



THURBER ENGINEERING LTD.

**PRELIMINARY
FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 17 TWINNING, RENFREW AREA
CULVERTS 10 AND 10N
STA. 19+200, HORTON TOWNSHIP
WP 4068-09-00 / ASSIGNMENT NO. 4018-E-0009**

Geocres No.: 31F07-005

Report to:

Ministry of Transportation Ontario

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TABLE OF CONTENTS

PART 1. FACTUAL INFORMATION

1	INTRODUCTION	1
2	SITE DESCRIPTION.....	1
2.1	General.....	1
2.2	Site Geology	2
3	SITE INVESTIGATION AND FIELD TESTING.....	3
4	LABORATORY TESTING	5
5	GENERAL DESCRIPTION OF SUBSURFACE CONDITIONS	5
5.1	Asphalt	5
5.2	Embankment Fill.....	6
5.2.1	Silty Sand, some Gravel Fill	6
5.2.2	Silty Clayey Sand with Gravel to Sandy Clayey Silt Fill	6
5.3	Clay to Silty Clay to Clayey Silt (CH to CI to CL/CL-ML)	7
5.4	Silty Sand with Gravel (Glacial Till)	8
5.5	Refusal	9
5.6	Groundwater.....	9
5.7	Analytical Testing	10
6	MISCELLANEOUS	10

PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7	INTRODUCTION	12
7.1	Background Information.....	12
7.2	Proposed Work.....	13
7.3	Applicable Codes and Design Considerations	14
8	SEISMIC CONSIDERATIONS	14
8.1	Spectral and Peak Acceleration Hazard Values.....	14
8.2	Seismic Liquefaction Potential	15
8.3	CHBDC Seismic Site Classification and Performance Category	15

9	DESIGN OPTIONS	16
9.1	Culvert Type and Foundation Alternatives	16
9.2	Construction Methodology Alternatives.....	17
9.3	Recommended Approach for Culvert Replacement	17
10	FOUNDATION DESIGN RECOMMENDATIONS	17
10.1	Concrete Pipe Culvert Foundation	18
10.2	Closed Box Concrete Culvert.....	18
10.3	Subgrade Preparation, Bedding and Backfilling	19
10.4	Backfill and Lateral Earth Pressures	20
10.4.1	Static Lateral Earth Pressure	21
10.4.2	Combined Static and Seismic Lateral Earth Pressure	22
10.5	Frost Penetration Depth.....	23
10.6	Cement Type and Corrosion Potential	23
10.7	Embankment Fill.....	24
10.7.1	Westbound Embankment Reinstatement	24
10.7.2	Embankment Stability	24
10.7.3	Embankment Settlement.....	26
10.7.4	Alternative Settlement Mitigation Measures	28
11	CONSTRUCTION CONSIDERATIONS	29
11.1	Temporary Excavations	29
11.2	Temporary Protection Systems.....	29
11.3	Surface and Groundwater Control	30
11.4	Erosion and Scour Control.....	31
12	DESIGN AND CONSTRUCTION CONCERNS	32
13	CLOSURE	34



APPENDICES

Appendix A.	Borehole Location Plan and Stratigraphic Drawings
Appendix B.	Record of Borehole Sheets
Appendix C.	Laboratory Testing
Appendix D.	Site Photographs
Appendix E.	GSC Seismic Hazard Calculation
Appendix F.	Foundation Comparison
Appendix G.	Slope Stability Analysis Figures
Appendix H.	List of Referenced Specifications Non-Standard Special Provisions



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PART 1. FACTUAL INFORMATION

1 INTRODUCTION

Thurber Engineering Ltd. (Thurber) has been engaged by the Ministry of Transportation Ontario (MTO) to carry out Foundation Investigations to support the design of the Highway 17 Twinning Project which extends from Scheel Drive westerly to 3 km west of Bruce Street within the County of Renfrew, Ontario. Thurber carried out the investigation under Ministry of Transportation (MTO) Assignment No. 4018-E-0009.

This report addresses the culvert crossing near Sta. 19+200 on Highway 17 in Horton Township within Renfrew County, Ontario. The existing Highway 17 alignment at this site will become the future Highway 17 westbound lanes and new eastbound lanes will be constructed to the south. The existing culvert will be replaced, and a new culvert is required to convey an unnamed tributary of the Bonnechere River below an embankment supporting the proposed Highway 17 eastbound lanes.

This section of the report presents the factual findings obtained from the foundation investigation conducted by Thurber as part of the current study.

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

It should be noted that the use of and reliance on Part 1 of the Report is governed by and limited to the terms and conditions set out in the Report and a reliance letter. The Preferred Proponent remains responsible to assess the need for additional investigations and to complete that work.

2 SITE DESCRIPTION

2.1 General

For project purposes, Highway 17 is herein described as oriented east-west, and the culvert is described as oriented north-south. The site is located on Highway 17 approximately 600 m east of the Highway 17 intersection with Bruce St and Castleford Rd in Horton Township, Renfrew, Ontario.



In the area of the culvert, existing Highway 17 is an undivided highway with two travelled lanes, a partially paved/gravel shoulder on the eastbound side, an asphalt shoulder on the westbound side and a posted speed limit of 90 km/hr. The road surface near the culvert is at approximate elevation 137.3 m. Steel cable guide rail on wooden posts is present along both shoulders. The traffic volume for this section of Highway 17 is understood to have been 12,300 AADT in 2016.

The existing culvert is a 900 mm diameter, 37 m long, corrugated steel pipe (CSP) culvert oriented approximately perpendicular to the highway alignment. The culvert has an approximate gradient of approximately 4.8 % with the invert of the culvert near elevations 132.2 and 130.4 m at the inlet and outlet, respectively. The cover above the existing culvert is approximately 5 m at the highway centerline. The tributary flows through the culvert under the highway embankment from north to south. It is understood that the general drainage is near parallel to the south side of the highway alignment to the east of the culvert. The elevation of standing water near the outlet was measured as 130.8 m on July 25, 2024.

Embankment side slopes, in the vicinity of the culvert, are inclined at approximately 2.5H:1V on the north side and 1.7H:1V on the south side. The existing embankment side slopes at the culvert site did not show any visible signs of global instability at the time of the investigation.

The site is in a rural setting, and the terrain along the ditch line is relatively flat on the south side and sloped on the north side in the vicinity of the culvert site. The area directly adjacent to the culvert is mostly farmland with some deciduous trees and shrubs. Bedrock outcrops are present on both sides of the highway approximately 135 m to the west of the site. It is noted that a tile drain from the adjacent farm field is present near the toe of the slope near the culvert outlet. Furthermore, it is understood that there have been reported issues with drainage of the pavement structure 150 m west of the culvert; water has been observed seeping from the shoulders at this location.

Photographs of the project area are included in Appendix D. These photographs show the existing condition of the highway embankment and the culvert at the time of the field investigation.

2.2 Site Geology

Under the same MTO Assignment, a foundation investigation was conducted by Thurber for several high fill locations within the Highway 17 twinning project boundaries. The available information was reviewed prior to this investigation and can be found in the Geocres Library under Geocres Number 31F-235. Borehole B-HF-03 and CPTu B-HF-02B from that investigation are relevant to the present report and have been included in Appendix B.

According to Crins et al. 2009¹, the project area is described as Ecoregion 6E (Lake Simcoe-Rideau Ecoregion) within the Mixedwood Plains Ecozone. According to Wester et al. 2018², the ecoregion is subdivided into Ecodistrict 6E-16 (Pembroke Ecodistrict). The area is characterized by glaciolacustrine dominated landscape overlying a mix of Paleozoic to Precambrian bedrock.

¹ <https://files.ontario.ca/mnrf-ecosystemspart1-accessible-july2018-en-2020-01-16.pdf>

² <https://files.ontario.ca/ecosystems-ontario-part2-03262019.pdf>



Based on published geological information in *The Physiography of Southern Ontario* by Chapman and Putnam (1984), the site lies within the physiographic region known as the Ottawa Valley Clay Plains. The Ottawa Valley Clay Plains are characterized primarily by clay plains deposited by the Champlain Sea (Leda Clay) interrupted by ridges of rock or sand.

Ontario Geological Survey Map P.2366³ suggests for the site area marine deeper water deposits of clay, silty clay and clayey silt.

Ontario Geological Survey Map 2460⁴ suggests the bedrock comprises calcitic carbonate metasedimentary bedrock including calcitic and siliceous marble.

3 SITE INVESTIGATION AND FIELD TESTING

Borehole B-HF-03 was drilled off-road in August 2021, using a CME 850 track mounted drill equipped with hollow stem augers and HQ casing. ConeTec Investigations Ltd. completed the CPT B-HF-02B test in August 2021; the hole was advanced with the support of a GTech GT6 track-mounted drill rig. Further details on the 2021 test holes can be found in Geocres Report Number 31F-235.

Additional foundation investigation and field-testing program was carried out between March 21 and April 15, 2024, and consisted of one on-road borehole identified as SC10-2 and four off-road boreholes identified as SC10-1, SC10-3, SC10-4 and SC10-5. Borehole SC10-2 was advanced with a CME 55 truck mounted drill rig utilizing hollow stem augers and NW casing. Boreholes SC10-4 and SC10-5 were advanced with a CME 75 track mounted drill rig utilizing hollow stem augers and NW casing. Boreholes SC10-1 and SC10-3 were advanced with portable drilling equipment. Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations.

A summary of the borehole coordinates, elevations, and termination depths is provided in Table 3-1. The locations and elevations of the 2024 boreholes were surveyed by Thurber with a Trimble Catalyst DA1 antenna with centimeter accuracy and were measured relative to BM HCP 102 (Elevation 129.023 m) and HCP118 (Elevation 139.303 m). Horizontal locations were measured by Thurber relative to existing site features. The elevations and borehole coordinates were reviewed and referenced to the survey data provided by the MTO. The borehole coordinates and elevations are shown on the Borehole Location and Soil Strata drawing included in Appendix A and on the individual Record of Borehole sheets included in Appendix B. The borehole coordinates are referenced to MTM Zone 9.

³ <https://www.geologyontario.mndm.gov.on.ca/mndmfiles/pub/data/imaging/P2366/P2366.pDf>

⁴ https://www.geologyontario.mndm.gov.on.ca/mndmaccess/mndm_dir.asp?type=pub&id=M2460

Table 3-1: Borehole Summary

Borehole No.	Drilled Location	Northing (Latitude)	Easting (Longitude)	Ground Surface Elevation (m)	Termination Depth (m)
SC10-1	Existing Inlet	5 039 147.0 (45.492124)	291 720.0 (-76.667346)	132.6	10.4
SC10-2	On-road	5 039 148.7 (45.492139)	291 702.8 (-76.667566)	137.3	22.5
SC10-3	Existing Outlet	5 039 124.1 (45.491917)	291 683.2 (-76.667817)	132.2	12.0
SC10-4	Near Proposed Culvert Inlet	5 039 119.0 (45.491871)	291 663.2 (-76.668073)	130.2	13.6
SC10-5	Near Proposed Culvert Outlet	5 039 104.2 (45.491737)	291 646.7 (-76.668284)	129.7	13.6
B-HF-03	East of Proposed Culvert	5 039 087.7 (45.491591)	291 685.7 (-76.667784)	129.9	25.3
B-HF-02B (CPTu)	West of Proposed Culvert	5 039 153.7 (45.492183)	291 649.8 (-76.668245)	130.5	18.8

Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in general accordance with ASTM D 1586. A full size hammer was used with the portable drill; thus, no hammer energy corrections were required. In-situ shear vane testing was carried out within the cohesive layers, where possible, using an MTO 'N' sized vane in general accordance with ASTM D 2573. A Thin-Walled (Shelby) Tube was pushed in Boreholes SC10-4 and SC10-5 to obtain relatively undisturbed cohesive soil samples for further laboratory testing.

Monitoring wells were installed in Boreholes SC10-1 (50 mm diameter), SC10-5 (50 mm diameter) and B-HF-03 (38 mm diameter) to allow for measurements of the groundwater level after drilling. The details for the well are illustrated on the respective Record of Borehole sheets provided in Appendix B. The monitoring wells installed as part of the current investigation will be decommissioned by Thurber, as outlined in the Hydrogeological Investigation and Design Report.

Boreholes SC10-2, SC10-3 and SC10-4 were backfilled in accordance with MOE requirements (O.Reg 903, as amended). Borehole SC10-2 was capped with cold patch asphalt to reinstate the pavement surface.

The drilling and sampling operations were supervised on a full-time basis by a member of Thurber's technical staff. The drilling supervisor logged the boreholes and processed the



recovered soil samples for transport to Thurber's Ottawa laboratory for further examination and testing.

4 LABORATORY TESTING

Laboratory testing on the 2024 samples was selected in accordance with the current MTO Guideline for Foundation Engineering Services, Section 5. Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all retained soil samples. At least 25% of the recovered soil samples were subjected to testing for grain size distribution analysis and, where appropriate, Atterberg Limits in accordance with MTO and ASTM standards.

One dimensional consolidation testing (ASTM D 2435) was completed on a selected Thin-Walled (Shelby) tube sample from borehole SC10-4.

Chemical analyses for determination of pH, conductivity, resistivity, sulphide, sulphate and chloride were carried out on two samples of the soil.

The results of the geotechnical tests are summarized on the Record of Borehole sheets included in Appendix B and all laboratory results are presented on the figures included in Appendix C.

5 GENERAL DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix B and the Borehole Location and Soil Strata Drawing included in Appendix A. A general description of the stratigraphy based on the conditions encountered in the boreholes is given in the following sections. However, the factual data presented on the Borehole Records takes precedence over the Soil Strata Drawing and the general description. It must be recognized that the soil and groundwater conditions may vary between and beyond borehole locations. Soil descriptions are in accordance with the MTO Guideline for Foundation Engineering Services Manual (April 2022) and the 4th Edition of the Canadian Foundation Engineering Manual.

In general, the encountered stratigraphy consists of a gravel with sand to silty sand some gravel fill, overlying a weathered clay to silty clay crust overlying a deep silty clay to clayey silt deposit overlying glacial till. Bedrock was not proven with coring but was inferred in borehole B-HF-03. One CPT test, available from the online Geocres Library under Geocres Number 31F-235, was carried out in a location close to the culvert site. The results are summarized on figures presented in Appendix B.

5.1 Asphalt

Asphalt was encountered at the ground surface in Borehole SC10-2. The asphalt was measured to have a thickness of 50 mm.

5.2 Embankment Fill

5.2.1 Silty Sand, some Gravel Fill

A fill layer consisting of silty sand some gravel was encountered below the asphalt in on-road Borehole SC10-2. The thickness of the layer was 5.3 m (base elevation at 132.0 m). The SPT N values ranged from 2 to greater than 100 blows, indicating a very loose to very dense condition.

The moisture content of the samples tested ranged from 3% and 18%. The results of grain size analyses conducted on two samples of this fill material are summarized in the table below and are illustrated on Figure C1 in Appendix C.

Summary of Grain Size Distribution Testing – Gravel with Sand to Silty Sand, some Gravel Fill

Soil Particle	Percentage (%)
Gravel	11 – 12
Sand	70 – 72
Silt & Clay	16 – 19

5.2.2 Silty Clayey Sand with Gravel to Sandy Clayey Silt Fill

A fill layer consisting of silty clayey sand with gravel to sandy clayey silt containing some organics was encountered at ground surface in Boreholes SC10-1 and SC10-3. The thickness of the layer ranged from 0.9 to 1.5 m (base elevation at 131.7 to 130.7 m). The SPT N values ranged from 2 to 12 blows, indicating a very loose to compact relative density.

The moisture content of the samples tested ranged from 22% to 38%. The results of grain size analyses conducted on two samples of this fill material are summarized in the table below and are illustrated on Figure C2 in Appendix C.

Summary of Grain Size Distribution Testing – Silty Sand with Clay and Gravel Fill

Soil Particle	Percentage (%)
Gravel	0
Sand	25 – 30
Silt	41 – 44
Clay	26 – 34

The results of Atterberg Limits testing carried out on two samples of this fill material are summarized below and are illustrated on Figure C3 in Appendix C. The laboratory results indicate the fill is of low plasticity (CL).

Summary of Atterberg Limit Testing – Silty Sand with Clay and Gravel Fill

Parameter	Value
Liquid Limit	30 – 31
Plastic Limit	17 – 20
Plasticity Index	11 – 13

5.3 Clay to Silty Clay to Clayey Silt (CH to CI to CL/CL-ML)

A native deposit of clay to silty clay to clayey silt was encountered below the fill layer in Boreholes SC10-1, SC10-2 and SC10-3 and at ground surface in Boreholes B-HF-03, SC10-4 and SC10-5. Sand seams were encountered throughout the layer and were noted to be more frequent with depth. The layer was fully penetrated only in borehole B-HF-03 but was proven to be at least 9.5 to 22.3 m thick and extend to depths ranging from 10.4 to 22.3 m (base elev. 122.2 to 107.6 m). In boreholes B-HF-03, SC10-4 and SC10-5, the top portion of the layer was noted to be weathered crust ranging in thickness from 7.6 m to 7.8 m (base elevation 122.4 m to 122.1 m).

Where SPT were conducted within the layer, the N-values typically ranged from weight-of-hammer (WH) to 17 blows. N-values as high as 20 to 26 blows were noted in the layer in the portable Boreholes SC10-1, SC10-3. Field vane tests were performed within this layer where possible. Undrained shear strengths were obtained and ranged from 52 to greater than 100 kPa. Remolded vane tests recorded sensitivities typically ranging from 3 to 18, indicating that the clay is medium to high sensitive (CFEM, 2023). The layer is described as stiff to very stiff in consistency based on N-values, undrained shear strength measurements, and tactile evaluations of strength.

The moisture content of the samples tested ranged from 21 to 48%. The results of grain size analysis tests conducted on nineteen samples of this material are summarized in the table below and are illustrated on Figures C4 to C7 in Appendix C.

Summary of Grain Size Distribution Testing – Clay to Silty Clay to Clayey Silt

Soil Particle	Percentage (%)
Gravel	0
Sand	0 – 10
Silt	40 – 73
Clay	21 – 59

The results of Atterberg Limits testing carried out on nineteen samples of this material are summarized below and are illustrated on Figure C8 to C11 in Appendix C. The laboratory results indicate that the clay to silty clay to clayey silt generally exhibits low to high plasticity (CH to CI to CL-ML).

Summary of Atterberg Limit Testing – Clay to Silty Clay to Clayey Silt

Parameter	Value
Liquid Limit	22 – 51
Plastic Limit	15 – 27
Plasticity Index	7 – 30

One-dimensional consolidation testing (ASTM D 2435) was carried out on one relatively undisturbed cohesive sample from Borehole SC10-4. Load increments were maintained for 24 hours. Photographs of the extruded sample are provided in Appendix C. The testing results are presented in Appendix C and are summarized in Table 5-1. The preconsolidation stress summarized in the table was obtained from the end-of-increment void ratio. It should be expected that compressibility characteristics will vary with depth in accordance with the soil index parameters and stress history.

Table 5-1: Advanced Laboratory Test Results

Borehole	SC10-4
Sample	TW8
Sample Depth (m)	9.2 – 9.8
Sample Elevation (m)	120.7
Soil Layer	Clayey Silt (CL)
Moisture Content (%)	41
Liquidity Index (-)	1
Initial Void Ratio (-)	1.095
Moist Unit Weight (kN/m ³)	17.9
In-situ Vertical Effective Stress (kPa)	76.9
Preconsolidation Stress (kPa)	247
Overconsolidation Ratio (-)	3.2
Recompression Index (-)	0.041
Compression Index (-)	0.583
Coefficient of Reconsolidation (cm ² /sec)	0.005
Coefficient of Consolidation (cm ² /sec)	0.001
Load Increment Duration (hrs.)	24

5.4 Silty Sand with Gravel (Glacial Till)

A native deposit of silty sand with gravel (glacial till), was encountered below the clay to silty clay to clayey silty layer in Borehole B-HF-03. The thickness of the layer was 3.0 m (base elevation at 104.6 m). The SPT N-value measured in this layer was greater than 100 blows, indicating a very dense relative density.

The moisture content of one sample tested was 8%.



5.5 Refusal

Borehole B-HF-03 was drilled to split spoon refusal on inferred bedrock, and a Dynamic Cone Penetration Test (DCPT) was carried out below the sampled depth in Borehole SC10-2. The refusal blow count was encountered at depths of 22.5 to 25.3 m (base elevation 114.8 m to 104.6 m).

The CPTu test (Borehole B-HF-02B) was advanced by ConeTec to a refusal depth of 18.8 m (elev. 111.7 m).

5.6 Groundwater

Monitoring wells with diameter of 50 mm were installed in Boreholes SC10-1 and SC10-5, and one monitoring well with diameter of 38 mm was installed in Borehole B-HF-03. Groundwater levels recorded in the wells are presented in Table 5-2.

Table 5-2: Summary of Groundwater Levels

Borehole No.	Bottom of Screen Elevation (m)	Groundwater Depth (m)	Groundwater Elevation (m)	Date of Measurement
SC10-1	126.4	1.1	131.5	March 22, 2024
		0.5	132.1	April 09, 2024
		0.8	131.8	April 26, 2024
		1.1	131.5	June 26, 2024
		1.3	131.3	June 28, 2024
		2.5	130.1	August 30, 2024
SC10-5	120.6	0.9	128.8	April 09, 2024
		0.9	128.8	April 24, 2024
		1.1	128.6	June 26, 2024
		1.2	128.4	June 28, 2024
		1.2	128.4	July 16, 2024
		2.0	127.7	August 30, 2024
B-HF-03	120.2	3.5	126.4	September 21, 2021
		0.7	129.2	December 20, 2021
		2.4	127.5	January 11, 2022
		0.9 ^(a)	129.0	April 25, 2024
		2.8 ^(a)	127.1	August 30, 2024

Notes: (a) water level taken after borehole log was finalized

The elevation of standing water near the existing culvert outlet was measured as 130.8 m on July 25, 2024.

These observations are considered short term as they were recorded at discrete times, and it should be noted that the groundwater level at the time of construction may be different and seasonal fluctuations of the groundwater level are to be expected. In particular, the creek water



and groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation.

Groundwater levels were also observed during drilling in Boreholes SC10-2 and SC10-4, however, the groundwater level in the boreholes was not stabilized thus these readings are not considered reliable.

5.7 Analytical Testing

Two samples of the native clay to silty clay to clayey silt were submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate, sulphide and chloride concentrations, resistivity, and conductivity. The analysis results are summarized in Table 5-3. Copies of the test results are provided in Appendix C.

Table 5-3: Results of Chemical Analysis

Borehole	Sample	Depth (m)	Chloride (µg/g)	Sulphate (µg/g)	Sulphide (%)	pH (-)	Resistivity (Ohm-cm)
SC10-1	SS2B	0.9 – 1.2	97	44	< 0.01	6.95	3,160
SC10-4	SS2	0.8 – 1.4	27	<10	< 0.01	6.84	4,050

6 MISCELLANEOUS

The borehole locations reflect existing site features and access constraints. The as-drilled locations and ground surface elevation were measured by Thurber following completion of the field program. George Downing Estate Drilling Ltd. of Hawkesbury, Ontario, supplied and operated the drill rigs used to drill, test, sample, and decommission the boreholes. Limitless Drilling Inc. of Renfrew, Ontario, supplied and operated the equipment used to drill, test, sample, and decommission the portable boreholes. Traffic control was performed in accordance with Ontario Book 7 and was provided by C&C Services of Renfrew, Ontario. The field investigation was supervised on a full-time basis by Mr. B. Coote, EIT, Mr. I. Khan, EIT, Mr. D. Amorim Pereira, Geotechnical Technician, and Mr. R. Howarth, Geotechnical Technician. Overall supervision of the field investigation program was provided by Mr. J. Gray, P.Eng.

Routine geotechnical laboratory testing were completed by Thurber's laboratory in Ottawa. Analytical testing was completed by Paracel Laboratories Ltd. in Ottawa.

Interpretation of the factual data and preparation of this report was completed by D. Amorim Pereira, Geotechnical Technician. The report was reviewed by Dr. F. Griffiths, P.Eng., and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundation Projects.



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PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 INTRODUCTION

Part 2 of the report provides an interpretation of the factual data from Part 1 and presents preliminary geotechnical recommendations to assist the project team in designing the foundations for a culvert replacement to be located on existing Highway 17 at approximate Station 19+200 Horton Township, Renfrew County and a new culvert crossing located at approximate Station 19+200 on the proposed new eastbound lanes of Highway 17. Thurber carried out the investigation under Ministry of Transportation (MTO) Assignment No. 4018-E-0009.

This preliminary 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 design-build contractors. It should be noted that the use of and reliance on Part 1 of the Report is governed by and limited to the terms and conditions set out in the Report and a reliance letter. The Preferred Proponent remains responsible to assess the need for additional investigations and to complete that work. The Preferred Proponent must make their own interpretation based on the factual data in Part 1 of the report. The information included in Part 2 is not to be relied upon for design purposes and foundation design is the sole responsibility of the Preferred Proponent. No use shall be made of Part 2 or any part thereof. The Preferred Proponent 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 preliminary geotechnical recommendations for the construction of foundation elements for the proposed works. The discussion and preliminary recommendations presented in this report are based on information provided by the MTO and the factual data obtained during the current field investigation.

7.1 Background Information

For project purposes, Highway 17 is herein described as oriented east-west and the creek flows from north to south. The site is located at on Highway 17 approximately 600 m east of the Highway 17 intersection with Bruce St and Castleford Rd in Horton Township.



The existing road is superelevated to the south with elevations at the existing culvert crossing ranging from 137.3 to 136.7 m. The existing culvert is a 900 mm diameter, 37 m long, corrugated steel pipe (CSP) culvert oriented approximately perpendicular to the highway alignment. The culvert has an approximate gradient of approximately 4.8 % with the invert of the culvert near elevations 132.2 and 130.4 m at the inlet and outlet, respectively with flow through the culvert from north to south. The elevation of standing water near the outlet was measured as 130.8 m on July 25, 2024.

It is noted that a tile drain from the adjacent farm field is present near the toe of the slope near the culvert outlet. Furthermore, it is understood that there have been reported issues with drainage of the pavement structure near this location.

The encountered stratigraphy consists of a gravel with sand to silty sand some gravel fill, overlying a weathered clay to silty clay crust overlying a deep stiff to very stiff silty clay to clayey silt deposit overlying glacial till encountered in one borehole at elevation 107.6 m. Bedrock was not proven with coring but was inferred in one borehole at an approximate elevation of 104.6 m. It is noted that the groundwater level in the monitoring wells installed in Boreholes SC10-1 and SC10-5 was at elevation 132.1 and 128.8 m, respectively, on April 9, 2024.

It is noted that a Foundation Investigation and Design Report was previously prepared for several proposed high fill embankment for the overall Highway 17 twinning assignment as documented in Geocres Number 31F-235. The current site is located within High Fill Area B which encompasses the new eastbound alignment from 19+025 to 19+875, Horton Township.

7.2 Proposed Work

The existing Highway 17 alignment at this site will become the future Highway 17 westbound lanes and new eastbound lanes will be constructed approximately 32.5 m south (rounding to rounding) of the existing alignment at this location. Culvert 10, currently present under the existing Highway 17 lanes, will require replacement and a new Culvert 10N will be required under the proposed eastbound lanes. These culverts will convey the tributary under the existing and proposed highway embankments.

The Structure and Culvert List of February 23, 2022, for this project indicated that the proposed culvert replacement (Culvert 10) beneath the new westbound lanes is to be a structural, pre-cast, closed-bottom concrete box culvert (CBC) with approximate length of 35.2 m, a span of 5.0 m, a rise of 5.0 m, and a 3.31% slope. The culvert will allow the passage of large and mid-sized mammals. It is assumed that the stream bed will be at approximately elevation 131.3 m at the culvert centreline. It is understood that the finished grade of the new westbound lanes will remain unchanged at approximate elevation 137.3 m; resulting in a fill height of 6.0 m above the culvert invert.

The Structure and Culvert List of February 23, 2022, for this project indicated that the proposed new culvert (Culvert 10N) beneath the new eastbound lanes is to be a structural, pre-cast, closed-bottom concrete box culvert (CBC) with approximate length of 35.0 m, a span of 5.0 m, a rise of 5.0 m, and a 3.31% slope. The culvert will allow the passage of large and mid-sized mammals. It



is assumed that the stream bed will be at approximately elevation 130.0 m at the culvert centreline as per measured ground elevations which range from 130.2 m to 129.7 m near the proposed alignment. It is understood that the finished grade of the new eastbound lanes is to be at approximate elevation 137.5 m; resulting in a fill height of 7.5 m above the culvert invert.

Based on preliminary information provided by MTO, no retaining walls or headwalls are proposed at the culverts.

It is noted that GA drawings are not available at the time of writing. The preliminary recommendations presented herein must be reassessed once the type, configuration, location, elevation, and orientation of the proposed works are established.

7.3 Applicable Codes and Design Considerations

The geotechnical assessment presented herein has been prepared based on the available data regarding the proposed work, existing ground conditions documented in Part 1 of this report, and in accordance with the Canadian Highway Bridge Design Code (CHBDC), version CSA S6-19.

In accordance with the 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 new culvert structures are being designed as a “Major Route” importance category. As per Section 6.14.2.1.b and 6.14.2.3.b of the CHBDC, a Major-Route geotechnical system is required to have a seismic performance criterion that meets a return period of 475-years.

It is understood that the culverts have been assigned a Typical Consequence Classification, in accordance with Section 6.5.1 of the CHBDC. Accordingly, a consequence factor (Ψ) of 1.0, as per Table 6.1 of the CHBDC, has been used in assessing factored geotechnical resistances. If the consequence classification changes, the geotechnical assessment and recommendations provided within this report may need to be reviewed and revised.

The degree of site and prediction model understanding for this site has been assessed to be typical understanding (Section 6.5.3 of CHBDC).

The frost penetration depth and associated recommendations are provided in Section 10.5.

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)⁵. The GSC seismic hazard calculation data sheet for

⁵ <https://earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/calc-en.php>



this site for the *reference* ground condition (Site Class C) is presented in Appendix E. The site coefficients used to determine the design spectral acceleration values are a function of the Site Class, PGA, and S_a (0.2). The PGA value at this site provided by GSC for a *reference* Site Class C with a 2% probability of exceedance in 50 years (2475-year event) is 0.225 g. This value is to be scaled by the $F(\text{PGA})$ based on the *site-specific* Site Class, as discussed in Section 8.3.

8.2 Seismic Liquefaction Potential

The susceptibility of the cohesive soils at this site to experience liquefaction/cyclic softening was assessed following the Boulanger and Idriss (2007)⁶ criteria which utilizes the measured undrained shear strengths. Based on the results of the analysis the cohesive materials at this site are not susceptible to liquefaction or cyclic mobility under the design earthquake.

The results of Atterberg Limit tests carried out on the cohesive soils at the site gave plasticity index (PI) values ranging from 7% to 30% but were generally between about 15% and 25%. Three samples obtained from different, isolated zones of the deposit gave the lower PI values of 7%, 10%, and 11%. These lower values may have been a result of the presence of localized sand seams. As noted in Section C6.14.8.1 of the Commentary to the CHBDC, silty soils with $7\% < \text{PI} < 12\%$ may be considered to exhibit behaviour that is in the transition zone between “clay-like” and “sand-like”. As such, these discrete zones may exhibit some local cyclic softening during the 2,475-year event; however, they are not considered to be indicative of the behaviour of the overall deposit.

It should be noted that as per Section 6.14.2.1.b and 6.14.2.3.b of the CHBDC, a Major Route geotechnical system must only meet seismic performance criterion for ground motions with a return period of 475yr.

8.3 CHBDC Seismic Site Classification and Performance Category

In accordance with Section 4.4.3.2 of the CHBDC, the selection of the seismic site classification is based on the nature of the soil deposits within the upper 30 m of the stratigraphy. Section 4.4.3.3 of the CHBDC indicates that for structures with a fundamental period of vibration equal to or less than 0.5 s that are built on liquefiable soils, the site class and corresponding values of $F(T)$ may be determined assuming the soils are not liquefiable. As per Table 4.1 within Section 4.4.3.2 of the CHBDC, this site has been classified as a Seismic Site Class D.

The $F(\text{PGA})$, as per Table 4.8 within Section 4.4.3.3 of the CHBDC, is equal to 1.14 for this site yielding a scaled *site-specific* Site Class D PGA of 0.256 g.

As per Section 4.4.4 of the CHBDC, the Seismic Performance Category is assigned based on the fundamental period, the importance category, and the spectral accelerations scaled to the site

⁶ Boulanger, R. W. and Idriss, I. M. (2007). *Evaluation of cyclic softening in silts and clays*, ASCE, *Journal of Geotechnical and Geoenvironmental Engineering*, 133(6), 641-652.



class. The $F(0.2)$ and $F(1.0)$, as per Tables 4.2 and 4.4 within Section 4.4.3.3 of the CHBDC, is equal to 1.12 and 1.42 for this site, yielding a scaled *site-specific* $S_a(0.2)$ of 0.393 and $S_a(1.0)$ of 0.138. A Seismic Performance Category of 3 is applicable to this site based on Table 4.10 of the CHBDC. The fundamental period of vibration of the structures and the seismic performance category should be confirmed by the structural engineer.

9 DESIGN OPTIONS

9.1 Culvert Type and Foundation Alternatives

Selection of the culvert type must consider the proposed construction procedures, staging requirements, geotechnical resistance available in the foundation soils, depth to suitable bearing stratum and post-construction settlement criteria. From a geotechnical perspective, the following culvert types were considered:

- Circular Pipes (Concrete, HDPE, Steel)

Although, from a foundation engineering perspective, a pipe culvert is a technically feasible alternative, the proposed pipe must meet the required flow capacity, navigation and hydraulic requirements as well as provide passage for mammals.

- Open-Bottom Culvert (Box, Arch)

The construction of an open-bottom culvert will have greater construction concerns due to the high water table and requirement for greater excavation depths to construct the culvert footings to satisfy frost depth requirements. The use of an open bottom culvert would require greater dewatering efforts and has the potential for larger settlement following construction when compared to other culvert options. It is anticipated that the underside of the footings for the replacement culvert would be as deep as approximately elevation 129.4 m which is 2.7 m below the observed groundwater level on April 9, 2024, and approximately 7.9 m below the existing road surface.

- Closed-Bottom Culvert (Box)

A pre-cast, segmental, closed-bottom, box culvert is considered a feasible option from a foundation engineering perspective. Precast sections, rather than cast-in-place construction, can be installed expediently with less potential for disturbance of the subgrade during installation, require less excavation depth than open bottom culverts, and allow for more manageable dewatering efforts. Utilization of a closed bottom culvert is considered a mitigation measure where a structure is underlain by potentially liquefiable soils.

A comparison of these alternatives, based on their respective advantages and disadvantages, is included in Appendix F. It is not considered to be economical or practical to support a culvert on deep foundations at this site and therefore this option is not presented in this report.



9.2 Construction Methodology Alternatives

At the time of the field investigation, ponded water surface elevations near the existing culvert outlet were at approximately 130.8 m. Groundwater levels were measured to be at approximate elevation 132.1 m and 128.8 m in the monitoring wells installed in Boreholes SC10-1 and SC10-5 on April 9, 2024. Excavations will likely extend below the water level of 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 11.3).

It is noted that the preliminary profile for the new eastbound lanes includes an embankment approximately 7.5 m above existing grade at Culvert 10N. A significant amount of settlement in the underlying soils is anticipated and mitigation measures will be needed. Embankment design recommendations are provided in Section 10.7.

At the time of preparation of this report, a construction staging plan has not yet been developed. The foundation recommendations presented herein have been prepared based on the assumption that construction of the new culvert (Culvert 10N) and the new eastbound embankment will be carried out while traffic remains on the existing alignment. Upon completion of the construction of the new lanes, all traffic would be temporarily directed onto those new lanes to allow culvert replacement (Culvert 10) for the westbound lanes to be constructed under a road closure of the existing alignment.

9.3 Recommended Approach for Culvert Replacement

From a geotechnical perspective, closed-bottom, box culverts are recommended at this site. It is anticipated that construction for the eastbound lanes would be carried out while traffic remains on the existing alignment. Once the new lanes are open, all traffic would be rerouted onto the new lanes, while the culvert structure under the existing lanes is replaced.

Multiple pipe culverts may also be considered a feasible alternative from a foundation point of view but are not recommended. Construction staging would be similar to that for the closed bottom box culvert option. Open bottom culverts are not recommended for this site.

A preload period is required prior to carrying out an open cut excavation for the installation of Culvert 10N for the new eastbound lanes (See Section 10.7.3). A temporary culvert will be required during the preload period.

10 FOUNDATION DESIGN RECOMMENDATIONS

From a foundation engineering perspective, concrete box culverts are recommended. The following bullets summarize the relevant elevations near each culvert:

Existing Highway 17 / Proposed Westbound Lanes – Culvert 10

- | | |
|---------------------------------------|---------|
| • Existing top of pavement | 137.3 m |
| • Culvert invert at centreline | 131.3 m |
| • Groundwater elevation April 9, 2024 | 132.1 m |



- Underside elevation of Silty Clay/Clayey Silt (B-HF-03) 107.6 m

Proposed Highway 17 Eastbound Lanes – Culvert 10N

- Top of pavement 137.5 m
- Culvert invert at centreline 130.0 m
- Groundwater elevation April 9, 2024 128.8 m
- Underside elevation of Silty Clay/Clayey Silt (B-HF-03) 107.6 m

10.1 Concrete Pipe Culvert Foundation

It is anticipated that the invert of the replacement culvert will be within the native silty clay layer. Bearing resistance values are not required for pipe culverts. The culvert should be founded on a granular bedding layer (see Section 10.3). Subgrade preparation should follow the recommendations provided in Section 10.3 to provide a suitable subgrade for the bedding. Surface water diversion and dewatering will be required to place the bedding material and install the culvert in the dry (see Section 11.3).

If a concrete pipe is selected, resistance to lateral forces/sliding resistance between concrete and the underlying granular 'A' bedding (see Section 10.3) should be evaluated based on the recommendations in Section 10.3.

10.2 Closed Box Concrete Culvert

It is anticipated that the subgrade soils within the footprint of Culvert 10N will be subjected to the additional loads from the proposed embankment for the new eastbound lanes with a height of approximately 7.5 m above culvert invert. Further discussion on the potential settlement of the subgrade soils is provided in Section 10.7.3. The subgrade should be prepared as described in Section 10.3.

The recommended geotechnical resistances for 5.6 wide (outside), pre-cast, closed-bottom, box culverts with the culvert base at or below approximate elevation 131.0, installed on a bedding layer as described in Section 10.3, and placed on an undisturbed native clayey silt/silty clay subgrade are as follows:

- Factored Geotechnical Resistance at ULS of 270 kPa
- Factored Geotechnical Resistance at SLS of 150 kPa (provided settlement mitigation is included in the design for Culvert 10N – see Section 10.7.3)

The factored geotechnical resistances include the following factors:

- Consequence factor (Ψ) of 1.0 (as per CHBDC Table 6.1)
- Geotechnical resistance factors (as per CHBDC Table 6.2):
 - $\phi_{gu} = 0.5$ (static analysis; typical degree of understanding)
 - $\phi_{gs} = 0.8$ (static analysis; typical degree of understanding)



The bearing resistance values are for vertical, concentric loading. In the case of eccentric or inclined loading, the bearing resistance must be reduced in accordance with CHBDC Clause 6.10.2. Foundation settlement, based on the supplied SLS resistance, is expected to be less than 25 mm for Culvert 10 if constructed on subgrades prepared with good workmanship and in accordance with Sections 10.3 and 10.7. Based on the supplied SLS resistance, and the addition of 7.5 m of fill, the settlement after the preload period is expected to be approximately 50 mm for Culvert 10N, see further discussion in Section 10.7.3.

Resistance to lateral forces/sliding resistance between the precast concrete and underlying Granular A bedding (Section 10.3) should be evaluated in accordance with the CHBDC assuming an unfactored coefficient of friction of 0.45. A resistance factor of 0.8 (as per CHBDC Table 6.2) should be used to estimate the factored sliding resistance between the culvert and Granular A. An unfactored coefficient of friction of 0.35 can be assumed for the interface between the Granular A and the silty clay. A resistance factor of 0.6 (as per CHBDC Table 6.2) should be used to estimate the factored sliding resistance between the Granular A and the clayey silt subgrade.

Surface water diversion and dewatering will be required to place the bedding material and install the culvert in the dry (Section 11.3).

10.3 Subgrade Preparation, Bedding and Backfilling

Granular A" in this section refer to OPSS Granular A meeting the specifications of OPSS.PROV 1010 and SP 110S06. "Granular A" is further defined as "Quarry-Source Granular A" unless specifically described as "Pit-Source Granular A". Fills should be placed and compacted as per OPSS.PROV 501 and OPSS.PROV 206.

The culvert should be constructed following OPSS.PROV 401 and either OPSS.PROV 421 (pipe culvert) or OPSS.PROV 422 (box culvert).

Subgrade preparation for the culvert replacement should include excavation and removal of the existing culvert if replaced along the same alignment. If the replacement culvert is placed on a new alignment, the existing culvert may be decommissioned in place (see Section 10.7.3 for further details).

Fill containing organic material with a thickness of approximately 0.8 to 0.9 m was encountered in the area of the proposed culvert during the drilling investigation and must be removed from beneath the culverts and embankment footprints.

For a pipe culvert, at the founding level any existing fill, soft/loose soils (including any topsoil and organic soils), disturbed soils, or otherwise deleterious materials encountered will need to be removed down to competent inorganic soils. Granular A should be used in dewatered excavations to backfill any sub-excavations required for subgrade improvement. Foundation preparation for a pipe culvert should be as per OPSD 802.031 and OPSD 803.031 with bedding extending to at least 300 mm below the pipe. It is recommended that culvert cover and bedding materials consist of OPSS.PROV 1010 Granular A.



The closed box culvert will be founded on existing clayey silt soils, the foundation subgrade should be prepared as per OPSS.PROV 902 using Granular A material as backfill of over-excavated areas, where required.

The culvert should be placed on a granular bedding layer with a minimum thickness of 0.3 m consisting of Granular A material. The top of the Granular A bedding layer must extend to 0.5 m beyond the outside edge of all sides of the culvert and sloped away from the culvert base at 1H:1V, or flatter. The granular bedding shall be compacted as per OPSS.PROV 501.

Given the sensitive subgrade clayey silt soils anticipated at the founding level of the culvert, construction equipment should not be permitted to travel on the exposed subgrade. The compaction of granular directly above the subgrade may result in disturbance of the material with pumping of fines into the granular and difficulty achieving the specified degree of compaction. After inspection and approval of the subgrade, protection of the subgrade should include installation of a Class II, non-woven geotextile with a maximum FOS of 150 μ m (OPSS.PROV 1860) installed beneath the Granular A bedding. The geotextile should be placed as soon as possible after preparation of the final subgrade level and the excavation should be backfilled to the top of the bedding elevation to protect the subgrade from disturbance from both construction traffic and weather. Alternatively, 150 mm of granular bedding could be placed above a 200 mm thick, concrete working slab placed on the prepared subgrade. The dewatering system must be designed to prevent groundwater from being trapped beneath the working slab and must be operational prior to pouring the slab. The working slab should extend at least 0.5 m beyond the outside dimensions of the culvert. An NSSP is provided in Appendix H to include in the contract documents to alert the Contractor of the sensitive nature of the foundation soils.

Backfill and cover for concrete box culverts should be as per OPSD 803.010 with cover material consisting of OPSS.PROV 1010 Granular A. Backfill above the granular cover material for a box or rigid pipe culvert should be in accordance with OPSS.PROV 902 and consist of materials meeting the requirements of OPSS Select Subgrade Material (SSM) or better.

Heavy compaction equipment, used adjacent to or directly above the culvert, must be restricted in accordance with OPSS.PROV 501 to protect the culvert from damage.

It is noted that construction will extend below the observed water level. Dewatering will be required to place the granular bedding and/or concrete in the dry. Please review Section 11.3 for additional comments on groundwater and surface water control.

10.4 Backfill and Lateral Earth Pressures

Structural backfill material should consist of Granular A or Granular B Type II meeting the OPSS.PROV 1010 and SP110S06 specifications. Large scale direct shear box testing on samples of Granular A and Granular B Type II from several nearby aggregate sources was completed for this project. The results indicate that for design of structural backfill for this project, an internal angle of friction of 40 degrees and 42 degrees can be used for quarry-sourced Granular A and Granular B Type II, respectively, generated within this area provided the effective vertical pressure on the material is less than 150 kPa (Geocres Memorandum 31F-213). An



Operational Constraint will be required in the contract restricting the source of Granular A to quarries. Throughout this report, the term “Granular A” is defined as “Quarry-Source Granular A” unless specifically described as “Pit-Source Granular A”.

The backfill must be in accordance with OPSS.PROV 902 and placed to the extents as generally shown on OPSD 3101.150. Structural backfill should consist of Granular A or Granular B Type II placed and compacted in accordance with OPSS.PROV 501. Heavy compaction equipment used adjacent to the walls must be restricted in accordance with OPSS.PROV 501.07.02a). The design of the retaining walls/headwalls, where required, must incorporate a subdrain as shown in OPSD 3101.150.

Lateral earth pressure parameters provided in Table 10-1 and Table 10-2 in the sections below are based on the assumptions that the wall is vertical and the backfill is fully drained so that there are no unbalanced hydrostatic pressures above the permanent groundwater level. If adequate drainage cannot be confirmed, the potential for buildup of hydrostatic pressures should be considered in design.

Where back slopes are horizontal, the corresponding coefficients provided in Table 10-1 and Table 10-2 should be used. For other backfill and wall geometries, Thurber will need to calculate the appropriate earth pressure coefficients once the final geometry is confirmed.

10.4.1 Static Lateral Earth Pressure

Lateral earth pressures acting on structures should be computed in accordance with the CHBDC. Under drained conditions the lateral earth pressure is generally given by the following expression:

$$\sigma_h = K * (\gamma h + q)$$

where:

σ_h	=	horizontal pressure on the wall at depth h (kPa)
K	=	earth pressure coefficient (see table below) (K_A for unrestrained walls, K_0 for restrained walls)
γ	=	unit weight of retained soil (see table below), use submerged unit weight below groundwater level
h	=	depth below top of fill where pressure is computed (m)
q	=	value of any surcharge (kPa)

A lateral earth pressure due to backfill compaction should be added to the calculated lateral earth pressure in accordance with Clause 6.12.3 of the CHBDC. Typical earth pressure coefficients for OPSS Granular A and OPSS Granular B Type II backfill are shown in Table 10-1.

Table 10-1: Static Earth Pressure Coefficients

Condition	Pit Sourced OPSS Granular A	Quarry Sourced OPSS Granular A	Quarry Sourced OPSS Granular B Type II
	$\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	$\phi = 40^\circ, \gamma = 22.8 \text{ kN/m}^3$	$\phi = 42^\circ, \gamma = 22.8 \text{ kN/m}^3$
Coefficient of at Rest Earth Pressure, K_0 (Restrained Wall)	0.43	0.36	0.33
Coefficient of Active Earth Pressure, K_A (Unrestrained Wall)	0.27	0.22	0.20
Coefficient of Passive Earth Pressure, K_p (Movement toward soil)	3.7	4.6	5.0

The parameters in Table 10-1 correspond to full mobilization of active and passive earth pressures and require certain relative movements between the wall and adjacent soil to produce these conditions. The movement required can be assessed from Table C6.12 of the Commentary to the CHBDC. Active earth pressures should be used for unrestrained walls. For rigid structures, at-rest horizontal earth pressures would apply for design.

10.4.2 Combined Static and Seismic Lateral Earth Pressure

In accordance with Clause 6.14 of the CHBDC, retaining structures should be designed using dynamic earth pressure coefficients that incorporate the effects of earthquake loading. The following recommendations are per Section C6.14 of the Commentary of the CHBDC which states that seismically induced lateral soil pressures may be calculated using Mononobe Okabe Method with:

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

The coefficients of horizontal earth pressure for seismic loading presented in Table 10-2 may be used for vertical walls. The provided earth pressure coefficients are based on a Seismic Site Class D. Please see Section 8.3 for the respective PGA and F(PGA) values.

Table 10-2: Combined Static and Seismic Earth Pressure Coefficients – Site Class D (2,475-year)

Condition	Pit Sourced OPSS Granular A $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	Quarry Sourced OPSS Granular A $\phi = 40^\circ, \gamma = 22.8 \text{ kN/m}^3$	Quarry Sourced OPSS Granular B Type II $\phi = 42^\circ, \gamma = 22.8 \text{ kN/m}^3$
Coefficient of Active Earth Pressure, K_{AE} (Restrained Wall)	0.44	0.37	0.34
Coefficient of Active Earth Pressure, K_{AE} (Unrestrained Wall)	0.35	0.28	0.26

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

$$\sigma_{hAE} = K * \gamma * d + (K_{AE} - K_A) * \gamma * (H - d)$$

where:

σ_{hAE}	=	combined static and seismic lateral earth pressure on wall at depth d (kPa)
d	=	depth below the top of the wall where pressure is computed (m)
K	=	static earth pressure coefficient (K_A for unrestrained walls, K_0 for restrained walls)
γ	=	unit weight of retained soil, adjusted below water level
K_{AE}	=	combined static and seismic earth pressure coefficient
H	=	total height of the wall (m)

10.5 Frost Penetration Depth

The depth of frost penetration at this site is estimated to be 1.9 m (as per OPSD 3090.101); shallow foundations, if any, should be founded at or below this depth or provided with equivalent insulation. Closed-bottom box culverts are not typically provided with frost protection. The earth cover should be measured perpendicular to the ground surface. Thermally equivalent frost protection could be in the form of insulation provided it is placed *above* the high-water level. It should be noted that open graded materials, such as rock protection, do not have the same thermal protection as soils.

Please refer to the pavement design report for frost taper recommendations for the pavement.

10.6 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 Section 5.7 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 Section 5.7 were compared with Table 3.2 of the MTO Gravity Pipe Design Guideline and generally indicate a moderate corrosive environment. The test results provided in Section 5.7 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 were compared with Table 3 of Canadian Standards Association Standards A23.1-19 (CSA A23.1) and indicate a less than moderate degree of sulphate attack potential on concrete structures at this site.

The corrosive effects of road de-icing salts should also be considered.

10.7 Embankment Fill

Embankments shall be constructed in accordance with OPSS.PROV 206. It is recommended that local marine clay not be used as embankment fill.

10.7.1 Westbound Embankment Reinstatement

The existing highway embankment side slopes are inclined at approximately 2.5H:1V on the north side and 1.7H:1V on the south side. The existing slopes did not show any visible signs of global instability at the time of the investigation.

It is understood that no grade raise or embankment widening is anticipated along the Highway 17 alignment.

Embankment reinstatement after construction of the replacement culvert should be carried out in accordance with OPSS.PROV 206. If constructed using Select Subgrade Material (SSM) or Granular B Type I, the embankment should be constructed with side slopes of 2H:1V (or flatter). The granular fill should be placed and compacted in accordance with OPSS.PROV 501.

Where newly placed embankment fill is placed against existing embankment slopes or on a sloping ground surface steeper than 3H:1V, benching of the existing slope should be carried out in accordance with OPSD 208.010.

10.7.2 Embankment Stability

Westbound - Culvert 10

As part of the current report, embankment stability has been assessed perpendicular to the roadway alignment for the reinstatement of the westbound embankment at Station 19+200. The



slope stability analyses were carried out using GeoStudio 2024 Slope/W software for limit equilibrium analysis. Input parameters, soil model and groundwater conditions for the analyses are based on the in situ testing, and the results of laboratory testing and are shown on the stability analyses outputs provided in Appendix G. The following additional parameters and assumptions were used in the analysis:

- The soil stratigraphy is based on the nearest boreholes.
- A maximum fill height of 6.0 m for westbound embankment at Culvert 10.
- Westbound embankment reinstatement with side slopes of 2H:1V and SSM/Granular B Type I Fill.
- A site adjusted PGA value for ground motions with a return period of at least 475 years of 0.049 g, equal to ½ of the site adjusted PGA value (0.097 g), was used for seismic analysis, as per Sections 4.4.3.3 and 6.14.2.3 of the CHBDC and outlined in Section 8.3.
- A traffic surcharge of 17 kPa has been applied as a temporary load.

Copies of the output from the stability analyses are provided in Appendix G. Each output figure shows the slope geometry, groundwater conditions, soil stratigraphy and soil strength parameters utilized in the analysis. The stability analyses generated the following factor of safety values for the proposed westbound embankment reinstatement:

Table 10-3: Slope Stability Analysis Results for Westbound Embankment, Sta. 19+200

Condition	Case	Factor of Safety
		2H:1V [SSM/Granular B I]
Temporary (traffic loading)	Short Term (Undrained)	2.0 (Fig G1-1)
Permanent (no traffic loading)	Long Term (Drained)	1.6 (Fig G2-2)
Temporary (includes seismic)	Pseudo-Static Seismic (Undrained)	1.9 (Fig G3-3)

The geotechnical resistance factors provided in Table 6.2 of the CHBDC for embankment fills with a typical degree of understanding and a consequence factor (Ψ) of 1.0 generates minimum target Factors of Safety of 1.5 and 1.3 for permanent and temporary conditions respectively. All the static results presented in Table 10-3 meet or exceed the target Factors of Safety.

Table 6.3 in Section 6.14.4.1 of the CHBDC indicates a minimum seismic resistance factor of 0.95 for force-based design and 1.0 for performance-based design. Based on these values and consequence factor (Ψ) of 1.0, a target Factor of Safety of 1.1 is considered appropriate for the pseudo-static seismic analysis. The pseudo-static results, presented in Table 10-3 above, meet the target Factor of Safety for seismic design. Further, it is noted that some displacement of the embankment can occur where the pseudo-static Factor of Safety is less than 1.3; this value is also exceeded.



Eastbound – Culvert 10N

As noted in Section 7.1 above, a Foundation Investigation and Design Report was previously prepared for several proposed high embankment fills for the overall Highway 17 twinning assignment as documented in Geocres Report 31F-235. The current site is located within High Fill Area B which encompasses the new eastbound alignment from 19+025 to 19+875, Horton Township. Stability analyses were completed for the new eastbound embankment and presented in that report. The analyses assessed a maximum embankment height of 11.8 m which will occur at Station 19+500. All of the static and pseudo-static cases generated acceptable factors of safety.

It was recommended that the embankment should be constructed with side slopes of 2H:1V (or flatter) if constructed using Granular B Type I or Select Subgrade Material (SSM) meeting the requirement of OPSS.PROV 1010. Alternatively, the embankments could be constructed of rock fill with slopes at 1.25H:1V. Further, mid-height berms comprising 2 m wide benches should be incorporated along the length of embankments with heights at or exceeding 8 m of granular fill. Similarly for rock fill embankments, mid-height berms comprising 2 m wide benches should be incorporated along the length of embankments with heights at or exceeding 10 m.

10.7.3 Embankment Settlement

Embankments must be overbuilt to compensate for the estimated settlements.

It is noted that the addition of a widened platform to accommodate future grade raises has not been included in the design assumptions. Similarly, the placement of slope flattening material on rock fill slopes has not been included in the analyses. Inclusion of these modifications to the cross-sections will affect the settlement magnitudes presented herein.

Westbound – Culvert 10

The reinstated westbound embankment will have a similar height and footprint to the existing. The proposed Culvert 10 opening is greater than the existing, thus, the construction represents a net unloading. No additional settlement from the underlying soils is expected along the existing alignment for Culvert 10. If the existing culvert is to be abandoned and fully grouted or removed and backfilled, it is estimated that this would induce further settlement of less than 10 mm beneath the existing culvert alignment as a result of the increased load imposed by the grout/fill. Settlement should be reviewed if the embankments are widened or reinstated to design grades greater than the existing grades.

Self-settlement of the 6 m high embankment required to reinstate the westbound lanes after installation of Culvert 10 will also occur. For an embankment constructed of compacted SSM material, approximately 30 mm of self settlement will occur with the majority of that complete during construction.

No special mitigation measures for settlement are anticipated for the replacement of Culvert 10.

Settlement of the westbound embankment due to the construction of the new eastbound embankment is expected to range from approximately 45 mm at the existing westbound

embankment south toe of slope to less than 10 mm below the existing south edge of pavement. The magnitude of the differential settlement at existing Culvert 10 will be affected by construction staging and methodology; the impacts of this movement and the need for mitigation measures will need to be assessed during the detailed design stage.

Eastbound – Culvert 10N

Settlement of the proposed eastbound embankment was assessed as part of Geocres Report 31F-235. The current site is located within High Fill Area B which encompasses the new eastbound alignment from 19+025 to 19+875, Horton Township. Please refer to the previous report for details on the soil parameters used in the settlement analyses. The calculated settlements for High Fill Area B are presented in the tables below.

Table 10-4: Predicted Settlement of Underlying Soil

Site	Height of Embankment	Thickness of Compressible Clay	Cumulative Settlement (Rock Fill/SSM Fill, mm)				
			3 Months	6 Months	12 Months	24 Months	20 Years
B	10.5	31.4	200/220	220/240	250/270	270/300	340/370 ⁽¹⁾

Note: (1) Includes secondary settlement (creep) analysis

Table 10-5: Predicted Embankment Fill Compression

Site	Fill Height (m)	Compression (mm)	
		Compacted Granular Fill Embankment	Compacted Rock Fill Embankment
B	11.7	60	175

The total embankment settlement at Site B exceeds MTO guidelines for post construction settlement criteria. A full height preload (embankment pre-construction) could be applied for a duration of 24 months to allow post-construction settlement to meet the guidelines for embankments constructed on compressible soils. Temporary culvert(s) will need to be installed to facilitate drainage.

The compressible silty clay to clayey silt deposits will continue to settle following the preload at the site. The results of the settlement analyses indicated that following a 24-month preload period an additional 30 mm of primary consolidation settlement and 40 to 50 mm of secondary consolidation settlement is expected to occur over a post-construction settlement period of 20 years.

If the settlement needs to be accelerated to meet a construction schedule that cannot accommodate the required preload period, consideration may be given to alternative treatment methods described in Section 10.7.4, below.

It is noted that although Culvert 10N is located within High Fill Area B, the fill height proposed at the culvert is 7.5 m compared to the maximum height assessed and documented above in Table 10-4 and Table 10-5. Furthermore, the thickness of the compressible layer at Culvert 10N is less



than that utilized in the calculations for maximum settlement described above. The estimated primary settlement of the underlying native soils at Culvert 10N, considering a total thickness of 25 m, is approximately 240 mm (235 mm of compression from the silty clay to clayey silt and 5 mm of elastic settlement in the silty sand). It is recommended that the Culvert 10N site undergo the recommended preload treatment in advance of installation of Culvert 10N as mitigation against settlement. A temporary culvert will be needed to allow drainage during the preload period.

It is noted that the compressible silty clay to clayey silt deposits at Culvert 10N will continue to settle following the preload at the site. The results of the settlement analyses indicated that following a 24-month preload period an additional 50 mm of primary and secondary consolidation settlement is expected to occur over a post-construction settlement period of 20 years. This settlement must be accounted for in the design of Culvert 10N, either as a camber or by over-sizing to accommodate the anticipated settlement without compromising hydraulic capacity. In this case, the SLS geotechnical resistance provided in Section 10.2 is associated with a settlement of 50 mm.

In addition to the settlement described above, there will also be self-settlement of the 7.5 m high eastbound embankment material itself. For embankments constructed with compacted rockfill the short term settlement will be approximately 60 mm (up to 1 year after completion of construction with 90% of this value occurring in the first six months). In addition, rockfill embankments will continue to settle after the first year with an estimate of an additional 10 mm. Similarly, an embankment constructed of compacted SSM material will undergo approximately 40 mm of self settlement with the majority of that complete during construction. The placement of asphalt should be delayed for several months after installation of Culvert 10N, and the associated backfilling to reestablish grades for the eastbound embankment.

10.7.4 Alternative Settlement Mitigation Measures

As recommended in Geocres Report 31F-235, full height preloading (embankment pre-construction) should be applied for a duration of 24 months in advance of installation of Culvert 10N to reduce post-construction settlement for the new eastbound embankment. Temporary culvert(s) will need to be installed to facilitate drainage during the preload period.

If the settlement needs to be accelerated to meet a construction schedule that cannot accommodate the required preload period, consideration may be given to alternative treatment methods. Surcharging the area and/or installing wick drains would increase the rate of settlement and, therefore, reduce the time required for treatment. Construction of the embankments with lightweight fill would reduce the applied load and, therefore, the anticipated total settlement of the embankments. The use of a limited thickness of lightweight fill in combination with a culvert camber could also be considered during detailed design.



11 CONSTRUCTION CONSIDERATIONS

11.1 Temporary Excavations

All temporary excavation must be conducted in accordance with the requirements of the Occupational Health & Safety Act & Regulations (OHSA) for Construction Projects. The existing fill containing organic material may be classified as a Type 4 soil. The native silty clay to clayey silt and silt sand materials may be classified as Type 3 soil above water level. **Side slopes for excavations through more than one soil type must be entirely based on the highest soil type number.**

Excavation should occur in a dewatered environment (see Section 11.3). Excavations must be planned and carried out in a manner that does not impact on the stability of existing roadway. The temporary cut slopes may have to be protected from precipitation and runoff to avoid surficial instabilities. The duration of temporary open excavations and cut slopes should be minimized to reduce the likelihood of causing instability concerns. Embankment and cut slope stability is the responsibility of the Contractor.

Excavation should be carried out in accordance OPSS.PROV 902, OPSS.PROV 421, and OPSS.PROV 422. The management and disposal of excess material shall be in accordance with OPSS.PROV 180. Excavations will extend through existing fills and into the underlying native soil deposits.

Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor. Material stockpiling is a temporary construction measure, and the associated stability implications are the responsibility of the Contractor. The selection and placement of construction equipment (such as cranes) and construction of temporary construction access roads are also the Contractor's responsibility. Placement of the crane or temporary stockpiling must not destabilize the embankment.

Although not anticipated, at locations where there are space restrictions or where a slope must be retained, the excavations will need to be carried out within a protection system. Further discussion on temporary protection systems (TPS) is presented in Section 11.2.

11.2 Temporary Protection Systems

Although not anticipated, Temporary Protection Systems (TPS) could be used for excavation support or groundwater control. They must be implemented in accordance with OPSS.PROV 539. Performance Level 2 (maximum 25 mm horizontal deflection) is considered appropriate where the protection supports an existing roadway. More stringent performance levels may be required if the protection system is intended to support existing structures or utilities. The pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall, and these factors must be considered when designing the shoring system.

Steel sheet piles are considered a suitable option for roadway protection for this site; however, the selection and design of protection systems are the responsibility of the Contractor. All protection systems should be designed by a licensed Professional Engineer experienced in such designs and retained by the Contractor. The design of the roadway protection system must incorporate traffic loading and surcharge loading due to construction equipment and operations. The lateral earth pressure coefficients and undrained strengths for the existing soils are given in Table 11-1 for a vertical wall and a horizontal backslope. Unit weights provided herein are to be adjusted for applications below the groundwater level. Unbalanced hydrostatic pressures should be considered in the design of the protection systems.

Table 11-1: Static Earth Pressure Coefficients for Existing Soils

Material	Unit Weight^(*) (kN/m³)	K_A	K_P	K₀	S_u (kPa)
Existing Granular Fills	20	0.33	3.00	0.50	-
Native Cohesive Clayey Silt	17.5	-	-	-	75
Native Silty Sand with Gravel (Till)	21	0.27	3.69	0.43	-

Note: () to be adjusted when below water level*

It is recommended that the protection systems within 3 m from the edges of the culvert should be left in place and cut off in accordance with OPSS.PROV 539. When designing roadway protection systems, the Contractor should consider the potential for obstructions such as cobbles and boulders in existing embankment. Although not encountered in the on-road boreholes at this site, cobbles and boulders have been noted in embankment fill and rockfill embankments have been noted along Highway 17 within the project limits. Suggested wording for an NSSP for obstructions is included in Appendix H.

11.3 Surface and Groundwater Control

Culvert subgrade preparation and placement and compaction of granular bedding/pads and culvert placement must be carried out in the dry. The Contractor must control groundwater, perched groundwater and surface water flow at the site with a flow passage system and a dewatering system to permit construction in a dry and stable excavation.

It is noted that a tile drain from the adjacent farm field is present near the toe of the slope near the existing culvert outlet. Furthermore, it is understood that there have been reported issues with drainage of the pavement structure near this location. Additional pavement investigation was completed in as part of Change Order 6 and is documented in a Supplemental Pavement document. These observations should be considered in designing the flow passage and dewatering systems.



The temporary flow diversion pipe should be placed outside the construction area. The design of flow passage systems is the responsibility of the Contractor. Given the site conditions and anticipated works, the Designer Fill-In (Note 2) in SP 517F01 Table 1 for flow passage systems should be “No; the design Engineer and design-checking Engineer do not need a minimum of 5 years of experience in designing similar flow passage systems.

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 517F01 which amends OPSS.PROV 517. The contractor's design should include an assessment of any adverse effects the dewatering method, construction layout and staging may have on adjacent structures, utilities and facilities. Given the site conditions (potential for bottom heave from underlying sand seams in the silt and clay) and anticipated works (excavating to approximately 1.4 m below groundwater level), the Designer Fill-In (Note 2) in SP 517F01 Table 1 should be “Yes” for dewatering systems; the design Engineer and design-checking Engineer need a minimum of 5 years of experience in designing similar dewatering systems. A preconstruction survey is not recommended; thus, Designer Fill-In Note 4 in this SP should be “N/A”. Based on the groundwater elevation at the time of the investigation, it is anticipated that the site will require dewatering to lower the groundwater to below the final excavation or footing level; Note 5 of SP 517F01 Table 1 should be 0.5 m but will need to be a minimum of 0.5 m below the underside of the planned excavation base prior to each stage of excavation.

The water level will fluctuate and the minimum design groundwater elevation for the site at the time of the excavation should be no lower than the highwater level in the creek generated by the return period flow estimates defined in SP 517F01.

The dewatering plan should be coordinated with TPS design, if needed. The dewatering system will be required to remain operational and effective until the temporary excavations are backfilled and then should be decommissioned and removed. It is anticipated that sump pumps will likely be sufficient to extract water from the excavation for the culverts. Pumping from within a sandbag cofferdam system is one option. More than one pump may be required. A sheet pile cofferdam enclosure driven into the foundation clayey silt may also be considered.

Further assessment of dewatering requirements and the need for registration on the Environmental Activity and Sector Registry (EASR) or a Permit to take Water (PTTW) should be carried out by specialists experienced in this field.

Please refer to Hydrogeological Investigation and Design Report for additional discussion on dewatering with respect to this assignment.

11.4 Erosion and Scour Control

The Contractor should provide silt fences and erosion control blankets as per OPSS.PROV 805 and OPSD 219.110 throughout the duration of construction to prevent transport of silt/sediment.



Particle size analysis on samples of the existing native materials indicate that the soils have a low to medium potential for soil erodibility (Wischmeier Nomograph factor, K).

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the new embankment slopes. A vegetation cover should be established on exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 803 and OPSS.PROV 804. Slope vegetation should be established as soon as possible after completion of construction in order to limit surficial erosion and water should be prevented from running down an unprotected slope.

Scour and erosion protection must be provided for the culvert inlet and outlet areas. Effective scour and erosion protection should be provided along the waterline and ditches. Design of the erosion protection measures must consider hydrologic and hydraulic factors and shall be carried out by specialists experienced in this field. Typically, rock protection should be provided over all earth surfaces subjected to flowing water in accordance with OPSS.PROV 511. Treatment at the outlet should be in accordance with OPSD 810.010.

Given the slopes proposed for the culvert inverts and to minimize the potential for piping and erosion around the inlets of the new culverts, a clay seal is recommended. The clay seal must extend to approximately 300 mm above the high water level and laterally for the width of the granular material, and have a minimum thickness of 500 mm. The material requirements should be in accordance with OPSS.PROV 1205. A geosynthetic clay liner could be considered for use as a clay seal.

Liaison between the Foundations Consultant, Structural Engineer and Hydraulic/Drainage Engineer will be required in design to ensure that scour protection, if required, is adequately addressed.

12 DESIGN AND CONSTRUCTION CONCERNS

The preliminary recommendations presented herein must be reassessed once the type, location, elevation, and orientation of the works are established.

The seismic hazard data considered for the preliminary design recommendations provided in this report were obtained from the fifth-generation seismic model developed by the Geological Survey of Canada (GSC). Additional seismic analyses will be required to reflect the reference seismic hazard available at the time of detailed design.

The DB Contractor must review the existing factual information and determine the extent of additional field investigations and laboratory testing required to support the foundation design of the proposed works. It is noted that drawings for the culverts are not available at the time of writing. The preliminary recommendations provided herein will need to be re-evaluated once the culvert details are confirmed.



The planned construction methodology includes open cut excavations for the installation of foundation elements of a new culverts. Potential construction concerns may include, but are not necessarily limited to:

- 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 culverts in the dry. Consideration must be given to the impact of the tile drain and pavement drainage issues observed near the existing culvert location during the design of the flow diversion and dewatering systems.
- Control of groundwater seepage during excavation.
- The clayey silt which will be exposed beneath the culvert bedding layers is sensitive and readily disturbed. A suggested Notice to Contractor is provided in Appendix H.
- The Contractor's selection of construction equipment and methodology must include assessment of the capability of the existing soils to support the proposed construction equipment and supplies.
- As per Geocres Report 31F-235, full height preloading (embankment pre-construction) applied for a duration of 24 months to reduce post-construction settlement is recommended for the new eastbound embankment in advance of installation of Culvert 10N. Temporary culvert(s) will need to be installed to facilitate drainage during the preload period. A settlement monitoring program should be incorporated into the construction to allow determination of the actual rate and magnitude of settlement and to determine the end of the treatment. Please refer to Geocres Report 31F-235 for additional information. Additional settlement is expected to occur over a post-construction settlement period of 20 years. This settlement must be accounted for in the design of Culvert 10N, either as a camber or by over-sizing to accommodate the anticipated settlement without compromising hydraulic capacity.
- It is anticipated that the construction of the new eastbound embankment will induce settlement beneath the existing embankment. The magnitude of the differential settlement at existing Culvert 10 will be affected by construction staging and methodology; the impacts of this movement and the need for mitigation measures will need to be assessed during the detailed design stage.

The successful performance of the structure installations will depend largely upon good workmanship and quality control during construction. Observation of the excavation and backfilling operations will be required as per OPSS.PROV 902 during construction to confirm that the foundation recommendations are correctly implemented, and material specifications are met.



13 CLOSURE

Engineering analysis and preparation of this report was carried out by D. Amorim Pereira, Geotechnical Technician. The report was reviewed by Dr. F. Griffiths, P.Eng., and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundation Projects.

Thurber Engineering Ltd.
Report Prepared By:

Darlan Amorim Pereira, M.Sc.
Geotechnical Technician



Dr. Fred Griffiths, P.Eng.
Principal, Senior Geotechnical Engineer

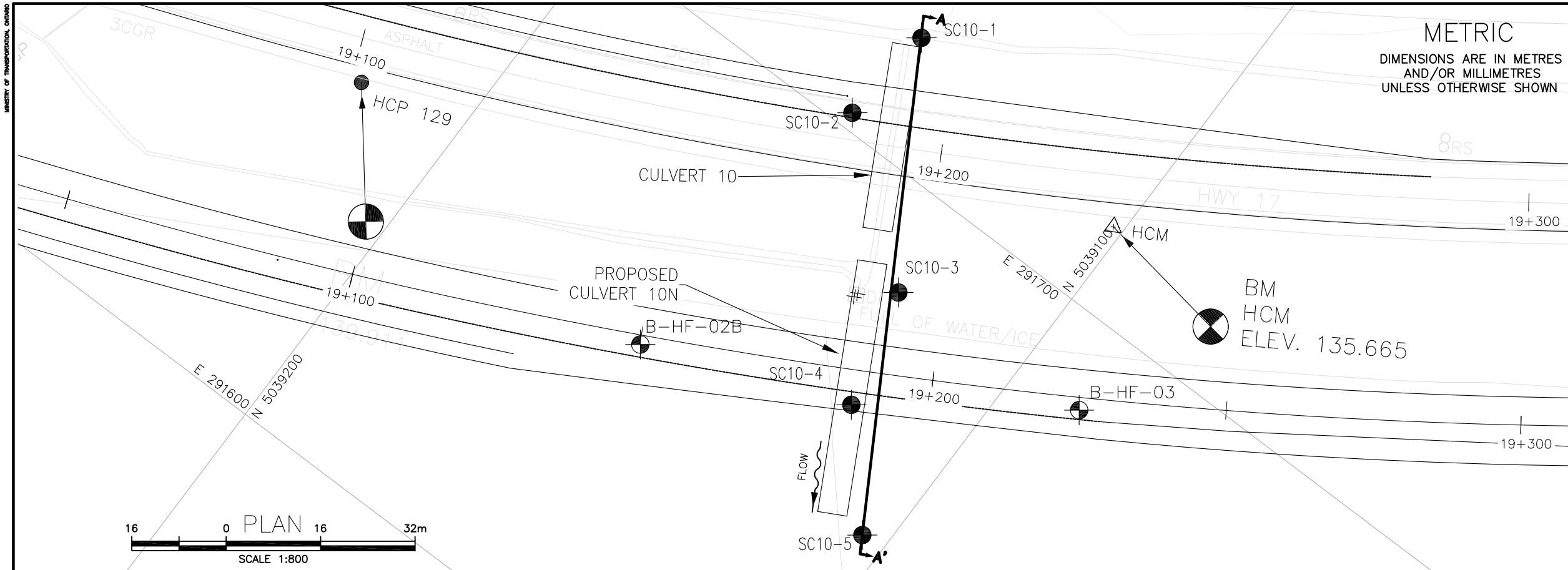


Dr. P.K. Chatterji, P.Eng.
Designated Principal Contact,
Principal, Senior Geotechnical Engineer



Appendix A.

Borehole Location Plan and Stratigraphic Drawings



16 0 16 32m
SCALE 1:800

EXISTING EMBANKMENT

SILTY SAND FILL
With Clay and Gravel
Compact

CULVERT 10

PROPOSED EMBANKMENT

PROPOSED CULVERT 10N

SILTY CLAY (CI)
Contains Sand Seams
Very Stiff to Stiff

CLAYEY SILT (CL)
Contains Sand Partings and Seams
Very Stiff to Stiff



SECTION A-A'

16 0 16 32m
4 0 4 8m
H 1:800
V 1:200

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

CONT No
GWP No 4068-09-00

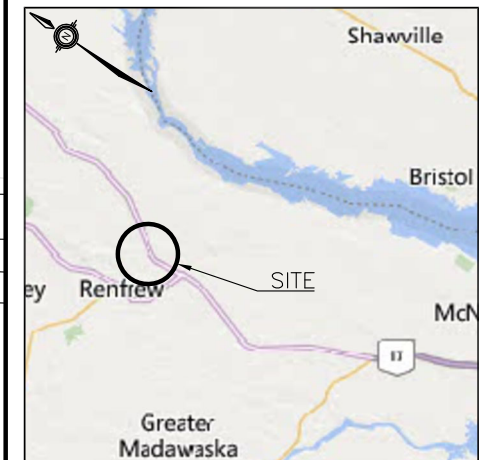
HIGHWAY 17 TWINNING
STATION 19+200, HORTON TWP.
CULVERT 10/10N
BOREHOLE LOCATION PLAN AND SOIL STRATA



SHEET
1

Ontario

THURBER



KEYPLAN

LEGEND

●	Borehole
⊙	Historic Borehole/Cone Penetration Test
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level Upon Completion of Drilling
▼	Water Level in Monitoring Well/Piezometer
—	Monitoring Well/Piezometer Screen
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

(GEOCRES 31F-235)
(GEOCRES 31F-235)

NO	ELEVATION	NORTHING	EASTING
SC10-1	132.6	5 039 147.0	291 720.0
SC10-2	137.3	5 039 148.7	291 702.8
SC10-3	132.2	5 039 124.1	291 683.2
SC10-4	130.2	5 039 119.0	291 663.2
SC10-5	129.7	5 039 104.2	291 646.7
B-HF-03	129.9	5 039 087.7	291 685.7
B-HF-02B	130.5	5 039 153.7	291 649.8

-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.
- Coordinate system is MTM NAD 83 Zone 9.

GEOCRES No. 31F07-005

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	AO	CHK	—
DRAWN	RH	CHK	FG
		CODE	
		LOAD	
		DATE	NOV 2024
		SITE	
		STRUCT	
		DWG	1



Appendix B.

Record of Borehole Sheets CPT Summary Sheets (ConeTec Investigations Ltd.)



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

RECORD OF BOREHOLE No SC10-1

1 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.492124°, Long: -76.667346°
Culvert 10/10N; Horton Township; MTM z9: N 5 039 147.0 E 291 720.0 ORIGINATED BY IK
HWY 17 BOREHOLE TYPE Portable Drilling / Tricone / NW Casing / NQ Coring COMPILED BY IK
DATUM Geodetic DATE 2024.03.21 - 2024.03.21 CHECKED BY JG

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 ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)			
132.6	Ground Surface							20 40 60 80 100		W _P W W _L			
0.0	SILTY CLAYEY SAND with gravel contains organics compact dark brown to brown FILL		1	SS	10			○ UNCONFINED + FIELD VANE					
131.7			2	SS	12			● QUICK TRIAXIAL × LAB VANE					0 30 44 26
0.9	SILTY CLAY (CI), trace sand very stiff brown												
			3	SS	14								
			4	SS	17								
			5	SS	10								
			6	SS	4								0 1 44 55
			7	SS	5								
			8	SS	7								
			9	SS	5								
122.8													
9.8	CLAYEY SILT (CL), trace sand												

Continued Next Page

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

RECORD OF BOREHOLE No SC10-1 2 OF 2 METRIC

WP# 4068-09-00 LOCATION Lat: 45.492124°, Long: -76.667346° Culvert 10/10N; Horton Township; MTM z9: N 5 039 147.0 E 291 720.0 ORIGINATED BY IK
HWY 17 BOREHOLE TYPE Portable Drilling / Tricone / NW Casing / NQ Coring COMPILED BY IK
DATUM Geodetic DATE 2024.03.21 - 2024.03.21 CHECKED BY JG

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 γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
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						
122.2	CLAYEY SILT (CL), trace sand very stiff brown		10	SS	26												GR SA SI CL 0 6 73 21	
10.4	End of Borehole Monitoring Well installed: Schedule 40 PVC standpipe with 50-mm diameter and 3.0-m slotted screen. Stick-up cover installed at ground surface. Water Level Readings: DATE DEPTH (m) ELEV. (m) 2024/03/22 1.1 131.5 2024/04/09 0.5 132.1 2024/04/26 0.8 131.8 2024/06/26 1.1 131.5 2024/06/28 1.3 131.3 2024/08/30 2.5 130.1 Note: Full-weight hammer was used to advance the split-spoons.																	

RECORD OF BOREHOLE No SC10-2

1 OF 3

METRIC

WP# 4068-09-00 LOCATION Lat: 45.492139°, Long: -76.667566°
Culvert 10/10N; Horton Township; MTM z9: N 5 039 148.7 E 291 702.8 ORIGINATED BY DAP
HWY 17 BOREHOLE TYPE CME 55 Truckmount / HSA / NW Casing COMPILED BY IK
DATUM Geodetic DATE 2024.03.21 - 2024.03.21 CHECKED BY JG

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 ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL		
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE												
137.3	Asphalt Surface							20	40	60	80	100	20	40	60						
0.0	ASPHALT (50 mm)																				
	SILTY SAND, some gravel very dense to very loose yellowish brown to grey FILL		1	SS	56								○								
			2	SS	45								○								
			3	SS	43								○					12	72	16 (SI+CL)	
			4	SS	100/ 75 mm								○								
			5	SS	17								○								
			6	SS	19								○								
			7	SS	2								○						11	70	19 (SI+CL)
132.0	SILTY CLAY (CI) very stiff brown																				
5.3			8	SS	8									○							
			9	SS	11									○							
			10	SS	9									○							
			11	SS	9									○							
			12	SS	7									○							
			13	SS	5									○							
																	</				

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No SC10-2

2 OF 3

METRIC

WP# 4068-09-00 LOCATION Lat: 45.492139°, Long: -76.667566°
Culvert 10/10N; Horton Township; MTM z9: N 5 039 148.7 E 291 702.8 ORIGINATED BY DAP
HWY 17 BOREHOLE TYPE CME 55 Truckmount / HSA / NW Casing COMPILED BY IK
DATUM Geodetic DATE 2024.03.21 - 2024.03.21 CHECKED BY JG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L		
	Continued From Previous Page							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	WATER CONTENT (%)				
	SILTY CLAY (CI) very stiff brown		14	SS	5		127	> 118 kPa					
							126	> 118 kPa					
			15	SS	3		125	> 118 kPa					
			16	SS	6		124	> 118 kPa					
			17	SS	7		123						
			18	SS	6		122						
			19	SS	7		121						
120.5							120						
16.8	CLAYEY SILT (CL) very stiff brown						119						
							118						

Continued Next Page

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

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No SC10-3

1 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.491917°, Long: -76.667817°
Culvert 10/10N; Horton Township; MTM z9: N 5 039 124.1 E 291 683.2 ORIGINATED BY RH
HWY 17 BOREHOLE TYPE Portable Drilling / Tricone / NW Casing / NQ Coring COMPILED BY RH
DATUM Geodetic DATE 2024.04.15 - 2024.04.15 CHECKED BY JG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)								
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT w _p w w _L WATER CONTENT (%)							
132.2	Ground Surface							20	40	60	80	100								
0.0	SILT CLAYEY SAND very loose brown FILL		1	SS	2		132													
131.4																				
0.8	SANDY CLAYEY SILT stiff grey FILL		2	SS	8		131													0 25 41 34
130.7																				
1.5	SILTY CLAY (CI) very stiff to stiff grey		3	SS	20		130													
			4	SS	16															
			5	SS	12		129													
			6	SS	8		128													0 1 43 56
			7	SS	11		127													
			8	SS	15															
							126													
			9	SS	6		125													
							124													
			10	SS	4															0 0 48 52
							123													

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10


(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No SC10-3

2 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.491917°, Long: -76.667817°
Culvert 10/10N; Horton Township; MTM z9: N 5 039 124.1 E 291 683.2 ORIGINATED BY RH
HWY 17 BOREHOLE TYPE Portable Drilling / Tricone / NW Casing / NQ Coring COMPILED BY RH
DATUM Geodetic DATE 2024.04.15 - 2024.04.15 CHECKED BY JG

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 ³	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	
120.2 12.0	SILTY CLAY (CI) stiff grey		11	SS	8		122										
			12	SS	4		121										
	End of Borehole																
	Note: Full-weight hammer was used to advance the split-spoons.																

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

RECORD OF BOREHOLE No SC10-4

1 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.491871°, Long: -76.668073°
Culvert 10/10N; Horton Township; MTM z9: N 5 039 119.0 E 291 663.2 ORIGINATED BY BC
HWY 17 BOREHOLE TYPE CME 75 Trackmount / HSA / NW Casing COMPILED BY IK
DATUM Geodetic DATE 2024.04.04 - 2024.04.04 CHECKED BY JG

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 ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)					
								○ UNCONFINED + FIELD VANE	w _p w w _L						
							● QUICK TRIAXIAL × LAB VANE								
130.2	Ground Surface						20 40 60 80 100	20 40 60							
0.0	SILTY CLAY (CI) contains sand partings very stiff brown WEATHERED CRUST		1	SS	10										
			2	SS	8										
			3	SS	8										
			4	SS	7										
			5	SS	4										
			6	SS	4										

Continued Next Page

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

DOUBLE LINE CULVERT 10 GINT LOGS.GPJ 2012TEMPLATE(MTO).GDT 12-17-24

METRIC

[illegible]

DOUBLE LINE CULVERT 10 GINT LOGS.GPJ 2012TEMPLATE(MTO).GDT 12-17-24

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No SC10-5

1 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.491737°, Long: -76.668284°
Culvert 10/10N; Horton Township; MTM z9: N 5 039 104.2 E 291 646.7 ORIGINATED BY BC
HWY 17 BOREHOLE TYPE CME 75 Trackmount / HSA / NW Casing COMPILED BY IK
DATUM Geodetic DATE 2024.04.05 - 2024.04.08 CHECKED BY JG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
129.7	Ground Surface							20 40 60 80 100					
0.0	SILTY CLAY (CI) , trace sand very stiff brown not varved to varved WEATHERED CRUST		1	SS	10								0 8 49 43
			2	SS	10								
			3	SS	8								
			4	SS	5								
			5	SS	4								0 1 45 54
		6	SS	1									

Continued Next Page



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

RECORD OF BOREHOLE No SC10-5

2 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.491737°, Long: -76.668284°
Culvert 10/10N; Horton Township; MTM z9: N 5 039 104.2 E 291 646.7 ORIGINATED BY BC
HWY 17 BOREHOLE TYPE CME 75 Trackmount / HSA / NW Casing COMPILED BY IK
DATUM Geodetic DATE 2024.04.05 - 2024.04.08 CHECKED BY JG

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 γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)	
	Continued From Previous Page							20	40	60	80	100							
	CLAYEY SILT (CL) contains sand partings and seams stiff to very stiff grey																		
			9	SS	WH		119												
							118												
			10	SS	WH		117												
116.1																			
13.6	End of Borehole																		
	Monitoring Well installed: Schedule 40 PVC standpipe with 50-mm diameter and 3.0-m slotted screen. Stick-up cover installed at ground surface. Water Level Readings: DATE DEPTH (m) ELEV. (m) 2024/04/09 0.9 128.8 2024/04/24 0.9 128.8 2024/06/28 1.2 128.5 2024/07/16 1.2 128.5 2024/08/30 2.0 127.7																		

RECORD OF BOREHOLE No B-HF-03

1 OF 3

METRIC

WP# 4068-09-00 LOCATION Lat: 45.491591°, Long: -76.667784°
High Falls; MTM Zone 9: N 5 039 087.7 E 291 685.7 ORIGINATED BY RH/BC
HWY 17 BOREHOLE TYPE CME 850 Trackmount / HSA / HQ Casing COMPILED BY AO
DATUM Geodetic DATE 2021.08.30 - 2021.08.31 CHECKED BY JG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
129.9	Ground Surface							20 40 60 80 100	20 40 60	W _P W W _L	kN/m ³	GR SA SI CL		
0.0	CLAY (CH) very stiff brown to grey-brown WEATHERED CRUST		1	SS	9			○ UNCONFINED + FIELD VANE						
			2	SS	11		129	● QUICK TRIAXIAL × LAB VANE				CH	0 1 41 58	
			3	SS	11		128							
			4	SS	8		127							
			5	SS	10		126					CH	0 1 45 54	
			6	SS	7		125							
			7	SS	8		124							
			8	SS	7		123							
			9	SS	5		122					CI	0 1 46 53	
			10	SS	6		121							
122.3			11	SS	6		120							
7.6	SILTY CLAY (CI) to CLAYEY SILT (CL-ML) occasional interbedded sand layers very stiff to stiff grey		12	SS	6									

Continued Next Page

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

RECORD OF BOREHOLE No B-HF-03

2 OF 3

METRIC



WP# 4068-09-00 LOCATION Lat: 45.491591°, Long: -76.667784°
High Fills; MTM Zone 9: N 5 039 087.7 E 291 685.7 ORIGINATED BY RH/BC
HWY 17 BOREHOLE TYPE CME 850 Trackmount / HSA / HQ Casing COMPILED BY AO
DATUM Geodetic DATE 2021.08.30 - 2021.08.31 CHECKED BY JG

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 γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)				GR
	Continued From Previous Page							20	40	60	80	100								
	SILTY CLAY (CI) to CLAYEY SILT (CL-ML) occasional interbedded sand layers very stiff to stiff grey -Su > 118 kPa -Su > 118 kPa -Su > 118 kPa		13	SS	7															
					14	SS	2													
					15	SS	3													
					16	SS	2													
			17	SS	2															
			18	SS	3															

Continued Next Page

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

METRIC

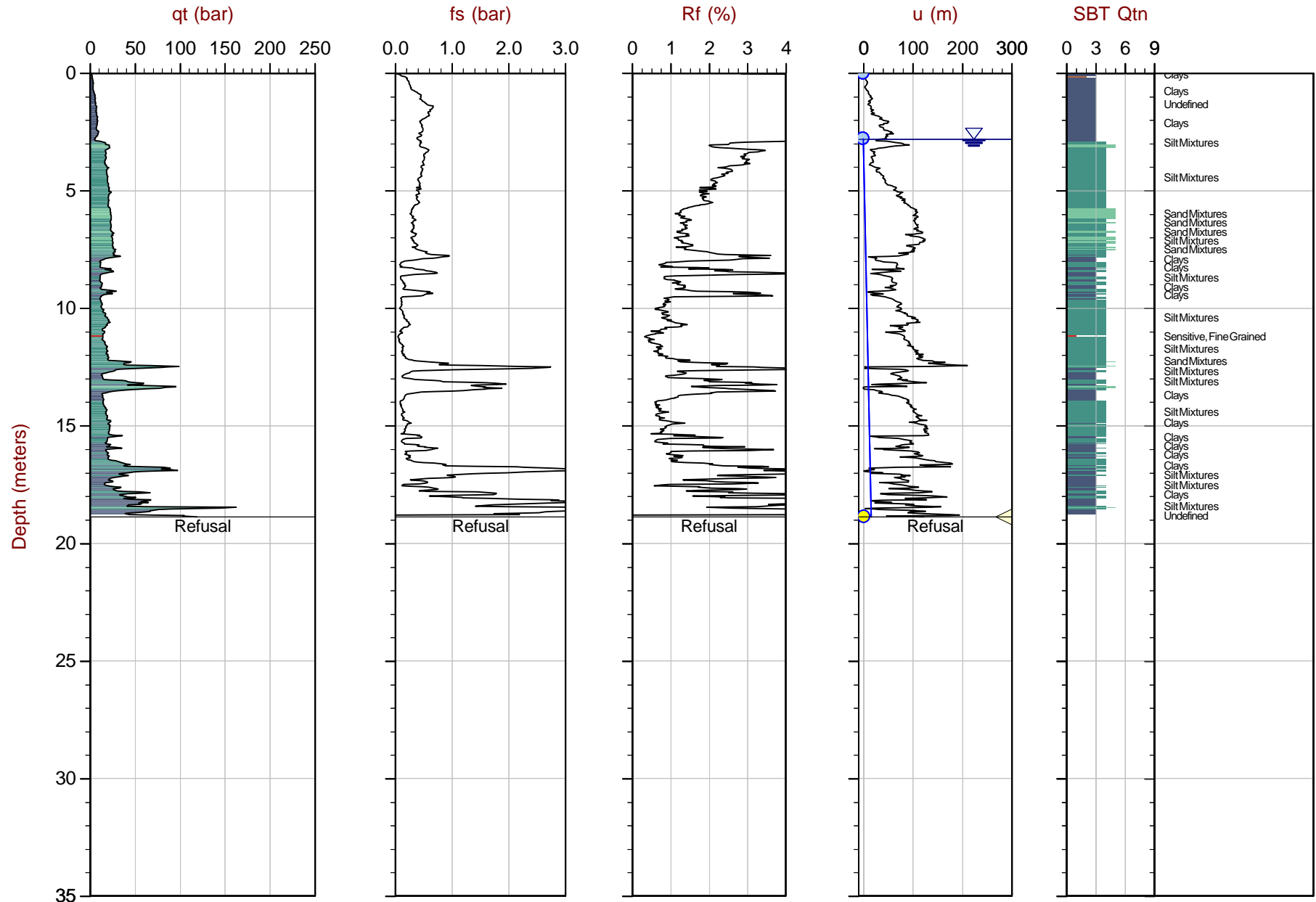
ELEV. DEPTH	SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						WATER CONTENT (%)
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE					
	Continued From Previous Page							20 40 60 80 100	20 40 60					

[illegible]

DOUBLE LINE CULVERT 10 GINT LOGS.GPJ 2012TEMPLATE(MTO).GDT 11-20-24

+³, ×³: Numbers refer to Sensitivity

Cone Penetration Test Summary and Standard Cone Penetration Test Plots



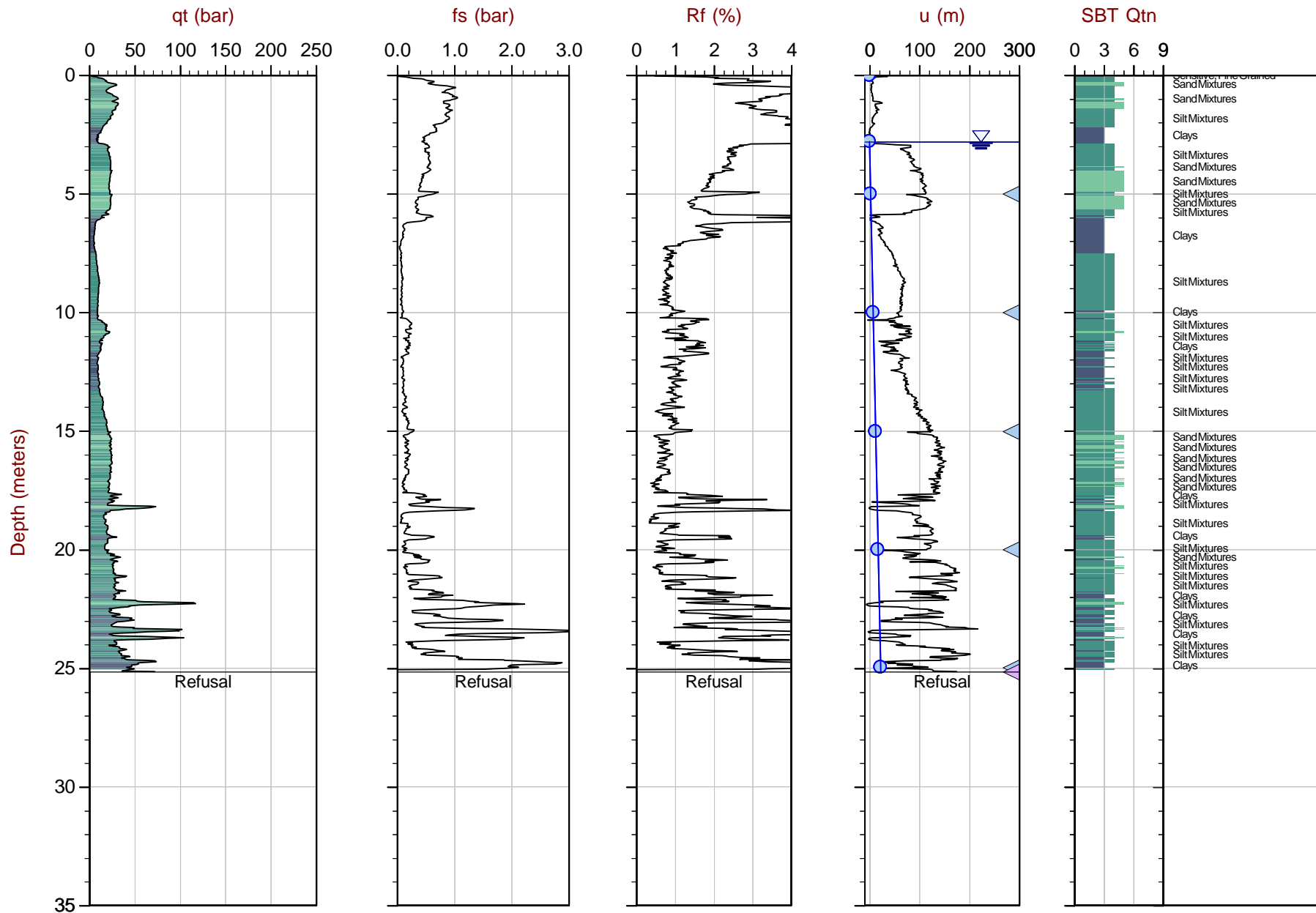
Max Depth: 18.875 m / 61.93 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 21-05-22576_CP-B-HF-2B.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM Zone 18 N: 5038985m E: 369648m
Page No: 1 of 1

Overplot Item:

- Assumed Ueq
- Ueq
- Dissipation, equilibrium achieved
- Dissipation, equilibrium assumed
- Hydrostatic Line
- Dissipation, equilibrium not achieved
- Equilibrium Profile

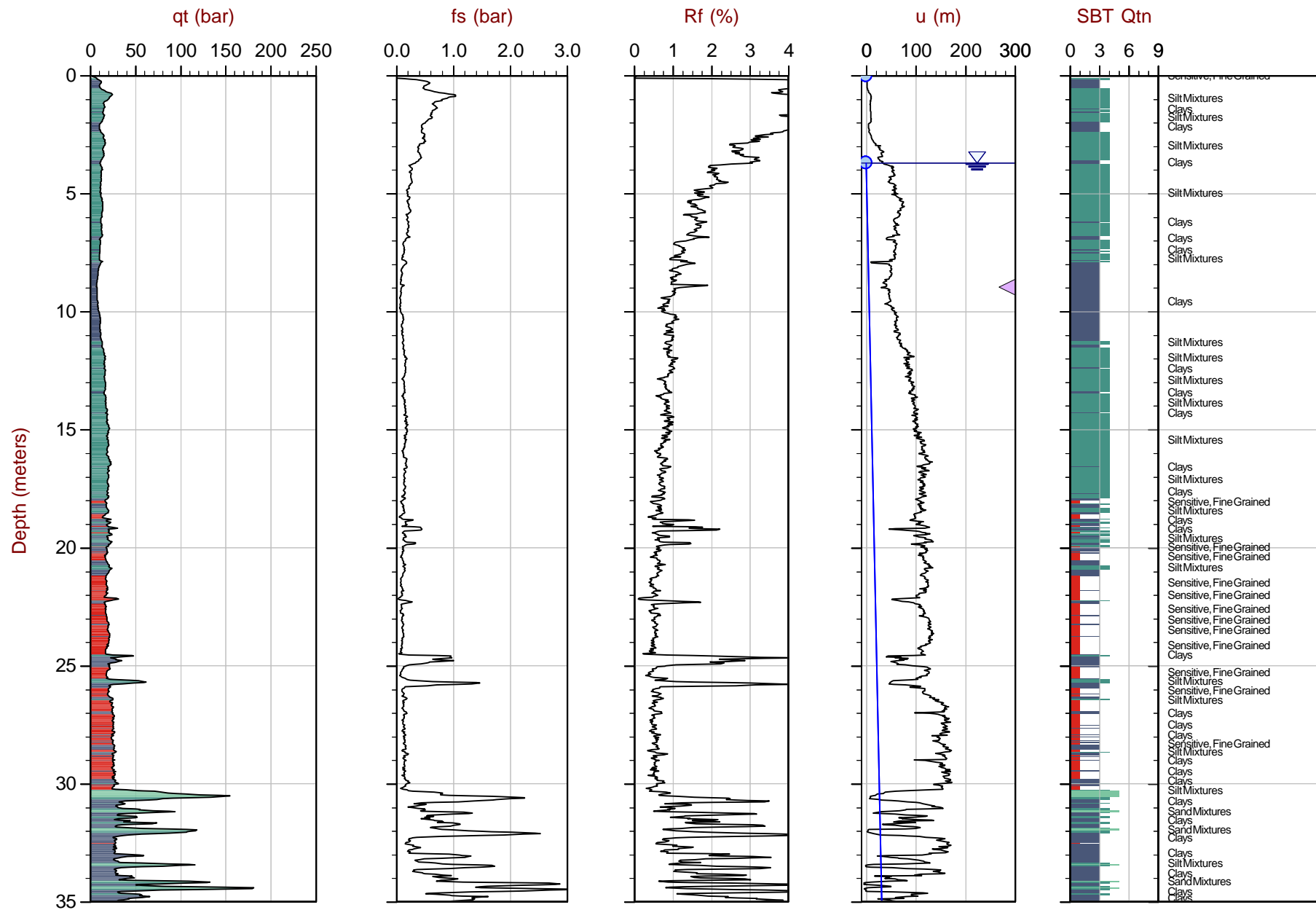


Max Depth: 25.150 m / 82.51 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 21-05-22576_SP-B-HF-5.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM Zone 18 N: 5038790m E: 369766m
Page No: 1 of 1

Overplot Item: ● Assumed Ueq ● Ueq ▲ Dissipation, equilibrium achieved ▲ Dissipation, equilibrium assumed — Hydrostatic Line — Equilibrium Profile ▲ Dissipation, equilibrium not achieved



Max Depth: 35.575 m / 116.71 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 21-05-22576_CP-B-HF-8.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
 Coords: UTM Zone 18 N: 5038619m E: 369949m
 Page No: 1 of 2

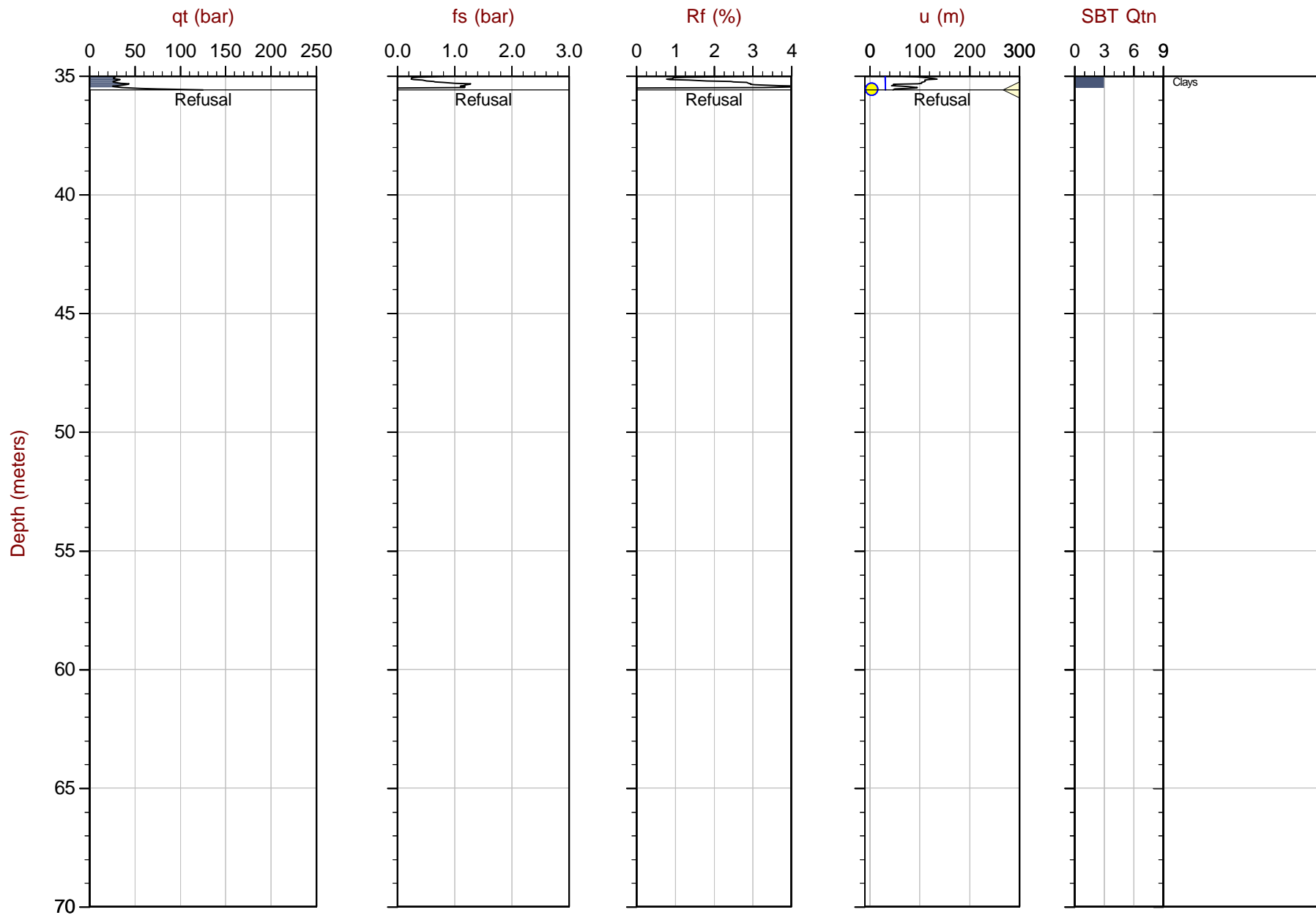
Overplot Item:

- Assumed U_{eq}
- U_{eq}

- ◀ Dissipation, equilibrium achieved
- ◀ Dissipation, equilibrium assumed

— Hydrostatic Line —
 ◀ Dissipation, equilibrium not achieved

- Equilibrium Profile



Max Depth: 35.575 m / 116.71 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 21-05-22576_CP-B-HF-8.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM Zone 18 N: 5038619m E: 369949m
Page No: 2 of 2

Overplot Item:

Assumed Ueq
Ueq

Dissipation, equilibrium achieved
Dissipation, equilibrium assumed

Hydrostatic Line
Dissipation, equilibrium not achieved

Equilibrium Profile

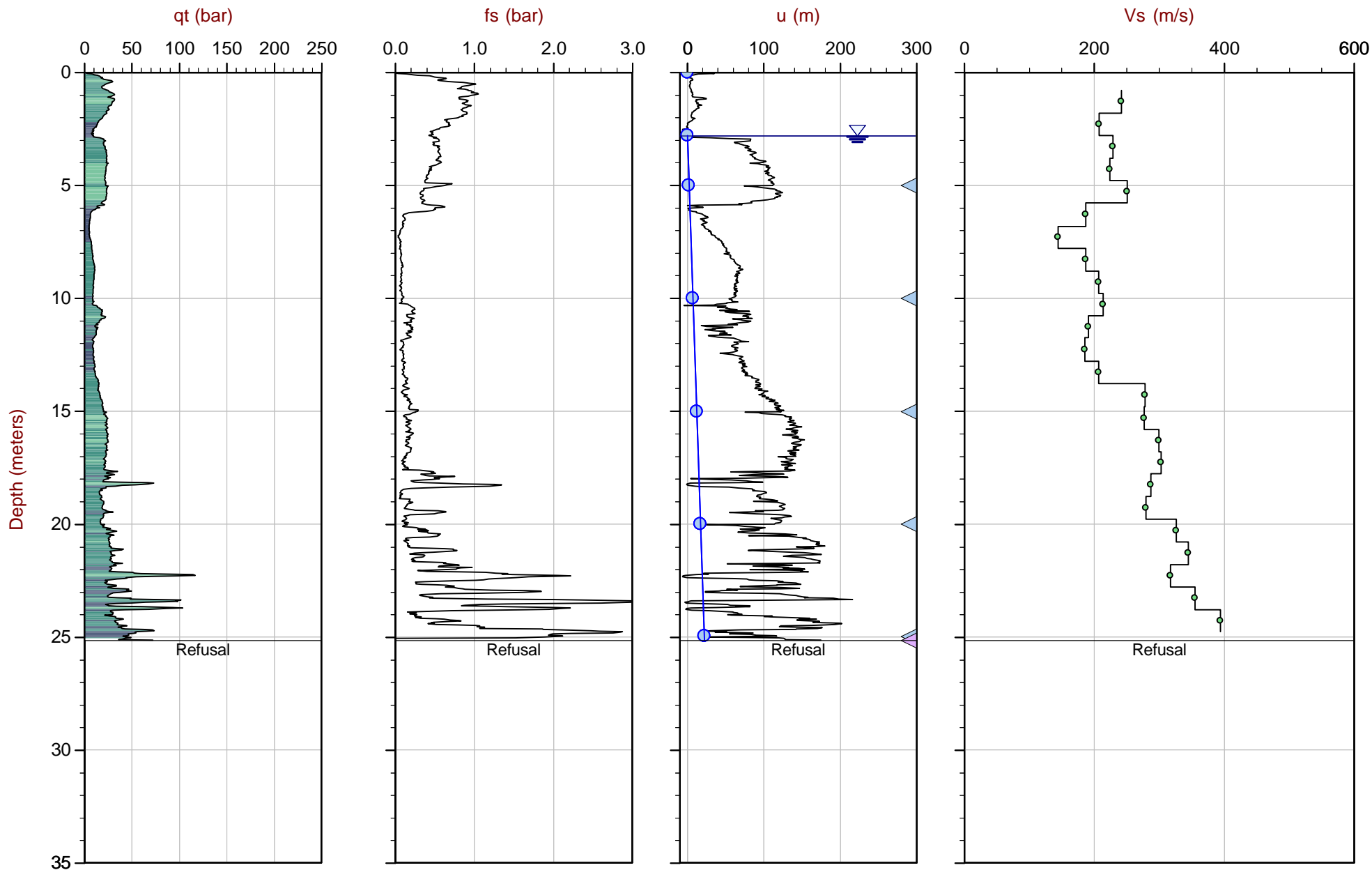
Seismic Cone Penetration Test Plots



Thurber Engineering

Job No: 21-05-22576
Date: 2021-08-05 09:15
Site: Renfrew Ontario

Sounding: B-HF-5
Cone: 609:T1500F15U35



Max Depth: 25.150 m / 82.51 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point
Overplot Item:

Assumed Ueq
Ueq

File: 21-05-22576_SP-B-HF-5.COR
Unit Wt: SBTQtn (PKR2009)

Dissipation, equilibrium achieved
Dissipation, equilibrium assumed

SBT: Robertson, 2009 and 2010
Coords: UTM Zone 18 N: 5038790m E: 369766m
Page No: 1 of 1

Hydrostatic Line
Dissipation, equilibrium not achieved
Equilibrium Profile



Appendix C.

Laboratory Testing



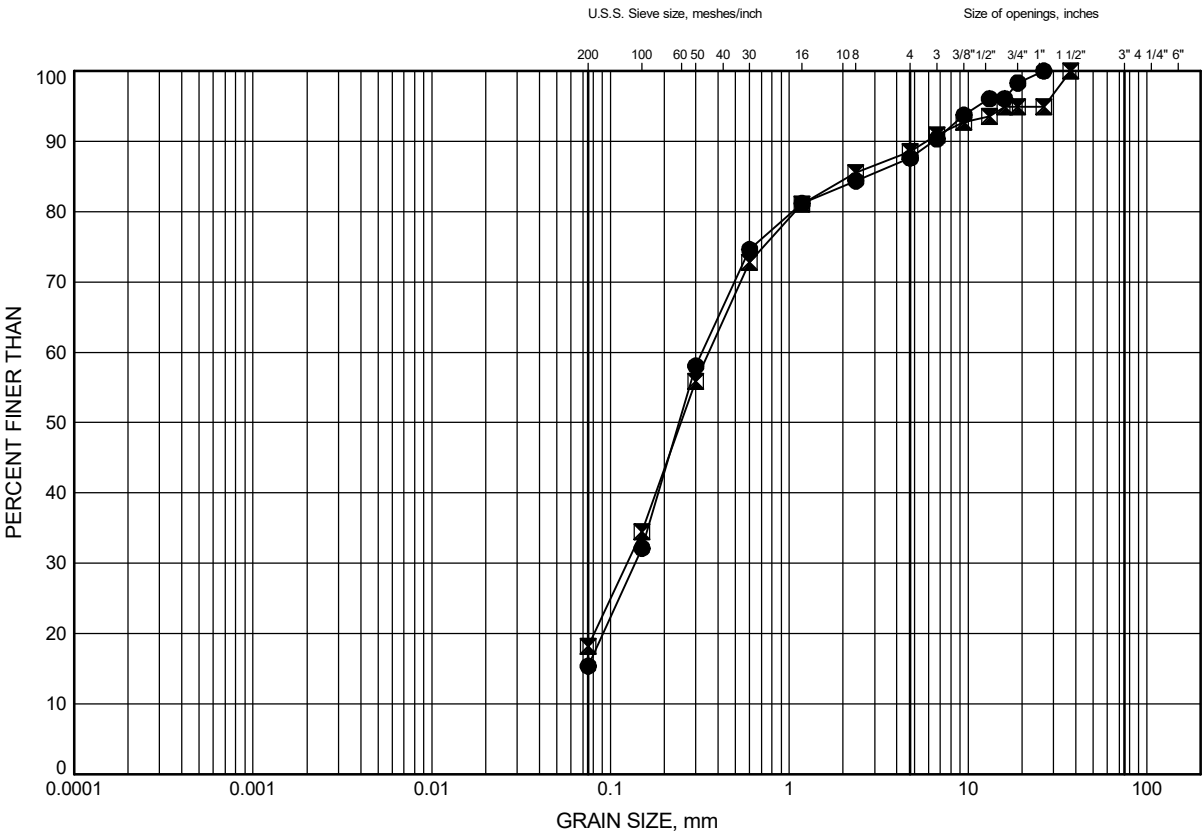
Appendix C.1
Particle Size Analysis Figures
Atterberg Limit Test Results
Consolidation Testing Results

Hwys 17

GRAIN SIZE DISTRIBUTION

FIGURE C1

FILL: Silty Sand some Gravel



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SC10-2	1.8	135.5
⊠	SC10-2	4.9	132.4

GRAIN SIZE DISTRIBUTION - THURBER CULVERT 10 GINT LOGS.GPJ 9-5-24

Date September 2024
GWP# 4018-E-0009



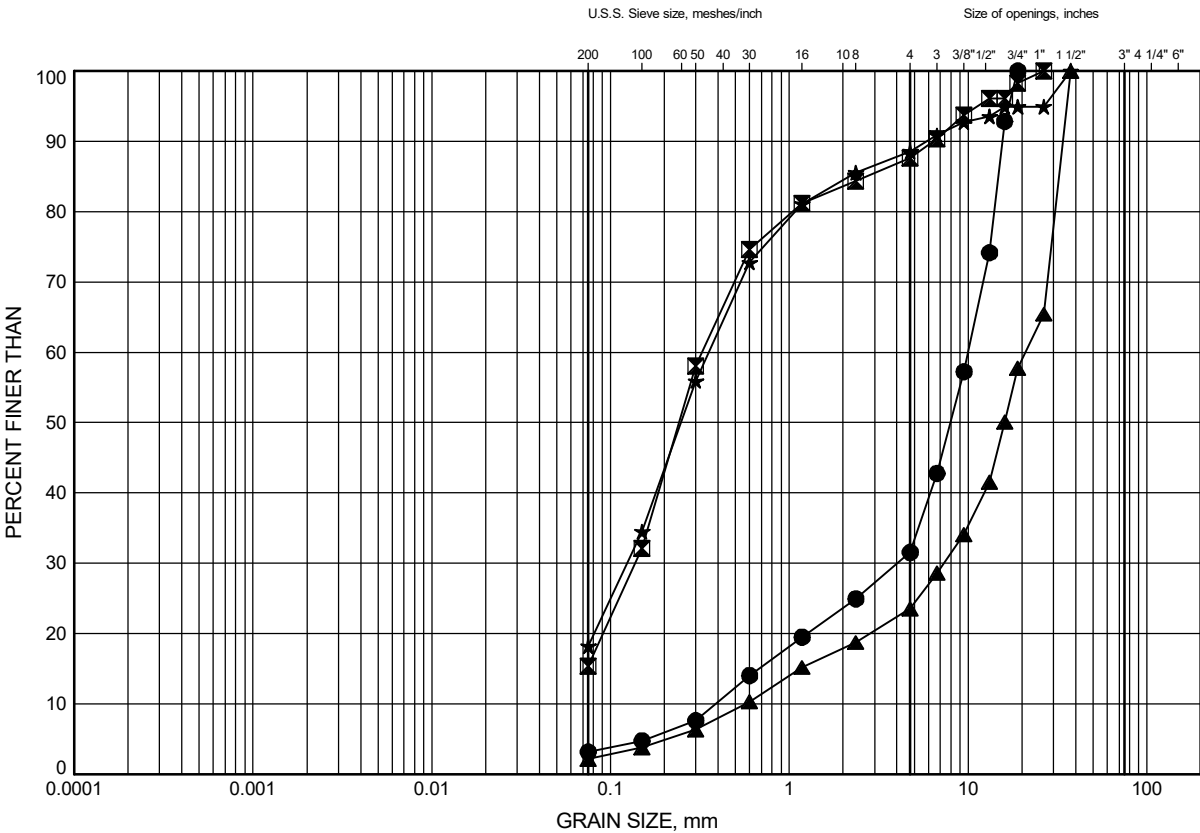
Prep'd RH
Chkd. MJK

Hwys 17

GRAIN SIZE DISTRIBUTION

FIGURE C1

FILL: Gravel with Sand to Silty Sand some Gravel



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SC 10-2	0.1	137.2
⊠	SC 10-2	1.8	135.5
▲	SC 10-2	3.5	133.8
★	SC 10-2	4.9	132.4

GRAIN SIZE DISTRIBUTION - THURBER CULVERT 10 GINT LOGS.GPJ 8-19-24

Date August 2024
GWP# 4018-E-0009



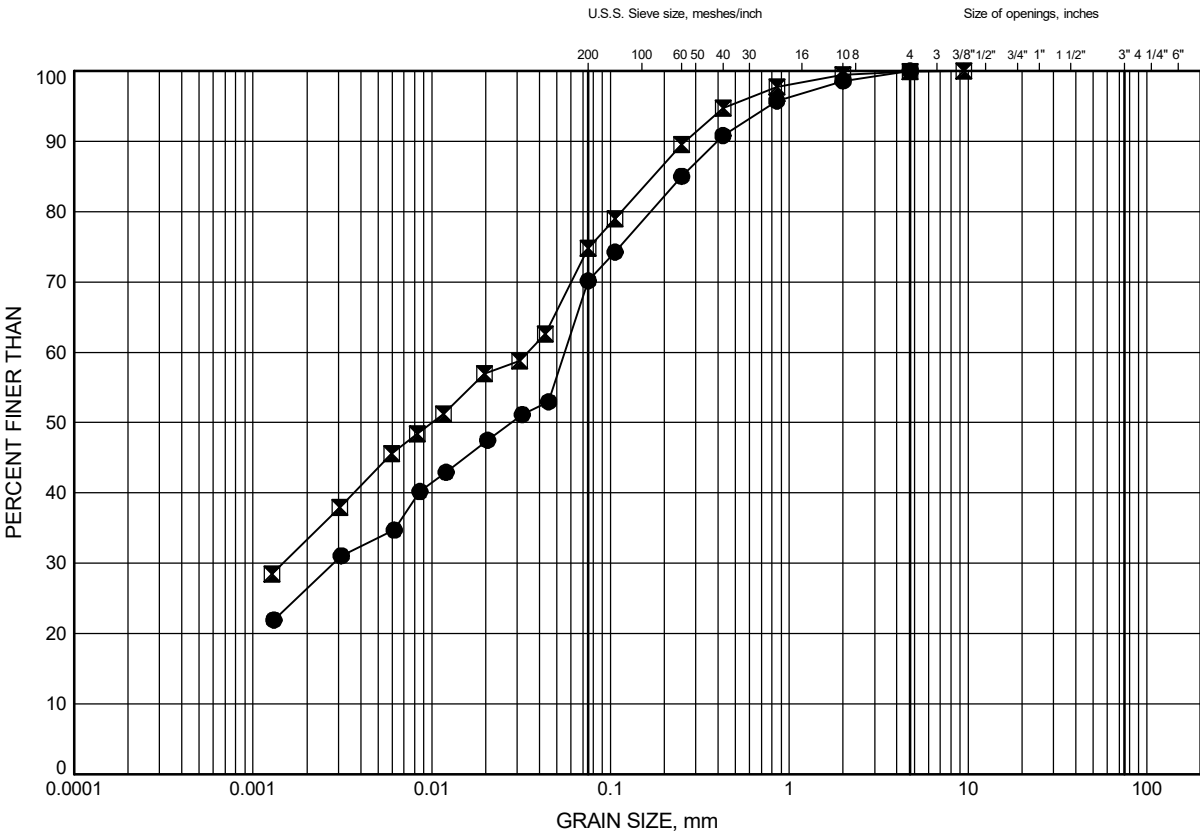
Prep'd RH
Chkd. JG

Hwys 17

GRAIN SIZE DISTRIBUTION

FIGURE C2

FILL: Silty Sand with Clay and Gravel



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SC 10-1	0.8	131.8
⊠	SC 10-3	0.9	131.3

GRAIN SIZE DISTRIBUTION - THURBER CULVERT 10 GINT LOGS.GPJ 8-19-24

Date August 2024
GWP# 4018-E-0009



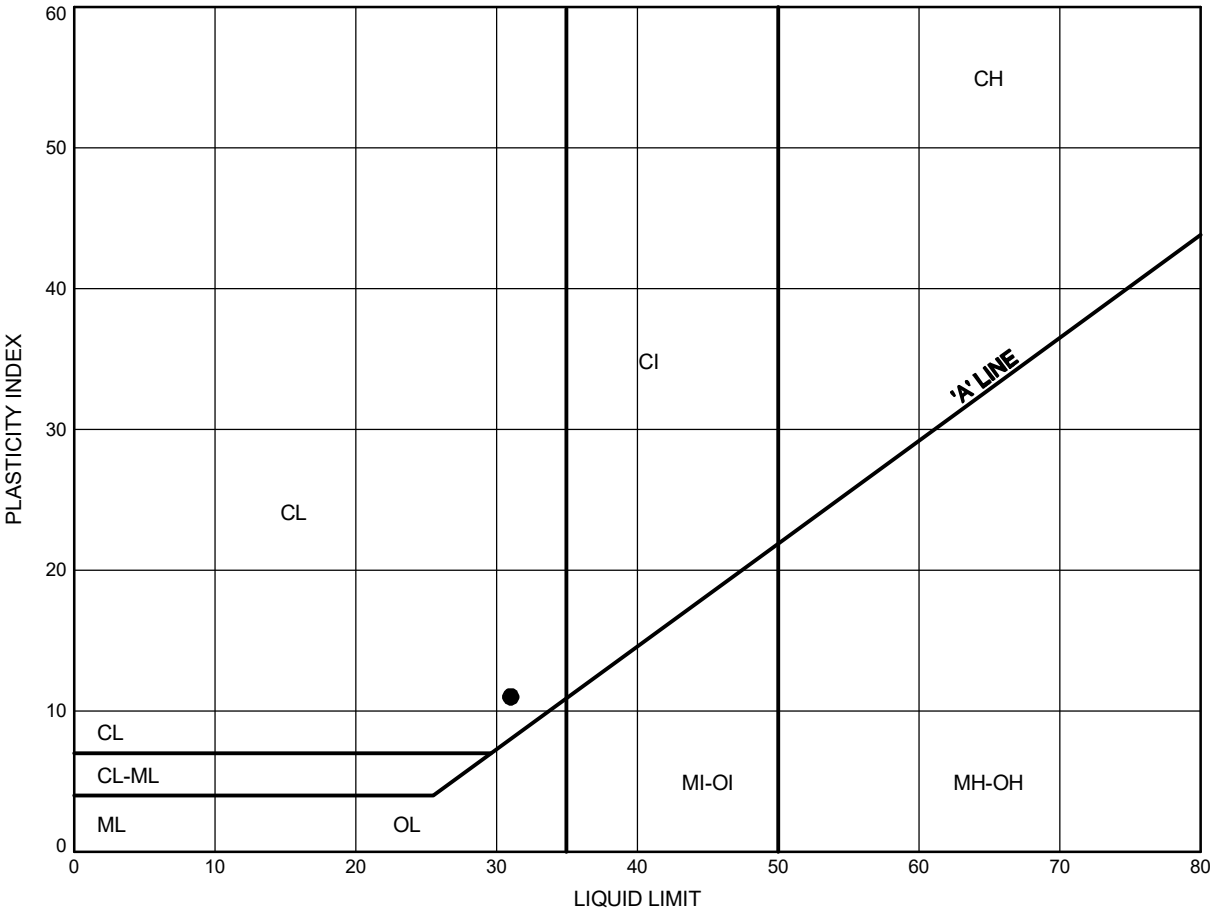
Prep'd RH
Chkd. JG

Hwys 17

ATTERBERG LIMITS TEST RESULTS

FIGURE C3

FILL: Silty Sand with Clay and Gravel



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SC 10-1	0.8	131.8

Date August 2024
GWP# 4018-E-0009



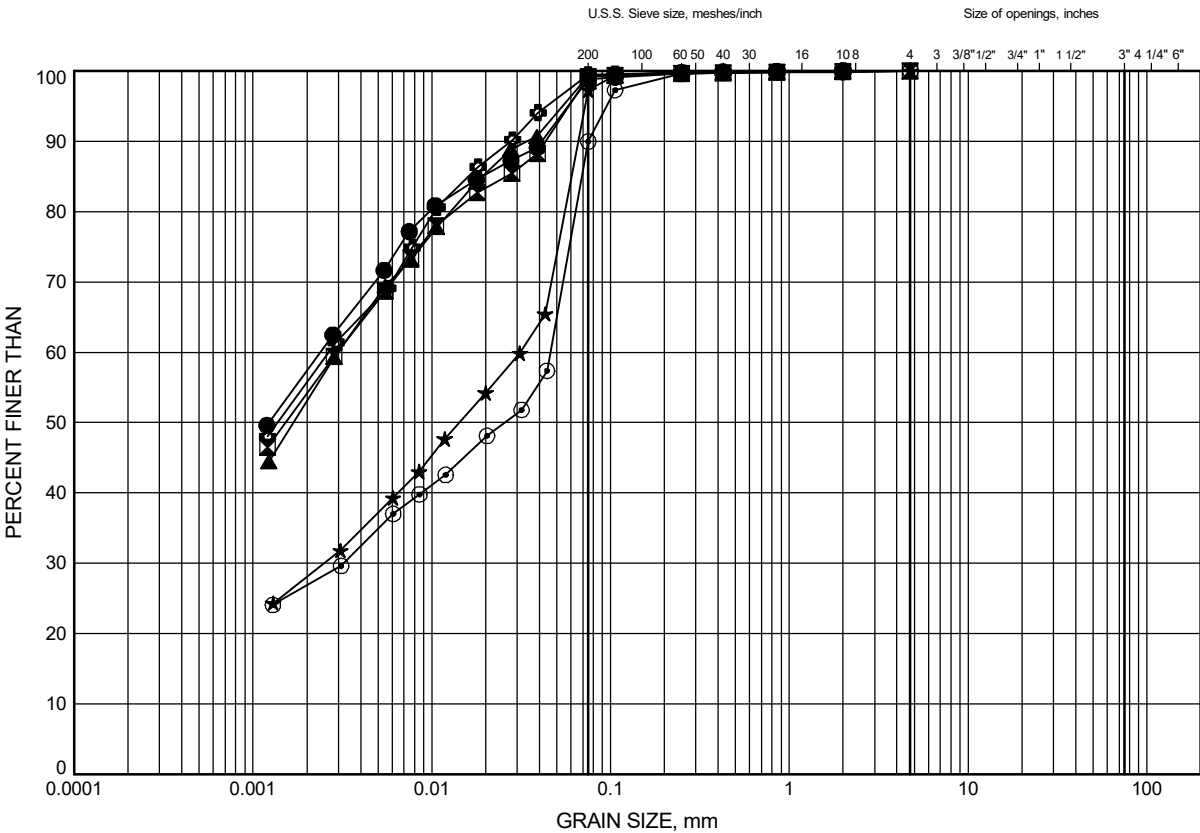
Prep'd RH
Chkd. JG

Hwys 17

GRAIN SIZE DISTRIBUTION

FIGURE C4

Clay to Silty Clay to Clayey Silt (CH to CI to CL/CL-ML)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	B-HF-03	1.1	128.8
⊠	B-HF-03	4.1	125.8
▲	B-HF-03	7.9	122.0
★	B-HF-03	14.0	115.9
⊙	B-HF-03	19.5	110.4
⊕	SC 10-1	4.9	127.7

GRAIN SIZE DISTRIBUTION - THURBER CULVERT 10 GINT LOGS.GPJ 8-19-24

Date August 2024
GWP# 4018-E-0009



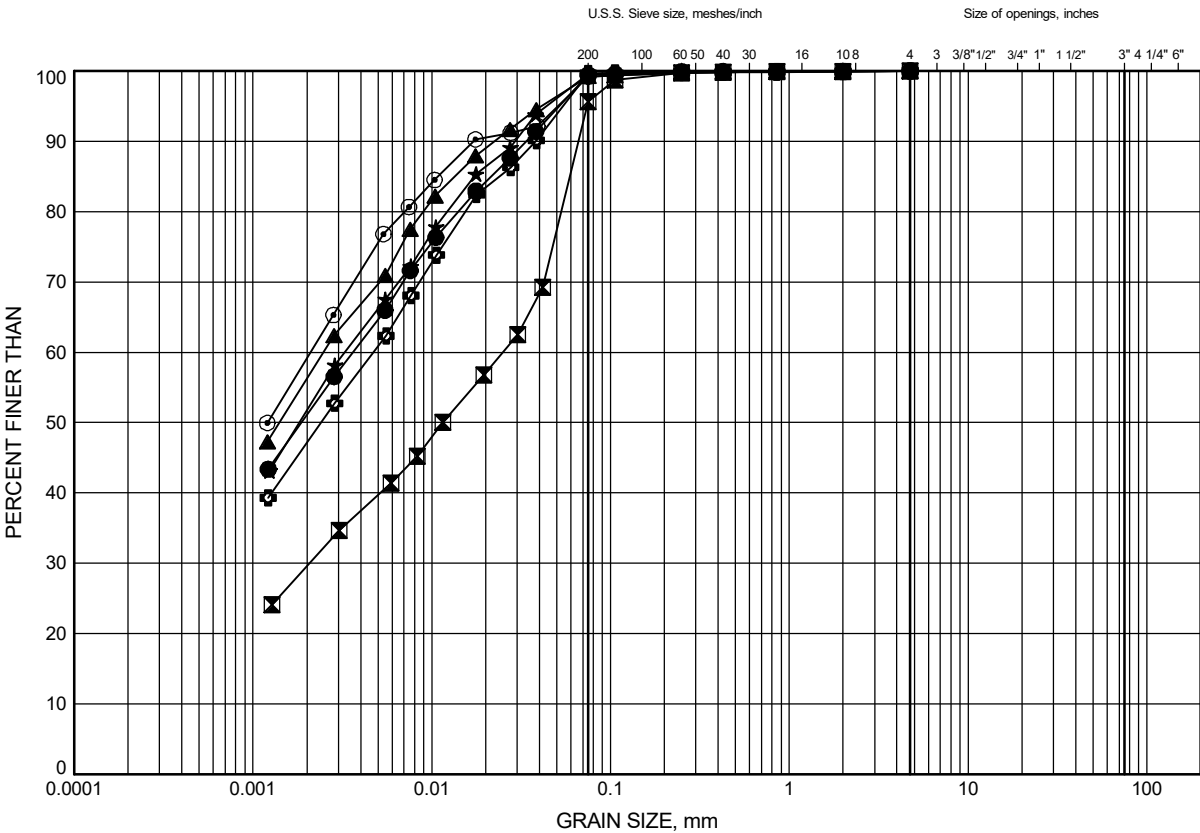
Prep'd RH
Chkd. JG

Hwys 17

GRAIN SIZE DISTRIBUTION

FIGURE C5

Clay to Silty Clay to Clayey Silt (CH to CI to CL/CL-ML)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SC 10-2	9.4	127.9
⊠	SC 10-2	17.1	120.2
▲	SC 10-3	4.1	128.1
★	SC 10-3	8.7	123.5
⊙	SC 10-4	1.8	128.4
⊕	SC 10-4	6.4	123.8

Date August 2024

GWP# 4018-E-0009



Prep'd RH

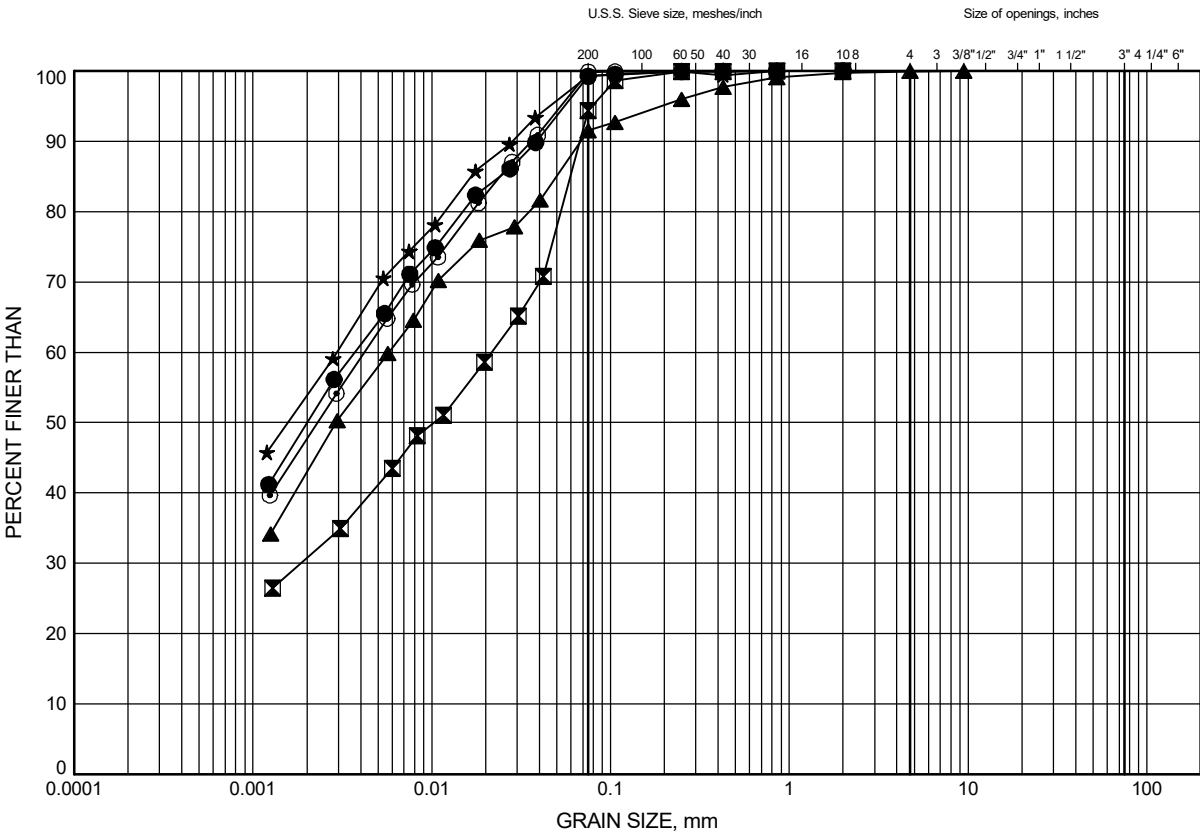
Chkd. JG

Hwys 17

GRAIN SIZE DISTRIBUTION

FIGURE C6

Clay to Silty Clay to Clayey Silt (CH to CI to CL/CL-ML)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SC 10-4	9.4	120.8
⊠	SC 10-4	12.5	117.7
▲	SC 10-5	0.3	129.4
★	SC 10-5	4.9	124.8
⊙	SC 10-5	7.9	121.8

GRAIN SIZE DISTRIBUTION - THURBER CULVERT 10 GINT LOGS.GPJ 8-19-24

Date August 2024
GWP# 4018-E-0009



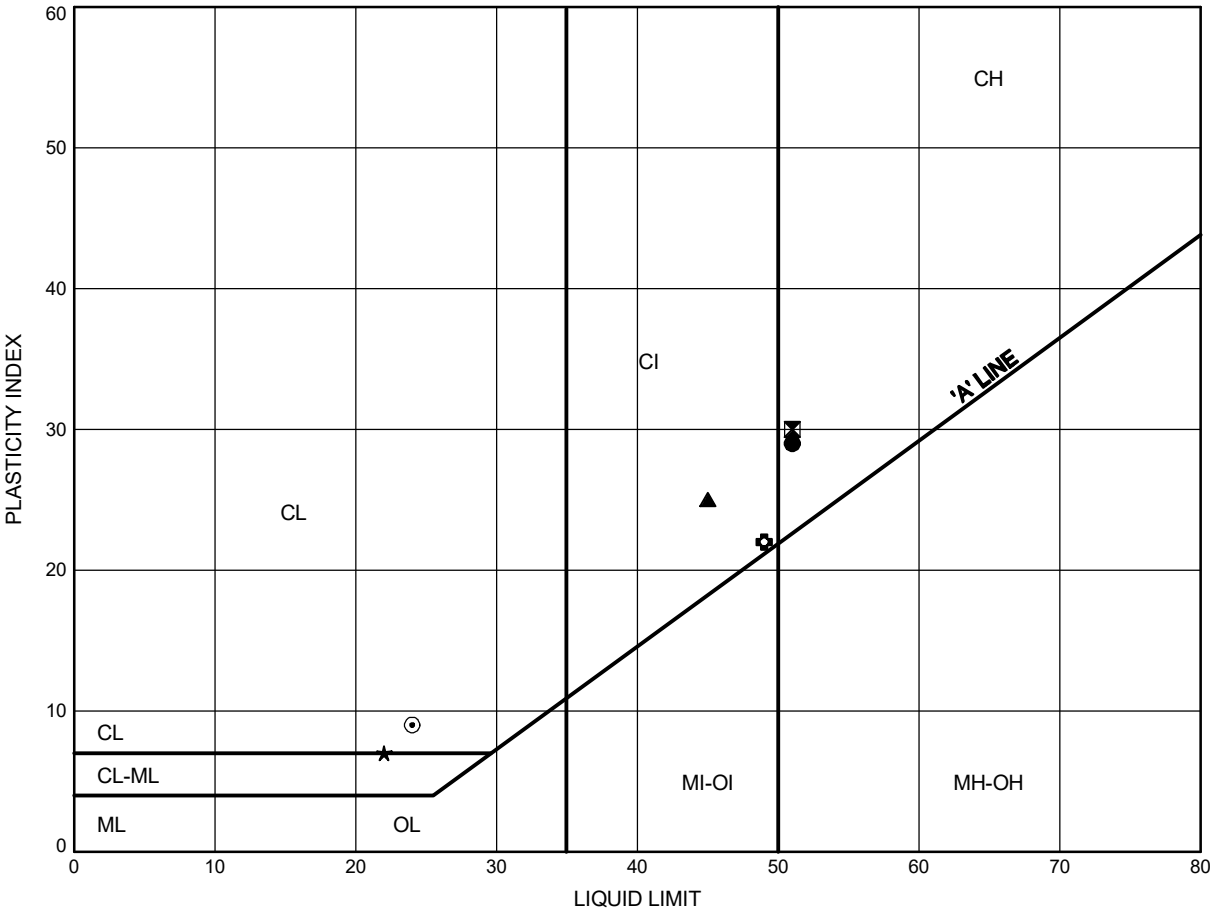
Prep'd RH
Chkd. JG

Hwys 17

ATTERBERG LIMITS TEST RESULTS

FIGURE C8

Clay to Silty Clay to Clayey Silt (CH to CI to CL/CL-ML)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	B-HF-03	1.1	128.8
⊠	B-HF-03	4.1	125.8
▲	B-HF-03	7.9	122.0
★	B-HF-03	14.0	115.9
⊙	B-HF-03	19.5	110.4
⊕	SC 10-1	4.9	127.7

Date August 2024
GWP# 4018-E-0009



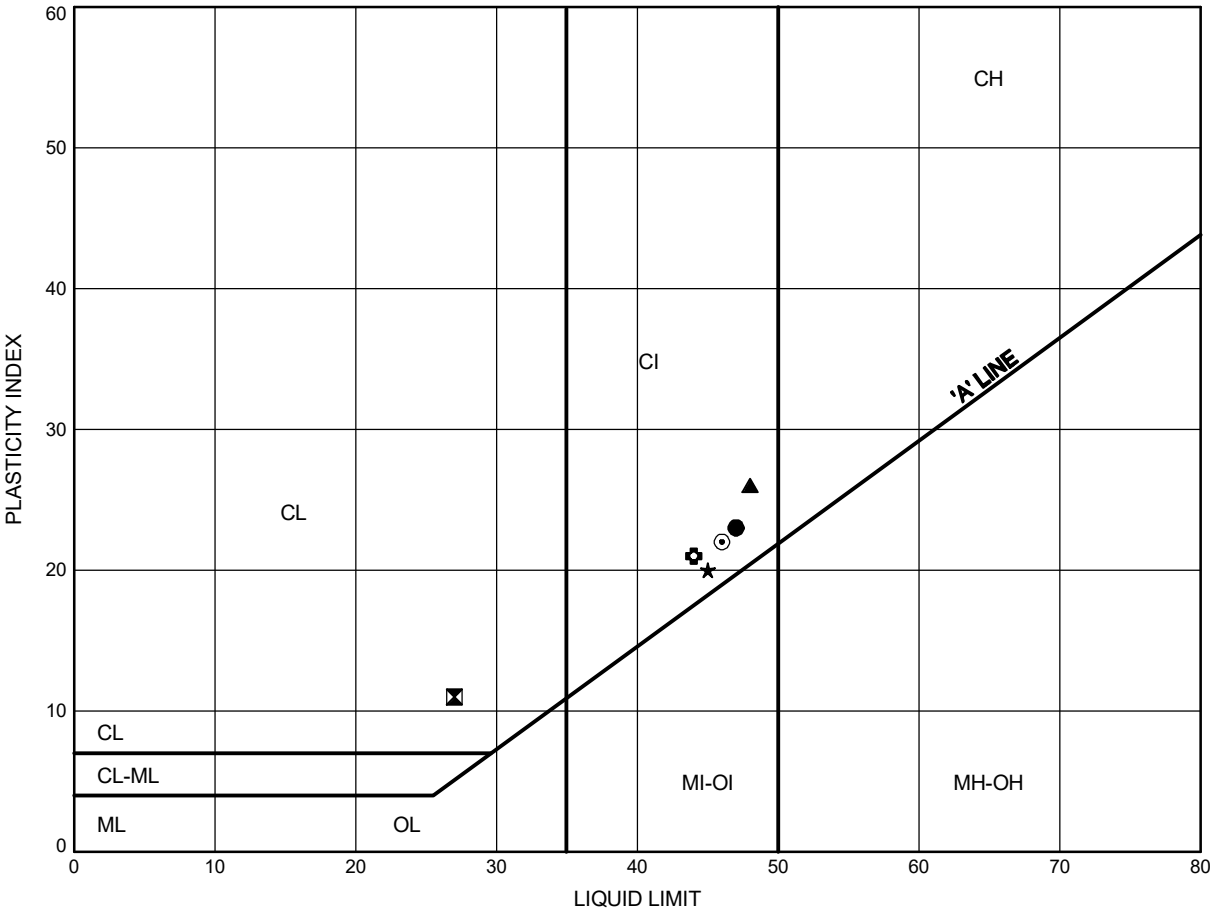
Prep'd RH
Chkd. JG

Hwys 17

ATTERBERG LIMITS TEST RESULTS

FIGURE C9

Clay to Silty Clay to Clayey Silt (CH to CI to CL/CL-ML)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SC 10-2	9.4	127.9
⊠	SC 10-2	17.1	120.2
▲	SC 10-3	4.1	128.1
★	SC 10-3	8.7	123.5
⊙	SC 10-4	1.8	128.4
⊕	SC 10-4	6.4	123.8

Date August 2024
GWP# 4018-E-0009



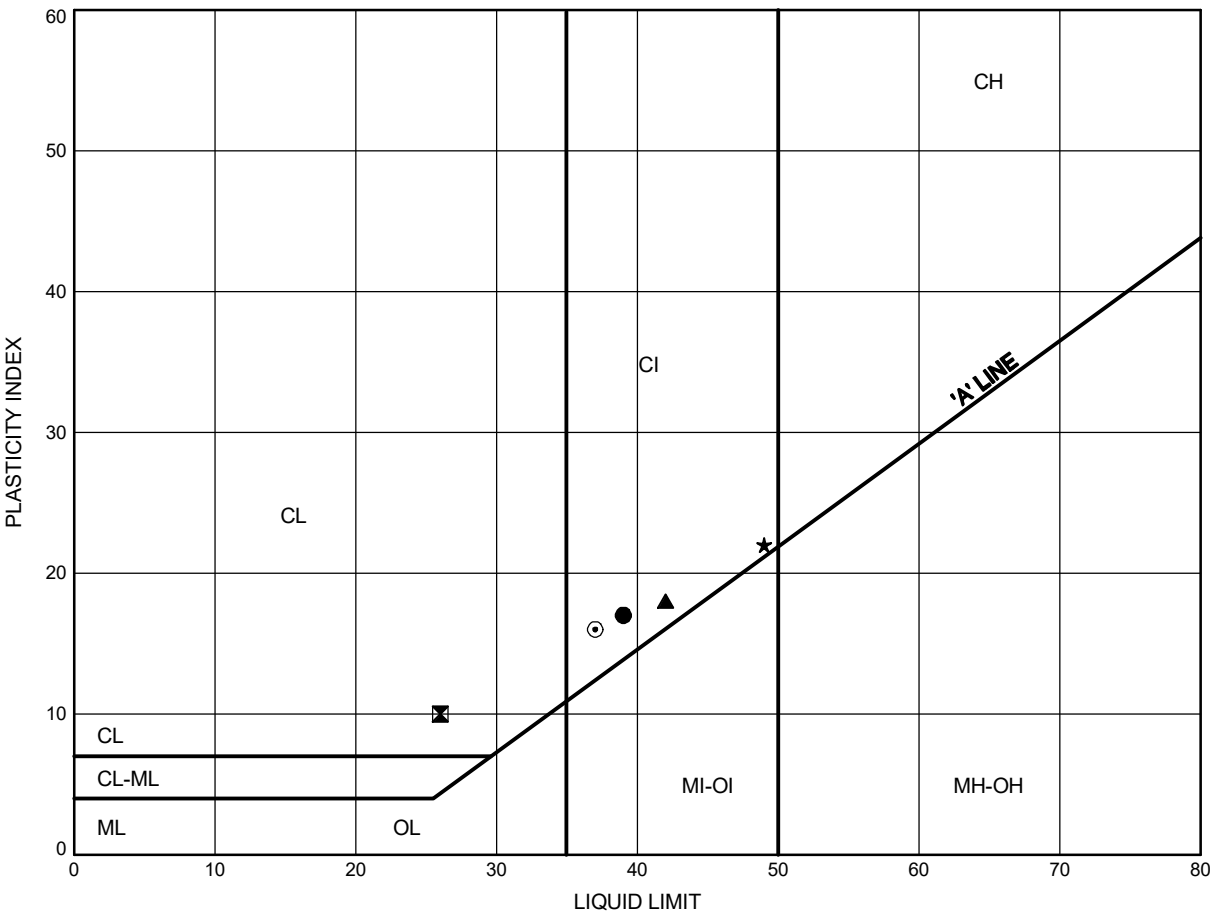
Prep'd RH
Chkd. JG

Hwys 17

ATTERBERG LIMITS TEST RESULTS

FIGURE C10

Clay to Silty Clay to Clayey Silt (CH to CI to CL/CL-ML)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SC 10-4	9.4	120.8
⊠	SC 10-4	12.5	117.7
▲	SC 10-5	0.3	129.4
★	SC 10-5	4.9	124.8
⊙	SC 10-5	7.9	121.8

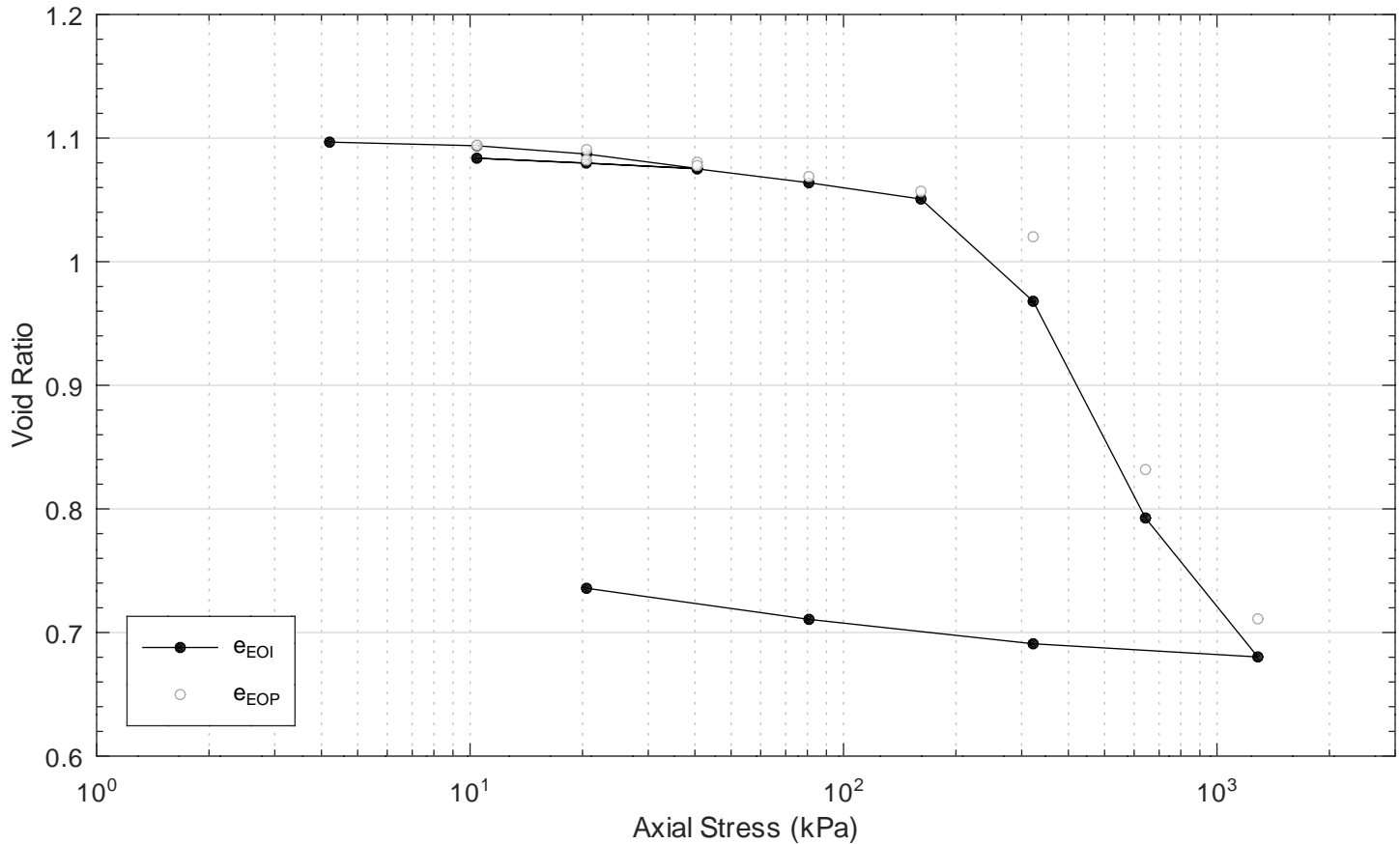
Date August 2024
GWP# 4018-E-0009



Prep'd RH
Chkd. JG



Project: 24726
 Hwy 17 Twinning
 Borehole: SC10-4
 Sample: TW8
 Depth: 9.5m
 Client: Ministry of Transportation



Start of Test		2024-06-28	
Diameter of Sample	cm	D	6.335
Height of Sample	cm	H _o	2.542
Height of Solids	cm	H _s	1.213
Water Content	%	w _o	40.57
Dry Density	g/cm ³	ρ _d	1.30
Moist Unit Weight	kN/m ³	γ	17.9
Void Ratio	-	e _o	1.095
Degree of Saturation	-	S _{ro}	1.01
Specific Gravity	-	G _s	2.718
End of Test		2024-07-13	
Height of Sample	cm	H _f	2.106
Water Content	%	w _f	27.92
Void Ratio	-	e _f	0.736

TRIMMING: the specimen was manually trimmed to the size of the consolidation ring, then mounted in a fixed ring consolidometer

LOADING: the consolidometer was flooded with water with the seating load adjusted to limit swelling

CALCULATIONS: coefficients of consolidation were calculated by the square root time method, secondary consolidation was calculated based on the available duration of the time step

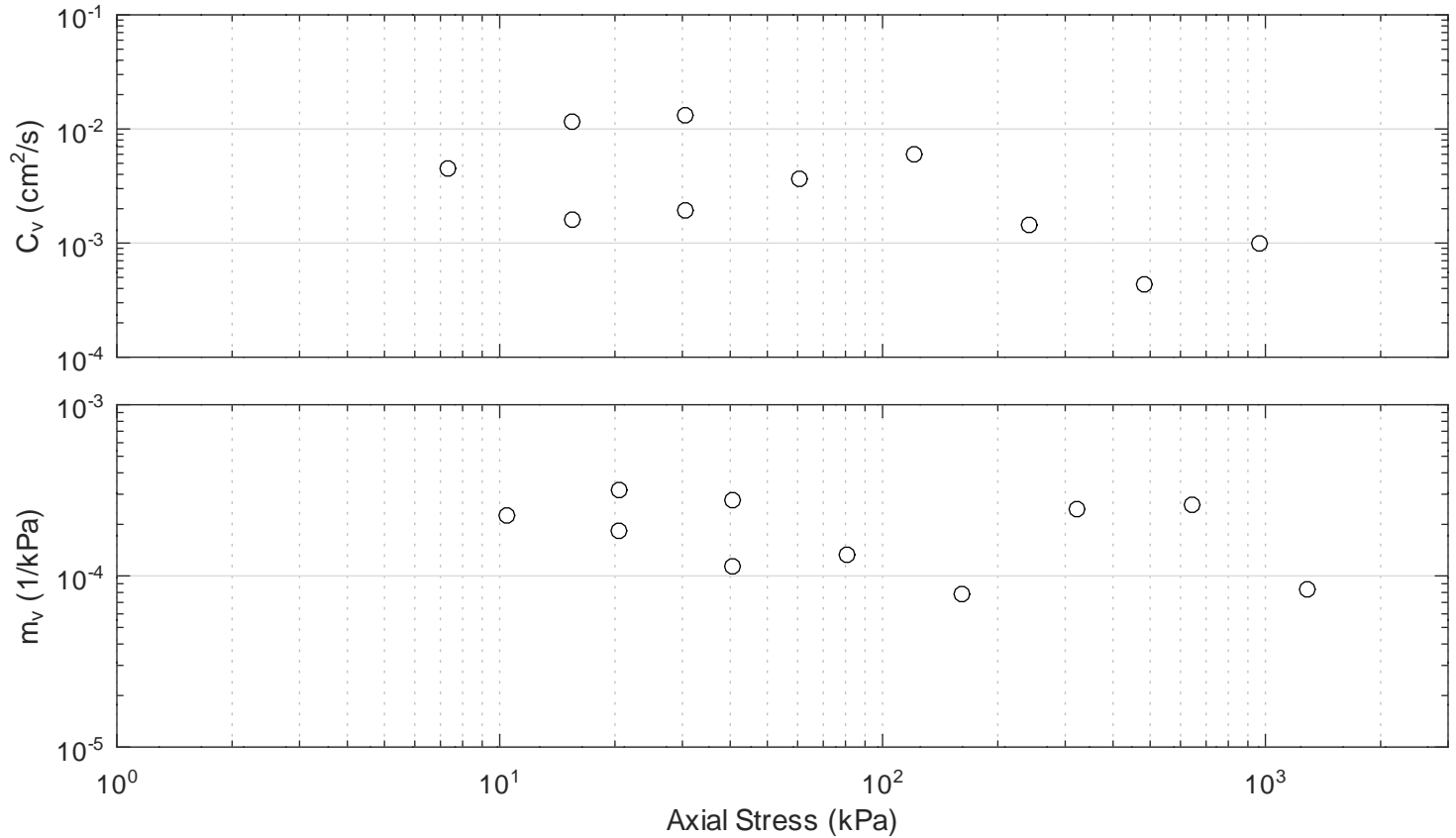
Interpreted Results

Recompression Index (reloading)	-	C _r	0.041
Compression Index	-	C _c	0.583
Recompression Index (unloading)	-	C _r	0.033
Probable Preconsolidation Pressure	kPa	p' _c	247

Check: AO/SP Review: KS



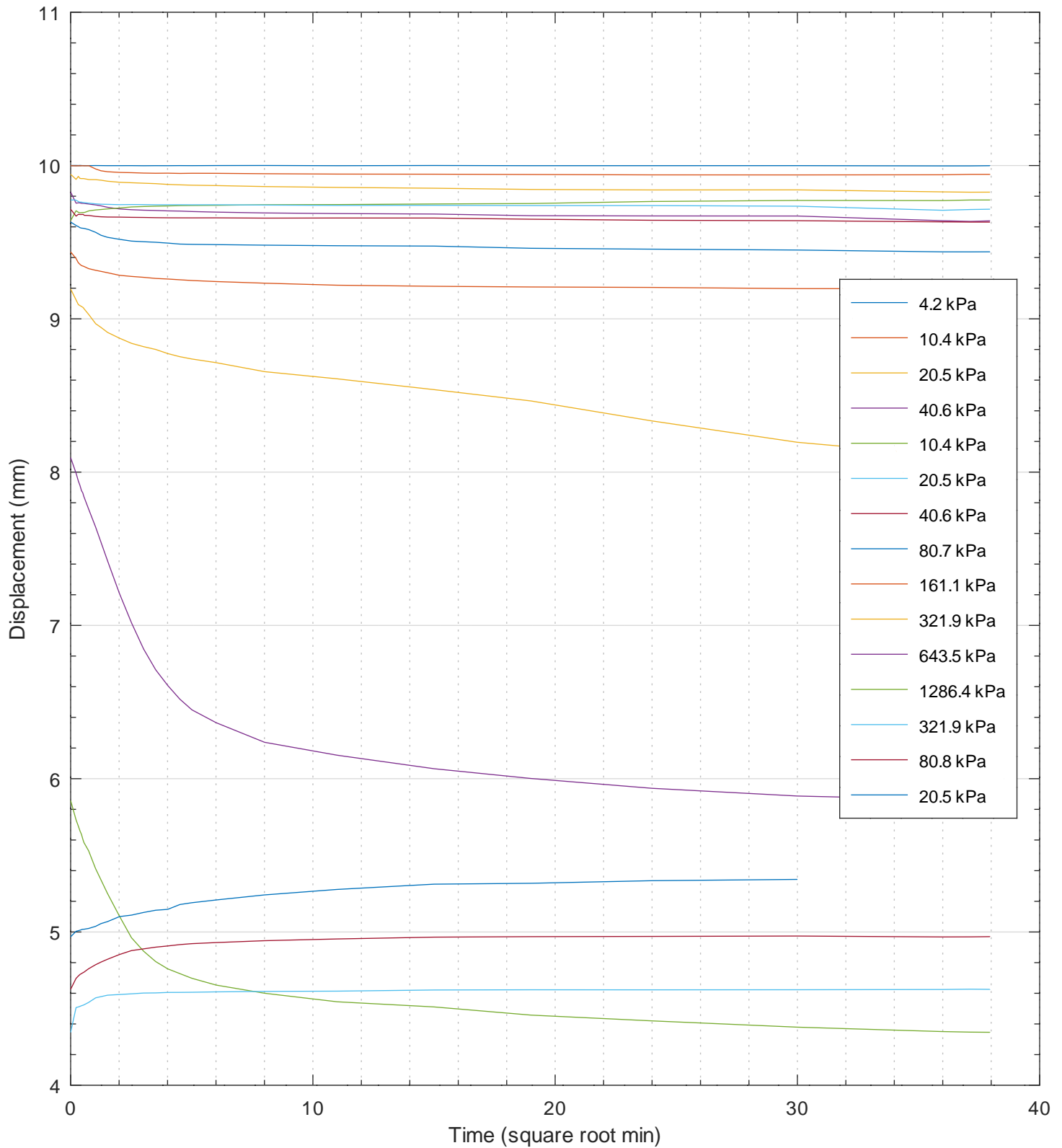
Project: 24726
 Hwy 17 Twinning
 Borehole: SC10-4
 Sample: TW8
 Depth: 9.5m
 Client: Ministry of Transportation

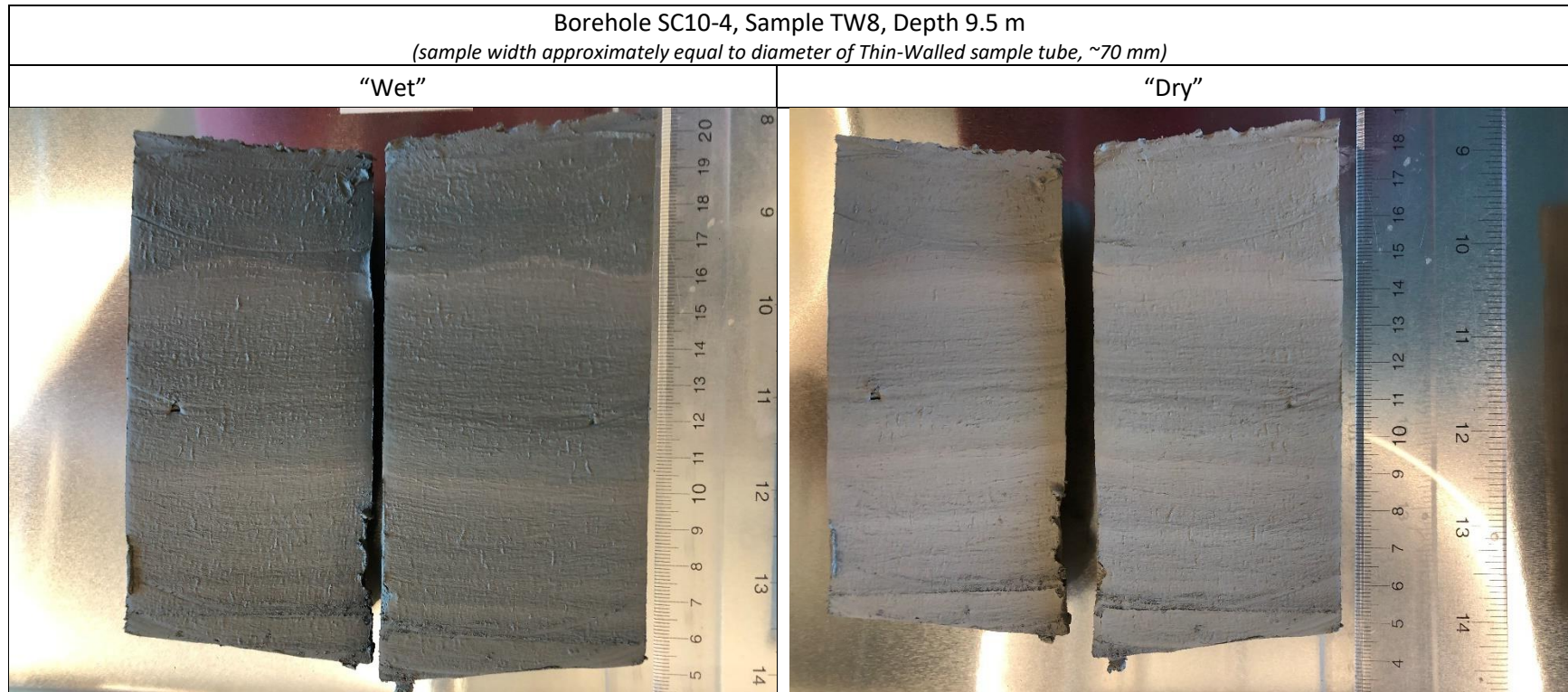


Load No.	Axial Stress	Load Duration	System Deflec.	Dial	Sample Height	Axial Strain	Void Ratio	Void Ratio	Time U(0.99)	C_v	k_v	C_{ae}
	kPa	min	mm	mm	cm	%	(EOI)	(EOP)	min	cm²/s	cm/s	-
0				10.000	2.542	0.00	1.095					
1	4.2	1440.2	0.021	9.998	2.544	-0.08	1.097					
2	10.4	1440.1	0.041	9.944	2.541	0.06	1.094	1.094	10.5	4.50e-03	9.96e-08	0.0002
3	20.5	1440.1	0.076	9.826	2.533	0.38	1.087	1.091	29.3	1.60e-03	5.00e-08	0.0010
4	40.6	1440.4	0.122	9.639	2.518	0.94	1.075	1.080	24.0	1.93e-03	5.26e-08	0.0014
5	10.4	1440.5	0.088	9.775	2.529	0.54	1.084					
6	20.5	1440.5	0.102	9.715	2.524	0.73	1.080	1.082	4.1	1.16e-02	2.08e-07	0.0005
7	40.6	1440.1	0.128	9.631	2.518	0.96	1.075	1.078	3.5	1.32e-02	1.47e-07	0.0005
8	80.7	1440.4	0.186	9.438	2.504	1.49	1.064	1.069	12.3	3.66e-03	4.77e-08	0.0011
9	161.1	1440.5	0.266	9.196	2.488	2.12	1.051	1.057	7.5	6.00e-03	4.61e-08	0.0013
10	321.9	1440.4	0.362	8.095	2.388	6.07	0.968	1.020	27.7	1.44e-03	3.47e-08	0.0170
11	643.5	1440.1	0.474	5.855	2.175	14.44	0.793	0.832	39.3	4.35e-04	1.11e-08	0.0127
12	1286.4	1440.1	0.622	4.345	2.039	19.80	0.680	0.711	20.1	9.93e-04	8.13e-09	0.0095
13	321.9	1440.1	0.470	4.626	2.052	19.29	0.691					
14	80.8	1440.4	0.367	4.969	2.076	18.35	0.711					
15	20.5	900.1	0.298	5.343	2.106	17.15	0.736					



Project: 24726
 Hwy 17 Twinning
 Borehole: SC10-4
 Sample: TW8
 Depth: 9.5m
 Client: Ministry of Transportation







Appendix C.2

Analytical Testing Results

Certificate of Analysis

Report Date: 18-Apr-2024

Client: Thurber Engineering Ltd.

Order Date: 12-Apr-2024

Client PO: Highway 17 Renfrew, Various Sites

Project Description: 24726 task 700.706a

Client ID:	BON24-2 SS4 10'-12'	NSC20-2 SS2A 2'6"-3'3"	SC10-1 SS2B 3'-4'	SC10-4 SS2 2'6"-4'6"	
Sample Date:	09-Apr-24 09:00	02-Apr-24 09:00	21-Mar-24 09:00	04-Apr-24 09:00	-
Sample ID:	2415421-05	2415421-06	2415421-07	2415421-08	-
Matrix:	Soil	Soil	Soil	Soil	
MDL/Units					

Physical Characteristics

% Solids	0.1 % by Wt.	72.6	69.1	73.2	77.5	-	-
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General Inorganics

Conductivity	5 uS/cm	286	203	316	247	-	-
pH	0.05 pH Units	6.79	6.65	6.95	6.84	-	-
Resistivity	0.1 Ohm.m	35.0	49.2	31.6	40.5	-	-

Anions

Chloride	10 ug/g	12	37	97	27	-	-
Sulphate	10 ug/g	24	21	44	<10	-	-

**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, Canada

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

19-April-2024

Date Rec. : 16 April 2024
LR Report: CA12714-APR24
Reference: Project#: 2415421

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	Sample Date & Time	Sulphide (Na ₂ CO ₃) %
1: Analysis Start Date		19-Apr-24
2: Analysis Start Time		13:06
3: Analysis Completed Date		19-Apr-24
4: Analysis Completed Time		13:12
5: RL		0.01
6: SC48-3 SC3A 5' 6"3"	11 Mar 24	< 0.01
7: SC23-2 SS5 10' 12"	13 Mar 24	0.83
8: DOC23-1 SS7, 15' 17"	11 Mar 24	0.01
9: OBR23-1 SC10 40' 50"	27 Mar 24	< 0.01
10: BON24-2 SS4 10' 12"	09-Apr-24	< 0.01
11: NSC20-2 SS2A 2'0"-3'3"	02-Apr-24	< 0.01
12: SC10-1 SS2B 3'-4"	21-Mar-24	< 0.01
13: SC10-4 SS2 2'6"- 4'6"	04-Apr-24	< 0.01

RL - SGS Reporting Limit

Note: Samples taken March 11 and 13th were past the 28 day holding time for sulphide analysis when received; result may be unreliable. Processed past holding time as per client's instructions.

Kimberley Didsbury
Project Specialist,
Environment, Health & Safety



Appendix D.

Site Photographs



Photo 1. Looking southeast along existing westbound embankment (March 21, 2024)



Photo 2. Looking northwest at existing culvert inlet (March 21, 2024)



Photo 3. Looking northwest along the existing eastbound embankment (July 25, 2024)



Photo 4. Looking southeast along the existing eastbound embankment (July 25, 2024)



Photo 5. Looking south from Highway 17 alignment (July 25, 2024)



Photo 6. Existing culvert outlet (July 25, 2024)



Appendix E.

GSC Seismic Hazard Calculation

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

Site: 45.492N 76.668W

User File Reference: CULVERT 10N STA. 19+200 HORTON

2024-08-13 18:04 UT

Probability of exceedance per annum	0.000404	0.001	0.0021	0.01
Probability of exceedance in 50 years	2 %	5 %	10 %	40 %
Sa (0.05)	0.354	0.181	0.104	0.031
Sa (0.1)	0.419	0.226	0.136	0.045
Sa (0.2)	0.351	0.196	0.122	0.043
Sa (0.3)	0.267	0.153	0.097	0.035
Sa (0.5)	0.190	0.112	0.072	0.026
Sa (1.0)	0.097	0.058	0.038	0.013
Sa (2.0)	0.047	0.028	0.018	0.005
Sa (5.0)	0.013	0.007	0.004	0.001
Sa (10.0)	0.005	0.003	0.002	0.001
PGA (g)	0.225	0.124	0.075	0.024
PGV (m/s)	0.159	0.090	0.055	0.017

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 m/s^2). Peak ground velocity is given in m/s . Values are for "firm ground" (NBCC2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are highlighted in yellow. 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.**

References

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

Structural Commentaries (User's Guide - NBC 2015: Part 4 of Division B)
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 and www.nationalcodes.ca for more information



Natural Resources
Canada

Ressources naturelles
Canada

Canada



Appendix F.

Foundation Comparison



COMPARISON OF ALTERNATIVE FOUNDATION TYPES

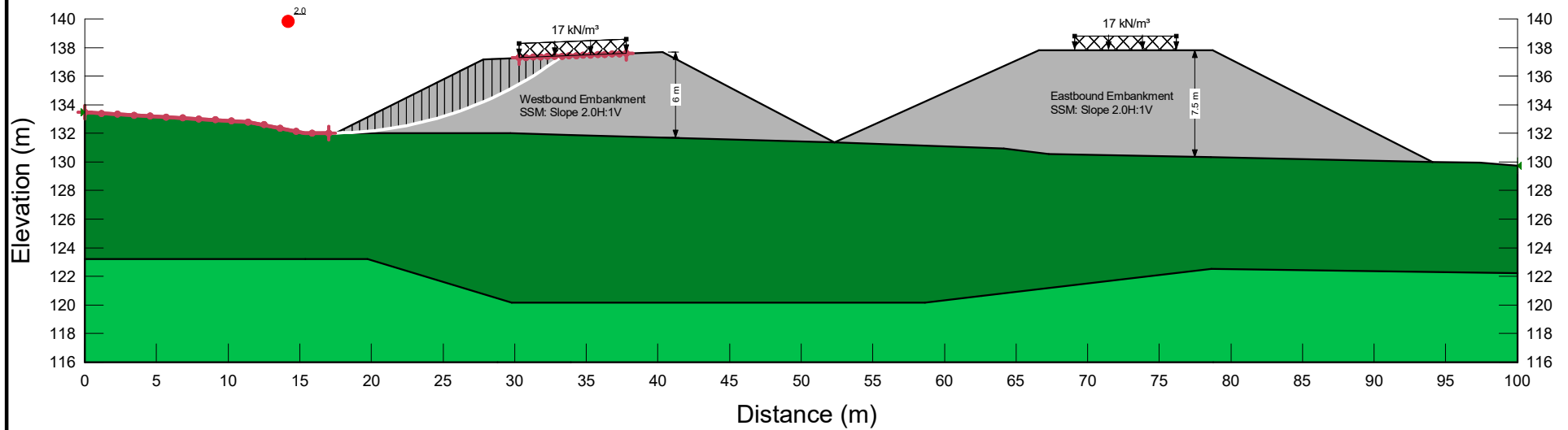
	Pipe Culverts	Open-Bottom Box Culverts	Closed-Bottom Box Culverts
Advantages	<p>Relatively expedient installation if precast units are used.</p> <p>Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade.</p>	<p>Possibility to maintain work zone outside of existing waterway.</p> <p>Readily encompasses natural substrate. Preferable from environmental perspective.</p>	<p>Relatively expedient installation if precast units are used.</p> <p>Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade.</p> <p>Closed box culvert mitigates risk of structural damage to liquefaction of underlying soils.</p>
Disadvantages	<p>Requires a temporary by-pass to maintain waterflow.</p> <p>Several parallel pipes may be required to provide hydraulic opening equivalent to box culvert.</p> <p>Protection system may require bracing, anchors and/or rakers.</p> <p>Difficult to include natural substrate.</p>	<p>May require protection system for construction of foundations.</p> <p>Deepest excavation increases quantities and dewatering concerns.</p> <p>Lower geotechnical resistances.</p> <p>Potential for post construction settlement.</p> <p>Less expedient installation as cast-in-place footings needed prior to placement of precast units.</p>	<p>Requires a temporary by-pass to maintain waterflow.</p> <p>Requires deeper concrete box with increased rise to include natural substrate.</p> <p>Protection system may require bracing, anchors and/or rakers.</p>
Risks/ Consequences	<p>Some risk of basal disturbance during footing excavation due to depth of excavation below water table.</p>	<p>Increased risk of basal disturbance of footing excavation due to depth of excavation below water table.</p> <p>Potential liquefaction of underlying soils/increased risk of structural damage.</p>	<p>Some risk of basal disturbance during footing excavation due to depth of excavation below water table.</p>
Relative Cost	Low to Moderate	Moderate	Moderate
Recommendation	Feasible	Not Feasible	Recommended



Appendix G.

Slope Stability Analysis Figures

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Undrained Shear Strength (kPa)	Piezometric Surface	Effective Cohesion (kPa)	Effective Friction Angle (°)
■	a) Silty Clay (Weathered Crust) (Undrained)	Undrained (Phi=0)	17.5	100	1		
■	b) Clayey Silt (Undrained)	Undrained (Phi=0)	17.5	55	1		
■	e) SSM	Mohr-Coulomb	21		1	0	32




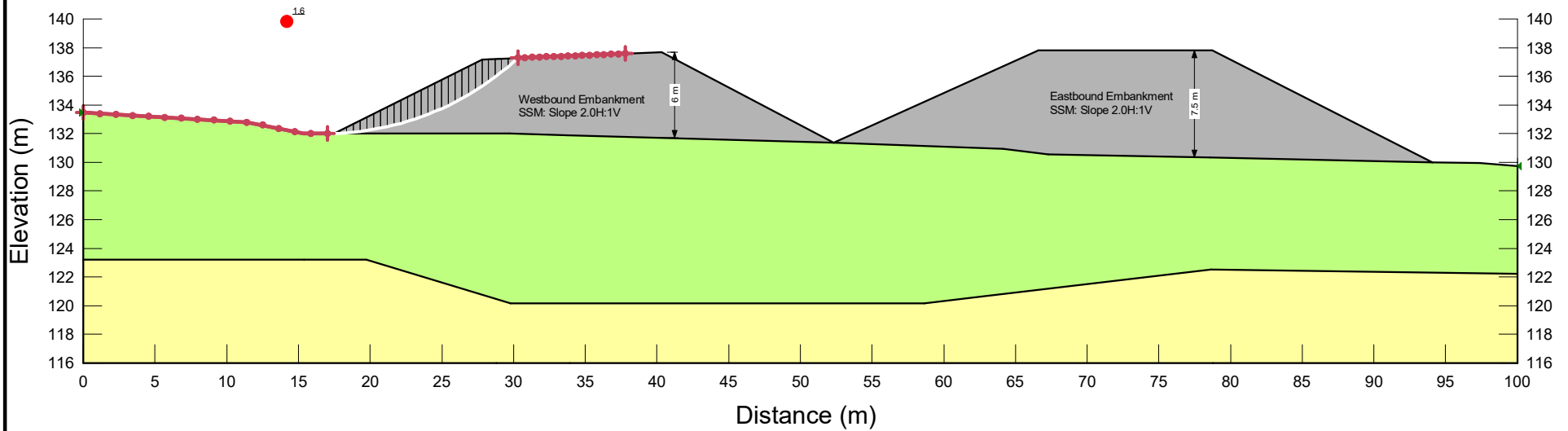
	Project			Additional Details	
	24726 - Hwy 17, Sta 19+200, Culvert 10/10N			Name: a) 2.0H:1V SSM embankment	
	Analysis			Comments:	
	a1) Temporary (traffic), short term, static, undrained			Method: Morgenstern-Price, Half-Sine	
Seismic Coefficient		Last Run		Minimum Slip Surface Depth: 1.5 m	
H: g, V: g		2024-11-28, 01:22:23 PM		Entry: (17, 132.03657) m, Exit: (33.3, 137.41632) m	
		Scale		Center: (17.28587, 158.5538) m, Radius: 26.518771 m	
		1:430			

Figure G1-1

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
■	a) Silty Clay (Weathered Crust) (Drained)	Mohr-Coulomb	17.5	5	28	1
■	b) Clayey Silt (Drained)	Mohr-Coulomb	17.5	2	28	1
■	e) SSM	Mohr-Coulomb	21	0	32	1




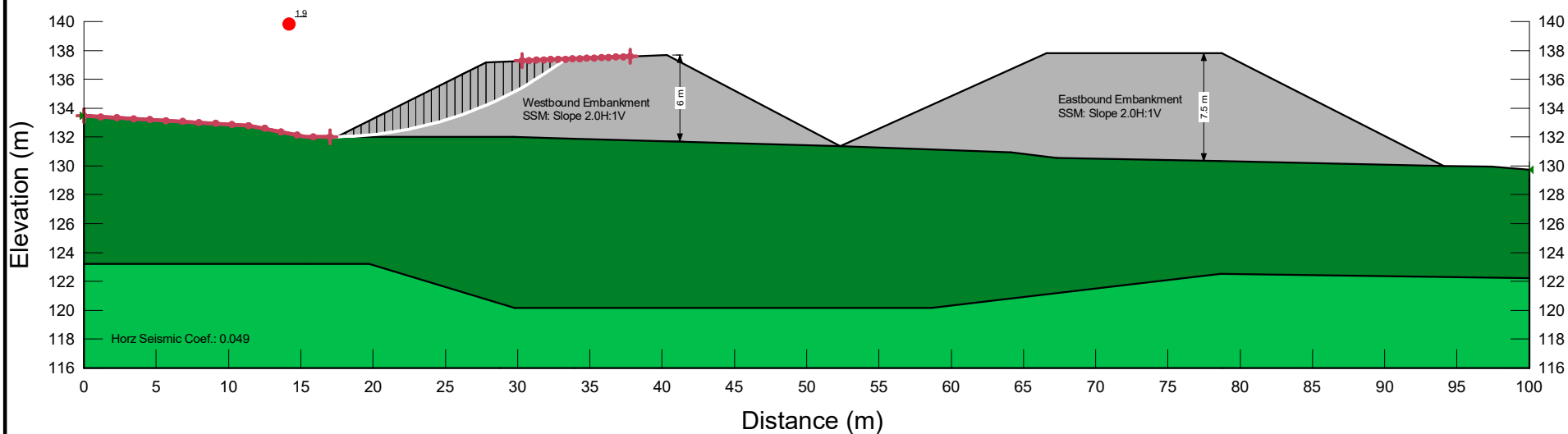
	Project			Additional Details	
	24726 - Hwy 17, Sta 19+200, Culvert 10/10N			Name: a) 2.0H:1V SSM embankment	
	Analysis			Comments:	
	a2) Permanent, long term, static, drained			Method: Morgenstern-Price, Half-Sine	
Seismic Coefficient		Last Run		Minimum Slip Surface Depth: 1.5 m	
H: g, V: g		2024-11-28, 01:22:24 PM		Entry: (15.860299, 132.03657) m, Exit: (30.3, 137.296) m	
		Scale		Center: (16.87026, 151.71546) m, Radius: 19.704786 m	
		1:430			

Figure G1-2

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Undrained Shear Strength (kPa)	Piezometric Surface	Effective Cohesion (kPa)	Effective Friction Angle (°)
■	a) Silty Clay (Weathered Crust) (Undrained)	Undrained (Phi=0)	17.5	100	1		
■	b) Clayey Silt (Undrained)	Undrained (Phi=0)	17.5	55	1		
■	e) SSM	Mohr-Coulomb	21		1	0	32




	Project			Additional Details	
	24726 - Hwy 17, Sta 19+200, Culvert 10/10N			Name: a) 2.0H:1V SSM embankment	
	Analysis			Comments:	
	a3) Temporary (seismic), pseudo-static, undrained			Method: Morgenstern-Price, Half-Sine	
Seismic Coefficient		Last Run		Minimum Slip Surface Depth: 1.5 m	
H: 0.049g, V: g		2024-11-28, 01:22:25 PM		Entry: (17, 132.03657) m, Exit: (33.3, 137.41632) m	
		Scale		Center: (17.28587, 158.5538) m, Radius: 26.518771 m	
		1:430			

Figure G1-3



Appendix H.

List of Referenced Specifications Non-Standard Special Provisions



1. The following Special Provisions and OPSS Documents are referenced in this report:

OPSS.PROV 180	Management of Excess Materials
OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 401	Trenching, Backfilling, and Compacting
OPSS.PROV 421	Pipe Culvert Installation in Open Cut
OPSS.PROV 422	Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 511	Construction Specification for Rip-Rap, Rock Protection, and Granular Sheetting
OPSS.PROV 517	Construction Specification for Dewatering
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 803	Vegetative Cover
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS.PROV 805	Construction Specification for Temporary Erosion and Sediment Control Measures
OPSS.PROV 902	Construction Specification for Excavating and Backfilling Structures
OPSS.PROV 1010	Material Specification for Aggregates Base, Subbase, Select Subgrade, and Backfill Material
OPSS.PROV 1205	Clay Seal
OPSS.PROV 1860	Material Specification for Geotextiles
OPSD 208.010	Benching of Earth Slopes
OPSD 219.110	Light-Duty Silt Fence Barrier
OPSD 802.031	Rigid Pipe Bedding, Cover and Backfill, Type 3 Soil, Earth Excavation
OPSD 803.031	Frost Treatment - Pipe Culverts, Frost Penetration Line Between Top of Pipe and Bedding Grade
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.101	Foundation Frost Depths for Southern Ontario
OPSD 3101.150	Walls Abutment, Backfill Minimum Granular Requirement
SP 110S06	Amendment to OPSS 1010, April 2013
SP 517F01	Amendment to OPSS 517 - Construction Specification for Dewatering



2. Suggested wording for NSSPs

“Protection of Sensitive Foundation Soils”

The Contractor is advised that the native silty and clayey soils that will be exposed at the subgrade are moisture sensitive and may become disturbed or otherwise negatively impacted when subjected to construction or personnel traffic, freeze-thaw actions, ingress or ponding water. The Contractor shall be responsible for selecting appropriate granular compaction equipment, implementing adequate groundwater control measures and to minimize construction and personnel traffic on the founding subgrade.

“Structural Backfill”

Structural backfill for the culvert and retaining walls shall consist of OPSS Granular B Type II or Quarry Sourced OPSS Granular A material.

“Notice to Contractor: Obstructions”

Buried obstructions may be encountered during construction and interfere with excavations and installation of temporary protection/dewatering systems. Cobbles and boulders may be encountered within the glacial till layer. The Contractor must be prepared to dislodge or penetrate obstructions. Where obstructions are encountered near the surface, the Contractor may choose to remove such obstructions, provided it does not destabilize the existing embankment or temporary works.