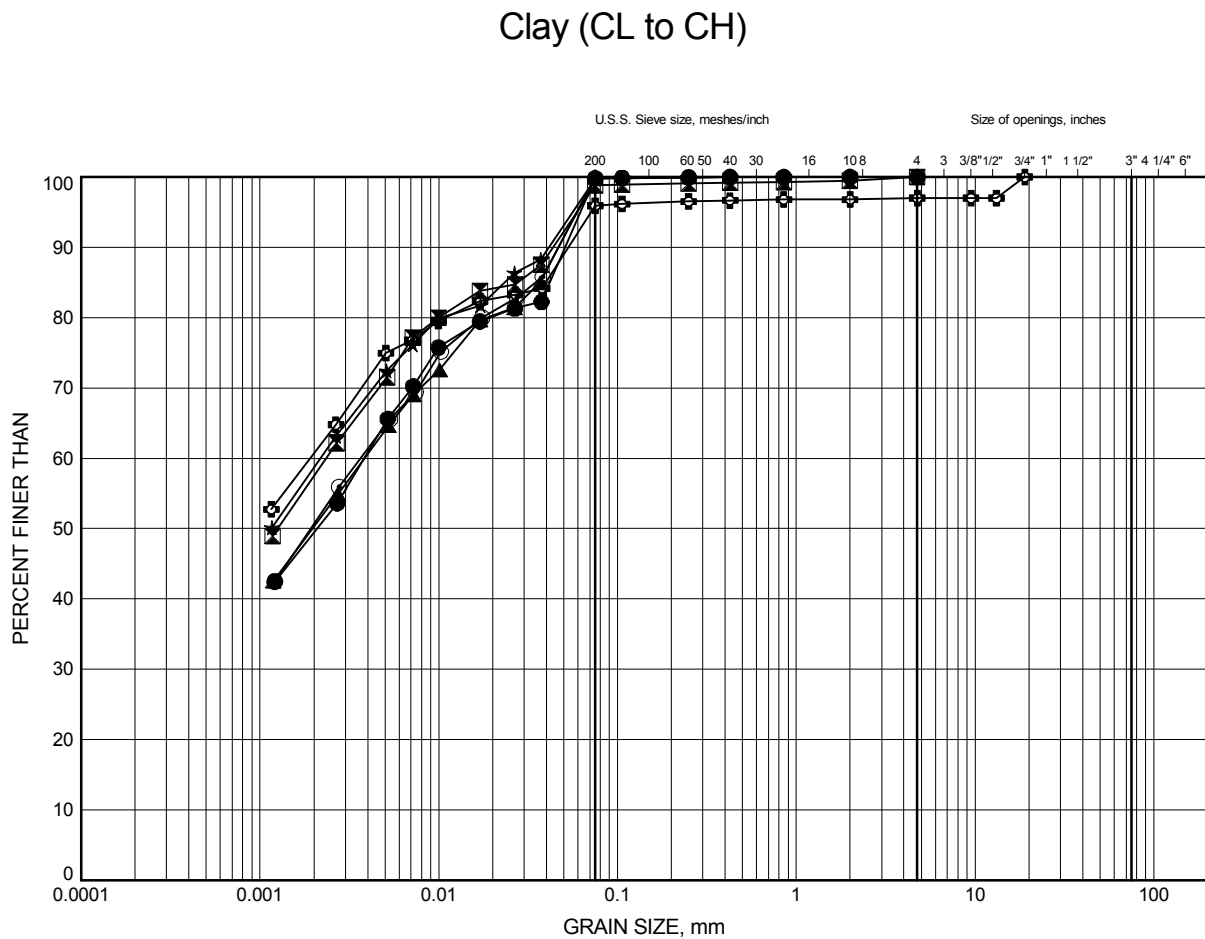


Prep'd KCP

Chkd. PC

Site 29-249/C1 Locha Creek Culvert  
GRAIN SIZE DISTRIBUTION

FIGURE 8



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-4	17.07	121.73
⊠	17-5	3.45	130.35
▲	17-5	9.55	124.25
★	17-6	3.35	129.35
⊙	17-6	10.97	121.73
⊕	17-7	1.83	132.47

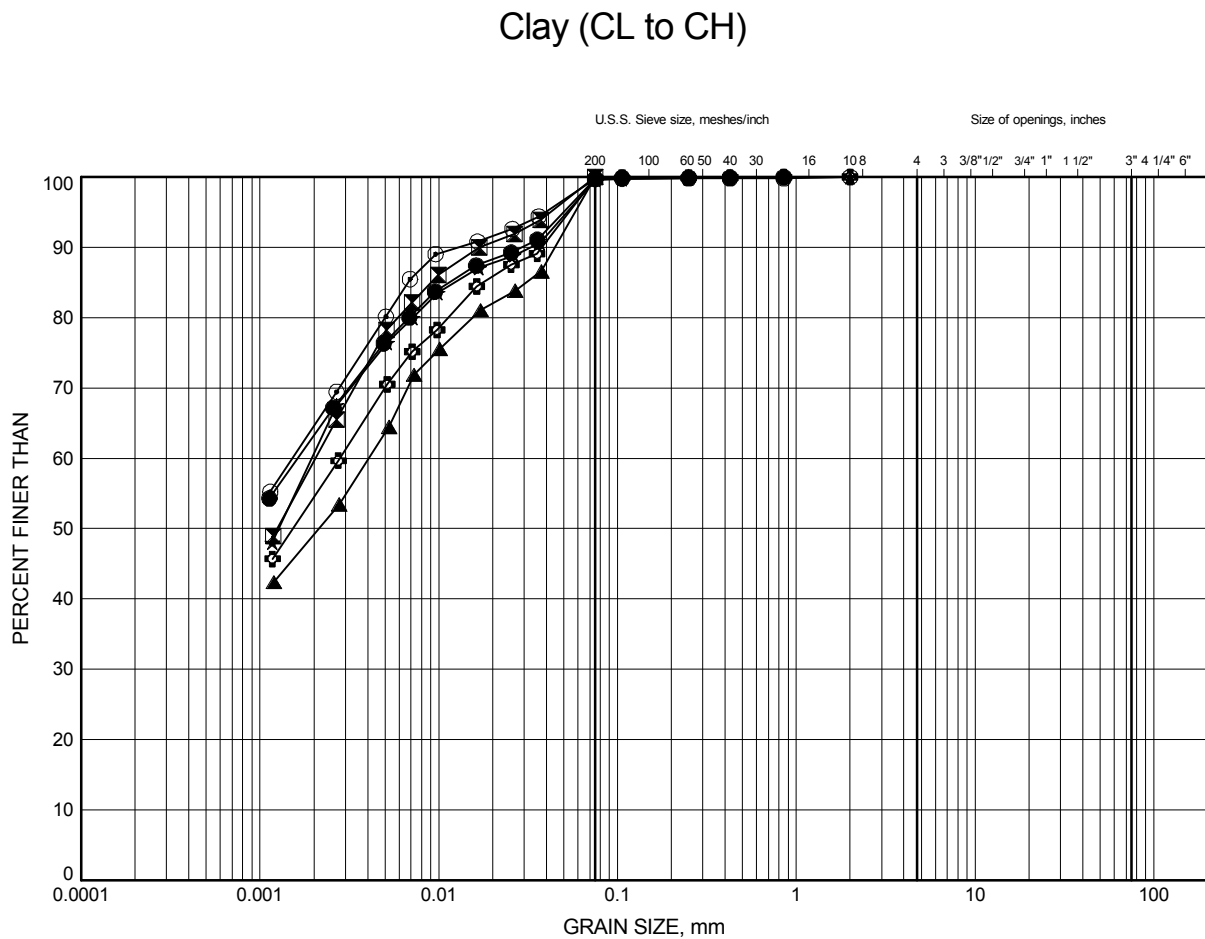
Date July 2018  
GWP# 4061-17-00



Prep'd KCP  
Chkd. PC

Site 29-249/C1 Locha Creek Culvert  
GRAIN SIZE DISTRIBUTION

FIGURE 9



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-7	4.11	130.19
⊠	17-7	6.40	127.90
▲	17-7	12.50	121.80
★	18-101	1.83	130.67
⊙	18-101	3.35	129.15
⊕	18-101	14.02	118.48

Date July 2018

GWP# 4061-17-00

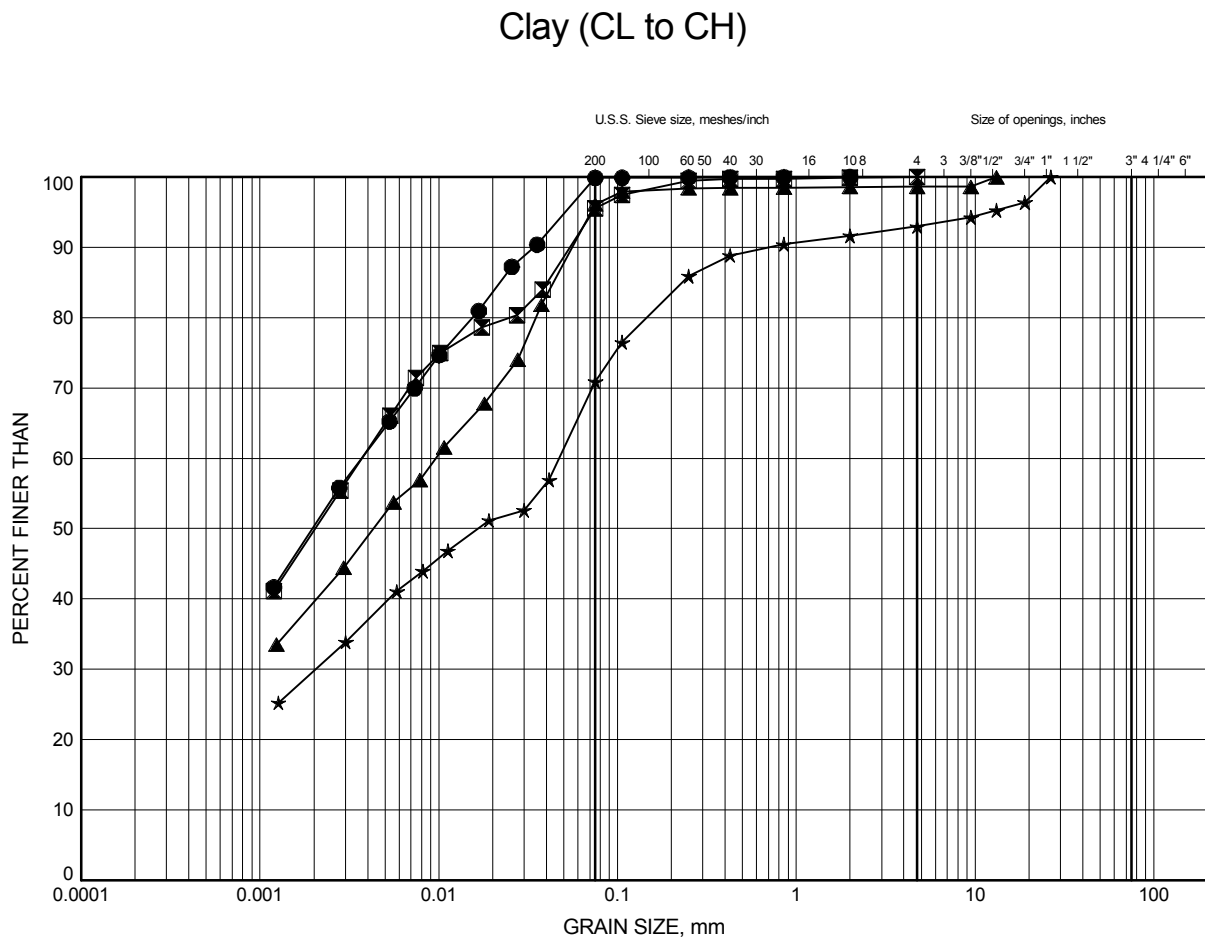


Prep'd KCP

Chkd. PC

Site 29-249/C1 Locha Creek Culvert  
GRAIN SIZE DISTRIBUTION

FIGURE 10



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-102	12.50	125.20
⊠	18-102	21.64	116.06
▲	18-103	11.89	122.01
★	18-103	22.56	111.34

Date July 2018  
GWP# 4061-17-00



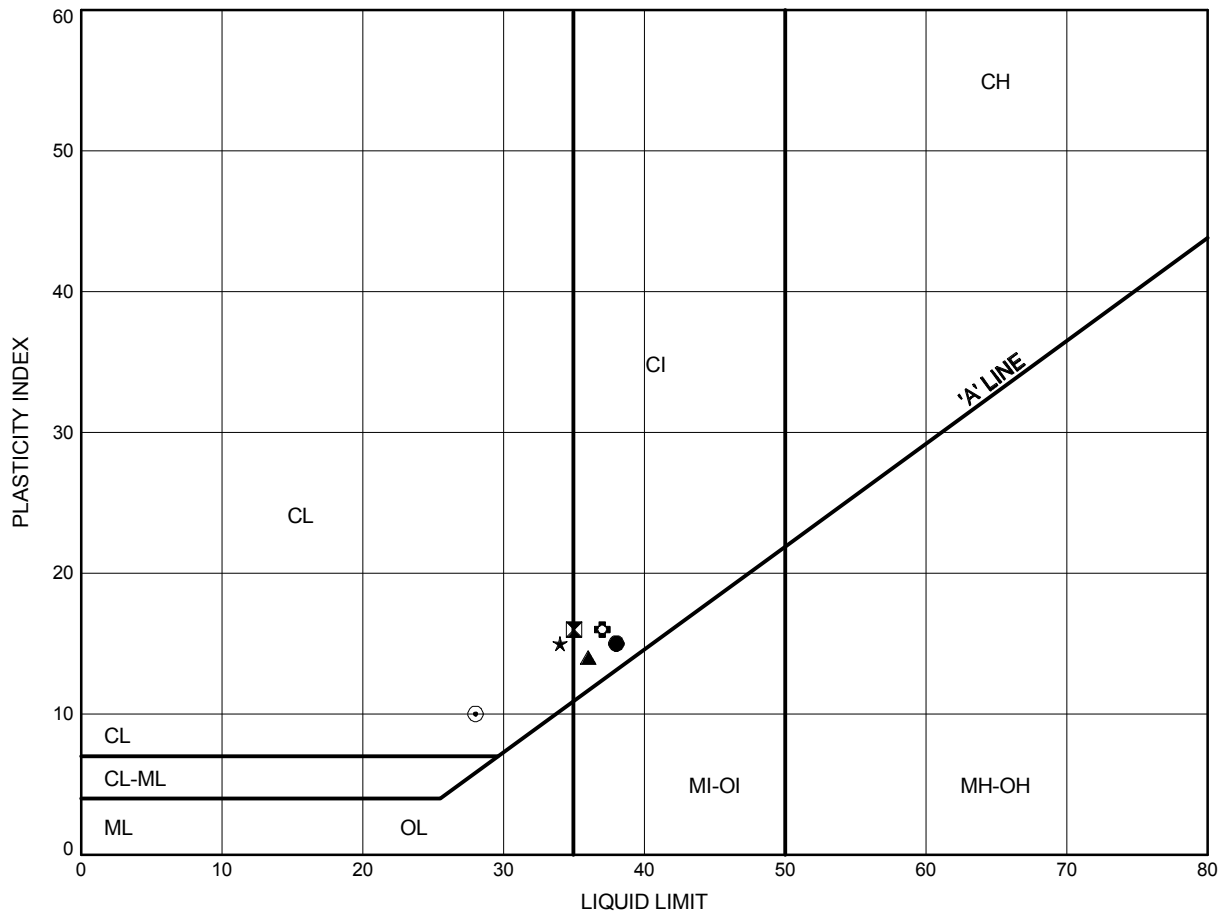
Prep'd KCP  
Chkd. PC

Site 29-249/C1 Locha Creek Culvert

# ATTERBERG LIMITS TEST RESULTS

FIGURE 11

Clay (CL to CH)



## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-1	4.11	128.39
⊠	17-1	10.97	121.53
▲	17-3	12.50	126.40
★	17-3	18.59	120.31
⊙	17-4	12.50	126.30
⊕	17-4	17.07	121.73

Date July 2018

GWP# 4061-17-00



Prep'd KCP

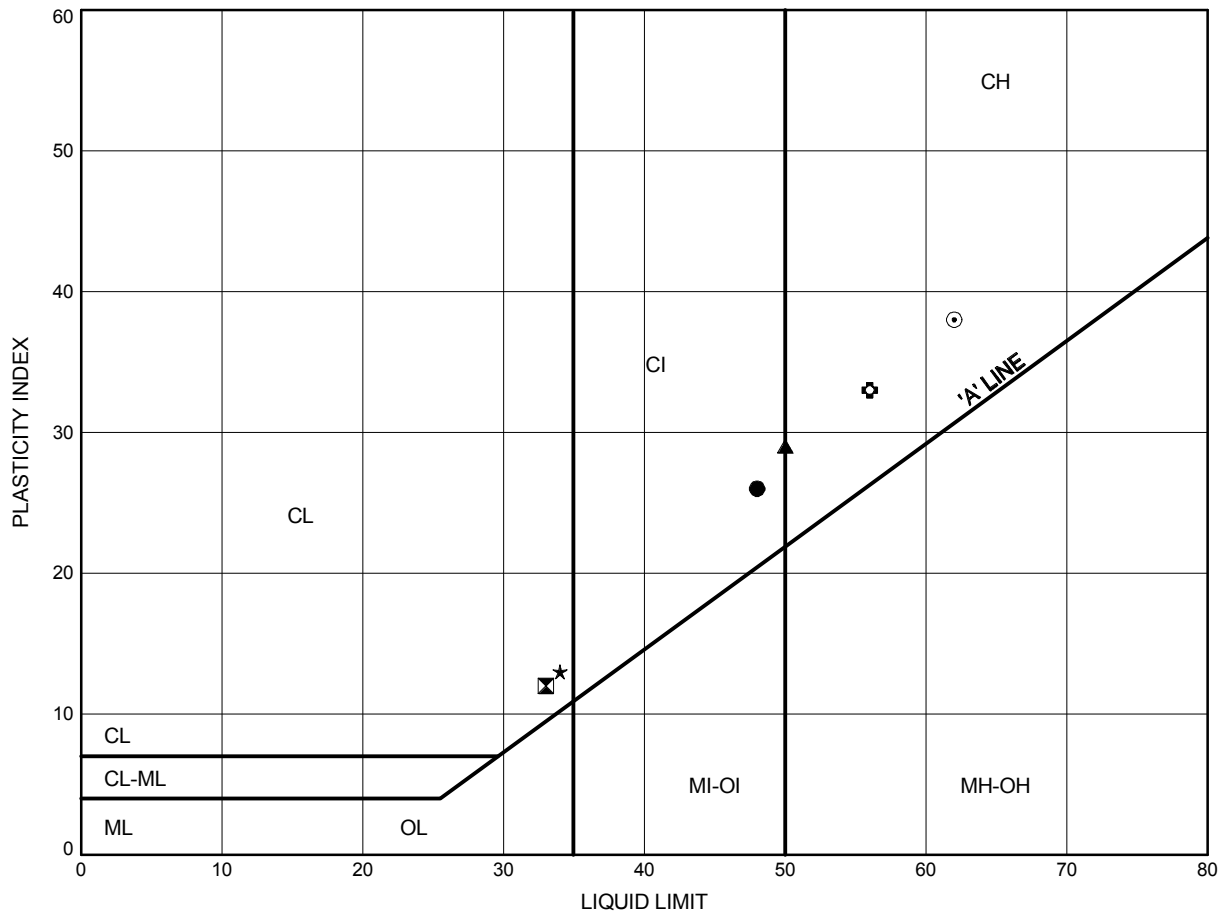
Chkd. PC

Site 29-249/C1 Locha Creek Culvert

# ATTERBERG LIMITS TEST RESULTS

FIGURE 12

Clay (CL to CH)



## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-5	3.45	130.35
⊠	17-5	9.55	124.25
▲	17-6	3.35	129.35
★	17-6	10.97	121.73
⊙	17-7	1.83	132.47
⊕	17-7	4.11	130.19

Date July 2018  
GWP# 4061-17-00



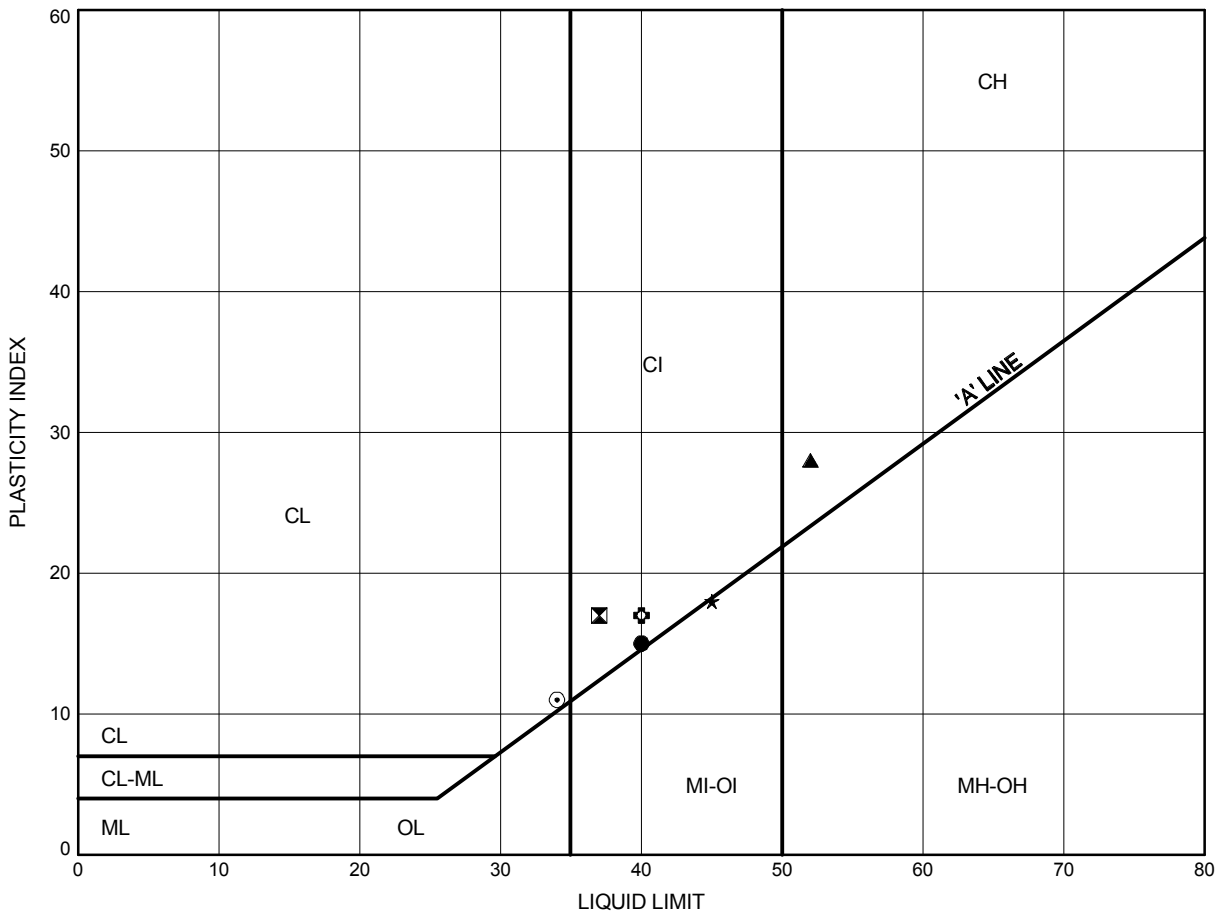
Prep'd KCP  
Chkd. PC

Site 29-249/C1 Locha Creek Culvert

# ATTERBERG LIMITS TEST RESULTS

FIGURE 13

Clay (CL to CH)



## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-7	6.40	127.90
⊠	17-7	12.50	121.80
▲	18-101	1.83	130.67
★	18-101	3.35	129.15
⊙	18-101	14.02	118.48
⊕	18-102	21.64	116.06

Date July 2018

GWP# 4061-17-00



Prep'd KCP

Chkd. PC

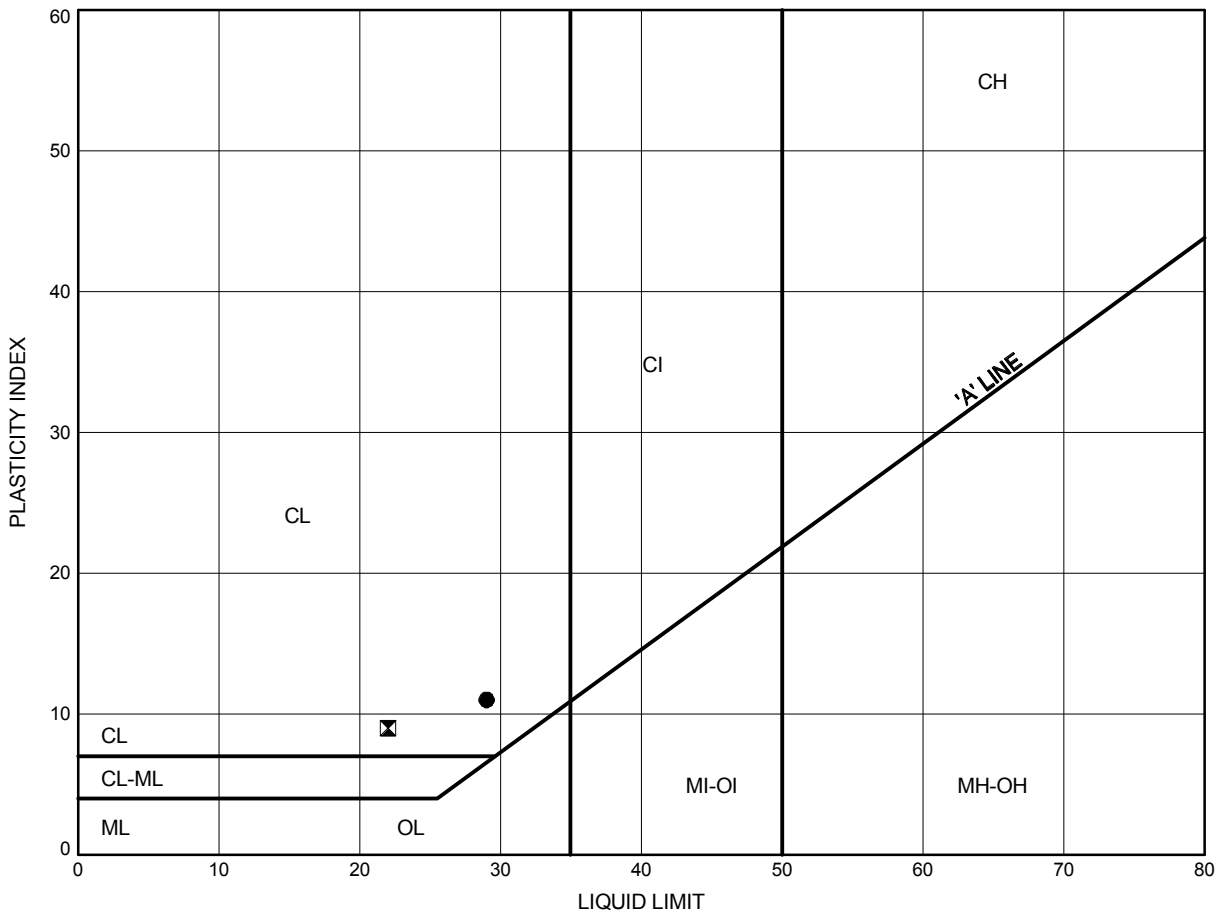


Site 29-249/C1 Locha Creek Culvert

# ATTERBERG LIMITS TEST RESULTS

FIGURE 14

Clay (CL to CH)



## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-103	11.89	122.01
⊗	18-103	22.56	111.34

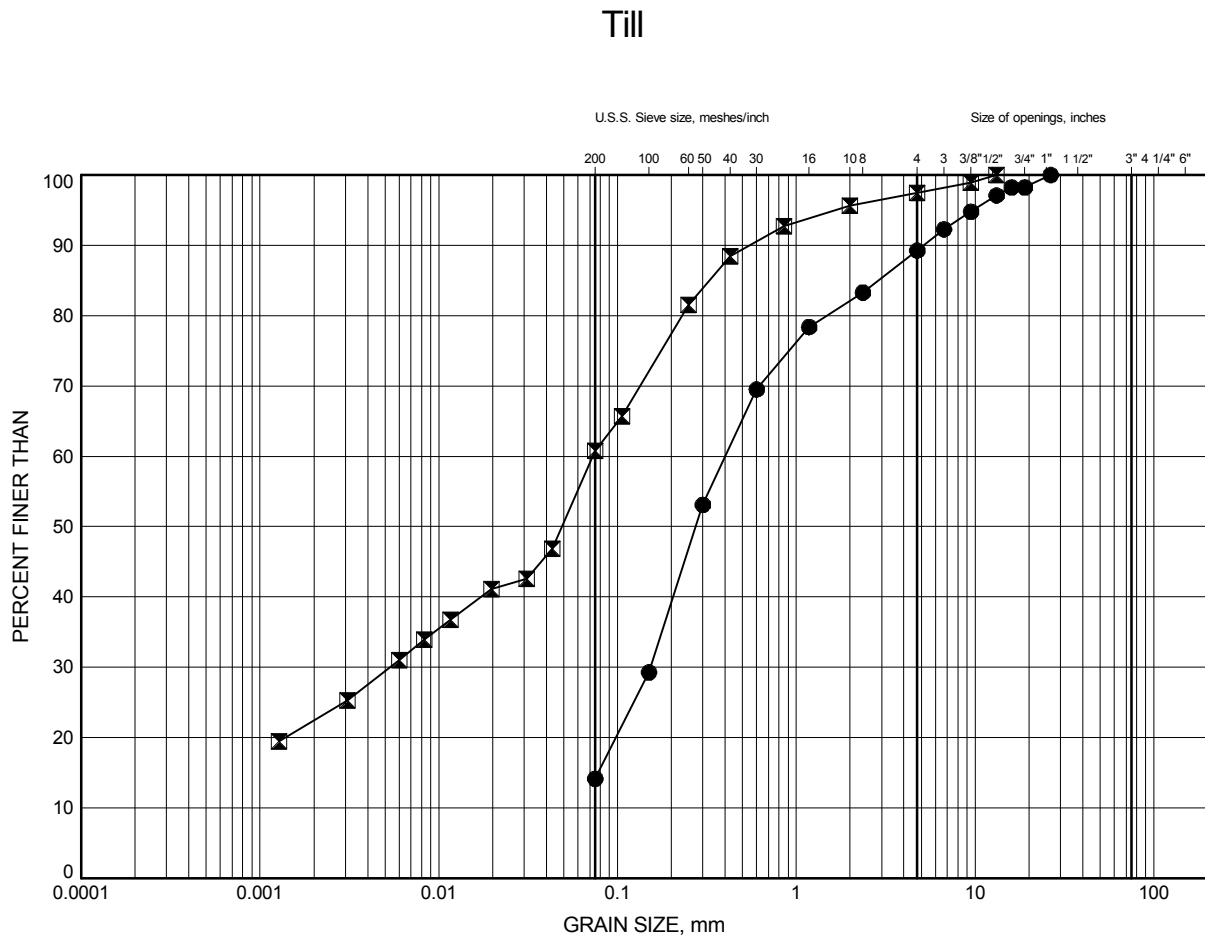
Date July 2018  
GWP# 4061-17-00



Prep'd KCP  
Chkd. PC

Site 29-249/C1 Locha Creek Culvert  
GRAIN SIZE DISTRIBUTION

FIGURE 15



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-101	26.21	106.29
⊠	18-102	27.74	109.96

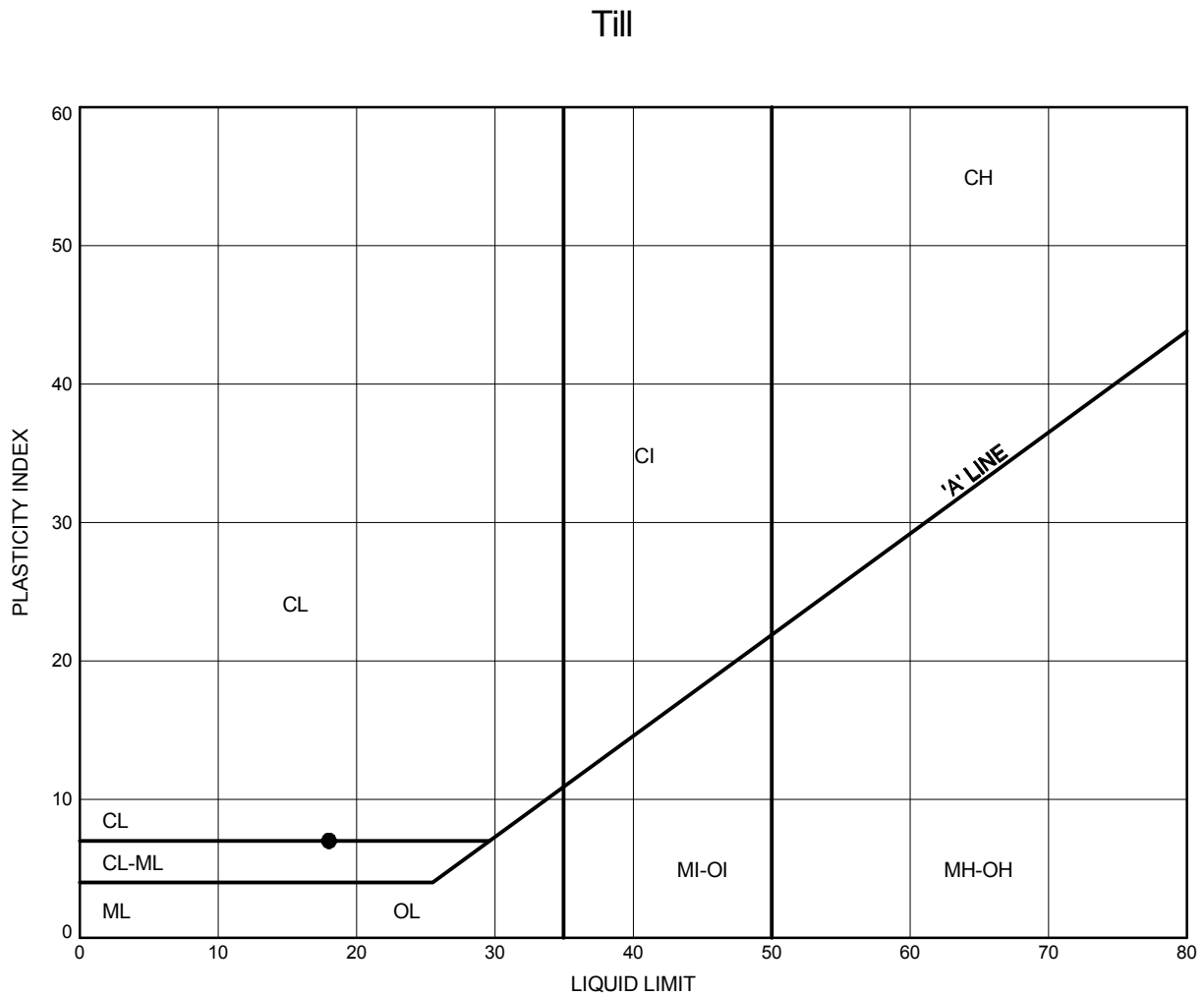
Date ..October 2018.....  
GWP# ..4061-17-00.....



Prep'd .....KCP.....  
Chkd. ....PC.....

Site 29-249/C1 Locha Creek Culvert  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE 16



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-102	27.74	109.96

Date ..October 2018.....  
 GWP# ..4061-17-00.....



Prep'd .....KCP.....  
 Chkd. ....PC.....



**Stantec Consulting Ltd.**

400 - 1331 Clyde Avenue, Ottawa ON K2C 3G4

November 1, 2017

File: 122410864

**Attention: Kenton Power**

Thurber Engineering Ltd.

104 – 2460 Lancaster Road

Ottawa, Ontario, Canada, K1B 4S5

Tel: 613-274-2121

E-mail: kpower@thurber.ca

Dear Mr. Power,

**Reference: Consolidation Test Results for Lochiel Project, Thurber Consulting Ltd.,**

**File #20482: BH 17-3, ST 17 & BH 17-2, ST 9, sampled on September 12 & 25, 2017**

This letter presents the results of one-dimensional consolidation tests carried out on the above referenced samples in accordance with ASTM D2435/D2435M - 11. The test results are provided in the attached tables and figures.

This letter provides test results only and does not constitute any interpretation or engineering recommendations with respect to material suitability or specification compliance.

We trust the information presented herein meets your present requirements. Should you have any questions or require additional information, please do not hesitate to contact us.

Regards,

**STANTEC CONSULTING LTD.**

A handwritten signature in blue ink, appearing to read "Ramy Saadeldin", written over a horizontal line.

Ramy Saadeldin, Ph.D., P.Eng.

Geotechnical Engineering

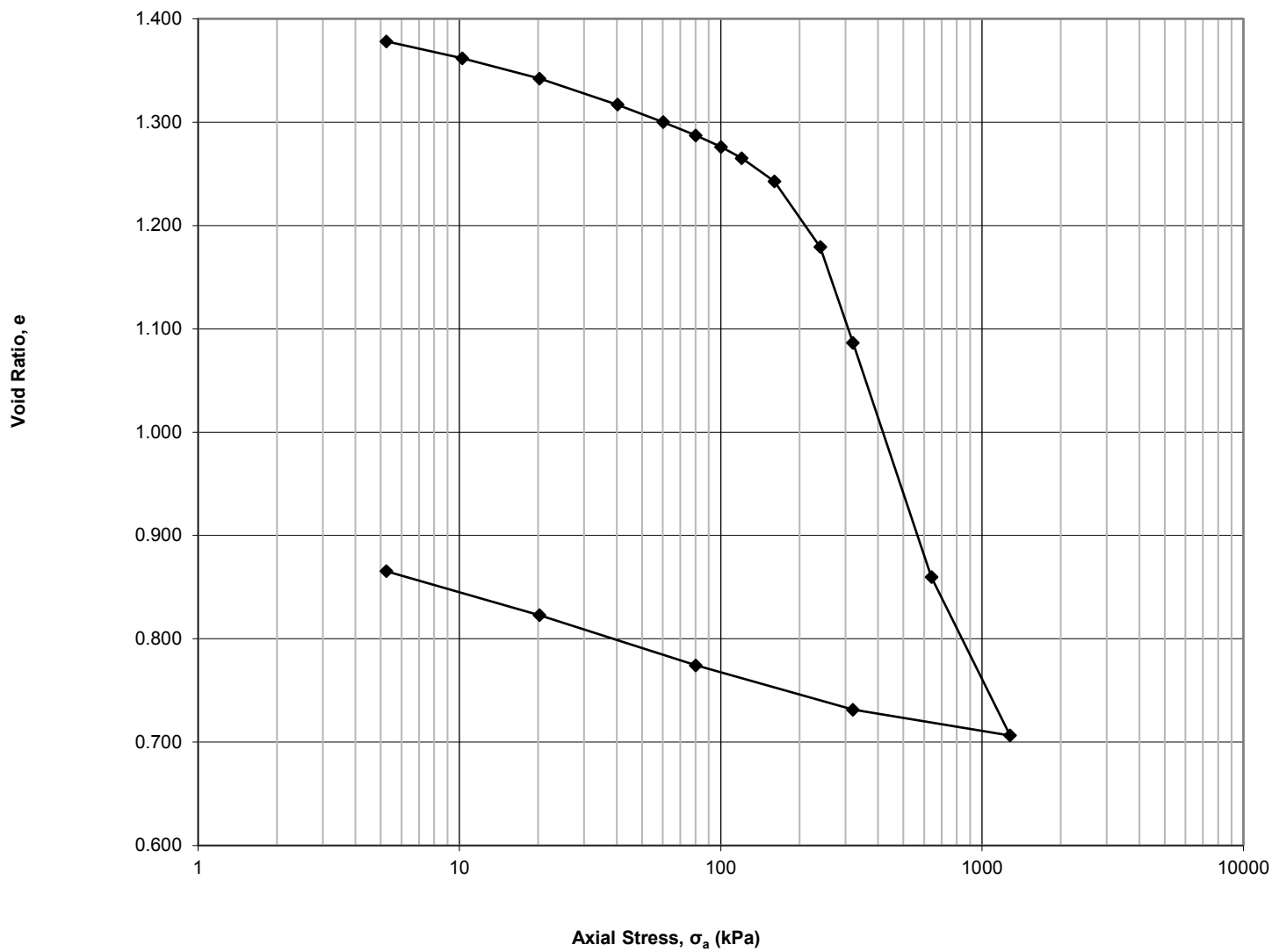
Phone: (613) 738-6047

Fax: (613) 722-2799

Ramy.Saadeldin@stantec.com

**Project**  
**Project No.**  
**Borehole No.**  
**Sample No.**  
**Sample Depth**

**Thurber Engineering, File# 20482**  
**122410864**  
**17-3**  
**ST 17**  
**50-52 ft**



**One-Dimensional Consolidation Test using Incremental Loading**  
**ASTM D2435/D2435M - 11**

1-Nov-17  
1-Nov-17

Date:  
Date:

D. Boateng  
R. Hache

Checked by:  
Approved by:

**Specimen Details**

Project Name	Thurber Engineering, File# 20482
Project Location	Lochiel, ON
Borehole	17-3
Sample No.	ST 17
Depth	50-52 ft
Sample Date	September 12, 2017
Test Number	One
Technician Name	Daniel Boateng

**Soil Description & Classification**

Not Requested	
Specific Gravity of Solids	2.746
Average water content of trimmings %	49
<b>Additional Notes (information source, occurrence and size of large isolated particles etc.)</b>	

**Initial Specimen Conditions**

Height	mm	20.00
Diameter	mm	50.00
Area	mm <sup>2</sup>	1963
Volume	mm <sup>3</sup>	39270
Mass	g	67.42
Dry Mass	g	45.26
Density	Mg/m <sup>3</sup>	1.717
Dry Density	Mg/m <sup>3</sup>	1.153
Water Content	%	48.96
Degree of Saturation	%	97.2
Height of Solids	mm	8.39
Initial Void Ratio		1.383

**Final Specimen Conditions**

Water Content	%	33.74
Final Void Ratio		0.865

## One-Dimensional Consolidation Test using Incremental Loading

### ASTM D2435/D2435M - 11

**Specimen Details**

Project Name	Thurber Engineering, File# 20482
Project Location	Lochiel, ON
Borehole	17-3
Sample No.	ST 17
Depth	50-52 ft
Sample Date	September 12, 2017
Test Number	One
Technician Name	Daniel Boateng

**Test Procedure**

Date Started	October 30, 2017
Date Finished	November 1, 2017
Machine Number	Frame C
Cell Number	C
Ring Number	C
Trimming Procedure	Turntable
Moisture Condition	Inundated
Axial Stress at Inundation kPa	5
Water Used	Distilled
Test Method	B
Interpretation Procedure for $c_v$	2

**All Departures from Outlined ASTM D2435/D2435M-11 Procedure**

--

**Calculations**

Load Increment	Increment Duration min	Axial Stress $\sigma_a$ kPa	Corrected Deformation $\Delta H$ mm	Specimen Height H mm	Axial Strain $\epsilon_a$ %	Void Ratio e
Seating	0.0	5	0.0000	20.0000	0.00	1.383
1	10.0	5	0.0372	19.9628	0.19	1.378
2	16.5	10	0.1754	19.8246	0.88	1.362
3	18.3	20	0.3391	19.6609	1.70	1.342
4	19.8	40	0.5514	19.4486	2.76	1.317
5	21.5	60	0.6935	19.3065	3.47	1.300
6	29.8	80	0.8005	19.1995	4.00	1.287
7	29.8	100	0.8948	19.1052	4.47	1.276
8	36.5	120	0.9858	19.0142	4.93	1.265
9	53.0	160	1.1741	18.8259	5.87	1.243
10	116.5	240	1.7085	18.2915	8.54	1.179
11	168.8	320	2.4859	17.5141	12.43	1.086
12	128.8	640	4.3883	15.6117	21.94	0.860
13	95.3	1280	5.6756	14.3244	28.38	0.706
14	18.3	320	5.4660	14.5340	27.33	0.731
15	36.8	80	5.1055	14.8945	25.53	0.774
16	63.5	20	4.6979	15.3021	23.49	0.823
17	103.8	5	4.3408	15.6592	21.70	0.865

## One-Dimensional Consolidation Test using Incremental Loading

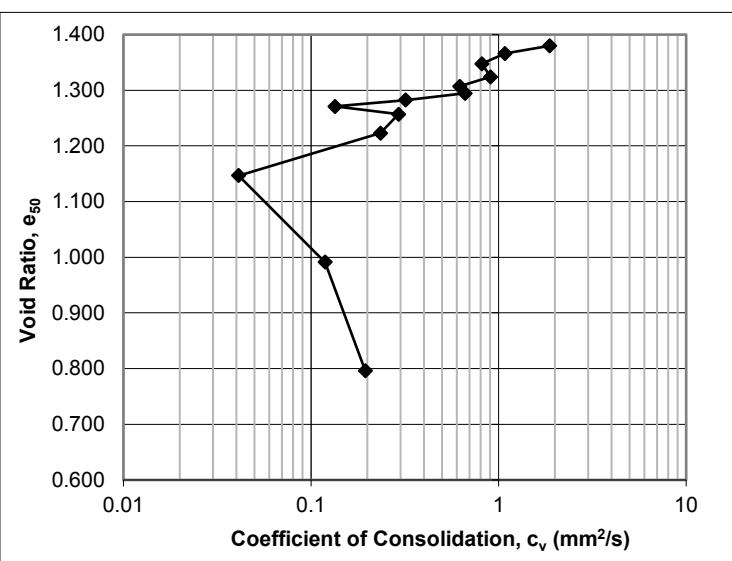
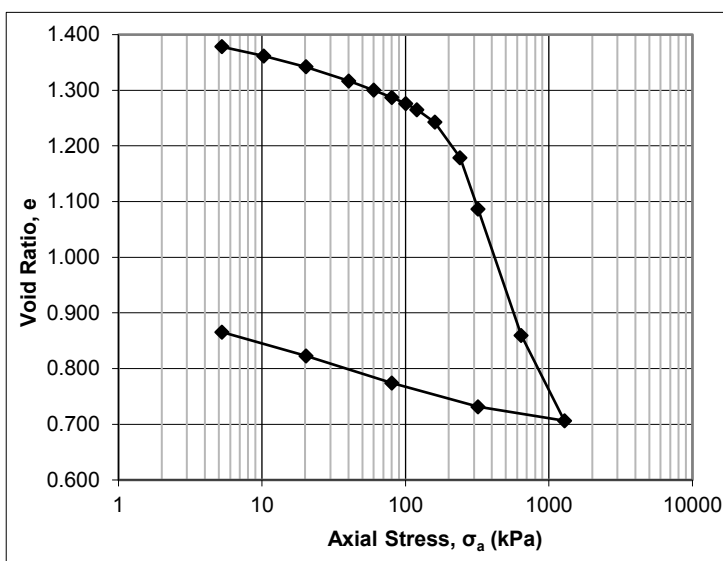
### ASTM D2435/D2435M - 11

**Specimen Details**

Project Name	Thurber Engineering, File# 20482
Project Location	Lochiel, ON
Borehole	17-3
Sample No.	ST 17
Depth	50-52 ft
Sample Date	September 12, 2017
Test Number	One
Technician Name	Daniel Boateng

**Calculations**

Load Increment	Axial Stress $\sigma_a$ , average kPa	Calculated using Interpretation Procedure 2				Interpretation Procedure 1		Interpretation Procedure 2	
		Corrected Deformation $\Delta H_{50}$ mm	Specimen Height $H_{50}$ mm	Axial Strain $\epsilon_{a,50}$ %	Void Ratio $e_{50}$	Time $t_{50}$ sec	Coeff. Consol. $c_v$ mm <sup>2</sup> /s	Time $t_{90}$ sec	Coeff. Consol. $c_v$ mm <sup>2</sup> /s
Seating	3								
1	5	0.0226	19.9774	0.11	1.380			45	1.87E+00
2	8	0.1394	19.8606	0.70	1.366			77	1.08E+00
3	15	0.2925	19.7075	1.46	1.348			101	8.13E-01
4	30	0.4904	19.5096	2.45	1.324			89	9.05E-01
5	50	0.6325	19.3675	3.16	1.307			128	6.20E-01
6	70	0.7391	19.2609	3.70	1.295			119	6.62E-01
7	90	0.8403	19.1597	4.20	1.282			244	3.19E-01
8	110	0.9366	19.0634	4.68	1.271			575	1.34E-01
9	140	1.0537	18.9463	5.27	1.257			260	2.93E-01
10	200	1.3376	18.6624	6.69	1.223			314	2.35E-01
11	280	1.9795	18.0205	9.90	1.147			1673	4.11E-02
12	480	3.2838	16.7162	16.42	0.991			497	1.19E-01
13	960	4.9221	15.0779	24.61	0.796			247	1.95E-01
14	800	5.5093	14.4907	27.55	0.726				
15	200	5.2302	14.7698	26.15	0.760				
16	50	4.8678	15.1322	24.34	0.803				
17	13	4.6825	15.3175	23.41	0.825				







Project No.: 122410864

Project Name: Thurber, File # 20482

Photo Log

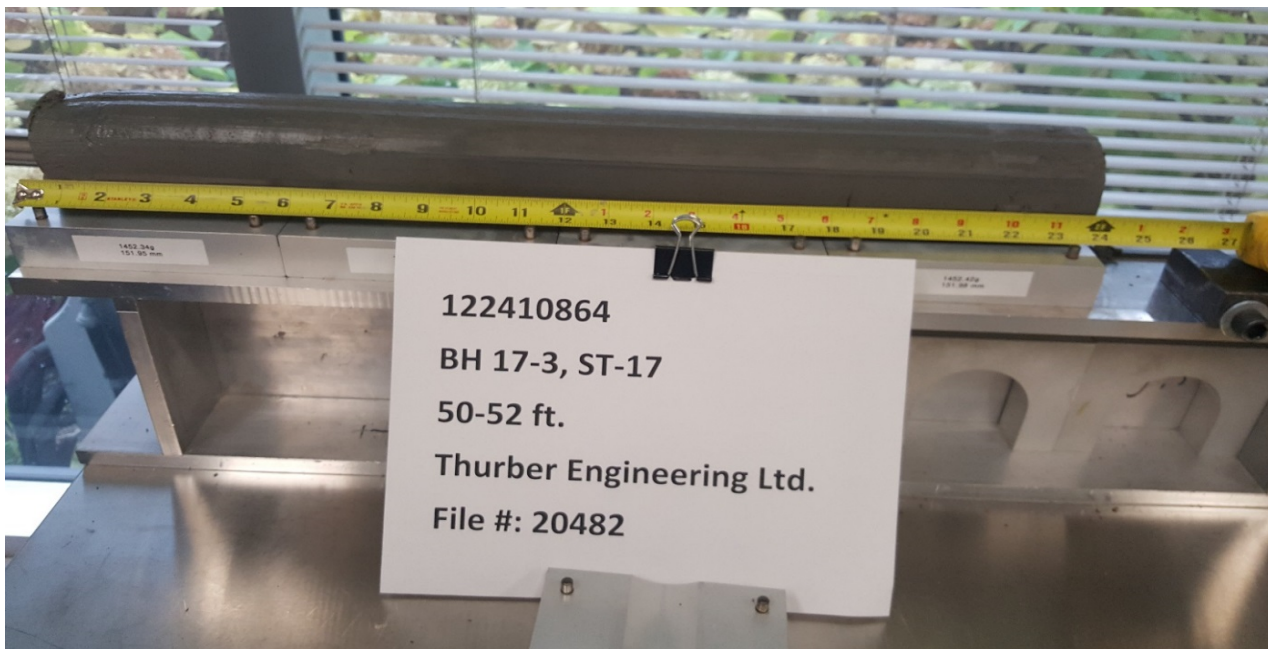


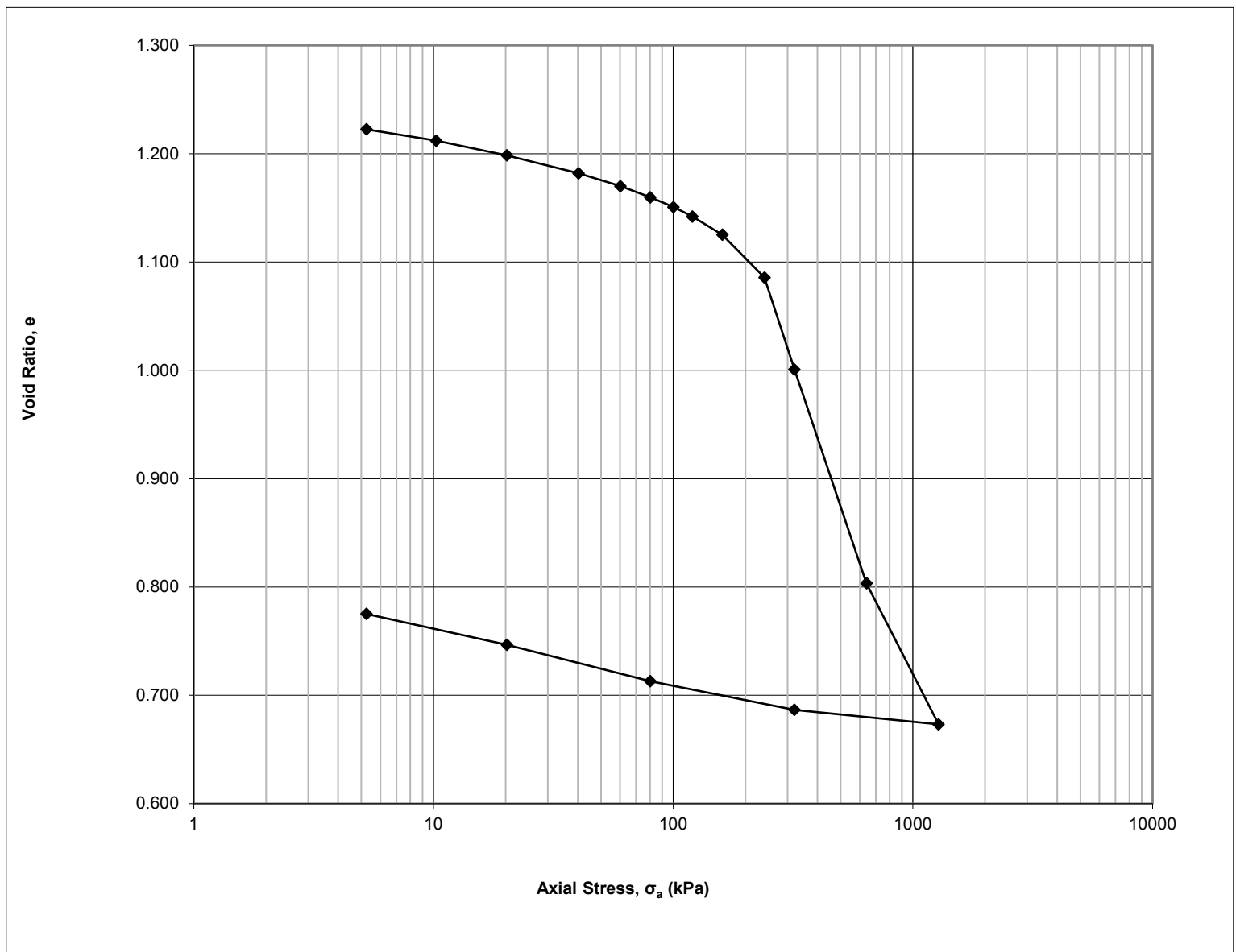
Photo No.: 1 Borehole: BH 17-3, ST 17 Depth: 50-52 ft



Photo No.: 2 Borehole: BH 17-3, ST 17 Depth: 50-52 ft

**Project**  
**Project No.**  
**Borehole No.**  
**Sample No.**  
**Sample Depth**

**Thurber Engineering, File# 20482**  
**122410864**  
**17-2**  
**ST 9**  
**35-37 ft**



**One-Dimensional Consolidation Test using Incremental Loading**  
**ASTM D2435/D2435M - 11**

1-Nov-17  
1-Nov-17

Date:  
Date:

D. Boateng  
R. Hache

Checked by:  
Approved by:

**Specimen Details**

Project Name	Thurber Engineering, File# 20482
Project Location	Lochiel, ON
Borehole	17-2
Sample No.	ST 9
Depth	35-37 ft
Sample Date	September 25, 2017
Test Number	Two
Technician Name	Daniel Boateng

**Soil Description & Classification**

Not Requested	
Specific Gravity of Solids	2.746
Average water content of trimmings %	45
<b>Additional Notes (information source, occurrence and size of large isolated particles etc.)</b>	
Specific Gravity of Solids Assumed	

**Initial Specimen Conditions**

Height	mm	20.00
Diameter	mm	50.00
Area	mm <sup>2</sup>	1963
Volume	mm <sup>3</sup>	39270
Mass	g	69.92
Dry Mass	g	48.38
Density	Mg/m <sup>3</sup>	1.780
Dry Density	Mg/m <sup>3</sup>	1.232
Water Content	%	44.52
Degree of Saturation	%	99.5
Height of Solids	mm	8.97
Initial Void Ratio		1.229

**Final Specimen Conditions**

Water Content	%	30.07
Final Void Ratio		0.775

## One-Dimensional Consolidation Test using Incremental Loading

### ASTM D2435/D2435M - 11

**Specimen Details**

Project Name	Thurber Engineering, File# 20482
Project Location	Lochiel, ON
Borehole	17-2
Sample No.	ST 9
Depth	35-37 ft
Sample Date	September 25, 2017
Test Number	Two
Technician Name	Daniel Boateng

**Test Procedure**

Date Started	October 30, 2017
Date Finished	November 1, 2017
Machine Number	Frame D
Cell Number	D
Ring Number	D
Trimming Procedure	Turntable
Moisture Condition	Inundated
Axial Stress at Inundation	5 kPa
Water Used	Distilled
Test Method	B
Interpretation Procedure for $c_v$	2

**All Departures from Outlined ASTM D2435/D2435M-11 Procedure**

--

**Calculations**

Load Increment	Increment Duration  min	Axial Stress $\sigma_a$ kPa	Corrected Deformation $\Delta H$ mm	Specimen Height H mm	Axial Strain $\epsilon_a$ %	Void Ratio e
Seating	0.0	5	0.0000	20.0000	0.00	1.229
1	14.8	5	0.0576	19.9424	0.29	1.223
2	14.8	10	0.1507	19.8493	0.75	1.212
3	21.5	20	0.2735	19.7265	1.37	1.198
4	19.8	40	0.4214	19.5786	2.11	1.182
5	19.8	60	0.5284	19.4716	2.64	1.170
6	28.3	80	0.6203	19.3797	3.10	1.160
7	24.8	100	0.7016	19.2984	3.51	1.151
8	29.8	120	0.7803	19.2197	3.90	1.142
9	34.8	160	0.9306	19.0694	4.65	1.125
10	64.8	240	1.2849	18.7151	6.42	1.086
11	183.5	320	2.0464	17.9536	10.23	1.001
12	132.0	640	3.8172	16.1828	19.09	0.804
13	87.0	1280	4.9864	15.0136	24.93	0.673
14	15.0	320	4.8663	15.1337	24.33	0.687
15	28.3	80	4.6286	15.3714	23.14	0.713
16	53.3	20	4.3271	15.6729	21.64	0.747
17	68.5	5	4.0719	15.9281	20.36	0.775

## One-Dimensional Consolidation Test using Incremental Loading

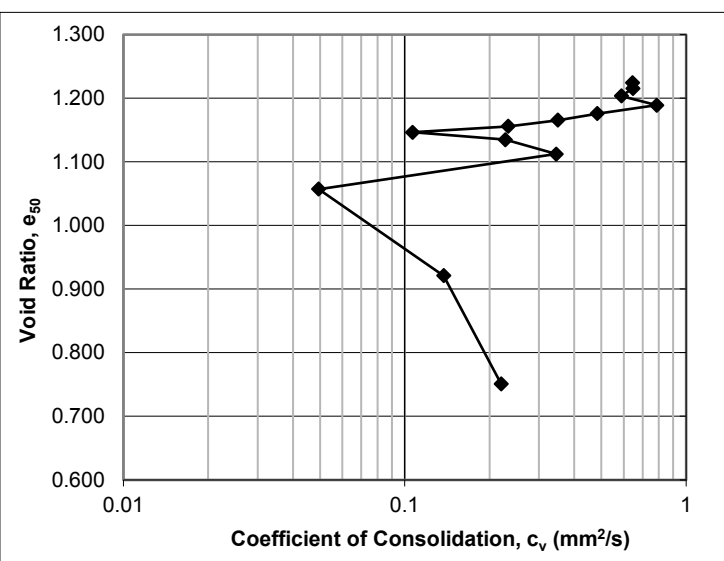
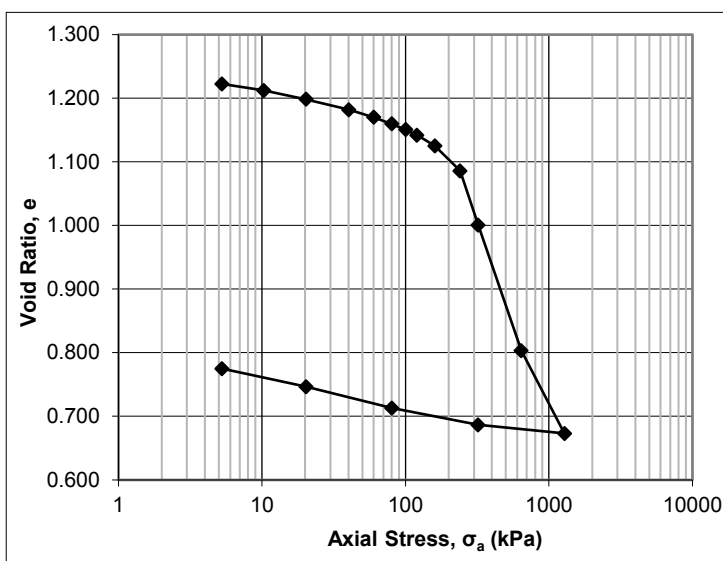
### ASTM D2435/D2435M - 11

**Specimen Details**

Project Name	Thurber Engineering, File# 20482
Project Location	Lochiel, ON
Borehole	17-2
Sample No.	ST 9
Depth	35-37 ft
Sample Date	September 25, 2017
Test Number	Two
Technician Name	Daniel Boateng

**Calculations**

Load Increment	Axial Stress $\sigma_a$ , average kPa	Calculated using Interpretation Procedure 2				Interpretation Procedure 1		Interpretation Procedure 2	
		Corrected Deformation $\Delta H_{50}$ mm	Specimen Height $H_{50}$ mm	Axial Strain $\epsilon_{a,50}$ %	Void Ratio $e_{50}$	Time $t_{50}$ sec	Coeff. Consol. $c_v$ mm <sup>2</sup> /s	Time $t_{90}$ sec	Coeff. Consol. $c_v$ mm <sup>2</sup> /s
Seating	3								
1	5	0.0411	19.9589	0.21	1.224			131	6.44E-01
2	8	0.1198	19.8802	0.60	1.216			129	6.48E-01
3	15	0.2283	19.7717	1.14	1.203			141	5.89E-01
4	30	0.3571	19.6429	1.79	1.189			104	7.86E-01
5	50	0.4767	19.5233	2.38	1.176			167	4.83E-01
6	70	0.5692	19.4308	2.85	1.165			229	3.50E-01
7	90	0.6562	19.3438	3.28	1.156			341	2.33E-01
8	110	0.7406	19.2594	3.70	1.146			737	1.07E-01
9	140	0.8425	19.1575	4.21	1.135			342	2.28E-01
10	200	1.0466	18.9534	5.23	1.112			221	3.45E-01
11	280	1.5415	18.4585	7.71	1.057			1461	4.95E-02
12	480	2.7615	17.2385	13.81	0.921			458	1.38E-01
13	960	4.2882	15.7118	21.44	0.751			238	2.20E-01
14	800	4.8863	15.1137	24.43	0.684				
15	200	4.7122	15.2878	23.56	0.704				
16	50	4.4499	15.5501	22.25	0.733				
17	13	4.3078	15.6922	21.54	0.749				







Project No.: 122410864

Project Name: Thurber, File# 20482

Photo Log

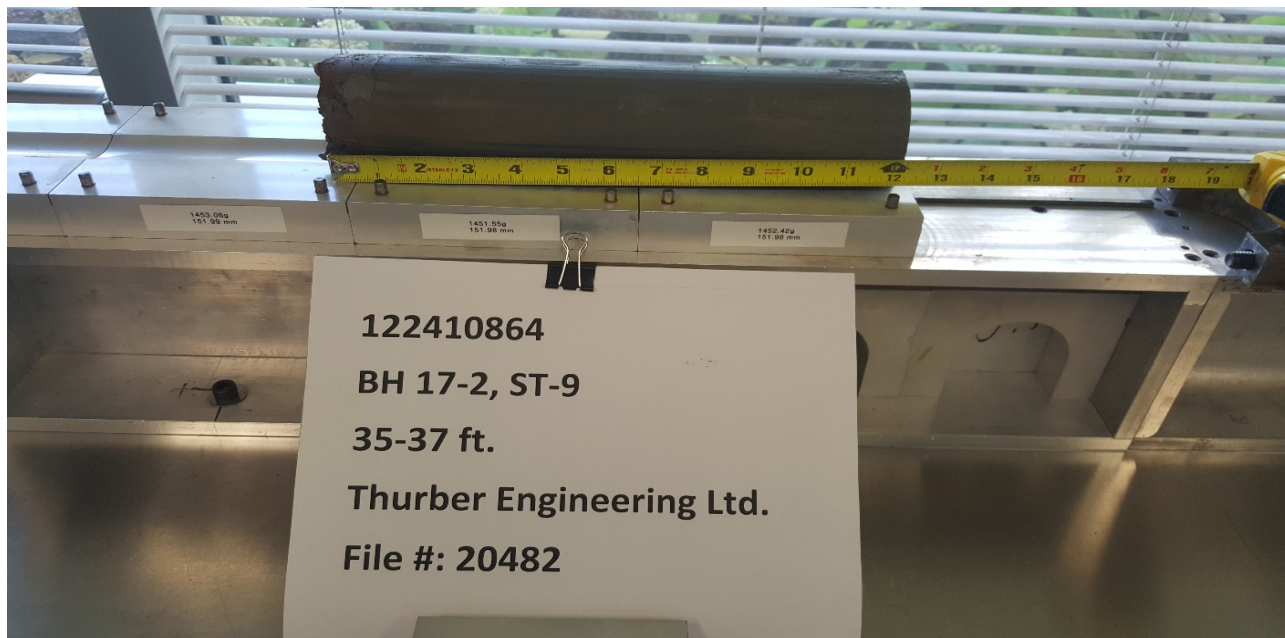


Photo No.: 1 Borehole: BH 17-2, ST 9 Depth: 35-37 ft

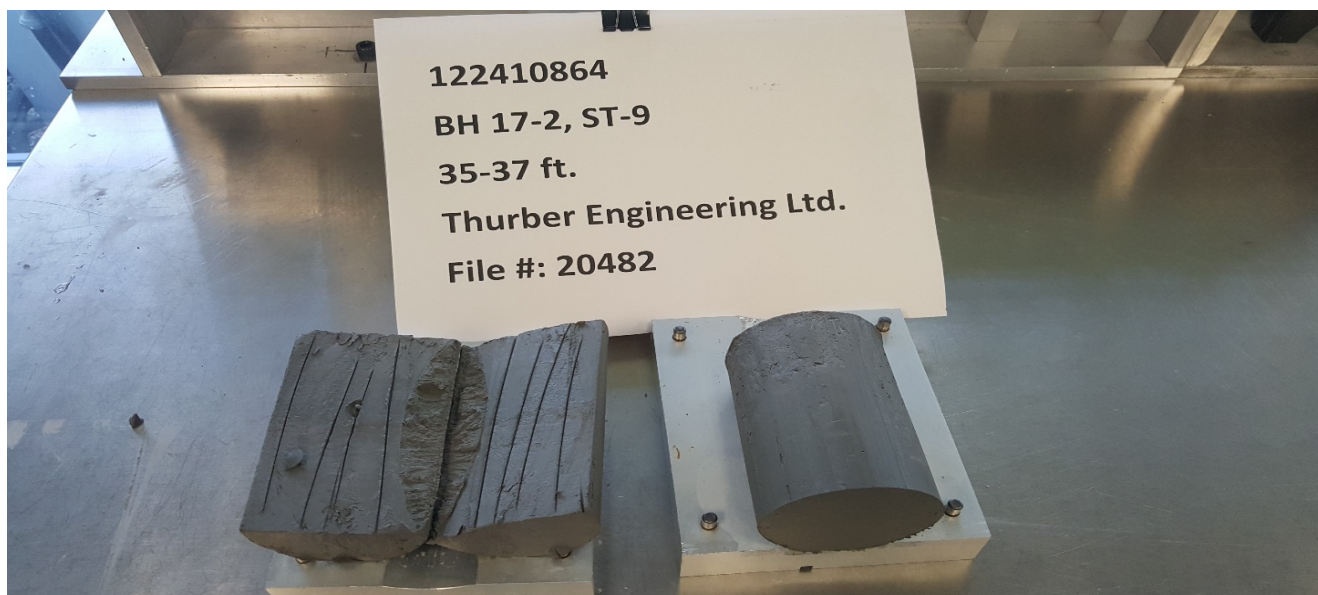


Photo No.: 2 Borehole: BH 17-2, ST 9 Depth: 35-37 ft



**Stantec Consulting Ltd.**  
400 - 1331 Clyde Avenue, Ottawa ON K2C 3G4

July 9, 2018  
File: 122410864

**Attention: Kenton Power**  
Thurber Engineering Ltd.  
104 – 2460 Lancaster Road  
Ottawa, Ontario, Canada, K1B 4S5  
Tel: 613-274-2121  
E-mail: kpower@thurber.ca

Dear Mr. Power,

**Reference: Consolidation Test Results for Locha Creek Culvert Project, Thurber Consulting Ltd.,  
File #20482: BH 18-101, ST 5 & 9, sampled on June 11, 2018**

This letter presents the results of one-dimensional consolidation tests carried out on the above referenced samples in accordance with ASTM D2435/D2435M - 11. The test results are provided in the attached tables and figures.

This letter provides test results only and does not constitute any interpretation or engineering recommendations with respect to material suitability or specification compliance.

We trust the information presented herein meets your present requirements. Should you have any questions or require additional information, please do not hesitate to contact us.

Regards,

**STANTEC CONSULTING LTD.**

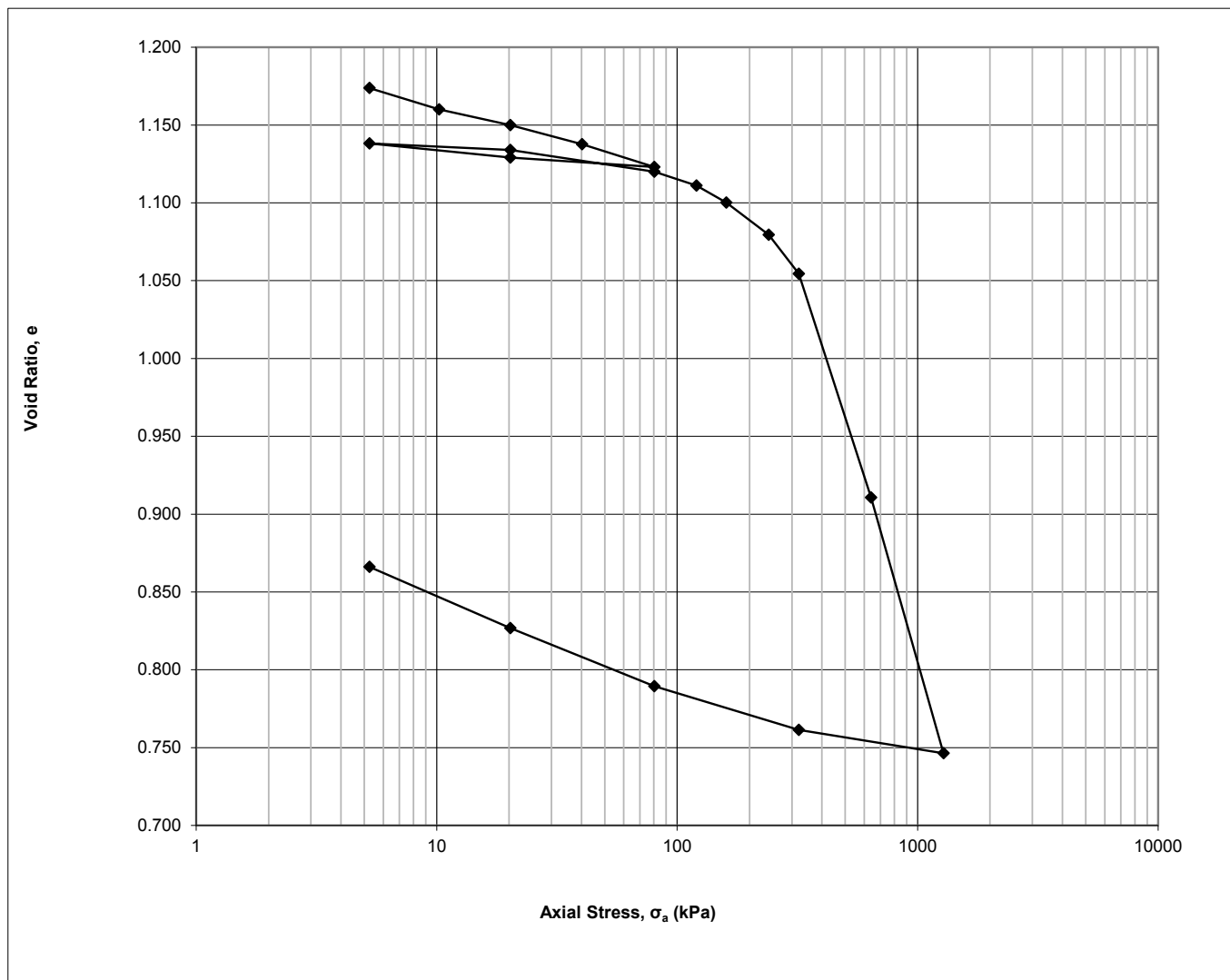
A handwritten signature in blue ink, appearing to read "Ramy Saadeldin", written over a horizontal line.

Ramy Saadeldin, Ph.D., P.Eng.  
Geotechnical Engineering  
Phone: (613) 738-6047  
Fax: (613) 722-2799  
Ramy.Saadeldin@stantec.com

v:\01216\active\laboratory\_standing\_offers\2018 laboratory standing offers\122410864 thurber engineering ltd\june 11, two consolidation, one specific gravity\consolidation letter & results\122410864\_let\_consolidationresults\_bh 18-101 st 5 9.docx

**Project**  
**Project No.**  
**Borehole No.**  
**Sample No.**  
**Sample Depth**

**Thurber Engineering, File# 20482**  
**122410864**  
**BH 18-101**  
**ST 5**  
**15 - 17 ft.**





**One-Dimensional Consolidation Test using Incremental Loading**  
**ASTM D2435/D2435M - 11**

7-Jul-18  
7-Jul-18

Date: Date:

D. Boateng  
R. Hache

Checked by:  
Approved by:

**Specimen Details**

Project Name	Thurber Engineering, File# 20482
Project Location	HWY 17, Ontario
Borehole	BH 18-101
Sample No.	ST 5
Depth	15 - 17 ft.
Sample Date	June 11, 2018
Test Number	One
Technician Name	Daniel Boateng

**Soil Description & Classification**

Silty Clay, Brown/Grey, Fissured, Moist	
Specific Gravity of Solids	2.750
Average water content of trimmings %	43
<b>Additional Notes (information source, occurrence and size of large isolated particles etc.)</b>	

**Initial Specimen Conditions**

Height	mm	20.00
Diameter	mm	50.00
Area	mm <sup>2</sup>	1963
Volume	mm <sup>3</sup>	39270
Mass	g	70.21
Dry Mass	g	49.16
Density	Mg/m <sup>3</sup>	1.788
Dry Density	Mg/m <sup>3</sup>	1.252
Water Content	%	42.82
Degree of Saturation	%	98.4
Height of Solids	mm	9.10
Initial Void Ratio		1.197

**Final Specimen Conditions**

Water Content	%	34.86
Final Void Ratio		0.866

## One-Dimensional Consolidation Test using Incremental Loading

### ASTM D2435/D2435M - 11

**Specimen Details**

Project Name	Thurber Engineering, File# 20482
Project Location	HWY 17, Ontario
Borehole	BH 18-101
Sample No.	ST 5
Depth	15 - 17 ft.
Sample Date	June 11, 2018
Test Number	One
Technician Name	Daniel Boateng

**Test Procedure**

Date Started	June 22, 2018
Date Finished	July 3, 2018
Machine Number	Frame C
Cell Number	C
Ring Number	C
Trimming Procedure	Turntable
Moisture Condition	Inundated
Axial Stress at Inundation kPa	5
Water Used	Distilled
Test Method	A
Interpretation Procedure for $c_v$	2

**All Departures from Outlined ASTM D2435/D2435M-11 Procedure**

--

**Calculations**

Load Increment	Increment Duration	Axial Stress $\sigma_a$ kPa	Corrected Deformation $\Delta H$ mm	Specimen Height H mm	Axial Strain $\epsilon_a$ %	Void Ratio e
Seating	0.0	5	0.0000	20.0000	0.00	1.197
1	720.0	5	0.2093	19.7907	1.05	1.174
2	720.0	10	0.3335	19.6665	1.67	1.160
3	720.0	20	0.4253	19.5747	2.13	1.150
4	720.0	40	0.5376	19.4624	2.69	1.138
5	720.0	80	0.6706	19.3294	3.35	1.123
6	720.0	20	0.6159	19.3841	3.08	1.129
7	720.0	5	0.5332	19.4668	2.67	1.138
8	720.0	20	0.5716	19.4284	2.86	1.134
9	720.0	80	0.6981	19.3019	3.49	1.120
10	1440.0	120	0.7793	19.2207	3.90	1.111
11	1440.0	160	0.8794	19.1206	4.40	1.100
12	1440.0	240	1.0681	18.9319	5.34	1.079
13	720.0	320	1.2957	18.7043	6.48	1.054
14	720.0	640	2.6039	17.3961	13.02	0.911
15	720.0	1280	4.1005	15.8995	20.50	0.746
16	720.0	320	3.9638	16.0362	19.82	0.761
17	720.0	80	3.7079	16.2921	18.54	0.789
18	720.0	20	3.3679	16.6321	16.84	0.827
19	720.0	5	3.0108	16.9892	15.05	0.866

## One-Dimensional Consolidation Test using Incremental Loading

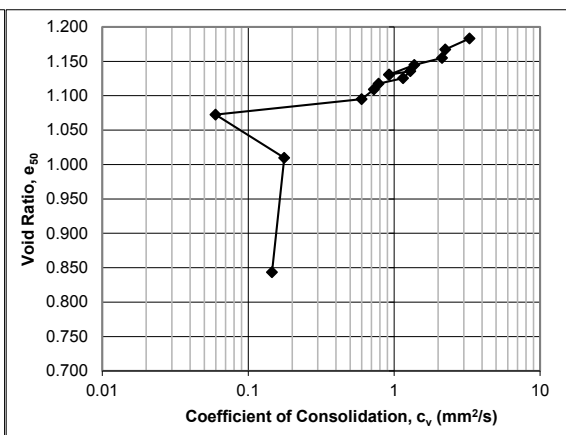
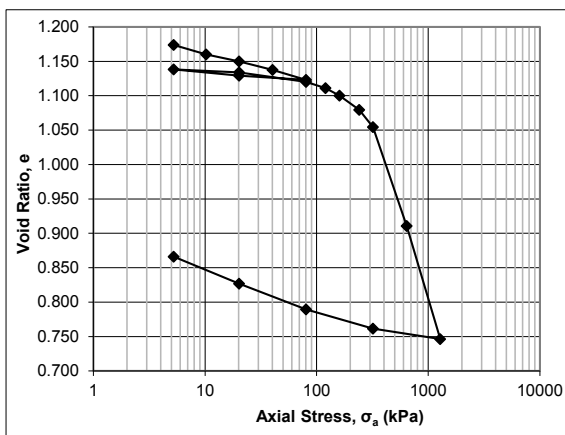
### ASTM D2435/D2435M - 11

**Specimen Details**

Project Name	Thurber Engineering, File# 20482
Project Location	HWY 17, Ontario
Borehole	BH 18-101
Sample No.	ST 5
Depth	15 - 17 ft.
Sample Date	June 11, 2018
Test Number	One
Technician Name	Daniel Boateng

**Calculations**

Load Increment	Axial Stress $\sigma_a$ , average kPa	Calculated using Interpretation Procedure 2				Interpretation Procedure 1		Interpretation Procedure 2	
		Corrected Deformation $\Delta H_{50}$ mm	Specimen Height $H_{50}$ mm	Axial Strain $\epsilon_{a,50}$ %	Void Ratio $e_{50}$	Time $t_{50}$ sec	Coeff. Consol. $c_v$ mm <sup>2</sup> /s	Time $t_{90}$ sec	Coeff. Consol. $c_v$ mm <sup>2</sup> /s
Seating	3								
1	5	0.1235	19.8765	0.62	1.183			25	3.29E+00
2	8	0.2685	19.7315	1.34	1.167			37	2.24E+00
3	15	0.3807	19.6193	1.90	1.155			38	2.13E+00
4	30	0.4727	19.5273	2.36	1.145			59	1.38E+00
5	60	0.6017	19.3983	3.01	1.131			86	9.26E-01
6	50	0.6319	19.3681	3.16	1.127				
7	13	0.5718	19.4282	2.86	1.134				
8	13	0.5570	19.4430	2.79	1.136			62	1.29E+00
9	50	0.6480	19.3520	3.24	1.126			69	1.15E+00
10	100	0.7217	19.2783	3.61	1.117			101	7.83E-01
11	140	0.7983	19.2017	3.99	1.109			108	7.26E-01
12	200	0.9248	19.0752	4.62	1.095			129	6.00E-01
13	280	1.1317	18.8683	5.66	1.072			1264	5.97E-02
14	480	1.7040	18.2960	8.52	1.010			401	1.77E-01
15	960	3.2145	16.7855	16.07	0.844			410	1.46E-01
16	800	4.0149	15.9851	20.07	0.756				
17	200	3.8295	16.1705	19.15	0.776				
18	50	3.5539	16.4461	17.77	0.806				
19	13	3.2472	16.7528	16.24	0.840				





Project No.: 122410864

Project Name: Thurber Engineering, File# 20482

Photo Log

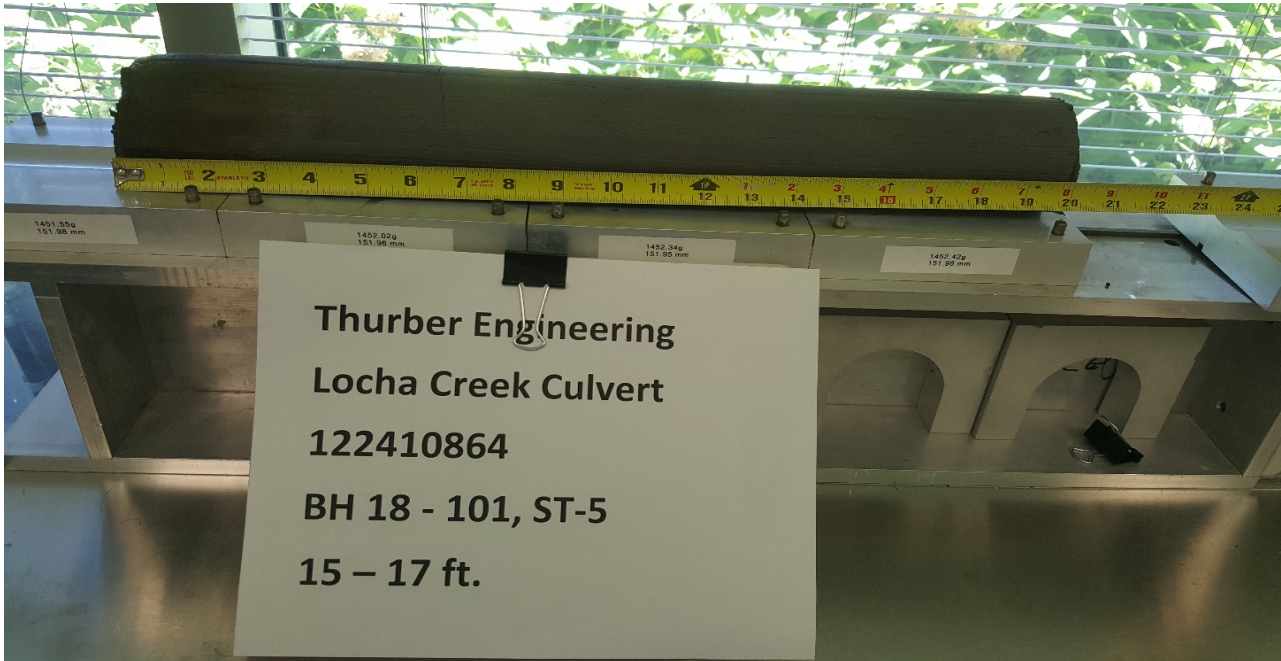


Photo No.:

1

Borehole: BH 18-101 ST 5

Depth: 15 - 17 ft.



Photo No.:

2

Borehole: BH 18-101 ST 5

Depth: 15 - 17 ft.




 <b>Stantec</b>	Project No.: 122410864	Photo Log
	Project Name: Thurber Engineering, File# 20482	



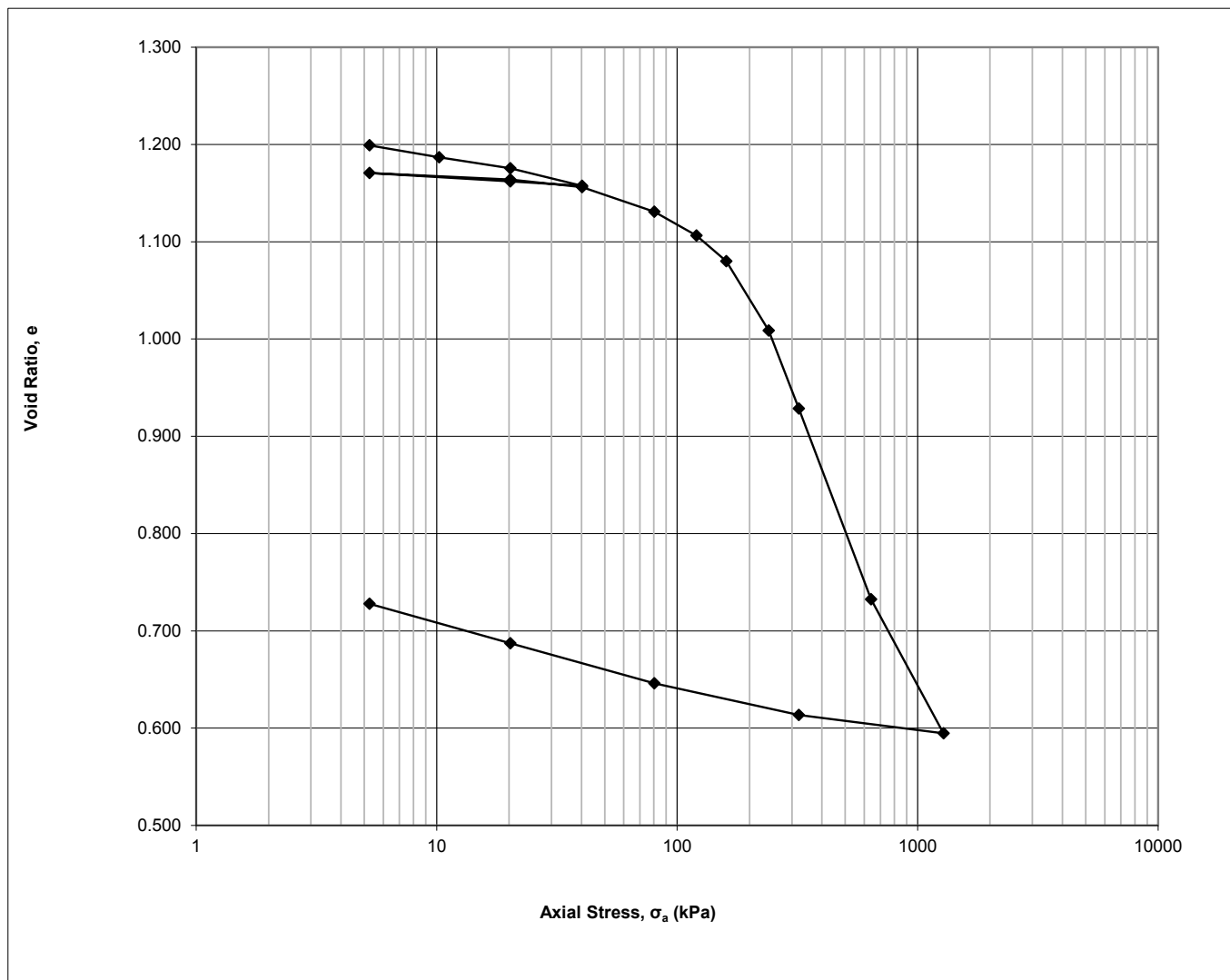
Photo No.: 3	Borehole: BH 18-101 ST 5	Depth: 15 – 17 ft.
--------------	--------------------------	--------------------



Photo No.: 4	Borehole: BH 18-101 ST 5	Depth: 15 – 17 ft.
--------------	--------------------------	--------------------

**Project**  
**Project No.**  
**Borehole No.**  
**Sample No.**  
**Sample Depth**

**Thurber Engineering, File# 20482**  
**122410864**  
**BH 18-101**  
**ST 9**  
**35 - 37 ft.**



**One-Dimensional Consolidation Test using Incremental Loading**  
**ASTM D2435/D2435M - 11**

7-Jul-18  
7-Jul-18

Date: Date:

D. Boateng  
R. Hache

Checked by:  
Approved by:

**Specimen Details**

Project Name	Thurber Engineering, File# 20482
Project Location	HWY 17, Ontario
Borehole	BH 18-101
Sample No.	ST 9
Depth	35 - 37 ft.
Sample Date	June 11, 2018
Test Number	Two
Technician Name	Daniel Boateng

**Soil Description & Classification**

Silty Clay, Grey, Wet	
Specific Gravity of Solids	2.750
Average water content of trimmings %	45
<b>Additional Notes (information source, occurrence and size of large isolated particles etc.)</b>	
Specific Gravity of Solids Assumed	

**Initial Specimen Conditions**

Height	mm	20.00
Diameter	mm	50.00
Area	mm <sup>2</sup>	1963
Volume	mm <sup>3</sup>	39270
Mass	g	70.81
Dry Mass	g	48.84
Density	Mg/m <sup>3</sup>	1.803
Dry Density	Mg/m <sup>3</sup>	1.244
Water Content	%	44.98
Degree of Saturation	%	100.0
Height of Solids	mm	9.05
Initial Void Ratio		1.211

**Final Specimen Conditions**

Water Content	%	33.27
Final Void Ratio		0.728

## One-Dimensional Consolidation Test using Incremental Loading

### ASTM D2435/D2435M - 11

**Specimen Details**

Project Name	Thurber Engineering, File# 20482
Project Location	HWY 17, Ontario
Borehole	BH 18-101
Sample No.	ST 9
Depth	35 - 37 ft.
Sample Date	June 11, 2018
Test Number	Two
Technician Name	Daniel Boateng

**Test Procedure**

Date Started	June 22, 2018
Date Finished	July 3, 2018
Machine Number	Frame D
Cell Number	D
Ring Number	D
Trimming Procedure	Turntable
Moisture Condition	Inundated
Axial Stress at Inundation kPa	5
Water Used	Distilled
Test Method	A
Interpretation Procedure for $c_v$	2

**All Departures from Outlined ASTM D2435/D2435M-11 Procedure**

--

**Calculations**

Load Increment	Increment Duration min	Axial Stress $\sigma_a$ kPa	Corrected Deformation $\Delta H$ mm	Specimen Height H mm	Axial Strain $\epsilon_a$ %	Void Ratio e
Seating	0.0	5	0.0000	20.0000	0.00	1.211
1	720.0	5	0.1089	19.8911	0.54	1.199
2	720.0	10	0.2195	19.7805	1.10	1.187
3	720.0	20	0.3210	19.6790	1.61	1.176
4	720.0	40	0.4844	19.5156	2.42	1.158
5	720.0	20	0.4446	19.5554	2.22	1.162
6	720.0	5	0.3650	19.6350	1.83	1.171
7	720.0	20	0.4256	19.5744	2.13	1.164
8	720.0	40	0.4975	19.5025	2.49	1.156
9	1440.0	80	0.7250	19.2750	3.63	1.131
10	1440.0	120	0.9479	19.0521	4.74	1.106
11	1440.0	160	1.1869	18.8131	5.93	1.080
12	720.0	240	1.8311	18.1689	9.16	1.009
13	720.0	320	2.5549	17.4451	12.77	0.929
14	720.0	640	4.3293	15.6707	21.65	0.733
15	720.0	1280	5.5757	14.4243	27.88	0.595
16	720.0	320	5.4056	14.5944	27.03	0.614
17	720.0	80	5.1101	14.8899	25.55	0.646
18	720.0	20	4.7390	15.2610	23.70	0.687
19	720.0	5	4.3705	15.6295	21.85	0.728



## One-Dimensional Consolidation Test using Incremental Loading

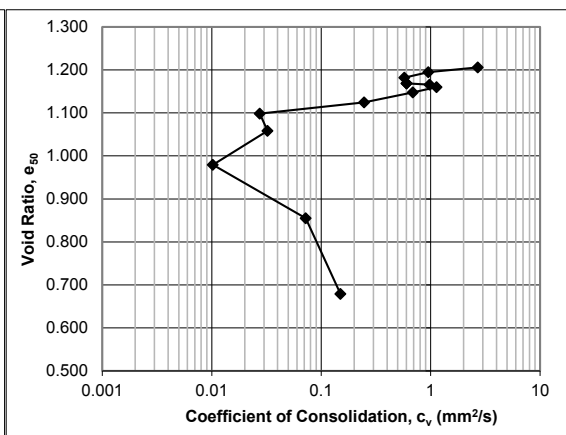
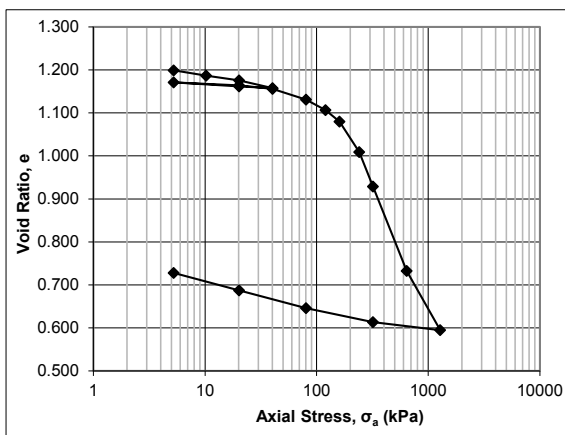
### ASTM D2435/D2435M - 11

**Specimen Details**

Project Name	Thurber Engineering, File# 20482
Project Location	HWY 17, Ontario
Borehole	BH 18-101
Sample No.	ST 9
Depth	35 - 37 ft.
Sample Date	June 11, 2018
Test Number	Two
Technician Name	Daniel Boateng

**Calculations**

Load Increment	Axial Stress $\sigma_a$ , average kPa	Calculated using Interpretation Procedure 2				Interpretation Procedure 1		Interpretation Procedure 2	
		Corrected Deformation $\Delta H_{50}$ mm	Specimen Height $H_{50}$ mm	Axial Strain $\epsilon_{a,50}$ %	Void Ratio $e_{50}$	Time $t_{50}$ sec	Coeff. Consol. $c_v$ mm <sup>2</sup> /s	Time $t_{90}$ sec	Coeff. Consol. $c_v$ mm <sup>2</sup> /s
Seating	3								
1	5	0.0473	19.9527	0.24	1.206			31	2.70E+00
2	8	0.1455	19.8545	0.73	1.195			88	9.55E-01
3	15	0.2642	19.7358	1.32	1.182			143	5.76E-01
4	30	0.3842	19.6158	1.92	1.169			135	6.05E-01
5	30	0.4595	19.5405	2.30	1.160				
6	13	0.3947	19.6053	1.97	1.168				
7	13	0.4081	19.5919	2.04	1.166			83	9.77E-01
8	30	0.4614	19.5386	2.31	1.160			71	1.13E+00
9	60	0.5709	19.4291	2.85	1.148			116	6.90E-01
10	100	0.7809	19.2191	3.90	1.125			317	2.47E-01
11	140	1.0188	18.9812	5.09	1.099			2775	2.75E-02
12	200	1.3809	18.6191	6.90	1.058			2277	3.23E-02
13	280	2.0988	17.9012	10.49	0.979			6626	1.03E-02
14	480	3.2219	16.7781	16.11	0.855			825	7.23E-02
15	960	4.8114	15.1886	24.06	0.679			326	1.50E-01
16	800	5.4659	14.5341	27.33	0.607				
17	200	5.2376	14.7624	26.19	0.632				
18	50	4.9354	15.0646	24.68	0.665				
19	13	4.5921	15.4079	22.96	0.703				





Project No.: 122410864

Project Name: Thurber Engineering, File# 20482

Photo Log

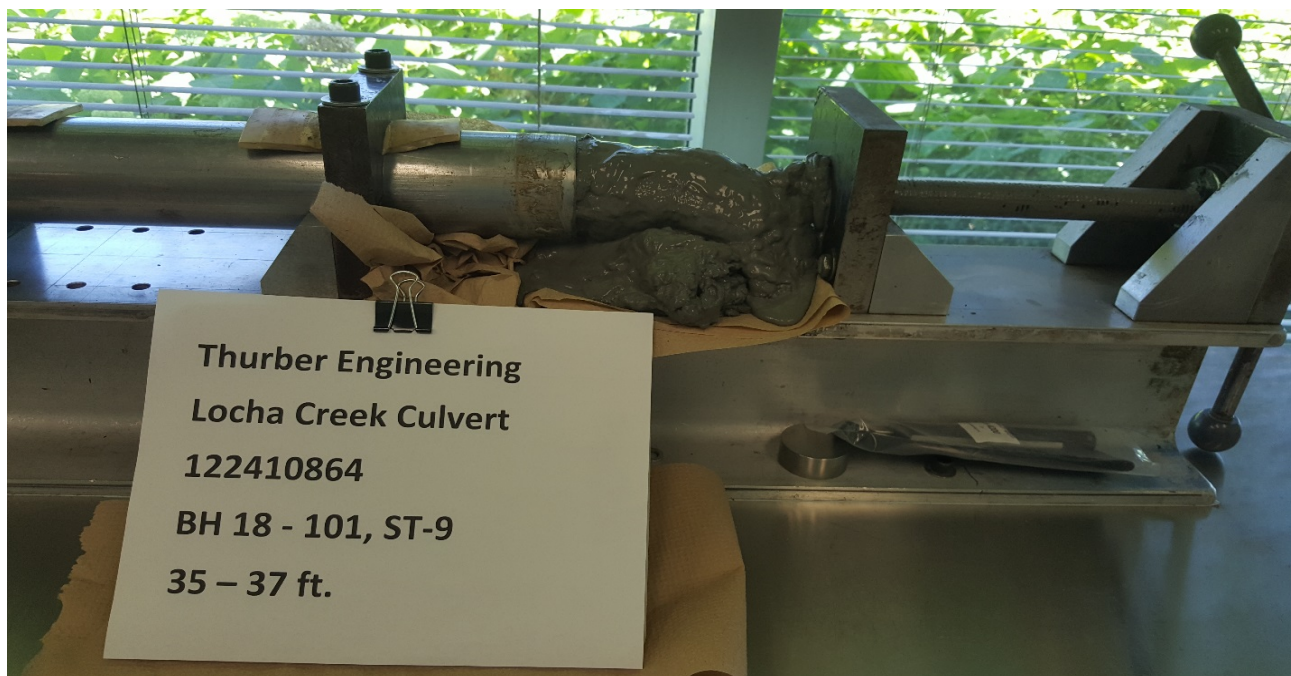


Photo No.: 1

Borehole: BH 18-101 ST 9

Depth: 35 - 37 ft.

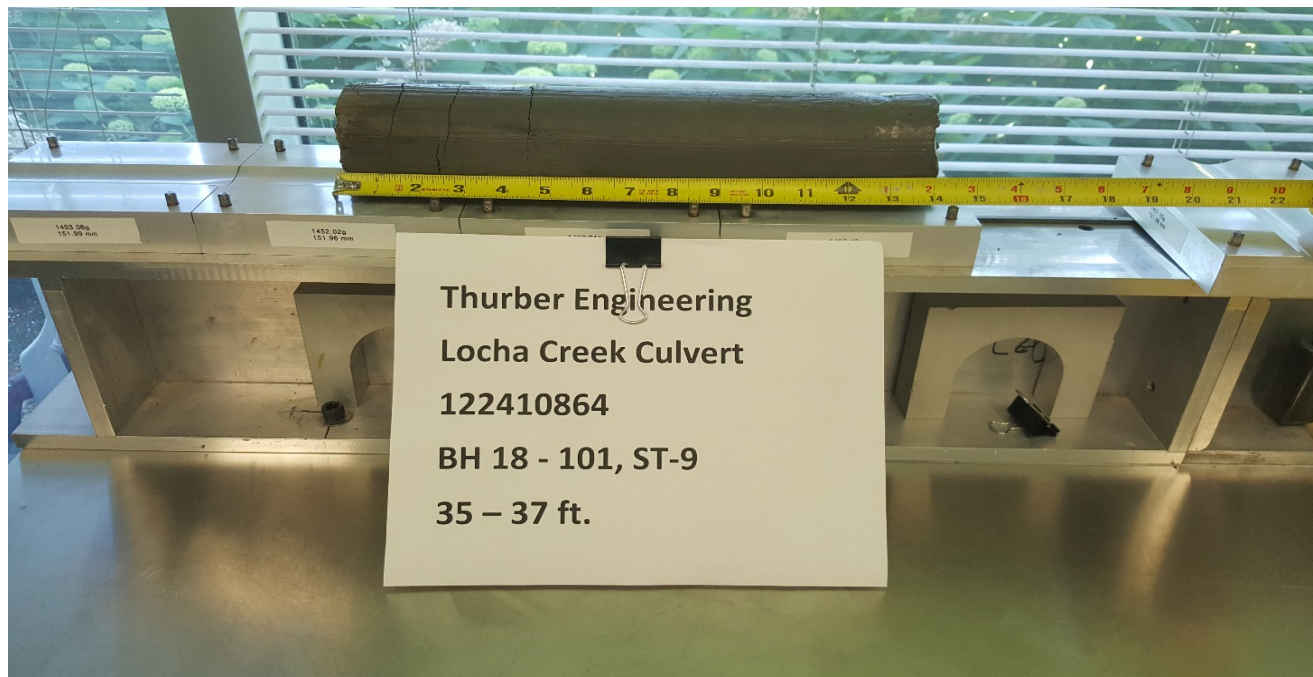


Photo No.: 2

Borehole: BH 18-101 ST 9

Depth: 35 - 37 ft.



Project No.: 122410864

Photo Log

Project Name: Thurber Engineering, File# 20482



Photo No.:

3

Borehole: BH 18-101 ST 9

Depth: 35 – 37 ft.

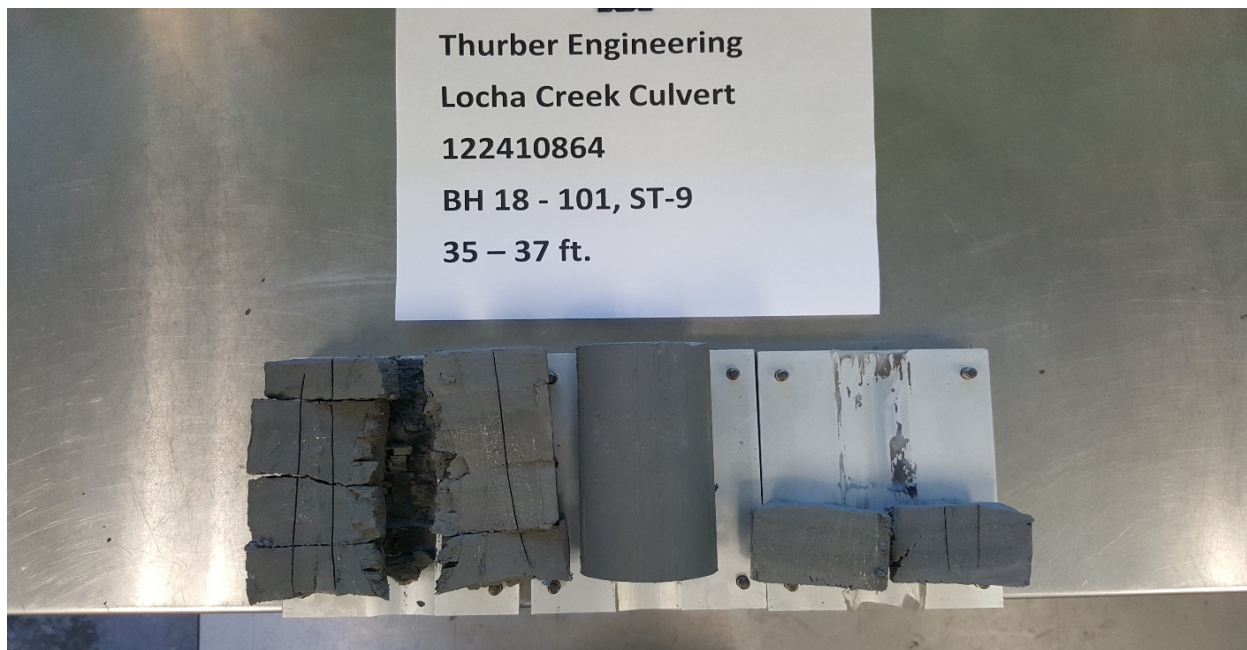


Photo No.:

4

Borehole: BH 18-101 ST 9

Depth: 35 – 37 ft.



**Borehole 18-101**  
**Run 1 to 3 (of 3)**  
**Elevation 104.0 m to 100.3 m**



**THURBER** ENGINEERING LTD.

**Foundation Investigation**  
**Locha Creek Culvert Replacement**

**GWP: 4061-17-00**

**Project No.: 20482**

**Borehole 18-102**  
**Run 1 to 3 (of 3)**  
**Elevation 107.9 m to 104.7 m**



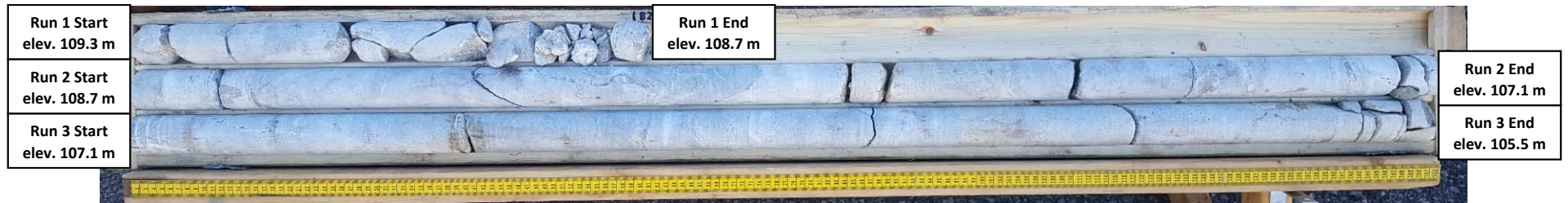
**THURBER** ENGINEERING LTD.

**Foundation Investigation**  
**Locha Creek Culvert Replacement**

**GWP: 4061-17-00**

**Project No.: 20482**

**Borehole 18-103**  
**Run 1 to 3 (of 3)**  
**Elevation 109.3 m to 105.5 m**



**THURBER** ENGINEERING LTD.

**Foundation Investigation**  
**Locha Creek Culvert Replacement**

**GWP: 4061-17-00**

**Project No.: 20482**



**Stantec**

**Stantec Consulting Ltd**  
2781 Lancaster Rd, Suite 100 A&B  
Ottawa, ON K1B 1A7  
Tel: (613) 738-6075  
Fax: (613) 722-2799

---

July 11, 2018  
File: 122410864

**Attention: Thurber Engineering Ltd., File #20482**

**Reference: ASTM D7012, Method C, Unconfined Compressive Strength of Intact Rock Core**

The table below summarizes three (3) rock core unconfined compressive strength results.

Location	Sample Depth	Compressive Strength (MPa)	Description of Break
18-101	Run 3 @ 103'10"	127.2	Diagonal fracture, no cracking in ends
18-102	Run 3 @ 106'	165.2	Specimen shattered
18-103	Run 3 @ 84'5"	156.0	Two well-formed cones both ends

Sincerely,

**Stantec Consulting Ltd**

Denis Rodriguez  
Laboratory Technician  
Tel: 613-738-6075  
[denis.rodriquez@stantec.com](mailto:denis.rodriquez@stantec.com)

Certificate of Analysis  
**Client:** Thurber Engineering Ltd.  
**Client PO:**

Report Date: 03-Oct-2017

Order Date: 27-Sep-2017

**Project Description:**

<b>Client ID:</b>	17-6 SS4 7.5 to 9.5	17-1 SS5 10.5-12.5	-	-
<b>Sample Date:</b>	19-Sep-17	22-Sep-17	-	-
<b>Sample ID:</b>	1739321-01	1739321-02	-	-
<b>MDL/Units</b>	Soil	Soil	-	-

**Physical Characteristics**

% Solids	0.1 % by Wt.	67.2	67.4	-	-
----------	--------------	------	------	---	---

**General Inorganics**

pH	0.05 pH Units	7.90	7.72	-	-
Resistivity	0.10 Ohm.m	8.49	17.3	-	-

**Anions**

Chloride	5 ug/g dry	741	174	-	-
Sulphate	5 ug/g dry	16	69	-	-



Certificate of Analysis  
**Client: Thurber Engineering Ltd.**  
**Client PO:**

Report Date: 25-Jun-2018

Order Date: 19-Jun-2018

**Project Description: 20482**

**Client ID:** BH18-101 SS2B 3'6"  
to 4'6"

**Sample Date:** 06/11/2018 09:00

**Sample ID:** 1825316-01

**MDL/Units** Soil

-

-

-

-

-

-

-

-

-

-

-

-

#### Physical Characteristics

% Solids	0.1 % by Wt.	69.5	-	-	-
----------	--------------	------	---	---	---

#### General Inorganics

Conductivity	5 uS/cm	137	-	-	-
pH	0.05 pH Units	7.32	-	-	-
Resistivity	0.10 Ohm.m	72.8	-	-	-

#### Anions

Chloride	5 ug/g dry	18	-	-	-
Sulphate	5 ug/g dry	20	-	-	-

## Subcontracted Analysis

**Thurber Engineering Ltd.**

2460 Lancaster Rd, Unit 107  
Ottawa, ON K1B4S5  
Attn: Kenton Power

Tel: (613) 247-2121  
Fax: (613) 247-2185

Paracel Report No **1825316**

Client Project(s): **20482**

Client PO:

Reference: **Standing Offer**

CoC Number: **39858**

Order Date: 19-Jun-18  
Report Date: 28-Jun-18

Sample(s) from this project were subcontracted for the listed parameters. A copy of the subcontractor's report is attached

Paracel ID	Client ID	Analysis
1825316-01	BH18-101 SS2B 3'6" to 4'6"	Sulphide, solid

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.  
Lakefield - Ontario - K0L 2H0  
Phone: 705-652-2000 FAX: 705-652-6365

**Paracel Laboratories**

Attn : Dale Robertson

300-2319 St.Laurent Blvd.  
Ottawa, ON  
K1G 4K6,

Phone: 613-731-9577  
Fax:613-731-9064

28-June-2018

**Date Rec. :** 21 June 2018  
**LR Report:** CA12710-JUN18  
**Reference:** Project#: 1825316

**Copy:** #1

## CERTIFICATE OF ANALYSIS

### Final Report

Sample ID	Sample Date & Time	Sulphide %
1: Analysis Start Date		28-Jun-18
2: Analysis Start Time		13:23
3: Analysis Approval Date		28-Jun-18
4: Analysis Approval Time		14:45
5: QC - Blank		< 0.02
6: QC - STD % Recovery		105%
7: QC - DUP % RPD		ND
8: RL		0.005
9: BH18-101 SS2B 3'6 to 4'6	11-Jun-18	< 0.02

RL - SGS Reporting Limit  
ND - Not Detected

Kimberley Didsbury  
Project Specialist  
Environmental Services, Analytical

**APPENDIX D**  
**SITE PHOTOGRAPHS**



**Photograph 1: Roadway platform over existing culvert looking northwest along Highway 17 (2017-09-22)**



**Photograph 2: Looking north towards the existing culvert inlet (2018-06-14)**





**Photograph 3: Looking south towards the existing culvert outlet (2017-09-22)**



**Photograph 4: North embankment looking west towards existing culvert (2018-06-14)**





**Photograph 5: South embankment looking west towards culvert inlet (2018-06-14)**



**Photograph 6: Looking north from Highway 17 towards Miller Road (2017-09-06)**

## **APPENDIX E**

### **COMPARISON OF CULVERT TYPE/FOUNDATION ALTERNATIVES**

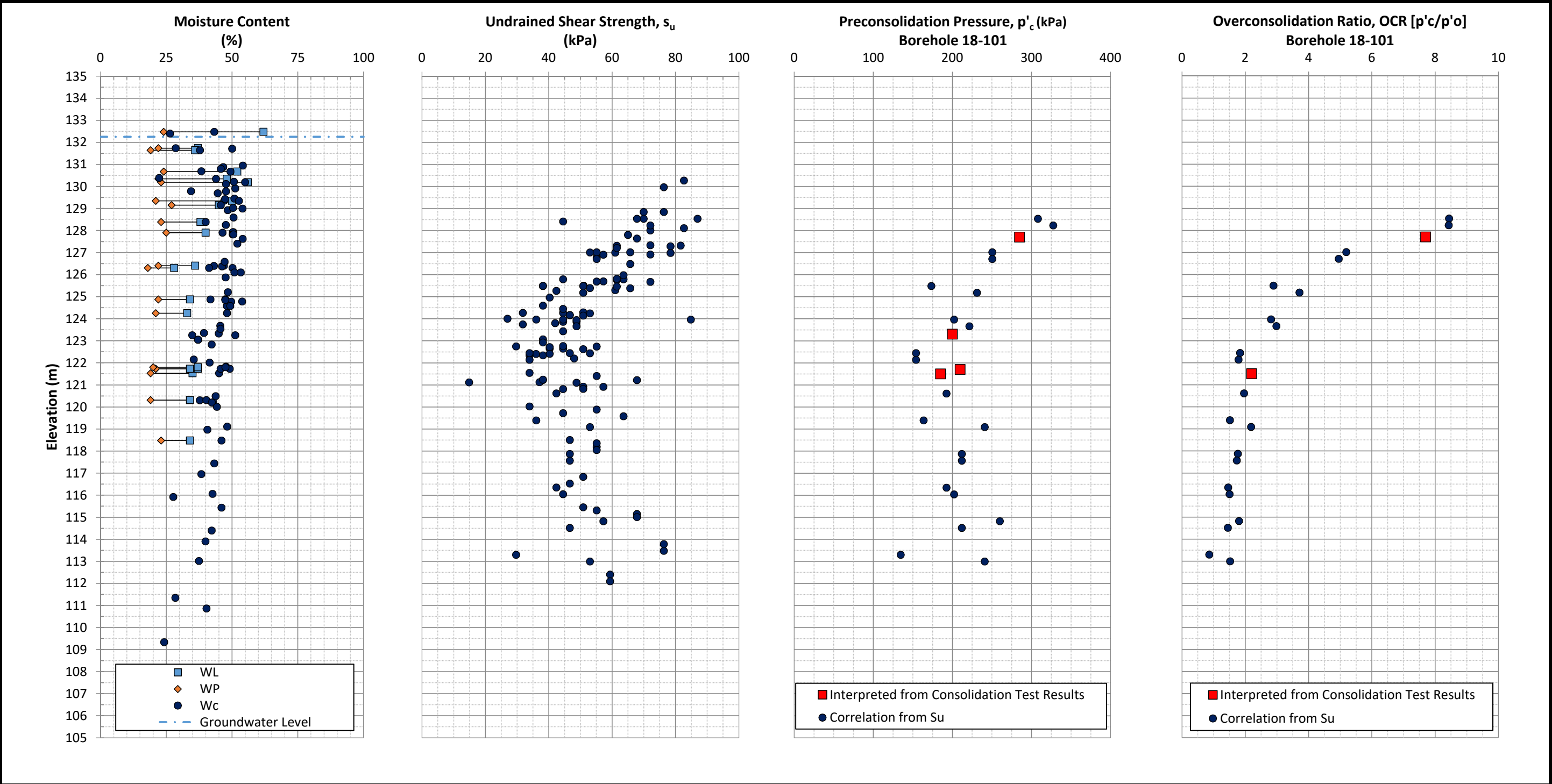


### Comparison of Culvert Type/Foundation Alternatives

Comment	Circular Pipes/Arches	Open Footing Culvert Shallow Foundation	Open Bottom with Deep Foundation Support	Closed Box Culvert
<b>Advantages</b>	Readily available materials and simple installation methods	Limits disturbance to streambed. Typically, favourable from an aquatic habitat perspective. Relatively expedient installation if precast units are used.	Allows for the installation of an open bottom culvert Deep foundations provide high axial geotechnical resistance  Addresses potential for differential settlement between existing embankment and future widening	Loading is spread over wider base resulting in lower required bearing resistance.  Less prone to effects of scour and erosion.
<b>Disadvantages</b>	Numerous parallel pipes required to provide hydraulic opening equivalent to existing culvert.  Differential settlement between north and south ends would require preloading and/or lightweight fill	Existing clay subgrade is not suitable for the use of open footed culverted supported on shallow foundations	Long pile sections are required to end bear on bedrock at this site, pile splicing may be required Pile installation will increase the time the excavation is left open increasing groundwater control requirements	Differential settlement between north and south ends would require preloading and/or lightweight fill.
<b>Risks / Consequences</b>	Potential for base disturbance if groundwater not controlled / added cost and schedule delays		Piles get hung up in the glacial deposit / reduced bearing resistance additional piles may be required	Potential for base disturbance if groundwater not controlled / added cost and schedule delays
<b>Relative Cost</b>	Moderate	Moderate	High	Moderate
	<b>NOT RECOMMENDED</b>	<b>NOT FEASIBLE</b>	<b>RECOMMENDED</b>	<b>Feasible</b>

## **APPENDIX F**

**CLAY PROPERTY SUMMARY FIGURES  
PILE ANALYSIS P-Y DATA OUTPUT  
LATERAL SOIL DISPLACEMENT PROFILE**



**Clay Properties**  
Locha Creek Culvert Replacement  
Site 29-249/C1  
Renfrew County

**G.W.P. 4061-17-00**  
**Project No.: 20482**



**THURBER**  
**GENERAL NOTES**

- The values P(kN/m) represent soil reaction per metre of pile length
- The values y(m) represent soil/pile deflection
- The base of the footing is at Elev. 130 m (as per Preliminary GA dated June, 2018)
- The p-y data provided is unfactored. Lateral resistance or deflection calculated based on these parameters should be factored using the geotechnical resistance factors ( $\phi_{gu}$  and  $\phi_{gs}$ ) provided in Table 6.2 of the CHBDC (S6-14)
- If lateral spacing between an adjacent pile or another structural element is less than four equivalent pile diameters, suitable reduction factors based on center to center spacing should be applied based on tables C6.11.3(r), C.6.11.3(s) and C6.11.3(t) of the CHBDC (S6-14)

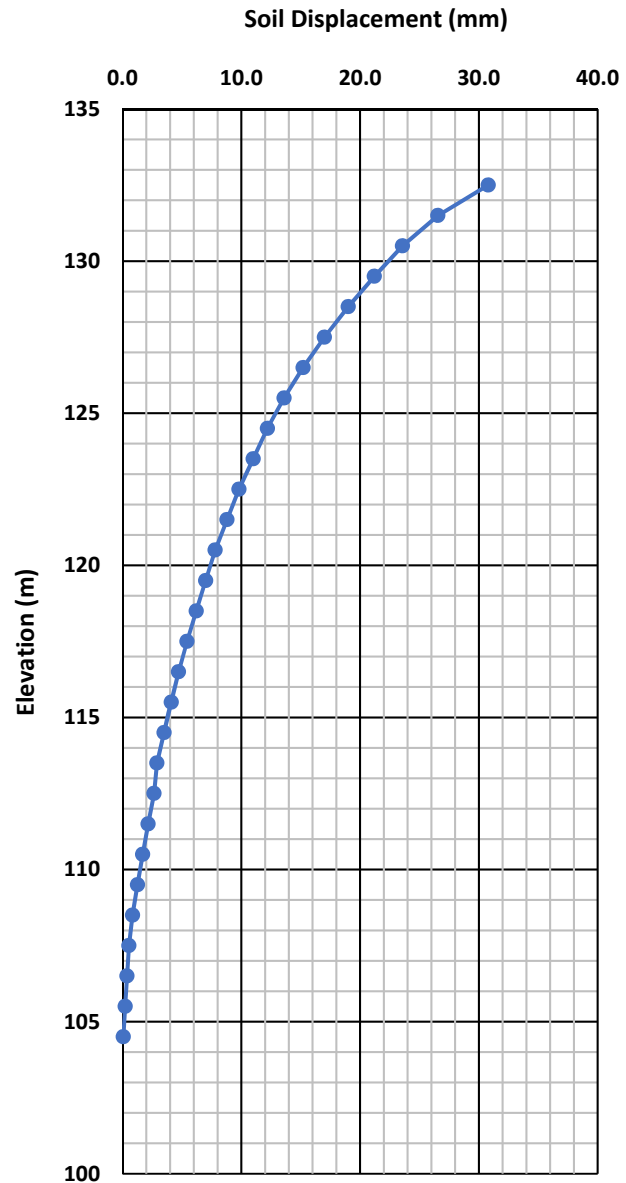
Soil Type	Stiff to Firm Clay (Below WT)		Stiff to Firm Clay (Below WT)		Stiff to Firm Clay (Below WT)		Stiff to Firm Clay (Below WT)		Stiff to Firm Clay (Below WT)		Firm to Stiff Clay (Below WT)		Firm to Stiff Clay (Below WT)		Firm to Stiff Clay (Below WT)		Firm to Stiff Clay (Below WT)		Firm to Stiff Clay (Below WT)		Firm to Stiff Clay (Below WT)		Firm to Stiff Clay (Below WT)		Firm to Stiff Clay (Below WT)		Firm to Stiff Clay (Below WT)	
Depth (m)	0.5		1.5		2.5		3.5		4.5		5.5		6.5		7.5		8.5		9.5		10.5		11.5		12.5		13.5	
Elev. (m)	129.5		128.5		127.5		126.5		125.5		124.5		123.5		122.5		121.5		120.5		119.5		118.5		117.5		116.5	
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
S T A T I C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.0007	71.7	0.0007	64.0	0.0007	56.4	0.0007	48.8	0.0010	41.2	0.0010	37.9	0.0010	39.0	0.0010	40.1	0.0010	41.2	0.0010	42.3	0.0010	43.4	0.0010	44.5	0.0007	45.6	0.0007	47.8
	0.0013	101.3	0.0013	90.6	0.0013	79.8	0.0013	69.0	0.0020	58.2	0.0020	53.6	0.0020	55.2	0.0020	56.7	0.0020	58.3	0.0020	59.8	0.0020	61.4	0.0020	62.9	0.0013	64.5	0.0013	67.6
	0.0020	118.1	0.0020	105.5	0.0020	92.9	0.0020	80.4	0.0031	67.8	0.0031	62.5	0.0031	64.3	0.0031	66.1	0.0031	67.9	0.0031	69.7	0.0031	71.5	0.0031	73.3	0.0020	75.1	0.0020	78.7
	0.0026	128.9	0.0026	115.2	0.0026	101.5	0.0026	87.8	0.0041	74.1	0.0041	68.2	0.0041	70.2	0.0041	72.1	0.0041	74.1	0.0041	76.1	0.0041	78.1	0.0041	80.1	0.0026	82.0	0.0026	86.0
	0.0033	136.3	0.0033	121.8	0.0033	107.3	0.0033	92.8	0.0051	78.3	0.0051	72.1	0.0051	74.2	0.0051	76.3	0.0051	78.4	0.0051	80.5	0.0051	82.6	0.0051	84.7	0.0033	86.8	0.0033	90.9
	0.0039	141.3	0.0039	126.3	0.0039	111.2	0.0039	96.2	0.0061	81.2	0.0061	74.7	0.0061	76.9	0.0061	79.1	0.0061	81.2	0.0061	83.4	0.0061	85.6	0.0061	87.7	0.0039	89.9	0.0039	94.2
	0.0046	144.4	0.0046	129.0	0.0046	113.6	0.0046	98.3	0.0072	82.9	0.0072	76.4	0.0072	78.6	0.0072	80.8	0.0072	83.0	0.0072	85.2	0.0072	87.4	0.0072	89.6	0.0046	91.8	0.0046	96.3
	0.0052	145.9	0.0052	130.3	0.0052	114.8	0.0052	99.3	0.0082	83.8	0.0082	77.2	0.0082	79.4	0.0082	81.6	0.0082	83.9	0.0082	86.1	0.0082	88.3	0.0082	90.6	0.0052	92.8	0.0052	97.3
	0.0059	146.1	0.0059	130.5	0.0059	115.0	0.0059	99.5	0.0092	83.9	0.0092	77.3	0.0092	79.5	0.0092	81.7	0.0092	84.0	0.0092	86.2	0.0092	88.5	0.0092	90.7	0.0059	92.9	0.0059	97.4
	0.0065	145.2	0.0065	129.8	0.0065	114.3	0.0065	98.9	0.0102	83.4	0.0102	76.8	0.0102	79.0	0.0102	81.3	0.0102	83.5	0.0102	85.7	0.0102	87.9	0.0102	90.2	0.0065	92.4	0.0065	96.8
	0.0072	143.3	0.0072	128.1	0.0072	112.8	0.0072	97.6	0.0113	82.3	0.0113	75.8	0.0113	78.0	0.0113	80.2	0.0113	82.4	0.0113	84.6	0.0113	86.8	0.0113	89.0	0.0072	91.2	0.0072	95.6
	0.0078	140.6	0.0078	125.7	0.0078	110.7	0.0078	95.8	0.0123	80.8	0.0123	74.4	0.0123	76.5	0.0123	78.7	0.0123	80.9	0.0123	83.0	0.0123	85.2	0.0123	87.3	0.0078	89.5	0.0078	93.8
	0.0130	101.4	0.0130	90.7	0.0130	79.9	0.0130	69.1	0.0205	58.3	0.0205	53.7	0.0205	55.2	0.0205	56.8	0.0205	58.9	0.0205	59.9	0.0205	61.4	0.0205	63.0	0.0130	64.5	0.0130	67.7
	0.0182	62.2	0.0182	55.6	0.0182	49.0	0.0182	42.3	0.0286	35.7	0.0286	32.9	0.0286	33.9	0.0286	34.8	0.0286	35.8	0.0286	36.7	0.0286	37.7	0.0286	38.6	0.0182	39.6	0.0182	41.5
	0.0234	22.9	0.0234	20.5	0.0234	18.1	0.0234	15.6	0.0368	13.2	0.0368	12.1	0.0368	12.5	0.0368	12.8	0.0368	13.2	0.0368	13.5	0.0368	13.9	0.0368	14.2	0.0234	14.6	0.0234	15.3
	0.0247	22.9	0.0247	20.5	0.0247	18.1	0.0247	15.6	0.0389	13.2	0.0389	12.1	0.0389	12.5	0.0389	12.8	0.0389	13.2	0.0389	13.5	0.0389	13.9	0.0389	14.2	0.0247	14.6	0.0247	15.3

Soil Type	Firm to Stiff Clay (Below WT)		Firm to Stiff Clay (Below WT)		Firm to Stiff Clay (Below WT)		Firm to Stiff Clay (Below WT)		Firm to Stiff Clay (Below WT)		Firm to Stiff Clay (Below WT)		Firm to Stiff Clay (Below WT)		Compact to Dense Till (Below WT)		Compact to Dense Till (Below WT)		Compact to Dense Till (Below WT)		Compact to Dense Till (Below WT)	
Depth (m)	15.5		16.5		17.5		18.5		19.5		20.5		21.5		22.5		23.5		24.5		25.5	
Elev. (m)	114.5		113.5		112.5		111.5		110.5		109.5		108.5		107.5		106.5		105.5		104.5	
	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)
S T A T I C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	0.0007	48.9	0.0007	50.0	0.0007	51.1	0.0007	52.2	0.0007	53.3	0.0007	54.4	0.0007	55.5	0.0010	630.2	0.0012	805.9	0.0015	1003.5	0.0017	1222.9
	0.0013	69.1	0.0013	70.7	0.0013	72.2	0.0013	73.8	0.0013	75.4	0.0013	76.9	0.0013	78.5	0.0020	1105.9	0.0024	1414.3	0.0029	1761.0	0.0035	2146.2
	0.0020	80.6	0.0020	82.4	0.0020	84.2	0.0020	86.0	0.0020	87.8	0.0020	89.6	0.0020	91.4	0.0029	1394.3	0.0036	1783.2	0.0044	2220.4	0.0052	2706.0
	0.0026	88.0	0.0026	89.9	0.0026	91.9	0.0026	93.9	0.0026	95.9	0.0026	97.8	0.0026	99.8	0.0039	1546.6	0.0049	1978.0	0.0059	2462.9	0.0069	3001.5
	0.0033	93.0	0.0033	95.1	0.0033	97.2	0.0033	99.3	0.0033	101.4	0.0033	103.5	0.0033	105.6	0.0049	1621.2	0.0061	2073.3	0.0073	2581.6	0.0086	3146.2
	0.0039	96.4	0.0039	98.6	0.0039	100.7	0.0039	102.9	0.0039	105.1	0.0039	107.2	0.0039	109.4	0.0059	1656.3	0.0073	2118.2	0.0088	2637.6	0.0104	3214.4
	0.0046	98.5	0.0046	100.7	0.0046	102.9	0.0046	105.1	0.0046	107.3	0.0046	109.6	0.0046	111.8	0.0069	1672.6	0.0085	2139.1	0.0102	2663.5	0.0121	3245.9
	0.0052	99.5	0.0052	101.8	0.0052	104.0	0.0052	106.2	0.0052	108.5	0.0052	110.7	0.0052	112.9	0.0079	1680.0	0.0097	2148.6	0.0117	2675.4	0.0138	3260.4
	0.0059	99.7	0.0059	101.9	0.0059	104.1	0.0059	106.4	0.0059	108.6	0.0059	110.9	0.0059	113.1	0.0088	1683.5	0.0109	2153.0	0.0132	2680.8	0.0156	3267.1
C t d	0.0065	99.1	0.0065	101.3	0.0065	103.5	0.0065	105.7	0.0065	108.0	0.0065	110.2	0.0065	112.4	0.0098	1685.0	0.0121	2155.0	0.0146	2683.3	0.0173	3270.1
	0.0072	97.8	0.0072	100.0	0.0072	102.2	0.0072	104.4	0.0072	106.6	0.0072	108.8	0.0072	111.0	0.0108	1685.7	0.0134	2155.9	0.0161	2684.4	0.0190	3271.5
	0.0078	95.9	0.0078	98.1	0.0078	100.3	0.0078	102.4	0.0078	104.6	0.0078	106.7	0.0078	108.9	0.0118	1686.1	0.0146	2156.3	0.0176	2684.9	0.0207	3272.1
	0.0130	69.2	0.0130	70.8	0.0130	72.3	0.0130	73.9	0.0130	75.4	0.0130	77.0	0.0130	78.5	0.0128	1686.2	0.0158	2156.5	0.0190	2685.2	0.0225	3272.4
	0.0182	42.4	0.0182	43.4	0.0182	44.3	0.0182	45.3	0.0182	46.2	0.0182	47.2	0.0182	48.2	0.0138	1686.3	0.0170	2156.6	0.0205	2685.3	0.0242	3272.5
	0.0234	15.7	0.0234	16.0	0.0234	16.4	0.0234	16.7	0.0234	17.1	0.0234	17.4	0.0234	17.8	0.0147	1686.3	0.0182	2156.6	0.0220	2685.3	0.0259	3272.6
	0.0247	15.7	0.0247	16.0	0.0247	16.4	0.0247	16.7	0.0247	17.1	0.0247	17.4	0.0247	17.8	0.0157	1686.3	0.0194	2156.6	0.0234	2685.4	0.0277	3272.6

Soil Type	Stiff to Firm Clay (Below WT)		Stiff to Firm Clay (Below WT)		Stiff to Firm Clay (Below WT)		Stiff to Firm Clay (Below WT)		Stiff to Firm Clay (Below WT)		Firm to Stiff Clay (Below WT)		Firm to Stiff Clay (Below WT)		Firm to Stiff Clay (Below WT)		Firm to Stiff Clay (Below WT)	
-----------	----------------------------------	--	----------------------------------	--	----------------------------------	--	----------------------------------	--	----------------------------------	--	----------------------------------	--	----------------------------------	--	----------------------------------	--	----------------------------------	--

## Soil Lateral Displacement Profile Locha Creek Culvert Replacement

Elevation (m)	Soil Displacement (mm)
132.5	30.8
131.5	26.5
130.5	23.6
129.5	21.2
128.5	19.0
127.5	17.0
126.5	15.2
125.5	13.6
124.5	12.2
123.5	11.0
122.5	9.8
121.5	8.8
120.5	7.8
119.5	7.0
118.5	6.2
117.5	5.4
116.5	4.7
115.5	4.1
114.5	3.5
113.5	2.9
112.5	2.7
111.5	2.2
110.5	1.7
109.5	1.3
108.5	0.8
107.5	0.5
106.5	0.4
105.5	0.2
104.5	0.1



**NOTE:** This soil displacement profile is for modelling purposes.

## **APPENDIX G**

### **2015 NBC SEISMIC HAZARD CALCULATION SLOPE STABILITY ANALYSIS RESULTS**

# 2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836  
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

October 27, 2017

Site: 45.444 N, 76.5348 W User File Reference: Lochiel Creek Culvert

Requested by: , Thurber Engineering

**National Building Code ground motions: 2% probability of exceedance in 50 years (0.000404 per annum)**

Sa(0.05)	Sa(0.1)	<b>Sa(0.2)</b>	Sa(0.3)	<b>Sa(0.5)</b>	<b>Sa(1.0)</b>	<b>Sa(2.0)</b>	<b>Sa(5.0)</b>	<b>Sa(10.0)</b>	<b>PGA (g)</b>	<b>PGV (m/s)</b>
0.357	0.424	<b>0.355</b>	0.270	<b>0.193</b>	<b>0.099</b>	<b>0.048</b>	<b>0.013</b>	<b>0.0048</b>	<b>0.228</b>	<b>0.161</b>

**Notes.** Spectral ( $S_a(T)$ , where  $T$  is the period in seconds) and peak ground acceleration (PGA) values are given in units of  $g$  ( $9.81 \text{ m/s}^2$ ). Peak ground velocity is given in  $\text{m/s}$ . Values are for "firm ground" (NBCC 2015 Site Class C, average shear wave velocity  $450 \text{ m/s}$ ). NBCC2015 and CSAS6-14 values are specified in **bold** font. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. *These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.*

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.05)	0.032	0.106	0.184
Sa(0.1)	0.046	0.139	0.229
Sa(0.2)	0.044	0.124	0.199
Sa(0.3)	0.036	0.099	0.155
Sa(0.5)	0.026	0.073	0.113
Sa(1.0)	0.013	0.038	0.059
Sa(2.0)	0.0054	0.018	0.028
Sa(5.0)	0.0011	0.0042	0.0070
Sa(10.0)	0.0006	0.0017	0.0029
PGA	0.025	0.076	0.126
PGV	0.018	0.056	0.091

## References

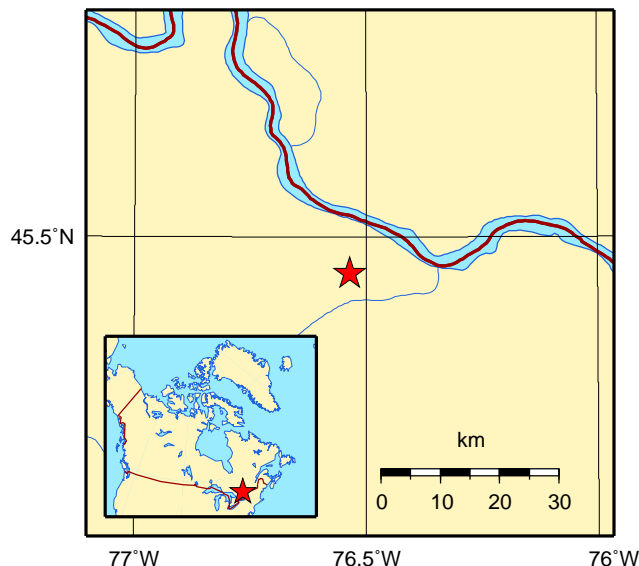
**National Building Code of Canada 2015 NRCC no. 56190;**  
**Appendix C:** Table C-3, Seismic Design Data for Selected Locations in Canada

**User's Guide - NBC 2015, Structural Commentaries NRCC no. xxxxxx** (in preparation)  
**Commentary J:** Design for Seismic Effects

**Geological Survey of Canada Open File 7893** Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada

See the websites [www.EarthquakesCanada.ca](http://www.EarthquakesCanada.ca) and [www.nationalcodes.ca](http://www.nationalcodes.ca) for more information

Aussi disponible en français



Natural Resources  
Canada

Ressources naturelles  
Canada

Canada

Title: Locha Creek Culvert

Comments: Embankment Stability Analysis

Name: N1. Short Term (TSA) - Static

Method: Morgenstern-Price, Half-Sine  
Minimum Slip Surface Depth: 1.52 m  
PWP Conditions Source: Piezometric Line  
Seismic: H\ 0 \ V\ 0  
Slip Surface Center: (77.892436, 143.09307) w/ Radius: 23.22817 m  
FoS Contours: 2.0 to 3.0, ++0.1

Embankment Fill	20 kN/m <sup>3</sup>	0 kPa	33 °	
Till	21 kN/m <sup>3</sup>	0 kPa	35 °	
Clay 1 (TSA)	17.3 kN/m <sup>3</sup>	100 kPa	-7 (kN/m <sup>2</sup> )/m	80 kPa
Clay 2 (TSA)	17.3 kN/m <sup>3</sup>	80 kPa	-8 (kN/m <sup>2</sup> )/m	40 kPa
Clay 3 (TSA)	17.3 kN/m <sup>3</sup>	40 kPa	1.18 (kN/m <sup>2</sup> )/m	60 kPa
Bedrock				

Materials

Embankment Fill

Till

Clay 1 (TSA)

Clay 2 (TSA)

Clay 3 (TSA)

Bedrock

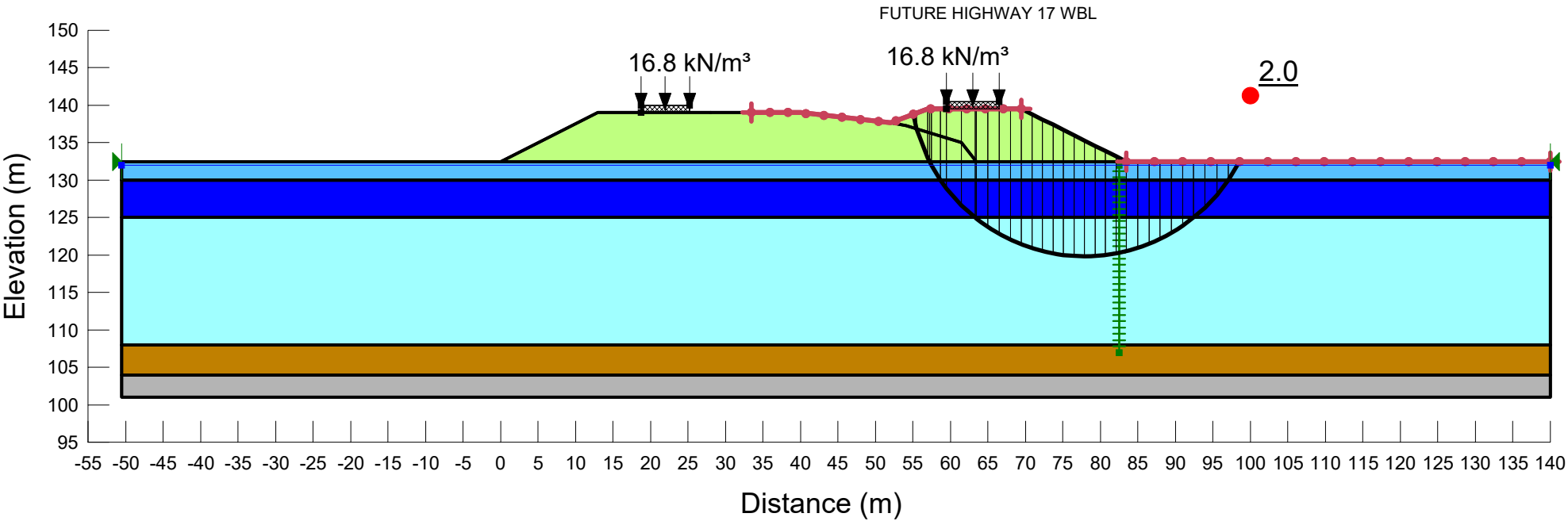


Figure 1



Title: Locha Creek Culvert  
Comments: Embankment Stability Analysis  
Name: N2. Long Term (ESA) - Static

Method: Morgenstern-Price, Half-Sine  
Minimum Slip Surface Depth: 1.52 m  
PWP Conditions Source: Piezometric Line  
Seismic: H\ 0 V\ 0  
Slip Surface Center: (83.205993, 148.24054) w/ Radius: 16.255805 m  
FoS Contours: 1.5 to 2.5, ++0.1

Embankment Fill	20 kN/m³	0 kPa	33 °
Till	21 kN/m³	0 kPa	35 °
Bedrock			
Clay 1 (ESA)	17.3 kN/m³	0 kPa	28 °
Clay 2 (ESA)	17.3 kN/m³	0 kPa	28 °
Clay 3 (ESA)	17.3 kN/m³	0 kPa	28 °

Materials

Embankment Fill

Till

Bedrock

Clay 1 (ESA)

Clay 2 (ESA)

Clay 3 (ESA)

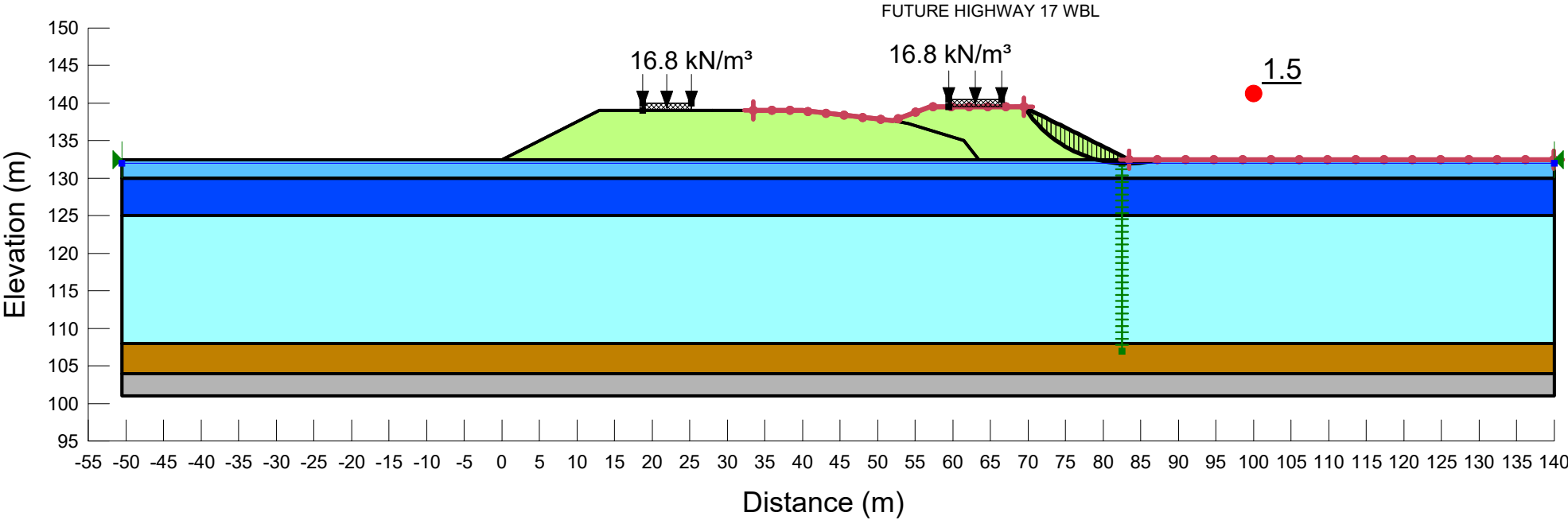


Figure 2

# Title: Locha Creek Culvert

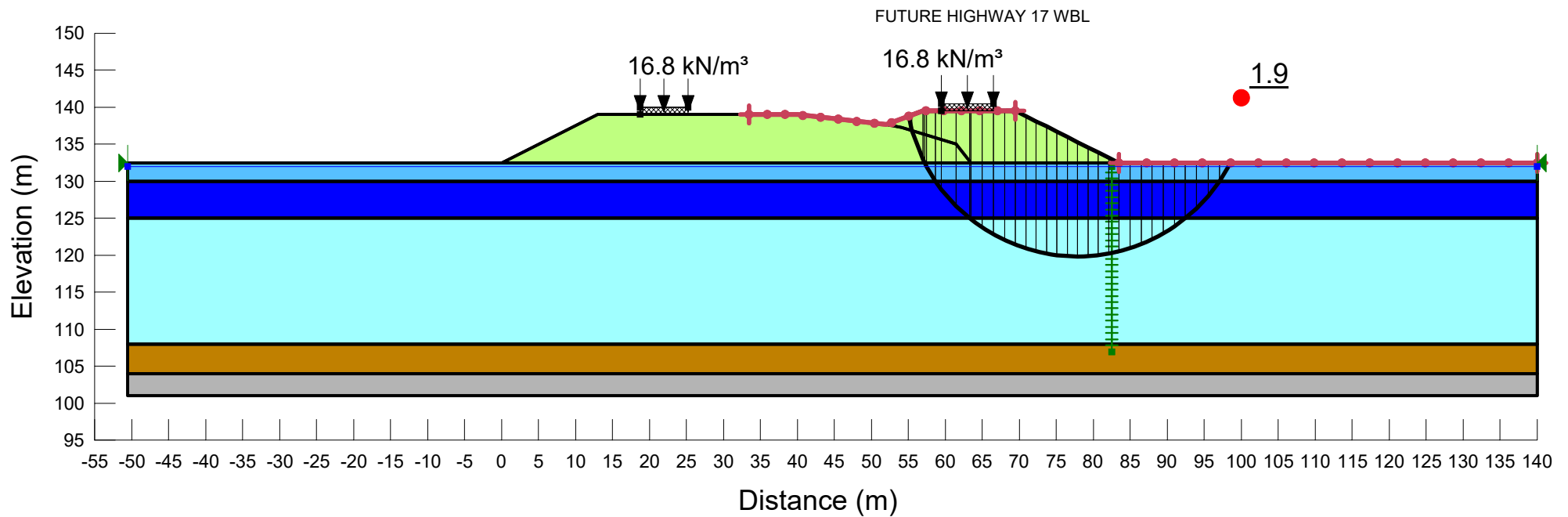
## Comments: Embankment Stability Analysis

### Name: N3. Flow Slide (TSA) - Seismic (kx=0)

Method: Morgenstern-Price, Half-Sine  
 Minimum Slip Surface Depth: 1.52 m  
 PWP Conditions Source: Piezometric Line  
 Seismic: H\ 0 V\ 0  
 Slip Surface Center: (77.892436, 143.09307) w/ Radius: 23.22817 m  
 FoS Contours: 1.9 to 2.9, ++0.1

Embankment Fill	20 kN/m <sup>3</sup>	0 kPa	33 °	
Till	21 kN/m <sup>3</sup>	0 kPa	35 °	
Clay 1 (TSA)	17.3 kN/m <sup>3</sup>	100 kPa	-7 (kN/m <sup>2</sup> )/m	80 kPa
Clay 2 (TSA)	17.3 kN/m <sup>3</sup>	80 kPa	-8 (kN/m <sup>2</sup> )/m	40 kPa
Bedrock				
Clay 3 (Res=0.85Su)	17.3 kN/m <sup>3</sup>	38 kPa	1 (kN/m <sup>2</sup> )/m	70 kPa

Materials	
<span style="color: green;">■</span>	Embankment Fill
<span style="color: brown;">■</span>	Till
<span style="color: lightblue;">■</span>	Clay 1 (TSA)
<span style="color: blue;">■</span>	Clay 2 (TSA)
<span style="color: gray;">■</span>	Bedrock
<span style="color: cyan;">■</span>	Clay 3 (Res=0.85Su)



Reviewed By: \_\_\_\_\_  
 Tool Version: 8.15.6.13446  
 Last Solved Date: 2019-03-01, 8:57:41 AM  
 Directory: H:\Projects\20001 to 30000\20482 - Hwy 17 Locha & Hwy 15 Rideau Culvert\Analysis\Locha\SlopeW\Stability Analysis\Locha Creek Embankment v4.gsz

Figure 3

Title: Locha Creek Culvert  
Comments: Embankment Stability Analysis  
Name: N4. Displacement (TSA) - Seismic (kx=0.5\*PGA)

Method: Morgenstern-Price, Half-Sine  
Minimum Slip Surface Depth: 1.52 m  
PWP Conditions Source: Piezometric Line  
Seismic: H\ 0.152 V\ 0  
Slip Surface Center: (77.892436, 143.09307) w/ Radius: 23.22817 m  
FoS Contours: 1.2 to 2.2, ++0.1

Embankment Fill	20 kN/m³	0 kPa	33 °	
Till	21 kN/m³	0 kPa	35 °	
Clay 1 (TSA)	17.3 kN/m³	100 kPa	-7 (kN/m²)/m	80 kPa
Clay 2 (TSA)	17.3 kN/m³	80 kPa	-8 (kN/m²)/m	40 kPa
Bedrock				
Clay 3 (Res=0.85Su)	17.3 kN/m³	38 kPa	1 (kN/m²)/m	70 kPa

Materials

Embankment Fill

Till

Clay 1 (TSA)

Clay 2 (TSA)

Bedrock

Clay 3 (Res=0.85Su)

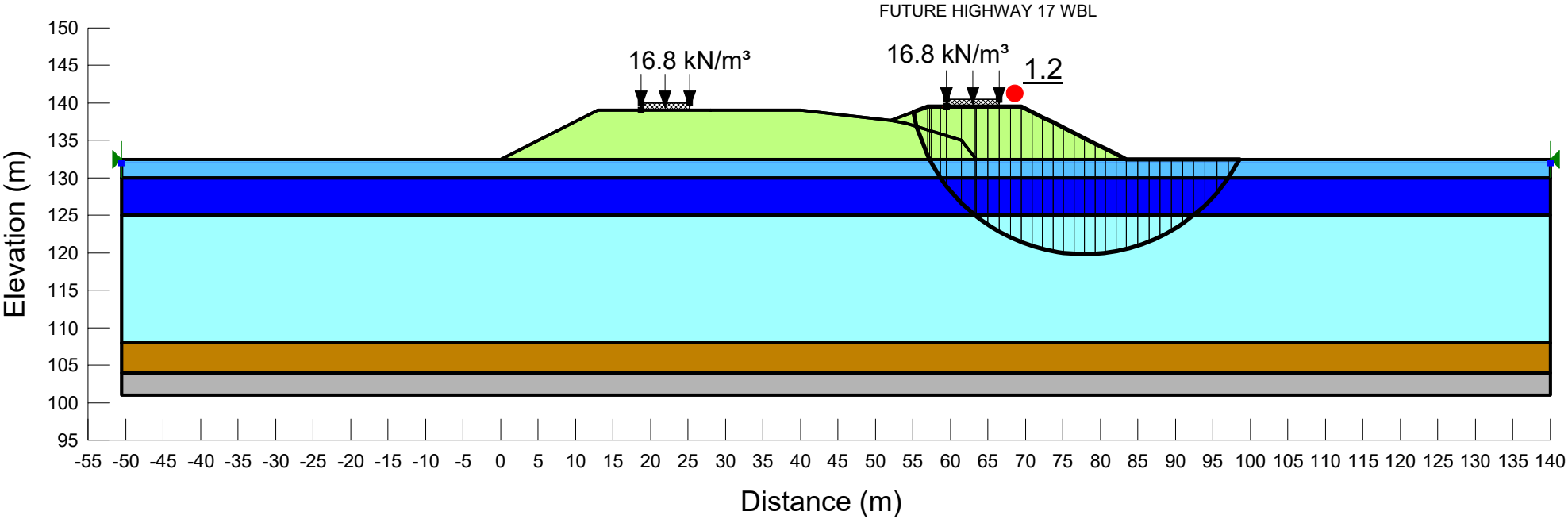


Figure 4

## **APPENDIX H**

### **LIST OF REFERENCED SPECIFICATIONS NON-STANDARD SPECIAL PROVISIONS**

## LIST OF REFERENCED SPECIFICATIONS

OPSD 208.010	Benching of Earth Slopes
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.101	Foundation, Frost Penetration Depths for Southern Ontario
OPSS.PROV 180	General Specification for the Management of Excess Materials
OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS 805	Construction Specification for Temporary Erosion and Sediment Control Measures
OPSS 902	Construction Specification for Excavating and Backfilling-Structures
OPSS.PROV 903	Construction Specification for Deep Foundations
OPSS.PROV 1010	Material Specification for Aggregates-Base, Subbase, Select Subgrade, and Backfill Material
OPSS.PROV 1205	Material Specification for Clay Seal
Special Provision 109S12	Amendment to OPSS 902, March 2018
Special Provision FOUN0003	Dewatering Structure Excavations, March 2018

## **NON-STANDARD SPECIAL PROVISIONS**

### **RECOMMENDED WORDING FOR NSSP – SPECIAL PROVISION FOUN0003 –DEWATERING STRUCTURE EXCAVATIONS**

Subsection 902.04.01 Design Requirements of SP FOUN0003 is amended by the addition of the following:

The design Engineer and design-checking Engineer of the dewatering system shall have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work.

### **RECOMMENDED WORDING FOR NOTICE TO CONTRACTOR – PILE LENGTH**

The bedrock surface elevation was observed to vary by approximately 4.7 m along the length of the culvert. The pile length is expected to vary based on the variation in the bedrock surface elevation.