



**THURBER** ENGINEERING LTD.

**PRELIMINARY  
FOUNDATION INVESTIGATION AND DESIGN REPORT  
HIGHWAY 17 TWINNING, RENFREW AREA  
CULVERT 23  
HIGHWAY 17, STA. 10+993, MCNAB TOWNSHIP  
WP 4068-09-00 / ASSIGNMENT NO. 4018-E-0009**

Geocres No.: 31F07-004

Report to:

**Ministry of Transportation Ontario**

Latitude: 45.446140°  
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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 proposed replacement of an existing CSPA culvert with a new structural culvert (29X-0409/C1) at about Sta. 10+993 on existing Highway 17 in McNab Township within Renfrew County, Ontario.

This section of the report presents the factual findings obtained from the foundation investigation conducted by Thurber as part of the current study. Thurber carried out the investigation under Ministry of Transportation (MTO) Assignment No. 4018-E-0009.

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**

The culvert crosses Highway 17 approximately 750 m east of the intersection between Highway 17 and Goshen Road. For project purposes, Highway 17 is herein described as oriented east-west, and the culvert is described as oriented north-south.

In the area of the culvert, the existing Highway 17 is a two-lane highway and has a posted speed limit of 90 km/h. The highway profile near the culvert is relatively flat and the road surface is at



approximate elevation 159.7 m at the centerline. The culvert is located within an approximately 1.6 km long highway curve; the highway alignment continues to curve both east and west of the culvert site. The shoulders are partially paved and have a width of approximately 3.9 m in both directions. Traffic volumes for this section of Highway 17 is understood to have been 13,900 AADT in 2016.

The existing culvert near the site is a corrugated steel pipe arch (CSPA) culvert with an approximately 1.6 m horizontal span, 1.0 m vertical rise, and 34.8 m length. The culvert is skewed approximately 53° to the highway alignment. The culvert is reported to have a relatively flat gradient (approx. 0.2%) with the invert of the culvert at the outlet at approximately 157.2 m. The inlet of the culvert was not visible on July 26, 2024; ponded water on the inlet side was surveyed at elevation 158.4 m. The water level at the outlet was surveyed at elevation 158.0 m on the same day. The cover above the existing culvert is approximately 1.5 m at the highway centerline. The water flows through the culvert from south to north.

Embankment side slopes, in the vicinity of the culvert, are shallow and inclined at approximately 3H:1V to 6H:1V. 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 area directly adjacent to the highway is undeveloped and densely vegetated with coniferous and deciduous trees. The terrain along the ditch line is relatively rugged in the vicinity of the culvert site. A low-lying marsh dominated with grasses and ponded water located on both sides of the highway. Rock cuts are visible approximately 250 m east of the culvert. Overhead utility lines are not present.

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

## 2.2 Site Geology

It is noted that Thurber completed a Foundation Investigation for the proposed Highway 17 culvert on the new west bound lanes at approximate Station 10+890 McNab. The results are presented in Geocres Report 31F-217.

According to Crins et al. 2009<sup>1</sup> the project area is described as Ecoregion 6E (Lake Simcoe-Rideau Ecoregion) within the Mixedwood Plains Ecozone. According to Wester et al. 2018<sup>2</sup> 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.

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 Shallow Till and Rock Ridges. Surficial mapping by Ontario Geological Survey (OGS) indicates

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

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



the site to be comprised of either coarse-textured glaciomarine deposits, organic deposits or Precambrian bedrock.

Ontario Geological Survey Map P.3784<sup>3</sup> suggests the bedrock in the project area comprises felsic intrusive rocks, such as monzogranites to syenogranites.

### 3 SITE INVESTIGATION AND FIELD TESTING

The foundation investigation and field-testing program was carried out between March 06 and March 14, 2024, and consisted of one on-road borehole identified as SC23-2 and two off-road boreholes identified as SC23-1 and SC23-3. All of the boreholes were advanced with CME 75 drill rigs utilizing Hollow Stem Augers, NW casing and coring techniques in bedrock. 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 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). 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 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.

**Table 3-1: Borehole Summary**

| <b>Borehole No.</b> | <b>Drilled Location</b> | <b>Northing (Latitude)</b> | <b>Easting (Longitude)</b> | <b>Ground Surface Elevation (m)</b> | <b>Termination Depth (m)</b> |
|---------------------|-------------------------|----------------------------|----------------------------|-------------------------------------|------------------------------|
| SC23-1              | Near Inlet              | 5034014.1<br>(45.446019)   | 297424.8<br>(-76.594282)   | 158.7                               | 12.8                         |
| SC7-2               | Westbound Lane          | 5034021.8<br>(45.446088)   | 297421.5<br>(-76.594324)   | 159.6                               | 16.2                         |
| SC7-3               | Near Outlet             | 5034042.6<br>(45.446275)   | 297421.0<br>(-76.594331)   | 158.5                               | 9.3                          |

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. 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 50 mm diameter monitoring well was installed in each of Boreholes SC23-1 and SC23-3 to allow for measurements of the groundwater level after drilling. The details for the wells are illustrated on the respective Record of Borehole sheets provided in Appendix B. The monitoring

<sup>3</sup> <http://www.geologyontario.mndm.gov.on.ca/mines/data/google/mrd126/doc.kml>



wells installed as part of the current investigation will be decommissioned by Thurber, as outlined in the Hydrogeological Investigation and Design Report.

Borehole SC23-2 was backfilled in accordance with MOE requirements (O.Reg 903, as amended).

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

#### **4 LABORATORY TESTING**

Laboratory testing 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. Chemical analysis for determination of pH, conductivity, resistivity, sulphide, sulphate and chloride was carried out on a sample 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 classification is in accordance with MTO Guideline for Foundation Engineering Services (GFES) Manual (April 2022) and the 4th Edition of the Canadian Foundation Engineering Manual.

In general, the encountered stratigraphy consists of sand with silt and gravel fill over native sand with silt over clayey silt, which is, in turn underlain by silty sand glacial till over bedrock. Peat was encountered below the ground surface in Borehole SC23-1.

##### **5.1 Embankment Fill**

###### **5.1.1 Sand with Silt and Gravel Fill**

A fill layer consisting of sand with silt and gravel was encountered at the ground surface in Borehole SC23-2. The thickness of the layer was 3.0 m (base elev. 156.6 m). The SPT N-values ranged from 10 to 52 blows, indicating a compact to very dense condition.





The moisture content of the samples tested ranged from 1 to 23% but typically less than 4%. The results of a grain size analysis conducted on a sample of this fill material are summarized below and are illustrated on Figure C1 in Appendix C.

**Summary of Grain Size Distribution Testing – Sand with Silt and Gravel Fill**

| Soil Particle | Percentage (%) |
|---------------|----------------|
| Gravel        | 42             |
| Sand          | 46             |
| Silt & Clay   | 12             |

### **5.1.2 Silty Sand Fill**

A fill layer consisting of silty sand with varying amounts of organics and wood fragments was encountered at the ground surface in Borehole SC23-3. The thickness of the layer was 1.8 m (base elev. 156.7 m). The SPT N-values ranged from 4 to 7, indicating a very loose to loose condition.

The moisture content of the samples tested were 40 and 43%.

## **5.2 Peat**

A native deposit of fine fibrous to amorphous peat was encountered below the ground surface in Borehole SC23-1. The thickness of the layer was 2.1 m (base elev. 156.6 m). The SPT N-values ranged from 2 to 4 blows, indicating a very soft consistency.

The moisture content of a sample tested was 235%.

## **5.3 Sand with Silt**

A native deposit of sand with silt containing varying amounts of organics was encountered beneath the peat in Borehole SC23-1, below the sand with silt and gravel fill in Borehole SC23-2, and below the silty sand fill in Borehole SC23-3. The thickness of the layer ranged from 0.5 to 1.1 m (base elev. 156.2 to 155.5 m). The SPT N-values ranged from 2 to 19 blows, indicating a very loose to compact relative density.

The moisture content of the samples tested ranged from 21 to 68%. The results of gradation analyses completed on two samples of the layer are illustrated in Figure C2 of Appendix C. The results of the tests are summarized below and on the Record of Borehole sheets in Appendix B.

#### Summary of Grain Size Distribution Testing – Sand with Silt

| Soil Particle | Percentage (%) |
|---------------|----------------|
| Gravel        | 1              |
| Sand          | 89 – 92        |
| Silt & Clay   | 7 – 10         |

#### 5.4 Clayey Silt (CL)

A native deposit of clayey silt was encountered below the sand with silt in all the boreholes. Sand partings and seams were encountered throughout the layer. The thickness of the layer ranged from 3.6 to 9.0 m (base elev. 152.6 to 146.5 m).

Where SPT was conducted within the layer, the N-values typically ranged from weight-of-hammer (WH) to 8 blows. Field vane tests were performed within this layer where possible. Undrained shear strengths were obtained and decreased with depth from greater than 100 kPa to 27 kPa. Remolded vane tests recorded sensitivities typically ranging from greater than 2 to 18, indicating that the clayey silt is medium sensitive to quick (CFEM, 2006). The layer is described as firm 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 18 to 47% but were typically greater than 27%. The results of grain size analysis tests conducted on six samples of this material are summarized in the table below and are illustrated in Figure C3 in Appendix C.

#### Summary of Grain Size Distribution Testing – Clayey Silt (CL)

| Soil Particle | Percentage (%) |
|---------------|----------------|
| Gravel        | 0              |
| Sand          | 2 – 5          |
| Silt          | 53 – 70        |
| Clay          | 26 – 42        |

The results of Atterberg Limits testing carried out on six samples of this material are summarized below and are illustrated in Figure C4 in Appendix C. The laboratory results indicate that the clayey silt is of low plasticity (CL).

#### Summary of Atterberg Limit Testing – Clayey Silt (CL)

| Parameter        | Value   |
|------------------|---------|
| Liquid Limit     | 25 – 34 |
| Plastic Limit    | 16 – 21 |
| Plasticity Index | 8 – 15  |

### 5.5 Silty Sand (Glacial Till)

A layer of silty sand till was encountered below the clayey silt deposit in the Boreholes SC23-1 and SC23-2. Varying amounts of gravel were encountered in the layer. Though not fully penetrated in Borehole SC23-1, the layer thickness was proven to be at least 0.6 m thick (base elev. 146.5 to 145.9 m). SPT N-values ranged from 45 blows to refusal, indicating a dense to very dense relative density. Although not observed in the boreholes, it should be anticipated that cobbles and boulders are also present in the glacial till deposit.

The moisture content of the samples tested ranged from 7 to 27%. The results of gradation analyses completed on a sample of the layer are illustrated in Figure C5 of Appendix C. The results of the tests are summarized below and on the Record of Borehole sheets in Appendix B.

#### Summary of Grain Size Distribution Testing – Silty Sand (Glacial Till)

| Soil Particle | Percentage (%) |
|---------------|----------------|
| Gravel        | 0              |
| Sand          | 65             |
| Silt          | 29             |
| Clay          | 6              |

### 5.6 Bedrock

Bedrock was proven by coring in Boreholes SC23-2 and SC23-3. The depth to bedrock was 5.9 to 13.1 m (elevation 152.6 and 146.5 m). Borehole SC23-1 was terminated upon auger refusal on inferred bedrock. The bedrock surface appears to slope down from the culvert outlet to the inlet.

The bedrock encountered consisted of slightly weathered to fresh jointed, coarse grained, light pinkish red monzogranite. Photographs of the bedrock cores are provided in Appendix C. The rock core quality measurements are summarized in the Table 5-1.

**Table 5-1: Bedrock Details**

| Parameter   | Range     |
|---|-----------|
| Total Core Recovery (TCR), %                        | 93 – 100  |
| Solid Core Recovery (SCR), %                        | 33 – 94   |
| Rock Quality Designation (RQD), %                   | 53 – 90   |
| Fracture Index (fractures per 0.3 m) <sup>(1)</sup> | 0 – >10   |
| Unconfined Compressive Strength (MPa)               | 104 – 128 |

Note: (1) Indicated as “FI” on Borehole Logs

The RQD values ranged from 53 to 90%, indicating a bedrock of fair to excellent quality (CFEM, 2023). The results of unconfined compressive strength tests (UCS) were 104 and 128 MPa, indicating that the tested samples of the bedrock are very strong (CFEM, 2023). The UCS test results are included in Appendix C.

## 5.7 Groundwater

Monitoring wells with diameters of 50 mm were installed in off-road Boreholes SC23-1 and SC23-3. 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 |
|--------------|--------------------------------|-----------------------|---------------------------|---------------------|
| SC23-1       | 155.3                          | 0.5                   | 158.2                     | March 08, 2024      |
|              |                                | 0.4                   | 158.3                     | April 09, 2024      |
|              |                                | 0.5                   | 158.2                     | May 01, 2024        |
|              |                                | 0.6                   | 158.1                     | June 07, 2024       |
|              |                                | 0.5                   | 158.2                     | June 28, 2024       |
|              |                                | 0.6                   | 158.1                     | July 12, 2024       |
|              |                                | 0.6                   | 158.1                     | August 28, 2024     |
| SC23-3       | 152.7                          | 0.5                   | 158.0                     | April 09, 2024      |
|              |                                | 0.6                   | 157.9                     | May 01, 2024        |
|              |                                | 0.8                   | 157.7                     | June 07, 2024       |
|              |                                | 0.7                   | 157.8                     | June 28, 2024       |
|              |                                | 0.8                   | 157.7                     | August 28, 2024     |

At the time of the field investigation frozen water was ponded near both inlet and outlet with both ends of the culvert visible (see Photos 1 and 2). However, during Thurber’s site visit on July 26, 2024, the culvert inlet was submerged (see Photo 3), and ponded water had a depth of approximately 0.8 m near the culvert outlet; the water surface was at approximate elevations of 158.4 and 158.0 m near the inlet and outlet, respectively.

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. Seasonal



fluctuations of the groundwater level are to be expected. Furthermore, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation.

## 5.8 Analytical Testing

One sample of the native sand with silt was 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) |
|----------|--------|-----------|-----------------|-----------------|--------------|--------|----------------------|
| SC23-2   | SS5    | 3.0 – 3.6 | 175             | 2,080           | 0.83         | 6.91   | 510                  |

## 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. 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, and Mr. D. Amorim Pereira, 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. UCS testing were completed by Thurber's laboratory in Oakville. Analytical testing was completed by Paracel Laboratories Ltd. in Ottawa.



Interpretation of the factual data and preparation of this report was completed by I. Khan, EIT, and A. de Oliveira, P.Eng. 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:

Ibrahim Khan, EIT  
Engineering Intern



Anderson de Oliveira, M.A.Sc., P.Eng.  
Geotechnical Engineer



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



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



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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 the replacement of a culvert located on Highway 17 near Station 10+993 in McNab Township within the County of Renfrew, Ontario. 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 structure. The discussion and preliminary recommendations presented in this report are based on information provided by MTO and the factual data obtained during the current field investigation.

**7.1 Background Information**

The culvert site is approximately 750 m west of the intersection between Highway 17 and Goshen Road. The existing road surface is near elevation 159.7 m. The existing culvert near the site is a corrugated steel pipe arch (CSPA) culvert with a 1.6 m horizontal span, 1.0 m vertical rise, and 34.8 m length. The invert of the existing culvert is near elevation 157.2 m near the outlet. The cover above the existing culvert is approximately 1.5 m at the highway centerline. Water flows through the culvert under the highway embankment from south to north.



In general, the encountered stratigraphy consists of sand with silt and gravel fill over sand with silt over clayey silt, which is, in turn underlain by silty sand glacial till over sloping bedrock at elevations ranging from 152.6 to lower than 145.9 m. The bedrock surface appears to slope down from the culvert outlet to the inlet. Groundwater was recorded in the monitoring wells at elevations ranging from 158.3 to 157.7 m. The culvert inlet was flooded, and approximately 0.8 m of water was ponding near the culvert outlet on July 26, 2024.

## **7.2 Proposed Structure**

The new west bound lanes will be constructed approximately 75 m to the north (centreline to centreline) and the existing highway will become the new eastbound lanes.

The Structure and Culvert List of February 23, 2022, for this project indicated that the existing culvert is to be replaced with a structural culvert along a similar alignment and with a similar invert. The preferred new culvert is a closed bottom, concrete box with a span of 3 m and a rise of 1.5 m. It is understood that the slope of the culvert invert is to be approximately 1.12%. It is assumed that the finished grade of the highway and the invert of the culvert will be the same as current conditions at 159.7 m and 157.2 m, respectively.

**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 document 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 structure is 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 criteria 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 ( $\Psi$ ) 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)<sup>4</sup>. The GSC seismic hazard calculation data sheet for 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 0.227 g. This value is to be scaled by the  $F(PGA)$  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 first assessed following the Boulanger and Idriss (2007)<sup>5</sup> criteria which utilizes 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.

Based on the assessment using the SPT data following the simplified method for cohesionless soil as outlined in Boulanger and Idriss (2014)<sup>6</sup>, discrete sections of the observed embankment fills and the native sand with silt are considered susceptible to liquefaction during a 1 in 2475yr design earthquake. It is anticipated that this material will be improved or removed from beneath the culvert structure as part of the subgrade preparation. The native soils and fill materials are not susceptible to liquefaction during a 1 in 475 year design earthquake.

### 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. As per Table 4.1 within Section 4.4.3.2 of the CHBDC, the site has been classified as a Seismic Site Class E.

The  $F(PGA)$ , as per Table 4.8 within Section 4.4.3.3 of the CHBDC, is equal to 1.34 for this site yielding a scaled *site-specific* Site Class E PGA of 0.303 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

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<sup>4</sup> <https://earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/calc-en.php>

<sup>5</sup> 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.

<sup>6</sup> Boulanger, R. W., and Idriss, I. M. (2014). CPT and SPT based liquefaction triggering procedures, Report No. UCD/CGM-14/01, Center for Geotechnical Modeling, Department of Civil and Environmental Engineering, University of California, Davis, CA, 134 pp.



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 1.31 and 2.21 for this site, yielding a scaled *site-specific*  $S_a(0.2)$  of 0.464 and  $S_a(1.0)$  of 0.217. A Seismic Performance Category of 3 is applicable to this site based on Table 4.10 of the CHBDC assuming the fundamental period of the structure is less than 0.5 seconds. The seismic performance category should be confirmed by the structural engineer.

## 9 DESIGN OPTIONS

### 9.1 Culvert Type and Foundation Alternatives

Selection of the replacement culvert type must typically consider the proposed construction procedures, staging requirements, geotechnical resistance available in the foundation soils, depth to suitable bearing stratum, and post-construction settlement. It is understood that for this structure a concrete box culvert has been identified as preferred due to increased durability. 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 and hydraulic requirements.

- Open-Bottom Culvert (Box, Arch)

The construction of an open-bottom culvert will have greater construction concerns due to the high water table and ponded water and requirement for greater excavation depths to construct the culvert footings to satisfy frost depth requirements. It is anticipated that the underside of the footings would be at approximately elevation 155.3 m which is more than 3 m below the observed groundwater level and approximately 4.4 m below the existing road surface. The use of an open bottom culvert would require greater dewatering and excavation efforts. It is also noted that the supporting soil would consist of clayey silt; the clayey silt will have limited geotechnical resistance.

- 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. Closed-bottom culverts require less excavation depth and allow for more manageable dewatering than open bottom culverts. It is anticipated that the underside of the bedding layer would be at approximately elevation 156.3 m which is approximately 2.1 m below the observed groundwater level. It is noted that the soil observed in the boreholes at this elevation consisted of very loose sand with silt containing organics. This material was considered to be susceptible to liquefaction during a 1 in 2475yr design earthquake; it should be removed and replaced with bedding material.



Given the depth to bedrock and the soil and groundwater conditions observed on site, a closed bottom culvert is recommended. A concrete pipe culvert is also considered as a viable alternative at this site.

## 9.2 Construction Methodology

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 the new west bound lanes would be constructed first and that all traffic would be temporarily directed onto those new lanes to allow culvert replacements for the eastbound lanes to be constructed under a road closure of the existing alignment.

## 9.3 Recommended Approach for Culvert Replacement

From a foundation engineering perspective, it is recommended that the existing culvert be replaced with a precast segmental closed bottom box culvert (or concrete pipe culvert) using open cut construction.

# 10 PRELIMINARY FOUNDATION DESIGN RECOMMENDATIONS

From a foundation engineering perspective, a concrete closed box culvert is recommended. The following bullets summarize the relevant elevations for this site:

|   |                     |
|---|---------------------|
| • Existing top of pavement Highway 17           | 159.7 m             |
| • Culvert invert                                | 157.2 m             |
| • Approximate elevation of underside of bedding | 156.3 m             |
| • Groundwater elevation                         | 158.4 m             |
| • Sand with Silt/Clayey Silt interface          | 156.2 to 155.5 m    |
| • Bedrock surface                               | 152.6 m to <145.9 m |

## 10.1 Concrete Pipe Culvert Foundation

As noted above portions of the native sand with silt are considered liquefiable and should be removed from beneath the culvert to expose the underlying clayey silt. It is anticipated that the base of the excavation for the replacement culvert will be within the clayey silt.

Bearing resistance values are not required for pipe culverts. A pipe 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-Bottom Box Concrete Culvert

It is understood that the replacement culvert will have the same invert elevation as the existing culvert (approximately 157.2 m). As noted above portions of the native sand with silt are considered liquefiable and should be removed from beneath the culvert. It is anticipated that the base of the excavation for the replacement culvert will be within the clayey silt. Subgrade preparation should follow the recommendation provided in Section 10.3. Surface water diversion and dewatering may be required to prepare the subgrade and install the culvert in the dry (see Section 11.3).

The existing subgrade soils at the founding elevation were observed to be clayey silt. For a box culvert with an exterior width of as much as 3.6 m founded on a properly prepared and compacted granular bedding layer, the design can be based on factored geotechnical resistance values as follows:

- Factored Geotechnical Resistance at ULS of 165 kPa
- Factored Geotechnical Resistance at SLS of 100 kPa

The factored geotechnical resistances include the following factors:

- Consequence factor ( $\Psi$ ) 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 culverts constructed on subgrades prepared with good workmanship and in accordance with Sections 10.3 and 10.7.

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 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 clayey silt. A resistance factor of 0.6 (as per CHBDC Table 6.2) should be used to estimate the 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” and “Granular B Type II” in this section refer to OPSS Granular A or Granular B Type II 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 (see Section 10.7 for further details).

As noted above portions of the native sand with silt are considered liquefiable and should be removed from beneath the culvert. It is anticipated that the base of the excavation for the replacement culvert will be within the clayey silt.

For a pipe culvert, at the founding level existing fill, soft/loose soils (including native sand with silt), disturbed soils, or otherwise deleterious materials encountered will need to be removed down to competent inorganic soils. Construction traffic should not travel on the exposed subgrade. As soon as practical, the excavation should be backfilled to the underside of the bedding elevation to protect the subgrade from disturbance from both construction traffic and weather. 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 pad with a minimum thickness of 0.3 m consisting of Granular A material. The top of the Granular A pad must extend to 0.5 m beyond the outside edge of all sides of the culvert and sloped away from the footing 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 µm (OPSS.PROV 1860) installed beneath the Granular A material. The geotextile should be placed as soon as possible after preparation of the final subgrade level. Alternatively, the geotextile and granular pad could be replaced with a 200 mm thick, concrete working slab placed on the



prepared subgrade. The working slab should extend at least 0.5 m beyond the outside dimensions of the culvert. An NSSP is provided in Appendix G 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 SP 110S06 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 local 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 must incorporate a subdrain as shown in OPSD 3101.150.

Lateral earth pressure parameters provided 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:

|            |   |   |
|------------|---|---|
| $\sigma_h$ | = | horizontal pressure on the wall at depth h (kPa)  |
| K          | = | earth pressure coefficient (see table below)<br>( $K_a$ for unrestrained walls, $K_o$ for restrained walls) |
| $\gamma$   | = | unit weight of retained soil (see table below),<br>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<br>OPSS Granular A<br>$\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$ | Quarry Sourced<br>OPSS Granular A<br>$\phi = 40^\circ, \gamma = 22.8 \text{ kN/m}^3$ | Quarry Sourced<br>OPSS Granular B<br>Type II<br>$\phi = 42^\circ, \gamma = 22.8 \text{ kN/m}^3$ |
|---|---|--|---|
| Coefficient of at Rest<br>Earth Pressure, $K_o$<br>(Restrained Wall)      | 0.43  | 0.36   | 0.33  |
| Coefficient of Active<br>Earth Pressure, $K_a$<br>(Unrestrained Wall)     | 0.27  | 0.22   | 0.20  |
| Coefficient of Passive<br>Earth Pressure, $K_p$<br>(Movement toward soil) | 3.69  | 4.60   | 5.04  |

The parameters in the table 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:

- $k_h = \frac{1}{2} * F(PGA) * PGA$ , for structures that allow 25 to 50 mm of movement, and
- $k_h = F(PGA) * PGA$ , for non-yielding 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 E. 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 E (2,475-year)**

| Condition  | Pit Sourced<br>OPSS Granular A<br>$\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$ | Quarry Sourced<br>OPSS Granular A<br>$\phi = 40^\circ, \gamma = 22.8 \text{ kN/m}^3$ | Quarry Sourced OPSS<br>Granular B Type II<br>$\phi = 42^\circ, \gamma = 22.8 \text{ kN/m}^3$ |
|--|---|--|--|
| Coefficient of Active Earth Pressure, $K_{AE}$ (Restrained Wall)   | 0.48  | 0.40   | 0.38   |
| Coefficient of Active Earth Pressure, $K_{AE}$ (Unrestrained Wall) | 0.36  | 0.30   | 0.28   |

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:

|                |   |  |
|----------------|---|--|
| $\sigma_{hAE}$ | = | 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<br>( $K_A$ for unrestrained walls, $K_o$ for restrained walls) |
| $\gamma$       | = | 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 also 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 5.8 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 5.8 were compared with Table 3.2 of the MTO Gravity Pipe Design Guideline and generally indicate a severe corrosive environment. The test results provided in Section 5.8 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 very severe 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 Reinstatement**

The existing highway embankment side slopes are generally sloped at approximately 3H:1V to 6H:1V. 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 with materials similar to the existing. 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.

As the permanent embankment envelope will not be enlarged from the current cross-section, the settlement beneath the embankment is expected to be negligible.

The magnitude of the embankment self-compression constructed with granular fill is in the order of 0.5% of the newly reconstructed embankment height and is expected to occur predominately during fill placement.

If the existing culvert is to be decommissioned by grouting or removed and backfilled, it is estimated that this would induce settlements of less than 10 mm beneath the existing culvert alignment as a result of the increased load imposed by the grout/fill.

## 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 fill above the groundwater table may be classified as Type 3 soil. All soils below the groundwater table are considered to be Type 4 soils. **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 actual 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 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. In Boreholes SC23-2 and SC23-3 the depth to bedrock was 14.1 and 5.9 m respectively (elevation 146.5 m and 156.2). Borehole SC23-1 was terminated upon auger refusal on inferred bedrock at elevation 145.9 m. The bedrock surface appears to slope down from the culvert outlet to the inlet. It is noted that shallow sloping bedrock could impact sheet pile installation at this site; suggested wording for a Contract Provision is provided in Appendix G. An anchoring and/or internal bracing system may need to be incorporated into the temporary protection design to resist lateral earth pressure loadings.

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 <sup>(*)</sup><br>(kN/m <sup>3</sup> ) | K <sub>A</sub> | K <sub>P</sub> | K <sub>0</sub> | S <sub>u</sub><br>(kPa) |
|-----------------------------|--|----------------|----------------|----------------|-------------------------|
| Existing Granular Fills     | 20   | 0.33           | 3.00           | 0.50           | -                       |
| Native Peat                 | 14   | 0.41           | 2.47           | 0.58           | -                       |
| Native Sand with Silt       | 19   | 0.33           | 3.00           | 0.50           | -                       |
| Native Cohesive Clayey Silt | 17.5   | -              | -              | -              | 40                      |

| Material               | Unit Weight <sup>(*)</sup><br>(kN/m <sup>3</sup> ) | K <sub>A</sub> | K <sub>P</sub> | K <sub>0</sub> | S <sub>u</sub><br>(kPa) |
|------------------------|--|----------------|----------------|----------------|-------------------------|
| Native Silty Sand 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.

### 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.

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 (including loose silty sand) and anticipated works (excavating to more than 2.5 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 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. 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 cofferdam system is likely sufficient. More than one pump may be required. A sheet pile cofferdam enclosure



driven into the foundation clayey silt may also be considered. It is noted that shallow sloping bedrock could impact sheet pile installation at this site; please refer to Section 11.2 for additional discussion. The groundwater level within the work zone should be lowered by pumping from sumps to a minimum of 0.5 m below the underside of the planned excavation base prior to each stage of excavation.

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 embankment fill and native sand with silt, clayey silt, and glacial till indicate that the soils have a 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 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.

It is understood that the slope of the culvert invert is to be approximately 1.12%. Given the low slope it is anticipated that water flow velocities will also be low and a clay seal is not warranted for this culvert replacement. This recommendation should be reviewed during detailed design.

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 preliminary GA drawings 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.**

**Of particular note at this site is the identification of potentially liquefiable soils. It has been assumed in the preliminary design that this material will be removed from beneath the culvert structure as part of the subgrade preparation; additional investigation and design may be required.**

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

- Construction will extend below the water level in the creek/pond. An adequate and effective surface water management and dewatering plan must be implemented to construct the culvert foundations in the dry.
- The native soil which could be exposed beneath the culvert bedding is sensitive and readily disturbed. A suggested Notice to Contractor is provided in Appendix G.
- 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.
- The bedrock elevation is variable across the site. Sloping bedrock will be encountered. A Notice to Contractor has been included in Appendix G.

The successful performance of the structure installation 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 A. de Oliveira, P.Eng. 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:



Anderson de Oliveira, M.A.Sc., P.Eng.  
Geotechnical Engineer



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



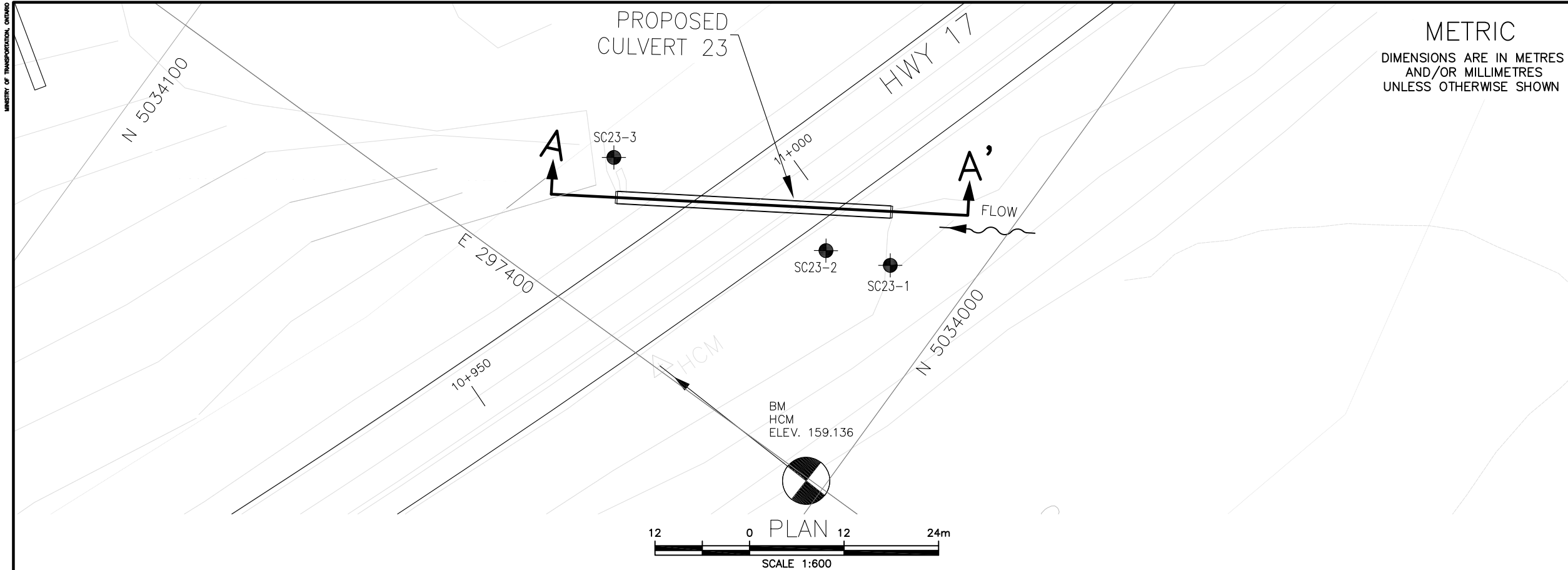
Dr. P.K. Chatterji, P.Eng.  
Designated Principal Contact,  
Principal, Senior Geotechnical Engineer



## **Appendix A.**

### **Borehole Location Plan and Stratigraphic Drawings**





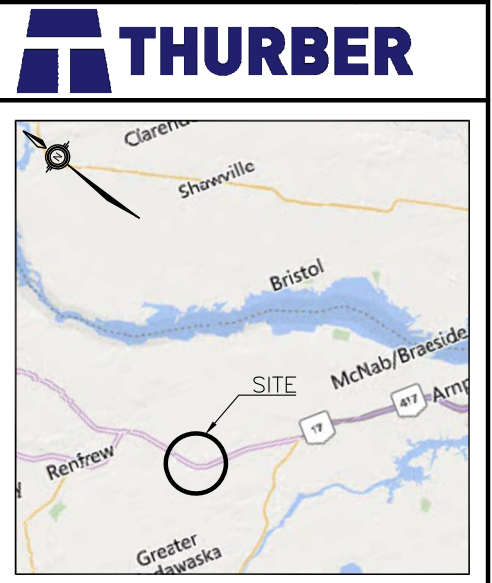
METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

CONT No  
GWP No 4068-09-00

HIGHWAY 17 TWINNING  
STA. 10+993, MCNAB TOWNSHIP  
CULVERT 23  
BOREHOLE LOCATION PLAN AND SOIL STRATA

Ontario

SHEET  
1



KEYPLAN

LEGEND

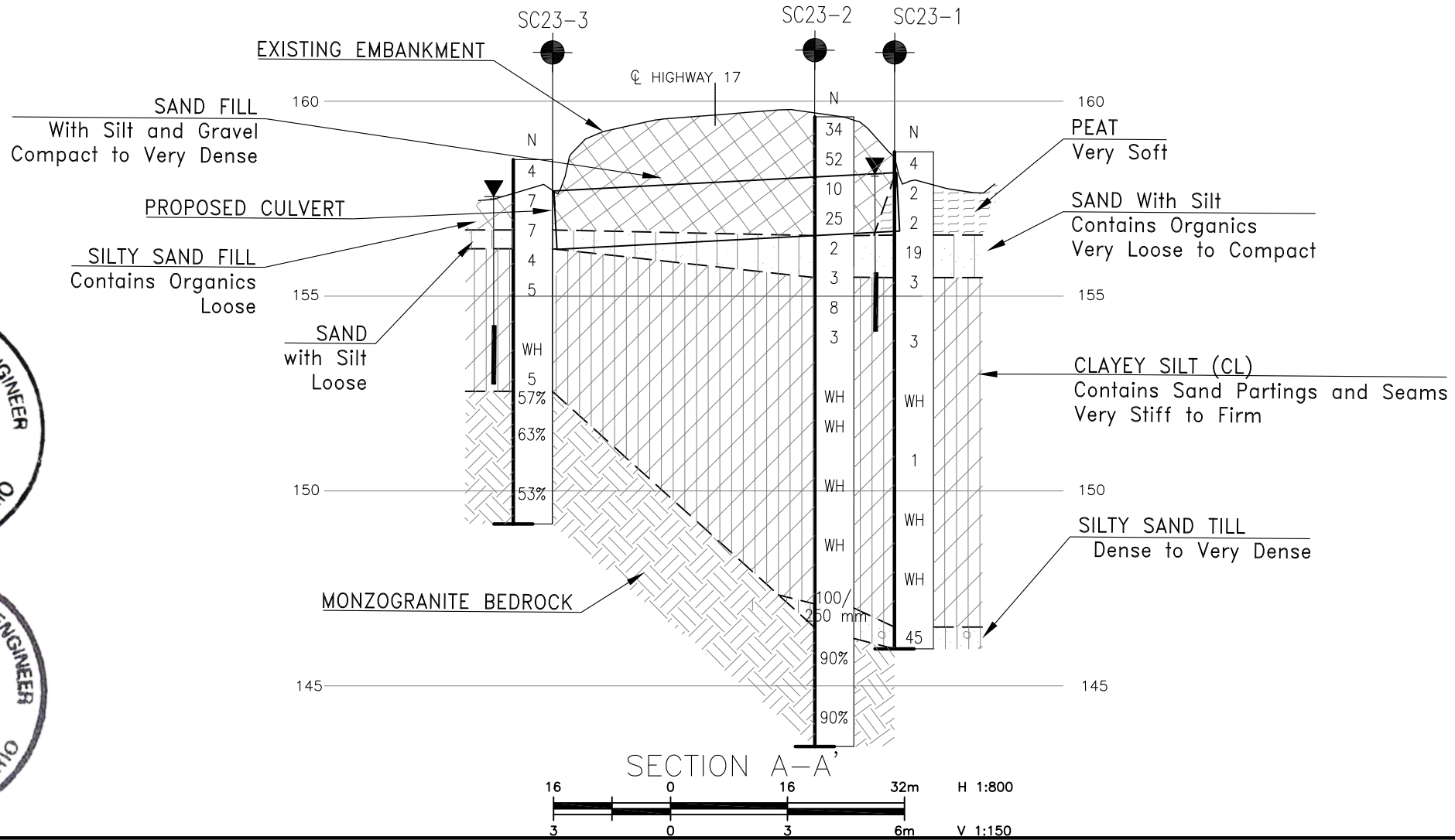
|      |   |
|------|---|
|      | Borehole                                  |
|      | Historic Borehole                         |
| N    | Blows /0.3m (Std Pen Test, 475J/blow)     |
| CONE | Blows /0.3m (60' Cone, 475J/blow)         |
| PH   | Pressure, Hydraulic                       |
|      | Water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

| NO     | ELEVATION | NORTHING    | EASTING   |
|--------|-----------|-------------|-----------|
| SC23-1 | 158.7     | 5 034 014.1 | 297 424.8 |
| SC23-2 | 159.6     | 5 034 021.8 | 297 421.5 |
| SC23-3 | 158.5     | 5 034 042.6 | 297 421.0 |

-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD 83 Zone 9.

GEOCRES No. 31F07-004



LICENSED PROFESSIONAL ENGINEER  
F. J. GRIFFITHS  
90360280  
Dec 19, 2024  
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER  
P. K. CHATTERJI  
Dec 19, 2024  
PROVINCE OF ONTARIO

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



**Appendix B.**  
**Record of Borehole Sheets**



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

### **TERMINOLOGY DESCRIBING COMMON SOIL GENESIS**

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

### **TERMINOLOGY DESCRIBING SOIL STRUCTURE:**

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

### **RECOVERY:**

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

### **N-VALUE:**

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

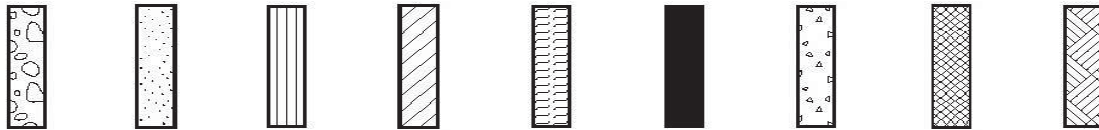
### **DYNAMIC CONE PENETRATION TEST (DCPT):**

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



### STRATA PLOT:

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



Boulders  
Cobbles  
Gravel      Sand      Silt      Clay      Organics      Asphalt      Concrete      Fill      Bedrock

### TEXTURING CLASSIFICATION OF SOILS

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

### TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

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

### SAMPLE TYPES

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

### TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

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

### MODIFIED UNIFIED SOIL CLASSIFICATION

| Major Divisions      |  | Group Symbol | Typical Description  |
|----------------------|--|--------------|--|
| COARSE GRAINED SOIL  | GRAVEL AND GRAVELLY SOILS                  | GW           | Well-graded gravels or gravel-sand mixtures, little or no fines.   |
|                      |  | GP           | Poorly-graded gravels or gravel-sand mixtures, little or no fines.   |
|                      |  | GM           | Silty gravels, gravel-sand-silt mixtures.  |
|                      |  | GC           | Clayey gravels, gravel-sand-clay mixtures.   |
|                      | SAND AND SANDY SOILS                       | SW           | Well-graded sands or gravelly sands, little or no fines.   |
|                      |  | SP           | Poorly-graded sands or gravelly sands, little or no fines.   |
|                      |  | SM           | Silty sands, sand-silt mixtures.   |
|                      |  | SC           | Clayey sands, sand-clay mixtures.  |
| FINE GRAINED SOILS   | SILT AND CLAY SOILS<br>$W_L < 35\%$        | 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<br>$35\% < W_L < 50\%$ | 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<br>$W_L > 50\%$        | 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 SC23-1

1 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.446019°, Long: -76.594282°  
Culvert 23, McNab Township; MTM z9: N 5 034 014.1 E 297 424.8 ORIGINATED BY BC  
HWY 17 BOREHOLE TYPE CME 75 Trackmount / HSA COMPILED BY AO  
DATUM Geodetic DATE 2024.03.07 - 2024.03.07 CHECKED BY JG



| SOIL PROFILE  |   |            | SAMPLES |      |            | GROUND WATER<br>CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT  |  |  |  | PLASTIC LIMIT<br>NATURAL MOISTURE<br>CONTENT<br>LIQUID LIMIT              |  |  | UNIT<br>WEIGHT<br><br>γ<br><br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%) |    |    |    |
|---------------|---|------------|---------|------|------------|----------------------------|-----------------|--|--|--|--|---|--|--|--|---|----|----|----|
| ELEV<br>DEPTH | DESCRIPTION   | STRAT PLOT | NUMBER  | TYPE | "N" VALUES |                            |                 | SHEAR STRENGTH kPa<br>○ UNCONFINED      + FIELD VANE<br>● QUICK TRIAXIAL    × LAB VANE |  |  |  | WATER CONTENT (%)<br>w <sub>p</sub> w                      w <sub>L</sub> |  |  |  | GR  | SA | SI | CL |
| 158.7<br>0.0  | Frozen Ground Surface<br><br>AMORPHOUS PEAT<br>to FINE FIBROUS PEAT<br>very soft<br>black |            | 1       | SS   | 4          |                            |                 |  |  |  |  |   |  |  |  |   |    |    |    |
|               |   |            |         | 2    | SS         |                            |                 | 2  |  |  |  |   |  |  |  |   |    |    |    |
|               |   |            |         | 3    | SS         |                            |                 | 2  |  |  |  |   |  |  |  |   |    |    |    |
| 156.6<br>2.1  | SAND with silt<br>contains organics<br>compact<br>grey                                    |            | 4       | SS   | 19         |                            |                 |  |  |  |  |   |  |  |  |   |    |    |    |
|               |   |            |         |      |            |                            |                 |  |  |  |  |   |  |  |  |   |    |    |    |
|               |   |            |         |      |            |                            |                 |  |  |  |  |   |  |  |  |   |    |    |    |
| 155.5<br>3.2  | CLAYEY SILT (CL)<br>contains sand partings and seams<br>very stiff to firm<br>grey        |            | 5       | SS   | 3          |                            |                 |  |  |  |  |   |  |  |  |   |    |    |    |
|               |   |            |         |      |            |                            |                 |  |  |  |  |   |  |  |  |   |    |    |    |
|               |   |            |         |      |            |                            |                 |  |  |  |  |   |  |  |  |   |    |    |    |
|               |   |            |         | 6    | SS         | 3                          |                 |  |  |  |  |   |  |  |  |   |    |    |    |
|               |   |            |         |      |            |                            |                 |  |  |  |  |   |  |  |  |   |    |    |    |
|               |   |            |         |      |            |                            |                 |  |  |  |  |   |  |  |  |   |    |    |    |
|               |   |            |         | 7    | SS         | WH                         |                 |  |  |  |  |   |  |  |  |   |    |    |    |
|               |   |            |         |      |            |                            |                 |  |  |  |  |   |  |  |  |   |    |    |    |
|               |   |            |         |      |            |                            |                 |  |  |  |  |   |  |  |  |   |    |    |    |
|               |   |            |         |      |            |                            |                 |  |  |  |  |   |  |  |  |   |    |    |    |
|               |   |            |         |      |            |                            |                 |  |  |  |  |   |  |  |  |   |    |    |    |
|               |   |            | 8       | SS   | 1          |                            |                 |  |  |  |  |   |  |  |  |   |    |    |    |
|               |   |            |         |      |            |                            |                 |  |  |  |  |   |  |  |  |   |    |    |    |
|               |   |            |         |      |            |                            |                 |  |  |  |  |   |  |  |  |   |    |    |    |
|               |   |            |         |      |            |                            |                 |  |  |  |  |   |  |  |  |   |    |    |    |
|               |   |            | 9       | SS   | WH         |                            |                 |  |  |  |  |   |  |  |  |   |    |    |    |
|               |   |            |         |      |            |                            |                 |  |  |  |  |   |  |  |  |   |    |    |    |
|               |   |            |         |      |            |                            |                 |  |  |  |  |   |  |  |  |   |    |    |    |

Continued Next Page

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

RECORD OF BOREHOLE No SC23-1 2 OF 2 METRIC

WP# 4068-09-00 LOCATION Lat: 45.446019°, Long: -76.594282° Culvert 23, McNab Township; MTM z9: N 5 034 014.1 E 297 424.8 ORIGINATED BY BC  
HWY 17 BOREHOLE TYPE CME 75 Trackmount / HSA COMPILED BY AO  
DATUM Geodetic DATE 2024.03.07 - 2024.03.07 CHECKED BY JG

| SOIL PROFILE  |   |   | SAMPLES |      |            | GROUND WATER<br>CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT              |    |    |    |     | PLASTIC LIMIT<br>NATURAL MOISTURE<br>CONTENT<br>LIQUID LIMIT |                |   | UNIT<br>WEIGHT<br><br>γ<br><br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%) |    |    |    |    |   |
|---------------|---|---|---------|------|------------|----------------------------|-----------------|--|----|----|----|-----|--|----------------|---|--|---|----|----|----|----|---|
| ELEV<br>DEPTH | DESCRIPTION   | STRAT PLOT  | NUMBER  | TYPE | "N" VALUES |                            |                 | SHEAR STRENGTH kPa                                       |    |    |    |     | WATER CONTENT (%)  |                |   |  | GR  | SA | SI | CL |    |   |
|               |   |   |         |      |            |                            |                 | ○ UNCONFINED + FIELD VANE<br>● QUICK TRIAXIAL × LAB VANE |    |    |    |     |  |                |   |  |   |    |    |    |    |   |
|               | Continued From Previous Page  |   |         |      |            |                            |                 | 20   | 40 | 60 | 80 | 100 |  | W <sub>p</sub> | W | W <sub>L</sub>                                   |   |    |    |    |    |   |
|               | CLAYEY SILT (CL)<br>contains sand partings and seams<br>firm<br>grey  |  |         |      |            |                            | 148             |  |    |    |    |     |  |                |   |  |   |    |    |    |    |   |
|               |   |   | 10      | SS   | WH         |                            |                 |  |    |    |    |     |  |                |   |  |   |    |    |    |    |   |
|               |   |   |         |      |            |                            |                 |  |    |    |    |     |  |                |   |  |   |    |    |    |    |   |
| 146.5         |   |   |         |      |            |                            |                 |  |    |    |    |     |  |                |   |  |   |    |    |    |    |   |
| 12.2          | SILTY SAND (SM)<br>dense<br>greyish brown<br>GLACIAL TILL   |  | 11      | SS   | 45         |                            | 146             |  |    |    |    |     |  |                |   |  |   |    | 0  | 65 | 29 | 6 |
| 145.9         |   |   |         |      |            |                            |                 |  |    |    |    |     |  |                |   |  |   |    |    |    |    |   |
| 12.8          | End of Borehole<br>Auger Refusal on inferred bedrock<br><br>Monitoring Well installed:<br>Schedule 40 PVC standpipe with<br>50-mm diameter and 1.5-m slotted<br>screen. Stick-up cover installed at<br>ground surface.<br><br>Water Level Readings:<br>DATE      DEPTH (m)      ELEV. (m)<br>2024/03/08      0.5      158.2<br>2024/04/09      0.4      158.3<br>2024/05/01      0.5      158.2<br>2024/06/07      0.6      158.1<br>2024/06/28      0.5      158.2<br>2024/07/12      0.6      158.1<br>2024/08/28      0.6      158.1 |   |         |      |            |                            |                 |  |    |    |    |     |  |                |   |  |   |    |    |    |    |   |



# RECORD OF BOREHOLE No SC23-2

1 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.446088°, Long: -76.594324° Culvert 23, McNab Township; MTM z9: N 5 034 021.8 E 297 421.5 ORIGINATED BY DAP  
 HWY 17 BOREHOLE TYPE CME 75 Truckmount / HSA / NW Casing / NQ Coring COMPILED BY AO  
 DATUM Geodetic DATE 2024.03.13 - 2024.03.14 CHECKED BY JG

| SOIL PROFILE  |  |            | SAMPLES |      |            | GROUND WATER<br>CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |                                 |                                  | UNIT<br>WEIGHT<br>$\gamma$<br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%) |             |
|---------------|--|------------|---------|------|------------|----------------------------|-----------------|---|---------------------------------|----------------------------------|---|---|-------------|
| ELEV<br>DEPTH | DESCRIPTION  | STRAT PLOT | NUMBER  | TYPE | "N" VALUES |                            |                 | SHEAR STRENGTH kPa                          |                                 |                                  |   |   |             |
| 159.6         | Ground Surface   |            |         |      |            |                            |                 | 20 40 60 80 100                             | PLASTIC LIMIT<br>W <sub>P</sub> | NATURAL MOISTURE<br>CONTENT<br>W | LIQUID LIMIT<br>W <sub>L</sub>                  |   |             |
| 0.0           | SAND with silt and gravel<br>compact to very dense<br>yellowish brown<br>FILL      |            | 1       | SS   | 34         |                            |                 |   | ○ UNCONFINED                    | + FIELD VANE                     |   |   | GR SA SI CL |
|               |  |            | 2       | SS   | 52         |                            |                 |   | ● QUICK TRIAXIAL                | × LAB VANE                       |   |   |             |
|               |  |            | 3       | SS   | 10         |                            |                 |   | WATER CONTENT (%)               |                                  |   |   |             |
|               |  |            | 4       | SS   | 25         |                            |                 |   |                                 |                                  |   |   |             |
| 156.6         |  |            |         |      |            |                            |                 |   |                                 |                                  |   |   |             |
| 3.0           | SAND with silt<br>contains organics<br>very loose<br>brown                         |            | 5       | SS   | 2          |                            |                 |   |                                 |                                  |   |   |             |
|               |  |            | 6       | SS   | 3          |                            |                 |   |                                 |                                  |   |   |             |
| 155.5         |  |            |         |      |            |                            |                 |   |                                 |                                  |   |   |             |
| 4.1           | CLAYEY SILT (CL)<br>contains sand partings and seams<br>very stiff to firm<br>grey |            | 7       | SS   | 8          |                            |                 |   |                                 |                                  |   |   |             |
|               |  |            | 8       | SS   | 3          |                            |                 |   |                                 |                                  |   |   |             |
|               |  |            | 9       | SS   | WH         |                            |                 |   |                                 |                                  |   |   |             |
|               |  |            | 10      | SS   | WH         |                            |                 |   |                                 |                                  |   |   |             |
|               |  |            | 11      | SS   | WH         |                            |                 |   |                                 |                                  |   |   |             |

Continued Next Page

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

RECORD OF BOREHOLE No SC23-2

2 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.446088°, Long: -76.594324°  
Culvert 23, McNab Township; MTM z9: N 5 034 021.8 E 297 421.5 ORIGINATED BY DAP  
HWY 17 BOREHOLE TYPE CME 75 Truckmount / HSA / NW Casing / NQ Coring COMPILED BY AO  
DATUM Geodetic DATE 2024.03.13 - 2024.03.14 CHECKED BY JG

| SOIL PROFILE  |   | SAMPLES |      |                | GROUND WATER<br>CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |  |  |  |  | PLASTIC<br>LIMIT<br>w <sub>p</sub> | NATURAL<br>MOISTURE<br>CONTENT<br>w | LIQUID<br>LIMIT<br>w <sub>L</sub> | UNIT<br>WEIGHT<br>γ<br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%)      |
|---------------|---|---------|------|----------------|----------------------------|-----------------|---|--|--|--|--|------------------------------------|-------------------------------------|-----------------------------------|--|--|
| ELEV<br>DEPTH | DESCRIPTION   | NUMBER  | TYPE | "N" VALUES     |                            |                 | SHEAR STRENGTH kPa                          |  |  |  |  |                                    |                                     |                                   |  |  |
|               |   |         |      |                |                            |                 |   |  |  |  |  |                                    |                                     |                                   |  |  |
|               | Continued From Previous Page  |         |      |                |                            |                 |   |  |  |  |  |                                    |                                     |                                   |  |  |
|               | CLAYEY SILT (CL)<br>contains sand partings and seams<br>firm<br>grey  |         |      |                |                            |                 |   |  |  |  |  |                                    |                                     |                                   |  |  |
|               |   | 12      | SS   | WH             |                            |                 |   |  |  |  |  |                                    |                                     |                                   |  |  |
|               |   |         |      |                |                            |                 |   |  |  |  |  |                                    |                                     |                                   |  |  |
|               |   |         |      |                |                            |                 |   |  |  |  |  |                                    |                                     |                                   |  |  |
| 147.1         |   | 13      | SS   | 100/<br>250 mm |                            |                 |   |  |  |  |  |                                    |                                     |                                   |  | 0 4 70 26  |
| 12.5          | SILTY SAND (SM) with gravel<br>very dense<br>brown  |         |      |                |                            |                 |   |  |  |  |  |                                    |                                     |                                   |  |  |
| 146.5         | GLACIAL TILL  |         |      |                |                            |                 |   |  |  |  |  |                                    |                                     |                                   |  |  |
| 13.1          | MONZOGRANITE BEDROCK<br>slightly weathered to fresh jointed<br>light pinkish red<br>coarse grained<br>very strong | 1       | RUN  | -              |                            |                 |   |  |  |  |  |                                    |                                     |                                   |  | RUN #1<br>TCR=100%<br>SCR=33%<br>RQD=90%               |
|               |   |         |      |                |                            |                 |   |  |  |  |  |                                    |                                     |                                   |  |  |
|               |   |         |      |                |                            |                 |   |  |  |  |  |                                    |                                     |                                   |  |  |
|               |   | 2       | RUN  | -              |                            |                 |   |  |  |  |  |                                    |                                     |                                   |  | RUN #2<br>TCR=100%<br>SCR=94%<br>RQD=90%<br>UCS=128MPa |
| 143.4         |   |         |      |                |                            |                 |   |  |  |  |  |                                    |                                     |                                   |  |  |
| 16.2          | End of Borehole   |         |      |                |                            |                 |   |  |  |  |  |                                    |                                     |                                   |  |  |

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

# RECORD OF BOREHOLE No SC23-3

1 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.446275°, Long: -76.594331° Culvert 23, McNab Township; MTM z9: N 5 034 042.6 E 297 421.0 ORIGINATED BY BC  
HWY 17 BOREHOLE TYPE CME 75 Trackmount / HSA / NW Casing / NQ Coring COMPILED BY AO  
DATUM Geodetic DATE 2024.03.06 - 2024.03.06 CHECKED BY JG

| SOIL PROFILE  |   |            | SAMPLES |      |            | GROUND WATER<br>CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |  |                                    | UNIT<br>WEIGHT<br>$\gamma$<br>kN/m <sup>3</sup> | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%) |  |
|---------------|---|------------|---------|------|------------|----------------------------|-----------------|---|--|------------------------------------|---|---|--|
| ELEV<br>DEPTH | DESCRIPTION   | STRAT PLOT | NUMBER  | TYPE | "N" VALUES |                            |                 | SHEAR STRENGTH kPa                          |  |                                    |   |   |  |
| 158.5         | Ground Surface  |            |         |      |            |                            |                 | 20 40 60 80 100                             |  | PLASTIC<br>LIMIT<br>W <sub>P</sub> | NATURAL<br>MOISTURE<br>CONTENT<br>W             | LIQUID<br>LIMIT<br>W <sub>L</sub>                 |  |
| 0.0           | SILTY SAND<br>contains organics and wood<br>fragments<br>loose<br>dark brown<br>FILL                              |            | 1       | SS   | 4          |                            |                 | 20 40 60 80 100                             |  |                                    |   |   |  |
|               |   |            | 2       | SS   | 7          |                            |                 |   |  |                                    |   |   |  |
| 156.7         |   |            | 3       | SS   | 7          |                            |                 |   |  |                                    |   |   |  |
| 1.8           | SAND with silt<br>loose<br>grey   |            |         |      |            |                            |                 |   |  |                                    |   |   |  |
| 156.2         |   |            | 4       | SS   | 4          |                            |                 |   |  |                                    |   |   |  |
| 2.3           | CLAYEY SILT (CL)<br>contains sand partings and seams<br>very stiff to firm<br>grey                                |            | 5       | SS   | 5          |                            |                 |   |  |                                    |   |   |  |
|               |   |            | 6       | SS   | WH         |                            |                 |   |  |                                    |   |   |  |
|               |   |            | 7       | SS   | 5          |                            |                 |   |  |                                    |   |   |  |
| 152.6         |   |            |         |      |            |                            |                 |   |  |                                    |   |   |  |
| 5.9           | MONZOGRANITE BEDROCK<br>slightly weathered to fresh jointed<br>light pinkish red<br>coarse grained<br>very strong |            | 1       | RUN  | -          |                            |                 |   |  |                                    |   |   |  |
|               |   |            | 2       | RUN  | -          |                            |                 |   |  |                                    |   |   |  |
|               |   |            | 3       | RUN  | -          |                            |                 |   |  |                                    |   |   |  |
| 149.2         |   |            |         |      |            |                            |                 |   |  |                                    |   |   |  |
| 9.3           | End of Borehole   |            |         |      |            |                            |                 |   |  |                                    |   |   |  |
|               | Monitoring Well installed:<br>Schedule 40 PVC standpipe with  |            |         |      |            |                            |                 |   |  |                                    |   |   |  |

Continued Next Page

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

20  
15  
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No SC23-3 2 OF 2 METRIC

WP# 4068-09-00 LOCATION Lat: 45.446275°, Long: -76.594331°  
Culvert 23, McNab Township; MTM z9: N 5 034 042.6 E 297 421.0 ORIGINATED BY BC  
HWY 17 BOREHOLE TYPE CME 75 Trackmount / HSA / NW Casing / NQ Coring COMPILED BY AO  
DATUM Geodetic DATE 2024.03.06 - 2024.03.06 CHECKED BY JG

| SOIL PROFILE  |  |            | SAMPLES |      |            | GROUND WATER<br>CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION<br>RESISTANCE PLOT |    |    |    |     | PLASTIC LIMIT<br>NATURAL MOISTURE<br>CONTENT<br>LIQUID LIMIT |                |   | UNIT<br>WEIGHT<br><br>γ | REMARKS<br>&<br>GRAIN SIZE<br>DISTRIBUTION<br>(%) |             |
|---------------|--|------------|---------|------|------------|----------------------------|-----------------|---|----|----|----|-----|--|----------------|---|-------------------------|---|-------------|
| ELEV<br>DEPTH | DESCRIPTION  | STRAT PLOT | NUMBER  | TYPE | "N" VALUES |                            |                 | SHEAR STRENGTH kPa                          |    |    |    |     | WATER CONTENT (%)  |                |   |                         |   |             |
|               | Continued From Previous Page   |            |         |      |            |                            |                 | 20  | 40 | 60 | 80 | 100 |  | W <sub>p</sub> | W | W <sub>L</sub>          |   | GR SA SI CL |
|               | 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      0.5      158.0   |            |         |      |            |                            |                 |   |    |    |    |     |  |                |   |                         |   |             |
|               | 2024/05/01      0.6      157.9   |            |         |      |            |                            |                 |   |    |    |    |     |  |                |   |                         |   |             |
|               | 2024/06/07      0.8      157.7   |            |         |      |            |                            |                 |   |    |    |    |     |  |                |   |                         |   |             |
|               | 2024/06/28      0.7      157.8   |            |         |      |            |                            |                 |   |    |    |    |     |  |                |   |                         |   |             |
|               | 2024/08/28      0.8      157.7   |            |         |      |            |                            |                 |   |    |    |    |     |  |                |   |                         |   |             |



## **Appendix C.**

### **Laboratory Testing**



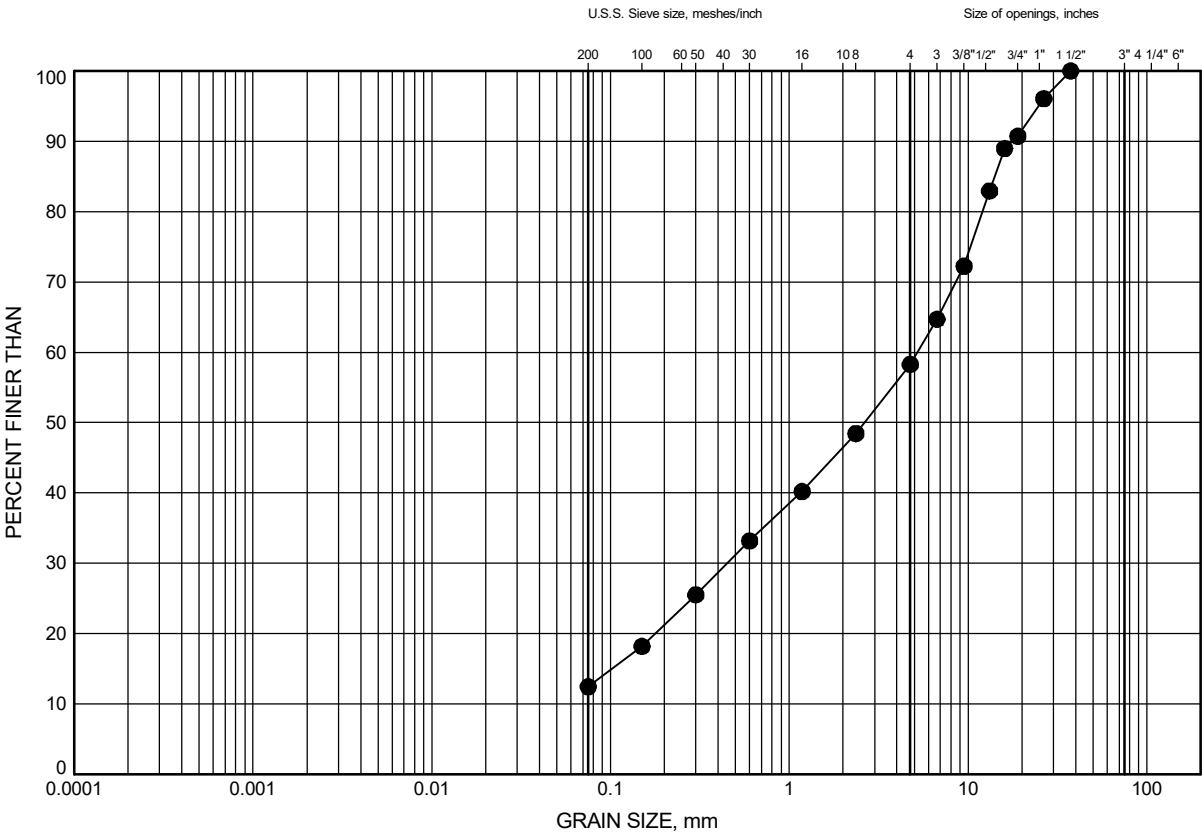
**Appendix C.1**  
**Particle Size Analysis Figures**  
**Atterberg Limit Test Results**  
**Unconfined Compressive Strength Testing Results**  
**Rock Core Photos**

Highway 17 twinning, Culvert 23, Sta. 10+993

# GRAIN SIZE DISTRIBUTION

FIGURE C1

FILL: Sand with Silt and Gravel



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

## LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ●      | SC23-2   | 0.3       | 159.3     |

GRAIN SIZE DISTRIBUTION - THURBER CULVERT 23 GINT LOGS.GPJ 7-31-24

Date July 2024  
GWP# 4018-E-0009



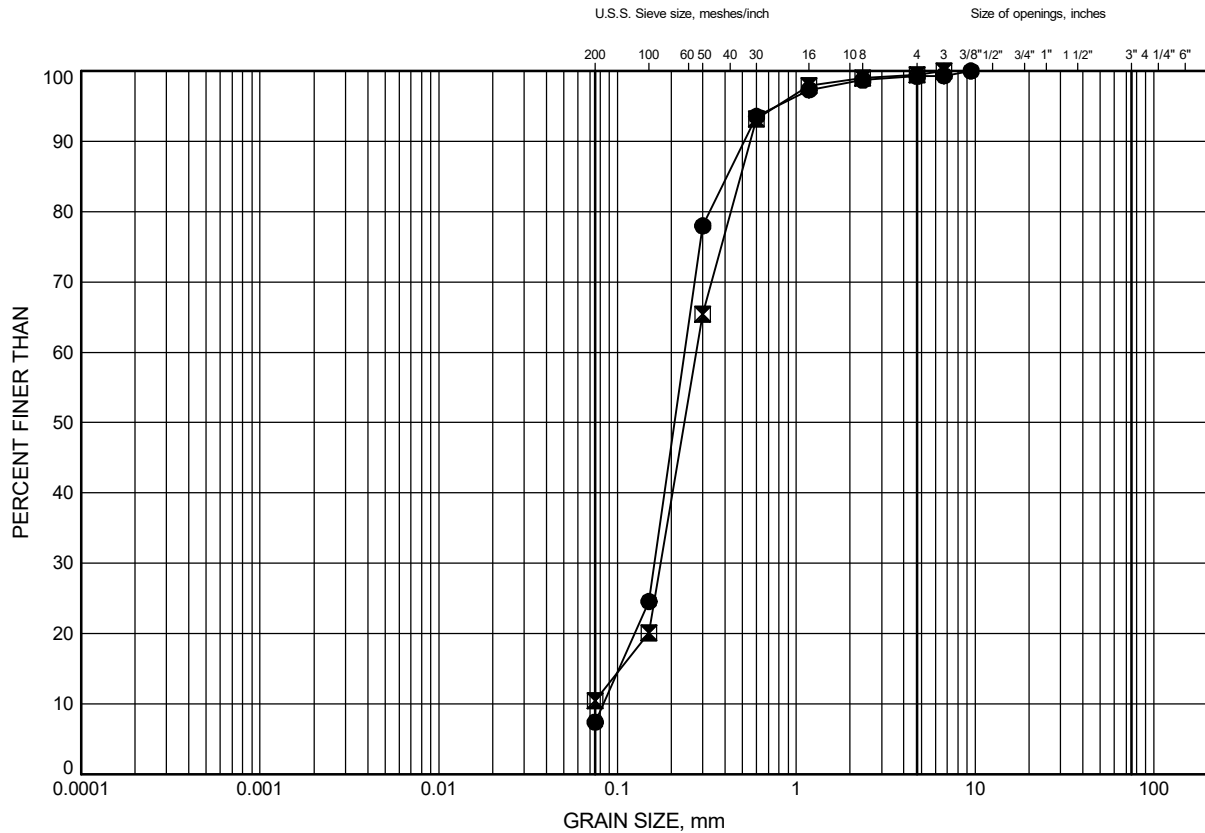
Prep'd RH  
Chkd. AO

Highway 17 twinning, Culvert 23, Sta. 10+993

# GRAIN SIZE DISTRIBUTION

FIGURE C2

## Sand with Silt



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

### LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ●      | SC23-1   | 2.6       | 156.1     |
| ⊠      | SC23-3   | 2.0       | 156.5     |

Date July 2024  
GWP# 4018-E-0009



Prep'd RH  
Chkd. AO

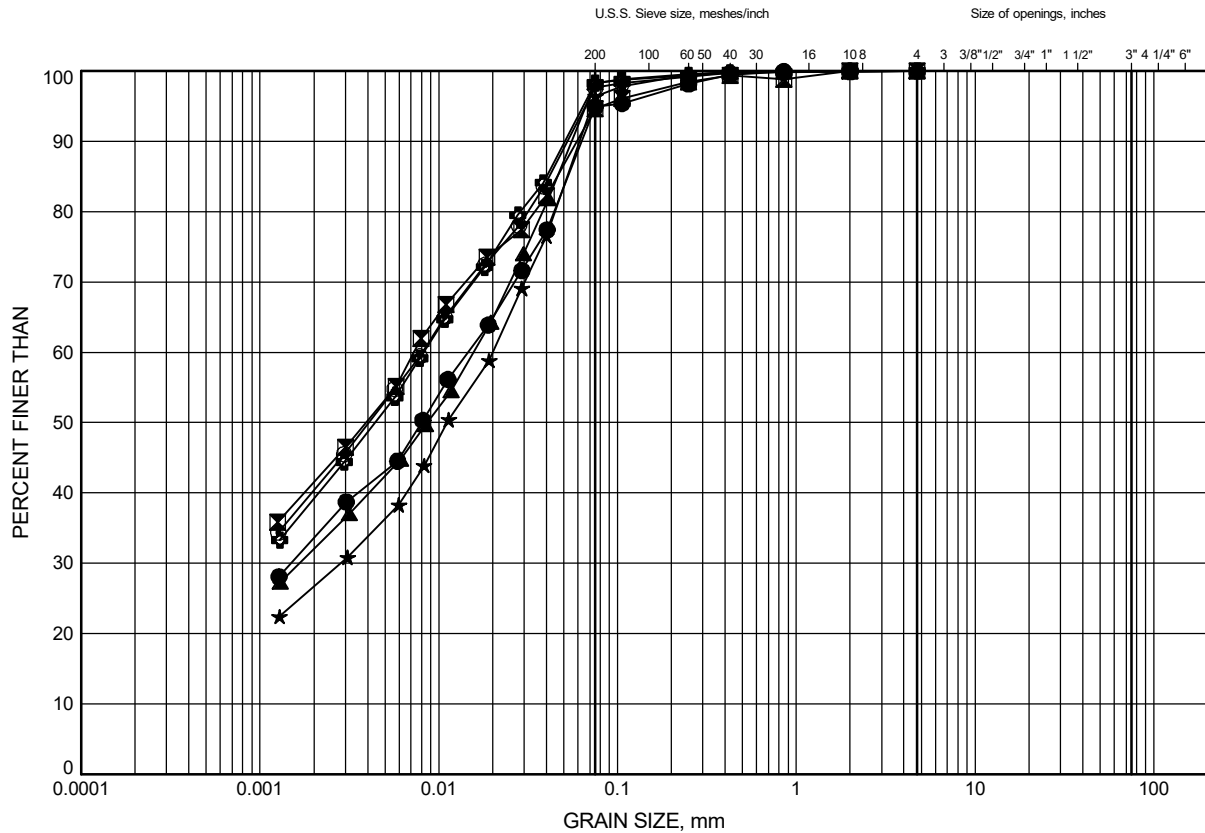


Highway 17 twinning, Culvert 23, Sta. 10+993

# GRAIN SIZE DISTRIBUTION

FIGURE C3

## Clayey Silt (CL)



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

## LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ●      | SC23-1   | 7.9       | 150.8     |
| ⊠      | SC23-2   | 4.9       | 154.7     |
| ▲      | SC23-2   | 7.9       | 151.7     |
| ★      | SC23-2   | 12.3      | 147.3     |
| ⊙      | SC23-3   | 2.6       | 155.9     |
| ⊕      | SC23-3   | 4.9       | 153.6     |

Date July 2024

GWP# 4018-E-0009



Prep'd RH

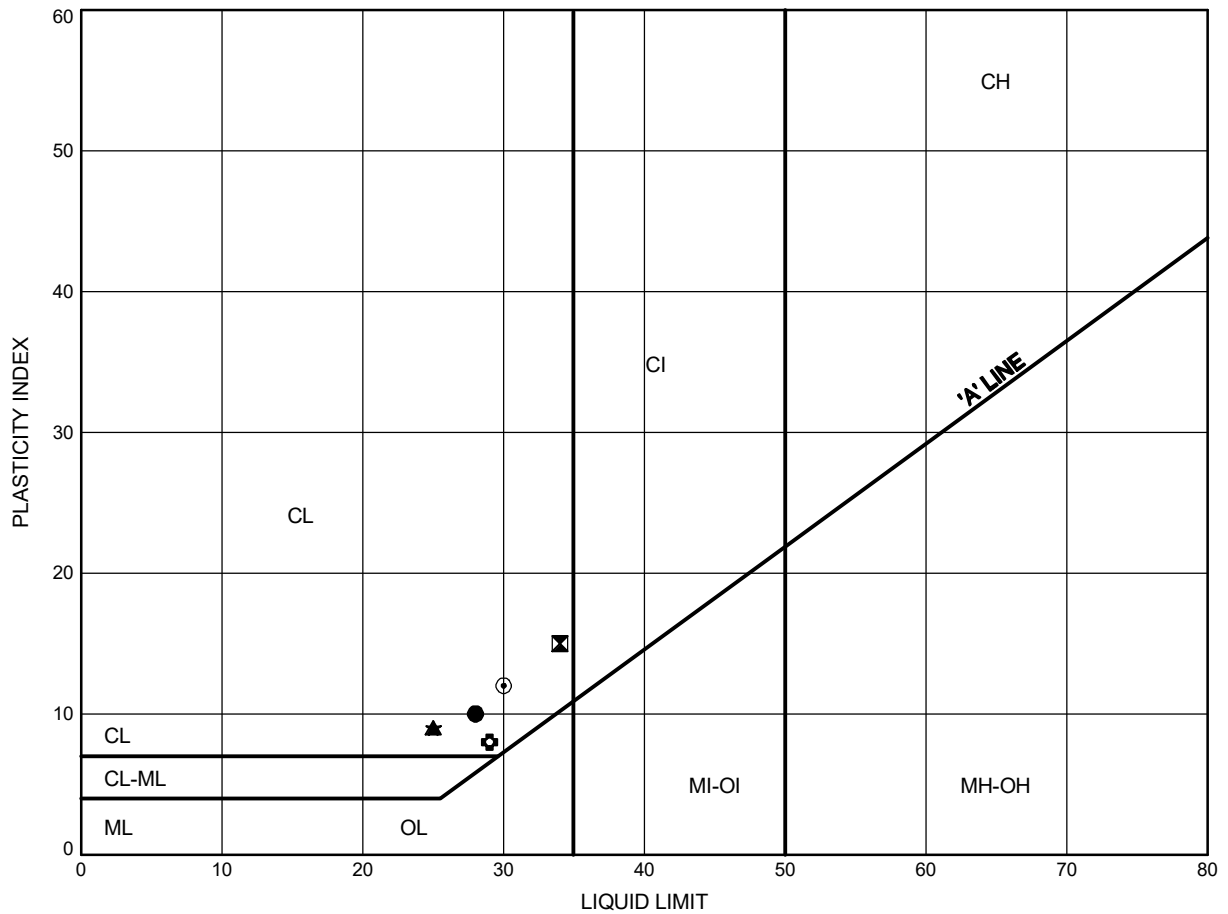
Chkd. AO

Highway 17 twinning, Culvert 23, Sta. 10+993

# ATTERBERG LIMITS TEST RESULTS

FIGURE C4

Clayey Silt (CL)



## LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ●      | SC23-1   | 7.9       | 150.8     |
| ⊠      | SC23-2   | 4.9       | 154.7     |
| ▲      | SC23-2   | 7.9       | 151.7     |
| ★      | SC23-2   | 12.3      | 147.3     |
| ⊙      | SC23-3   | 2.6       | 155.9     |
| ⊕      | SC23-3   | 4.9       | 153.6     |

Date July 2024

GWP# 4018-E-0009



Prep'd RH

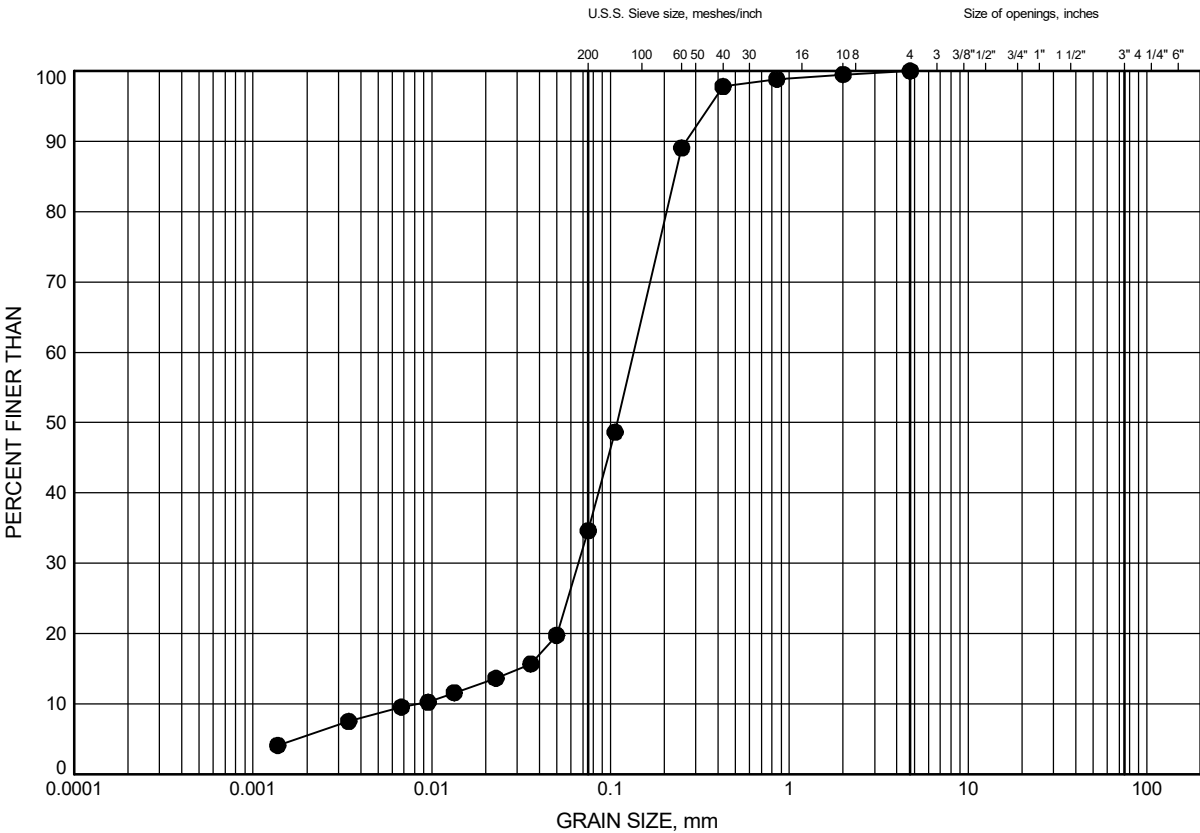
Chkd. AO

Highway 17 twinning, Culvert 23, Sta. 10+993

# GRAIN SIZE DISTRIBUTION

FIGURE C5

## Silty Sand (Glacial Till)



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

### LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ●      | SC23-1   | 12.4      | 146.3     |

GRAIN SIZE DISTRIBUTION - THURBER CULVERT 23 GINT LOGS.GPJ 7-31-24

Date July 2024  
GWP# 4018-E-0009



Prep'd RH  
Chkd. AO

## UNCONFINED COMPRESSION TEST REPORT

### ASTM D7012-14

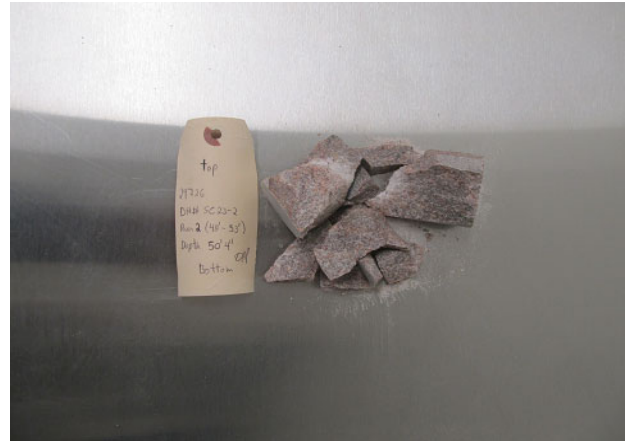
|               |                               |              |          |
|---------------|-------------------------------|--------------|----------|
| CLIENT:       | Thurber Engineering (Ottawa)  | FILE NUMBER: | 24726    |
| PROJECT NAME: | Highway 17 Twinning - Renfrew | REPORT DATE: | 1-Aug-24 |
| BOREHOLE No.: | SC23-2                        | TEST DATE:   | 9-May-24 |
| SAMPLE No.:   | Run 2                         |              |          |
| SAMPLE DEPTH: | 15.34 m                       |              |          |
| DESCRIPTION:  | Granite                       |              |          |

|  |        |                                   |       |
|--|--------|-----------------------------------|-------|
| Avg. Height (cm):                        | 9.5    | Weight (g):                       | 434.0 |
| Avg. Diameter (cm):                      | 4.7    | Wet Density (kg/m <sup>3</sup> ): | 2,633 |
| H. to Dia. Ratio**:                      | 2:1    | Dry Density (kg/m <sup>3</sup> ): | 2,633 |
| Cross Sectional Area (cm <sup>2</sup> ): | 17.35  | Moisture Content* (%):            | N/A   |
| Sample Volume (cm <sup>3</sup> ):        | 164.82 |                                   |       |

ORIGINAL SPECIMEN



FRACTURED SPECIMEN



|                                  |             |
|----------------------------------|-------------|
| AVG. RATE OF STRAIN TO FAILURE:  | 0.250 MPa/s |
| MAXIMUM COMPRESSIVE LOAD:        | 223.2 kN    |
| UNCONFINED COMPRESSIVE STRENGTH: | 128.6 MPa   |

Note: \* The moisture content was obtained before the test.  
 \*\* Dimensions of Specimen conform to ASTM D 4543-04.

TEST DONE BY: GF  
 REVIEWED BY: WM

UCS SC23-2 Run 2

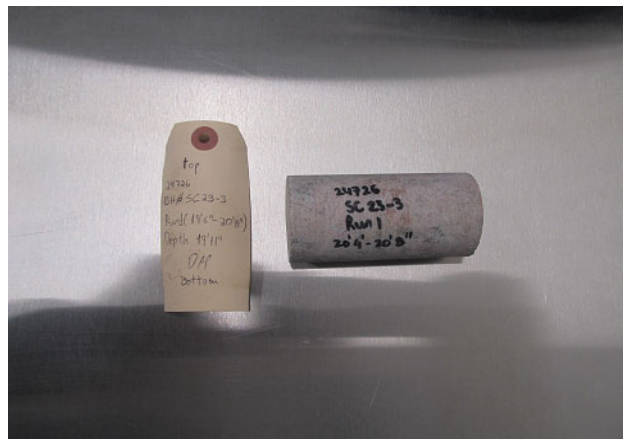
## UNCONFINED COMPRESSION TEST REPORT

### ASTM D7012-14

|               |                               |              |          |
|---------------|-------------------------------|--------------|----------|
| CLIENT:       | Thurber Engineering (Ottawa)  | FILE NUMBER: | 24726    |
| PROJECT NAME: | Highway 17 Twinning - Renfrew | REPORT DATE: | 1-Aug-24 |
| BOREHOLE No.: | SC23-3                        | TEST DATE:   | 9-May-24 |
| SAMPLE No.:   | Run 1                         |              |          |
| SAMPLE DEPTH: | 6.07 m                        |              |          |
| DESCRIPTION:  | Granite                       |              |          |

|  |        |                                   |       |
|--|--------|-----------------------------------|-------|
| Avg. Height (cm):                        | 9.6    | Weight (g):                       | 436.1 |
| Avg. Diameter (cm):                      | 4.7    | Wet Density (kg/m <sup>3</sup> ): | 2,618 |
| H. to Dia. Ratio**:                      | 2:1    | Dry Density (kg/m <sup>3</sup> ): | 2,618 |
| Cross Sectional Area (cm <sup>2</sup> ): | 17.35  | Moisture Content* (%):            | N/A   |
| Sample Volume (cm <sup>3</sup> ):        | 166.55 |                                   |       |

ORIGINAL SPECIMEN



FRACTURED SPECIMEN



|                                  |             |
|----------------------------------|-------------|
| AVG. RATE OF STRAIN TO FAILURE:  | 0.250 MPa/s |
| MAXIMUM COMPRESSIVE LOAD:        | 181.2 kN    |
| UNCONFINED COMPRESSIVE STRENGTH: | 104.4 MPa   |

Note: \* The moisture content was obtained before the test.  
 \*\* Dimensions of Specimen conform to ASTM D 4543-04.

TEST DONE BY: GF  
 REVIEWED BY: WM

UCS SC23-3 Run 1

**Borehole SC23-2**  
**Run 1 and 2**  
**Depth 13.1 to 16.2 m**  
**Elevation 146.5 to 143.4 m**  
**Dry Sample**



**Borehole SC23-2**  
**Run 1 and 2**  
**Depth 13.1 to 16.2 m**  
**Elevation 146.5 to 143.4 m**  
**Wet Sample**





**Borehole SC23-3**  
**Run 1, 2, and 3**  
**Depth 5.9 to 9.3 m**  
**Elevation 152.6 to 149.2 m**  
**Dry Sample**

Run 1 Start  
elev. 152.6 m

Run 1 End  
elev. 152.2 m

Run 2 Start  
elev. 152.2 m



Run 2 End  
elev. 150.7 m

Run 3 Start  
elev. 150.7 m



Run 3 End  
elev. 149.2 m



**Borehole SC23-3**  
**Run 1, 2, and 3**  
**Depth 5.9 to 9.3 m**  
**Elevation 152.6 to 149.2 m**  
**Wet Sample**

Run 1 Start  
elev. 152.6 m

Run 1 End  
elev. 152.2 m

Run 2 Start  
elev. 152.2 m



Run 2 End  
elev. 150.7 m

Run 3 Start  
elev. 150.7 m



Run 3 End  
elev. 149.2 m



## **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:   | SC18-3 SS3A 5'-6'3" | SC23-2 SS5 10'-12' | DOC23-1 SS7, 15'-17' | OBR23-1 SS16 48'-50' |   |   |
|                          |               | Sample Date: | 11-Mar-24 09:00     | 13-Mar-24 09:00    | 11-Mar-24 09:00      | 27-Mar-24 09:00      | - | - |
|                          |               | Sample ID:   | 2415421-01          | 2415421-02         | 2415421-03           | 2415421-04           |   |   |
|                          |               | Matrix:      | Soil                | Soil               | Soil                 | Soil                 |   |   |
|                          |               | MDL/Units    |                     |                    |                      |                      |   |   |
| Physical Characteristics |               |              |                     |                    |                      |                      |   |   |
| % Solids                 | 0.1 % by Wt.  |              | 87.8                | 62.4               | 62.0                 | 87.9                 | - | - |
| General Inorganics       |               |              |                     |                    |                      |                      |   |   |
| Conductivity             | 5 uS/cm       |              | 108 [1]             | 1950 [2]           | 1660 [1]             | 100                  | - | - |
| pH                       | 0.05 pH Units |              | 7.32 [1]            | 6.91 [2]           | 7.12 [1]             | 7.37                 | - | - |
| Resistivity              | 0.1 Ohm.m     |              | 92.9 [1]            | 5.1 [2]            | 6.0 [1]              | 100                  | - | - |
| Anions                   |               |              |                     |                    |                      |                      |   |   |
| Chloride                 | 10 ug/g       |              | 10 [1]              | 175 [1]            | 682 [1]              | <10                  | - | - |
| Sulphate                 | 10 ug/g       |              | <10 [1]             | 2080 [1]           | 29 [1]               | <10                  | - | - |

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

**Qualifier Notes:****Login Qualifiers :**

Sample - One or more parameter received past hold time - Conductivity, chloride, pH, resistivity, and sulphate.

Applies to Samples: SC18-3 SS3A 5'-6'3", DOC23-1 SS7, 15'-17'

**Sample Qualifiers :**

- 1: Holding time had been exceeded upon receipt of the sample at the laboratory or prior to the analysis being requested.
- 2: This analysis was conducted after the accepted holding time had been exceeded.

**Sample Data Revisions:**

None

**Work Order Revisions / Comments:**

None

**Other Report Notes:**

n/a: not applicable

ND: Not Detected

MDL: Method Detection Limit

Source Result: Data used as source for matrix and duplicate samples

%REC: Percent recovery.

RPD: Relative percent difference.

NC: Not Calculated

Soil results are reported on a dry weight basis unless otherwise noted.

Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.

Any use of these results implies your agreement that our total liability in connection with this work, however arising, shall be limited to the amount paid by you for this work, and that our employees or agents shall not under any circumstances be liable to you in connection with this work.

**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 <sub>2</sub> CO <sub>3</sub> ) % |
|---------------------------------------|----------------------|---|
| 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  |
| <del>6: SC18-3 SC3A 5' 6"</del>       | <del>11-Mar-24</del> | <del>&lt; 0.01</del>                          |
| 7: SC23-2 SS5 10'-12'                 | 13-Mar-24            | 0.83  |
| <del>8: DCC23-1 SC7, 15' 17"</del>    | <del>11-Mar-24</del> | <del>0.01</del>                               |
| <del>9: OBR23-1 SS16 48'-50'</del>    | <del>27-Mar-24</del> | <del>&lt; 0.01</del>                          |
| <del>10: DON24-2 SC4 10' 12"</del>    | <del>09-Apr-24</del> | <del>&lt; 0.01</del>                          |
| <del>11: NCC20-2 SC2A 2'6" 3'3"</del> | <del>02-Apr-24</del> | <del>&lt; 0.01</del>                          |
| <del>12: SC10-1 SS2B 3'-4"</del>      | <del>21-Mar-24</del> | <del>&lt; 0.01</del>                          |
| <del>13: SC10-4 SC2 2'6" 4'6"</del>   | <del>04-Apr-24</del> | <del>&lt; 0.01</del>                          |

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 west along frozen ponded water and culvert inlet (March 5, 2024)**



**Photo 2. Looking east along north embankment and culvert outlet (May 01, 2024)**





**Photo 3. Looking west along ponded water near culvert inlet (July 26, 2024)**



**Photo 4. Looking east along Highway 17 eastbound (June 26, 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: 45.446N 76.594W

User File Reference: Culvert 23, Highway 17, Sta. 10+993

2024-07-31 17:03 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)                             | 0.357    | 0.183 | 0.105  | 0.032 |
| Sa (0.1)                              | 0.423    | 0.228 | 0.137  | 0.045 |
| Sa (0.2)                              | 0.353    | 0.198 | 0.123  | 0.043 |
| Sa (0.3)                              | 0.269    | 0.154 | 0.098  | 0.035 |
| Sa (0.5)                              | 0.192    | 0.113 | 0.072  | 0.026 |
| Sa (1.0)                              | 0.098    | 0.059 | 0.038  | 0.013 |
| Sa (2.0)                              | 0.048    | 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)                               | 0.227    | 0.125 | 0.076  | 0.025 |
| PGV (m/s)                             | 0.161    | 0.090 | 0.056  | 0.018 |

**Notes:** Spectral ( $S_a(T)$ , where  $T$  is the period in seconds) and peak ground acceleration (PGA) values are given in units of  $g$  ( $9.81 \text{ m/s}^2$ ). Peak ground velocity is given in  $\text{m/s}$ . Values are for "firm ground" (NBCC2015 Site Class C, average shear wave velocity  $450 \text{ m/s}$ ). 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](http://www.EarthquakesCanada.ca) and [www.nationalcodes.ca](http://www.nationalcodes.ca) for more information



Natural Resources  
Canada

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Canada

Canada



## **Appendix F.**

### **Foundation Comparison**



## COMPARISON OF ALTERNATIVE FOUNDATION TYPES

|                           | Rigid Pipe Culverts  | Open-Bottom Box Culverts  | Closed-Bottom Box Culverts  |
|---------------------------|--|---|---|
| <b>Advantages</b>         | <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>Readily encompasses natural substrate. Preferable from environmental perspective</p> <p>Possibility to maintain work zone to span the existing culvert; however, the replacement would need to be significantly wider than existing to allow for foundation excavation without conflict with existing pipe.</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>   |
| <b>Disadvantages</b>      | <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 will 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>Protection system will require bracing, anchors and/or rakers</p> <p>Deepest excavation increases quantities and dewatering concerns.</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> |
| <b>Risks/Consequences</b> | Some risk of basal instability during excavation due to depth of excavation below water table.   | Increased risk of basal instability during footing excavation due to depth of excavation below water table.   | Some risk of basal instability during excavation due to depth of excavation below water table.  |
| <b>Relative Cost</b>      | Low to Moderate  | Moderate  | Moderate  |
| <b>Recommendation</b>     | <b>Feasible</b>  | <b>Not Recommended</b>  | <b>Recommended</b>  |



## **Appendix G.**

### **List of Referenced Specifications Non-Standard Special Provisions**



1. The following Special Provisions and OPS 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 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 803.010   | Backfill and Cover for Concrete Culverts with Spans Less Than or Equal To 3.0 m               |
| 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 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.

### **“Shallow and Sloping Bedrock”**

The contractor is hereby notified that bedrock was encountered at variable elevation in the boreholes drilled at the site. The presence of shallow bedrock may affect the installation of Temporary Protection Systems. The Contractor's Temporary Protection System design shall include consideration of shallow bedrock.