THURBER ENGINEERING LTD.

FINAL
FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 17 CULVERT AT STATION 14+242
DULHUT TOWNSHIP, ONTARIO
ASSIGNMENT NO.: 5020-E-0025
GWP 5207-18-00

GEOCRES NO.: 41N00-037

Location: Lat: 47.846242°, Long: -84.886665°

Client Name: AECOM Canada Ltd.
Date: November 23, 2023
File: 31653

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PART 1. FACTUAL INFORMATION

1. INTRODUCTION

This section of the report presents the factual findings obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) for the replacement of the culvert that crosses Highway 17 at Sta. 14+242 in Dulhut Township, Ontario. Thurber carried out the foundation investigation as a subconsultant to AECOM Canada Ltd. (AECOM) under Agreement No. 5020-E-0025, Change Order 1.

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

It is a condition of this report that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

2. SITE DESCRIPTION

2.1 General

The culvert site crosses Highway 17 approximately 17.5 km south of the junction between Highway 17 and Highway 101. For project purposes, Highway 17 is herein described as oriented north-south, and the culvert is described as oriented east-west.

In the area of the culvert, Highway 17 is a two-lane highway and has a posted speed limit of 90 km/h. The road surface near the culvert is at approximate elevation 288.9 m. The culvert is located within a section of highway with a superelevated curve, and the highway alignment continues to curve east both north and south of the culvert site. The shoulders to the highway are paved and steel cable guiderails on wooden posts are present along both northbound and southbound shoulders of the highway. The 2023 traffic volume projection for this section of Highway 17 is understood to be 2200 AADT.

The existing culvert is reported in AutoCAD drawings provided by AECOM to be an 1800 mm diameter, 49.5 m long, corrugated steel pipe (CSP) culvert with approximately 55 degree skew to the highway alignment. The culvert has a relatively flat gradient with the invert of the culvert near elevations 280.2 m and 279.9 m at the inlet and outlet, respectively. The cover above the existing culvert is approximately 6.9 m at the highway centerline.

The water flows through the culvert from east to west and ponded water, in the order of 0.8 m depth, was present during the time of the field investigation. The ponded water was likely due to beaver dams visible in the vicinity of the culvert site and partial culvert blockage at the outlet.

Embankment side slopes, in the vicinity of the culvert, are inclined at approximately 2.1H:1V and 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 adjacent to the highway is undeveloped and densely vegetated with mixed forests of coniferous and some deciduous trees and shrubs. Overhead utility lines were not present. Bedrock outcrops are present northwest of the culvert. Lake Superior is located approximately 1.9 km west of the highway alignment.

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

2.2 Site Geology

According to Crins et al. 2009[1] the project area is described as Ecoregion 4E (Lake Temagami Ecoregion) within the Ontario Shield Ecozone. According to Wester et al. 2018[2] the ecoregion is subdivided into Ecodistrict 4E-1 (Michipicoten Ecodistrict). The project area is located in the north part of the ecodistrict, which is characterized by glaciofluvial material sediments and morainal deposits overlying Precambrian bedrock. Bedrock Geology Map (MRD126)[3] indicates the site is underlain by mafic to intermediate metavolcanic rocks: basalt and andesite.

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[1] *https://files.ontario.ca/mnrf-ecosystemspart1-accessible-july2018-en-2020-01-16.pdf*
[2] *https://files.ontario.ca/ecosystems-ontario-part2-03262019.pdf*
[3] *http://www.geologyontario.mndm.gov.on.ca/mines/data/google/mrd126/doc.kml*

2.3 Existing Information

A historical foundation investigation report was not available for this site within the online Geocres Library.

Base plan mapping was provided by AECOM for the preparation of this report.

3. SITE INVESTIGATION AND FIELD TESTING

The foundation investigation and field-testing program was carried out from May 8 to 13, 2023, and consisted of two on-road boreholes identified as 23-501 and 23-502 and two off-road boreholes identified as 23-503 and 23-504. The on-road boreholes were advanced with a CME 75 truck mounted drill rig utilizing NW casing, and coring techniques and the off-road boreholes were advanced with portable drilling equipment. Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations.

A summary of the borehole coordinates, elevations, and termination depths is provided within the table below. The as-drilled borehole elevations were surveyed by Thurber with a surveyor's level with a reported vertical accuracy of +/- 1.5 mm and were measured relative to BM HCP 178 (Elevation 288.9 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 AECOM. 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 13.

Table 3-1 Borehole Summary

BOREHOLE NO.	DRILLED LOCATION	NORTHING (Latitude)	EASTING (Longitude)	GROUND SURFACE ELEVATION (m)	TERMINATION DEPTH (m)
23-501	Southbound lane	5 301 181.9 (47.846242)	238 442.8 (-84.886665)	288.9	17.0
23-502	Northbound lane	5 301 164.7 (47.846087)	238 448.1 (-84.886592)	288.8	13.1
23-503	East embankment toe	5 301 184.3 (47.846266)	238 465.1 (-84.886368)	282.3	6.1
23-504	West embankment toe	5 301 165.4 (47.846091)	238 423.5 (-84.886921)	281.2	9.7

The boreholes were advanced to depths ranging from 6.1 to 17.0 m (base elev. 276.2 to 271.5 m). Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in general accordance with ASTM D 1586. A third-weight hammer was used for SPT testing within Borehole 23-504 and a hammer weight correction has been applied for the N-values on the borehole record. It is noted that an automatic hammer could not be used with the portable drill thus the SPT N-values from the portable drilling equipment are considered to be less reliable.

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.

A 32 mm diameter well was installed in each of Boreholes 23-503 and 23-504 to allow for measurements of the groundwater level after drilling. The details for the well are illustrated on the respective Record of Borehole sheets provided in Appendix B. The wells were decommissioned in July 2023.

Following completion of the field investigation, Boreholes 23-501 and 23-502 were decommissioned in general in accordance with O.Reg. 903, as amended. Boreholes 23-501 and 23-502 were capped with cold patch asphalt to reinstate the pavement surface.

4. LABORATORY TESTING

Laboratory testing was selected in general 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. Recovered soil samples were selected for grain size distribution and, where appropriate, Atterberg Limit testing in accordance with MTO and ASTM standards. The results of these tests are summarized on the Record of Borehole sheets included in Appendix B.

One soil sample was selected and submitted for analytical testing of corrosivity parameters and sulphate content.

All laboratory test results from the field investigation are provided in Appendix C.

5. DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix B and on 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 Record of Borehole sheets takes precedence over this general description for interpretation of the site conditions. It must be recognized that the soil and groundwater conditions will vary between and beyond borehole locations. Soil classification is in accordance with ASTM D2487. Description of cohesive soils and secondary components are described as per the current MTO Guideline for Foundation Engineering Services Manual.

In general, the encountered stratigraphy consists of gravelly sand embankment fill overlaying rockfill overlying native deposits of silty sand to sandy silt. Organic sandy silt was encountered in the off-road boreholes.

5.1 Surficial Materials

5.1.1 Asphalt

Asphalt was encountered at the ground surface in both on-road boreholes. The asphalt was measured to have a thickness of 115 mm Boreholes 23-501. Borehole 23-502 had 140 mm thickness of asphalt followed by a 25 mm layer of granulars overlying 65 mm of asphalt.

5.1.2 Topsoil

Borehole 23-504 encountered topsoil at the ground surface with a recorded thickness of 100 mm.

5.2 Fill

5.2.1 Gravelly Sand Fill

A fill layer consisting of gravelly sand to sand some gravel was encountered beneath the asphalt in Boreholes 23-501 and 23-502 and below the topsoil in off-road Borehole 23-504. Cobbles as well as fines were also encountered within the layer. The fill layer was 4.3 to 4.4 m thick (base elev. 284.5 m to 284.2 m) within the on-road boreholes. SPT N-values in the fill layer ranged from 2 to 63 blows, indicating a very loose to very dense relative density.

The recorded moisture contents ranged from 5 to 18%. The results of gradation analyses completed on five samples of the layer are illustrated in Figure C1 of Appendix C. The results of the tests are summarized in the table below and on the Record of Borehole sheets in Appendix B.

<table>
<tr><th>SOIL PARTICLE</th><th>PERCENTAGE (%)</th></tr>
<tr><td>Gravel</td><td>16 – 38</td></tr>
<tr><td>Sand</td><td>54 – 81</td></tr>
<tr><td>Silt</td><td rowspan="2">3 – 20</td></tr>
<tr><td>Clay</td></tr>
</table>

5.2.2 Rock Fill

A layer of cobble and boulder sized rockfill with sand and gravel was encountered below the gravelly sand to sand fill in Boreholes 23-501, 23-502 and 23-504. NQ coring techniques were required to penetrate the rockfill layer resulting in less retained sample. The rockfill layer was 4.8 to 6.5 m thick with an underside depth of 9.4 to 10.9 m (base elev. 279.4 to 278.0 m) within the on-road boreholes. SPT testing was attempted and, where obtainable, N-values ranged from 7 to 26 blows.

The recorded moisture contents of the non-cohesive infill ranged from 3 to 7%.

5.3 Silt and Sand

A deposit of silt and sand to sand trace to some gravel and trace organics was encountered beneath the rock fill in Boreholes 23-501 and 23-504. The layer was 0.7 m to 1.5 m thick with an underside depth of 3.0 to 11.6 m (base elev. 278.2 to 277.3 m). SPT N-values in the layer ranged from 15 to 29 blows, indicating a compact relative density.

The recorded moisture content ranged from 26 to 39%. 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 in the table below and on the Record of Borehole sheets in Appendix B.

<table>
<tr><th>SOIL PARTICLE</th><th colspan="2">PERCENTAGE (%)</th></tr>
<tr><td>Gravel</td><td colspan="2">1 – 5</td></tr>
<tr><td>Sand</td><td colspan="2">49 – 83</td></tr>
<tr><td>Silt</td><td>45</td><td rowspan="2">12</td></tr>
<tr><td>Clay</td><td>5</td></tr>
</table>

5.4 Organic Sandy Silt

A deposit of organic sandy silt containing wood was encountered at the ground surface in Borehole 23-503 and beneath the sand layer in Borehole 23-504. The thickness of the layer ranged from 1.5 to 1.6 m with a base depth of 1.5 to 4.6 m (base elev. 280.8 to 276.6 m). SPT N-values ranged from 2 to 6 blows, indicating a very loose to loose relative density.

The moisture content of the samples tested ranged from 53 to 86%. The results of gradation analyses completed on two samples of the layer are illustrated in Figure C3 of Appendix C. The results of the tests are summarized in the table below and on the Record of Borehole sheets in Appendix B.

SOIL PARTICLE	PERCENTAGE (%)
Gravel	0 – 4
Sand	22 – 28
Silt	57 – 73
Clay	5 – 11

The Atterberg Limits testing was completed on fines portion for one sample of this material. The results are on Figure C4 in Appendix C and summarized below and on the Record of Borehole sheets in Appendix B. The test results indicate an organic silt exhibiting high plasticity.

PARAMETER	VALUE (%)
Liquid Limit	76
Plastic Limit	70
Plasticity Index	6

5.5 Sandy Silt to Silty Sand

A deposit of sandy silt to silty sand was encountered beneath the organic silty sand in Borehole 23-504. The thickness of the layer was 4.5 m with a base depth of 9.1 m (base elev. 272.1 m). SPT N values ranged from 4 to 46 blows, indicating a very loose to dense relative density.

The moisture content of the samples tested ranged from 18 to 32%. The results of gradation analyses completed on two samples of the layer are illustrated in Figure C5 of Appendix C. The results of the tests are summarized in the table below and on the Record of Borehole sheets in Appendix B.

SOIL PARTICLE	PERCENTAGE (%)
Gravel	0
Sand	23 – 66
Silt	32 – 68
Clay	2 – 9

5.6 Sandy Silt to Silty Sand, Some Gravel to Gravelly

A deposit consisting of sandy silt to silty sand with varying amounts of gravel was encountered beneath the silt and sand deposit in Borehole 23-501, beneath the fill in Borehole 23-502 and beneath the sandy silt to silty sand in Borehole 23-504. The layer contained more gravel at the base of Borehole 23-504. The thickness of the layer was 0.7 and 2.1 m in Boreholes 23-502 and 23-501, respectively with an underside depth of 10.1 and 13.7 m (base elev. 278.7 and 275.2 m). Borehole 23-504 was terminated in this layer at a depth of 9.7 m (base elev. 271.5 m) indicating the layer had a thickness of at least 0.6 m. The SPT N-values ranged from 16 to 20 blows, indicating a compact relative density.

The moisture content of the sample tested ranged from 7 to 23%. The results of gradation analyses completed on three samples of the layer are illustrated in Figure C6 of Appendix C. The results of the tests are summarized below and on the Record of Borehole sheets in Appendix B.

<table>
<tr><th>SOIL PARTICLE</th><th colspan="2">PERCENTAGE (%)</th></tr>
<tr><td>Gravel</td><td colspan="2">14 – 20</td></tr>
<tr><td>Sand</td><td colspan="2">25 – 59</td></tr>
<tr><td>Silt</td><td>35 – 56</td><td rowspan="2">21</td></tr>
<tr><td>Clay</td><td>3 – 5</td></tr>
</table>

5.7 Sandy Gravel

A layer of sandy gravel with varying amounts of fines, cobbles and inferred boulders was encountered below the organic sandy silt in Borehole 23-503. NQ coring was required to advance into the borehole. The borehole was terminated within this layer at a depth of 6.1 m (base elev.

276.2 m), indicating the layer had a thickness of at least 4.6 m. The SPT N values ranged from 27 to 105 blows, indicating a compact to very dense relative density.

The recorded moisture content of the layer ranged from 4 to 10%. The results of grain size analyses conducted on one sample of the layer are illustrated in Figures C7 in Appendix C. The test results are summarized below and on the Record of Borehole sheets in Appendix B.

SOIL PARTICLE	PERCENTAGE (%)
Gravel	56
Sand	34
Silt	10
Clay	

5.8 Bedrock

Bedrock outcrops were observed in close proximity to the culvert. Bedrock was proven by coring in Boreholes 23-501 and 23-502. The depth to bedrock was 10.1 and 13.7 m (elev. 278.7 m and 275.2 m).

The bedrock encountered consisted of fine grained, highly weathered, dark greenish grey strong Greenschist Bedrock containing calcite inclusions. Photographs of the bedrock cores are provided in Appendix C. The rock core quality are summarized in the following table.

Table 5-1 Bedrock Details

PARAMETER	RANGE
Total Core Recovery (TCR), %	52 – 100
Solid Core Recovery (SCR), %	9 – 88
Rock Quality Designation (RQD), %	9 – 95
Fracture Index (fractures per 0.3 m)(1)	0 – >10

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

The RQD values encountered in the Borehole 23-501 were between 9% to 24% indicating a very poor quality and the RQD value was 95% in Borehole 23-502 indicating a bedrock of excellent quality (CFEM, 2006).

5.9 Groundwater Level

The measured groundwater levels within the wells installed in Boreholes 23-503 and 23-504 are summarized in the following table.

A representative open-hole groundwater level measurement was not obtained due to the introduction of water during drilling in Boreholes 23-501 and 23-502.

Table 5-2 Measured Water Levels

Borehole	Bottom of Screen Depth /Elevation (m)	Soil in Zone of Screen	Groundwater Level		Date of Measurement
			Depth (mbgs)	Elevation (m)	
23-503	6.0 276.3	Sandy Gravel	0.9 0.9 1.0 1.0 1.0	281.4 281.4 281.3 281.3 281.3	2023-05-13 2023-06-09 2023-07-11 2023-07-12 2023-07-13
23-504	5.1 276.1	Sandy Silt	0.3 0.6 0.5 0.5 0.5 0.5 0.5	280.9 280.6 280.7 280.7 280.7 280.7 280.7	2023-05-10 2023-05-11 2023-05-12 2023-05-13 2023-06-09 2023-07-12 2023-07-13

Ponded water was present near both embankment toes likely due to beaver dams and debris within the culvert. The surface water depth was recorded to be 0.8 m near the culvert inlet at the time of the field investigation.

It should be noted that the values shown above are considered short-term readings and may not reflect groundwater levels at the time of construction. Seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation events. The water level should also be expected to change based on the presence or removal of the beaver dam.

A Single Well Response Test (SWRT), or “slug test”, was carried out on July 15, 2023 in the monitoring well installed in BH 23-504 by lowering the water level within the monitoring well and recording the recovery of the water level over time with a data logger. The slug tests were completed and analyzed using the Hvorslev method and the plots of the slug test results are included in Appendix B. The hydraulic conductivity value calculated from the in-situ slug test is summarized in the following table.

Table 5-3 Single Well Response Test Results

Borehole /Monitoring Well	Bottom of Screen Depth /Elevation (m)	Soil in Zone of Screen	Estimated Hydraulic Conductivity (m/s)
23-504	5.1 276.1	Sandy Silt	1.4×10^{-5}

It should be expected that variations in hydraulic conductivity will exist within the various soil deposits that were encountered.

Both wells were decommissioned following the completion of the testing on July 15, 2023.

5.10 Analytical Testing

One soil sample was submitted for analytical testing. The analysis results are included in Appendix C and are summarized in Table 5-4.

Table 5-4 Analytical Test Results

BOREHOLE	23-504
SAMPLE	SS6
DEPTH (ft/m)	7'6" – 9'6" 2.3 – 2.9
ELEVATION (m)	278.6
SOIL TYPE	Sand
CONDUCTIVITY (µS/cm)	172
pH	6.85
RESISTIVITY (Ohm-cm)	582
CHLORIDE (µg/g)	59
SULPHATE (µg/g)	69
SULPHIDE (%)	< 0.04

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, and Ohlmann Geotechnical Services Inc. of Almonte, 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 Provost Ltd. of Wawa, Ontario. The field investigation was supervised on a full-time basis by Mr. I. Khan, EIT and Mr. Arie Simpson, EIT. Overall supervision of the field investigation program was provided by Mr. A. de Oliveira, EIT.

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

Interpretation of the factual data and preparation of this report was completed by Ibrahim Khan, EIT and Stephen Peters, P.Eng. The report was reviewed by Dr. F. Griffiths, P.Eng., a Designated Principal Contact for MTO Foundation Projects.

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PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7. GENERAL

This section of the report provides an interpretation of the factual data from Part 1 of this report and presents foundation design recommendations to assist the project team in the design of the replacement of the culvert located on Highway 17 near Station 14+242 in the Township of Dulhut within the District of Michipicoten, Ontario. Thurber Engineering Limited (Thurber) carried out the current field investigation as a sub-consultant to AECOM Canada Ltd. (AECOM) under Agreement No. 5020-E-0025, Change Order 1. The discussion and recommendations presented in this report are based on information provided by AECOM and the factual data obtained during the current field investigation.

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

It is a condition of this report that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

7.1 Background Information

The culvert site is approximately 17.5 km south of the junction between Highway 17 and Highway 101 in Dulhut Township, Ontario. The road surface near the culvert is near elevation 288.9 m, and the invert of the culvert is near elevations 280.2 and 279.9 m at the inlet and outlet, respectively. The cover above the existing culvert is approximately 6.9 m at the highway centerline. The ditch drainage flows through the culvert under the highway embankment from east to west. The existing culvert is reported in AutoCAD drawings by AECOM to be an 1800 mm diameter, 49.5 m long corrugated steel pipe (CSP) culvert.

In general terms, the encountered stratigraphy consists of gravelly sand embankment fill overlying rockfill overlying native deposits varying from sandy silt to sandy gravel. A deposit of organic sandy silt was encountered near the embankment toes. The overburden was underlain by greenschist bedrock, proven by coring in the on-road boreholes. Ponded surface water was present near the culvert inlet and outlet, likely due to nearby beaver dams. Groundwater was recorded at 281.3 to 280.7 m near the inlet and outlet, respectfully.

7.2 Proposed Work

The proposed works for this non-structural culvert is indicated in the AECOM Foundations Investigations Program Summary Memorandum dated July 2022 with the preferred approach to be insertion of a liner. However, should a liner not satisfy project needs, consideration should be given to culvert replacement with half and half staging. AECOM indicated that a new culvert alignment would be located to the south of existing.

Contract Drawings were not available at the time of writing this report but it is assumed the replacement culvert will have similar alignment, invert and length as the existing.

7.3 Applicable Codes and Design Considerations

The geotechnical assessment presented below has been prepared based on the available data regarding the proposed work, existing ground conditions and in accordance with the Canadian Highway Bridge Design Code (CHBDC), version CSA S6-19. 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 culvert is to be designed to the “Major Route” importance category.

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

As per Section 6.5.3.2 of the CHBDC, the degree of site prediction model understanding is considered to be *Typical* based on the current information.

The frost penetration depth and associated recommendations are provided in Section 10.4.

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)[4]. 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 Sa (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 0.035g. 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 Liquefaction Potential

The susceptibility of the cohesionless soils below the culvert invert to experience liquefaction was assessed using the SPT data following the simplified method for cohesionless soil as outlined in Boulanger and Idriss (2014)[5]. The cohesionless foundation soils are not considered to be susceptible to liquefaction under the design earthquake.

8.3 CHBDC Seismic Site Classification and Performance Category

In accordance with 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 1.81 for this site yielding a scaled *site-specific* Site Class C PGA of 0.063g.

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 class. The F(0.2), as per Table 4.2 within Section 4.4.3.3 of the CHBDC, is equal to 1.64 for this

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[4] *https://earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/calc-en.php*

[5] *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.*

site yielding a scaled site specific Sa(0.2) of 0.10. A Seismic Performance Category of 1 is applicable to this site based on Table 4.10 of the CHBDC.

9. DESIGN OPTIONS

9.1 Culvert Type and Foundation Alternatives

Selection of the replacement culvert type must consider the proposed construction procedures, staging requirements, geotechnical resistance available in the foundation soils, depth to suitable bearing stratum and post-construction settlement. It is understood that lining the existing culvert may also be reviewed for this site. The options that have been considered from a foundation perspective are presented below:

- Closed Pipe (Concrete, HDPE, Steel)
  Pipe culverts are considered a feasible option from a foundation engineering perspective. Open cut or trenchless installation methods are typically considered for pipe culverts.

- Open Bottom Culvert (Box, Arch)
  An open bottom culvert would require a greater excavation depth than a closed bottom culvert to satisfy frost protection requirements. This leads to greater dewatering efforts to construct the culvert in the dry and would typically have greater differential settlement due to reduced footing widths when compared to a closed bottom culvert. The footings would be founded in native cohesionless soils. This option is likely not considered appropriate for the anticipated size of culvert required at this site.

- Closed Bottom Culvert (Box)
  A precast segmental 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 founding soils during installation, require less excavation depth than open bottom culverts leading to more manageable dewatering conditions.

Given the size of the replacement culvert and the presence of frequent cobbles and boulder sized rockfill and the relatively shallow and undulating bedrock, a culvert supported on deep foundations or a culvert consisting of precast concrete cap panels supported on parallel alignments of contiguous sheet piles are not feasible for this site.

A comparison of the alternatives, based on their respective advantages and disadvantages, in included in Appendix F. This report focuses on providing foundation recommendations on the design and construction of a pipe culvert or closed bottom concrete culvert replacement.

9.2 Construction Methodology Alternatives

For the proposed culvert replacement, construction methods that were considered are presented below. Common to all techniques discussed below is excavation through rockfill materials. It is understood that only a single lane of traffic is required to be maintained during replacement of the existing culvert. For an open cut through the embankment fill the side slopes of the open excavation for the culvert replacement should follow the recommendations of OSHA as outlined in Section 11.1. Alternatively, if space restrictions prohibit the use of slopes, a temporary protection system as per Section 11.2 should be used.

- Open Cut with Full Road Closure and Temporary Detour
  Installation of a new culvert using open cut techniques and a full road closure would allow for an expedited construction schedule and could reduce costs associated with roadway protection. However, it is anticipated that an acceptable detour route is not available and therefore this option is not carried forward and recommendations for replacement with a partial road closure/staging are included in the following sections.

- Open Cut with Staged Temporary Widening or Detour Embankment
  Installation of a new culvert using an open cut with a temporary widening to accommodate passage of traffic during construction is considered feasible from a foundation perspective. However, the available right-of-way, the curved highway alignment and the presence of organic sandy silt, ponded surface water and bedrock outcrops limit the feasibility of significant embankment widening and would need to be considered in design. Depending on the temporary alignment and length, an additional borehole investigation program may be required to determine the subsurface conditions along the potential detour alignment.

- Open Cut with Staged Construction and Temporary Protection System
  Installation of a new culvert using an open cut staged replacement is considered feasible from a foundation perspective. The option would require roadway protection, as discussed further in Section 11.2, installed near the embankment centerline to maintain a single lane of traffic flow along the current highway embankment. The Contractor would need to consider the rockfill and shallow bedrock during the installation of roadway protection. To reduce lateral deflections, the TPS may need to include anchoring and/or bracing. The height of the TPS could be reduced if the road alignment constraints allowed for a temporary grade lowering to be included.

- Open Cut with Staged Construction and Temporary Grade Lowering
  Installation of a new culvert using an open cut staged replacement with grade lowering to maintain movement of traffic within the existing embankment footprint is considered a feasible option from a foundation perspective. It is noted that grade lowering in the order of 3.5 m would be required which would be near the elevation that rockfill was encountered. Over excavation may be required to allow placement of granulars for a temporary pavement structure and the excavation equipment should be selected appropriately. The curved highway alignment and the presence of bedrock outcrops may limit the feasibility from a foundations perspective of significant embankment lowering and would need to be considered in design.

- Open Cut with Temporary Modular Bridge
  Installation of a new culvert using an open cut with a temporary modular bridge (TMB) to provide a single lane of traffic passage over the open excavation is generally considered feasible. Additional boreholes would be required at the TMB abutment locations to provide foundation design recommendations. It is expected that this alternative would be more expensive than the other open cut options, therefore it is not recommended.

- Trenchless Techniques
  Installation of a new culvert using trenchless techniques is not considered feasible due to the presence of a thick layer of cobble and boulder sized rockfill and the potential for encountering a mixed soil face. It is also noted that the groundwater level is partially within the tunnel zone adding further complications and risk to a trenchless approach.

9.3 Recommended Approach for Culvert Replacement

From a foundation engineering perspective, it is recommended that the existing culvert be replaced with either a pipe or precast segmental closed box culvert using open cut staged construction and temporary protection systems (TPS). The height of the TPS could be reduced if the road alignment constraints allowed for a temporary grade lowering to be included.

10. OPEN CUT FOUNDATION DESIGN RECOMMENDATIONS

10.1 Foundation Bearing Resistances

It is understood that the replacement pipe or closed box culvert will be founded near the same invert elevation as the existing culvert. Therefore, it is anticipated that the underside of a culvert will be founded within rockfill and within the native sand to sandy gravel deposits. There is a potential that the culvert ends could encounter organic sandy silt. Relatively shallow bedrock was encountered at one of the boreholes, it is conceivable that bedrock could be encountered along the alignment during culvert subgrade preparation.

The replacement culvert should be founded on a bedding layer (see Section 10.2). Subgrade preparation should follow the recommendation provided in Section 10.2 in order 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 (Section 11.3).

10.1.1 Pipe Culvert

Bearing resistance values are not required for pipe culverts. However, a modulus of subgrade reaction of 20 MN/m^3 can be used for a pipe culvert at this site if required. The value should be divided by the pipe diameter when estimating the soil's spring constant.

If a concrete pipe is selected, resistance to lateral forces/sliding resistance between concrete and the underlying granular bedding layer should be evaluated following the recommendations presented in Section 10.1.2.

10.1.2 Closed Box Culvert

A closed box culvert would not need to be founded below the depth of frost (see Section 10.4). For a box culvert with an exterior width of as much as 1.8 m founded on a properly prepared granular bedding layer, the design can be based on factored geotechnical resistance values as follows:

- Factored Geotechnical Resistance at ULS of 275 kPa
- Factored Geotechnical Resistance at SLS of 200 kPa

The factored geotechnical resistances include the following factors:

- Consequence factor (Ψ) of 1.0 (as per CHBDC, Table 6.1)
- Geotechnical resistance factors (as per CHBDC, Table 6.2)
  - ϕ_{gu} = 0.50 (static analysis; *typical* degree of understanding)
  - ϕ_{gs} = 0.80 (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 adjusted in accordance with CHBDC Clause 6.10.2. Foundation settlement, based on the supplied SLS resistance, is expected to be as much as 25 mm. The bearing resistances provided above are based on the assumption that subgrade is prepared as recommended in Section 10.2.

Resistance to lateral forces/sliding resistance between precast concrete and the underlying Granular bedding (see Section 10.2) should be evaluated in accordance with the CHBDC assuming an unfactored coefficient of 0.45 for precast concrete. A geotechnical resistance factor of 0.8 (ϕ_{gu}), as per Table 6.2 of the CHBDC (static analysis – typical understanding) should be applied to the sliding frictional capacity between concrete and Granular bedding.

10.2 Subgrade Preparation, Embedment, Bedding, Cover 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 SP110S06. 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. It is understood that the replacement culvert may be placed south of the existing alignment, and therefore the existing culvert may be abandoned in place.

At the founding level, existing fill, organic material (elev. 276.6 m in Borehole 23-504), soft/loose soils, 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, see further comments below for excavations in the wet.

Foundation preparation for a pipe culvert should be as per OPSS.PROV 421 and OPSD 802.031 and OPSD 803.031 (with frost depth as noted in Section 10.4). Bedding, Cover and Backfill for rigid pipes should be in accordance with OPSD 802.031 with bedding extending to 300 mm below the pipe. It is recommended that culvert cover, embedment and bedding materials consist of OPSS.PROV 1010 Granular A.

In order to provide a more uniform foundation subgrade condition for a closed box culvert, bedding and cover material conforming to OPSS.PROV 1010 Granular A requirements must be provided under the base of the culvert as per OPSS 422 and OPSD 803.010. The Granular bedding layer should be a minimum of 300 mm thick and covered with a 75 mm levelling course of Granular A.

It is noted that construction will extend below the observed water level. Dewatering will be required to place the granular bedding in the dry. Please review Section 11.3 for additional comments on groundwater and surface water control. Due to the anticipated difficulty in dewatering at this site, in select areas, consideration may be given to preparing the subgrade in the wet during periods of significant precipitation and/or when the groundwater level is seasonally high and cannot be effectively lowered below the founding elevation by pumping. It may be prudent to carry forward subgrade preparation in the wet in the contract drawings. Backfill below the bedding layer should consist of clear stone meeting the requirements of OPSS.PROV 1004. The clear stone should be completely wrapped in a non-woven geotextile meeting OPSS.PROV 1860 Class II and have a FOS not greater than 212 μm to minimize migration of the fines into the clear stone. Clear stone placed above the water level must be compacted as per OPSS.PROV 206. Culvert bedding, as described above, placed on a clear stone layer at least 150 mm thick, should have a minimum thickness of 150 mm.

Culvert backfill above the granular cover material 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.

10.3 Lateral Earth Pressure

Lateral earth pressure provided in the equations in the sections below are based on the assumption that the backfill is fully drained so that there are no unbalanced hydrostatic pressures. If adequate drainage cannot be confirmed, the potential for buildup of hydrostatic pressures should be considered in design.

10.3.1 Static Lateral earth Pressure

Lateral earth pressures acting on vertical walls should be computed in accordance with the Section 6.12 of the CHBDC but under fully drained conditions, the lateral pressures are generally given by the following expression:

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

where:

σ_h = static lateral earth pressure on the wall at depth d (kPa)
K = static earth pressure coefficient (see table below)
γ = unit weight of retained soil (see table below), adjusted below water level
d = 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 vertical walls for backfill material are shown in Table 10-1.

Table 10-1 Static Earth Pressure Coefficients

MATERIAL	UNIT WEIGHT (kN/m^3)	K_A (YIELDING WALL)	K_0 (NON-YIELDING WALL)	K_p (MOVEMENT TOWARD SOIL)	GROUND SURFACE BEHIND WALL
OPSS Granular A	22.8	0.27	0.43	3.7	Horizontal
		0.40	-	-	2H:1V
OPSS Granular B Type II	22.0	0.27	0.43	3.7	Horizontal
		0.40	-	-	2H:1V

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. Figure C6.27 and Table C6.12 of the Commentary to the CHBDC indicates the relative movement required to fully mobilize the active earth pressure. Where ground surfaces are sloped at 2H:1V behind the walls, the corresponding coefficients provided in Table 10-1 should be used.

If lateral movement is not permissible and/or the wall is restrained, the at rest earth pressure coefficient should be used. If the wall design allows lateral movement, the active earth pressures should be used.

A geotechnical resistance factor of 0.5 (ϕ_{gu}) should be applied in static design to the passive earth pressures in accordance with Table 6.2 of the CHBDC (static analysis typical understanding). The soils within the depth of frost should be ignored from providing passive lateral resistance; however, the equivalent surcharge loading from the weight of the soils above the frost depth should be incorporated into the lower soils layers.

10.3.2 Combined Static and Seismic Lateral Earth Pressure

In accordance with Clause 6.14 of the CHBDC, structures should be designed using dynamic earth pressure coefficients that incorporate the effects of earthquake loading. The following recommendations are per Section C6.14.7.2 of the Commentary of the CHBDC which states that seismically induced lateral soil pressures may be calculated using Mononobe Okabe Method with:

- k_h = ½ * 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 1 in 2475yr seismic event and on a Seismic Site Class E.

Table 10-2 Combined Static and Seismic Earth Pressure Coefficients

MATERIAL	UNIT WEIGHT (kN/m^3)	K_{AE} (YIELDING WALL)	K_{AE} (NON-YIELDING WALL)	GROUND SURFACE BEHIND WALL
OPSS Granular A	22.8	0.29	0.31	Horizontal
		0.42	0.46	2H:1V
OPSS Granular B Type II	22.0	0.29	0.31	Horizontal
		0.42	0.46	2H:1V

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

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

where:

σ_{hAE} = combined static and seismic lateral earth pressure on wall at depth d (kPa)

d = depth below the top of the wall where pressure is computed (m)

K	=	static earth pressure coefficient
		(K_A for yielding walls, K_o for non-yielding walls)
γ	=	unit weight of retained soil, adjusted below water level
K_{AE}	=	combined static and seismic earth pressure coefficient
H	=	total height of the wall (m)

10.4 Frost Depth

The frost penetration depth at this site is 2.2 m as per OPSD 3090.100. It is not necessary to found a pipe or a closed box culvert below the depth of frost penetration.

10.5 Cement Type and Corrosion Potential

Analytical tests were completed to determine the potential for degradation of concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel used in buried infrastructure. The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. Soluble sulphate concentrations less than 1000 μg/g generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater. The sulphate content in the soils is 69 μg/g, see Section 5.10. The selection for class of concrete should include consideration of the effects of road de-icing salts.

The pH, resistivity, and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The tests results provided in Section 5.10 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects. The corrosive effects of road de-icing salts should also be considered.

10.6 Embankment Design and Reinstatement

10.6.1 Embankment Reinstatement

The existing highway embankment side slopes are generally sloped at approximately 2.1H: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 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 rock fill, the embankment could be reconstructed with side slopes of 1.5H:1V (or flatter). 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 earth 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 is to remain unchanged, 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 abandoned and fully grouted or removed and backfilled, it is estimated that this would induce settlements of less than 15 mm beneath the existing culvert alignment as a result of the increased load imposed by the grout/fill.

10.6.2 Temporary Grade Lowering

It is anticipated that a grade lowering of approximately 3.5 m would be required to create a working surface wide enough to replace the culvert in two stages without temporary protection systems. Rockfill was encountered within 4.4 to 4.6 m below the existing highway grade. Sub-excavation of the embankment fill may be required to prepare a temporary pavement structure. The existing embankment side slopes should remain stable if the slopes are maintained at 2.0H:1V (or flatter). The excavated slopes are the responsibility of the Contractor and should be constructed following the recommendations described in Section 11.1. After culvert installation, the embankment should be reinstated as described in Section 10.6.1. It is likely this option is not feasible.

10.6.3 Temporary Widening or Detour Embankment

A foundation investigation was not completed for a temporary detour embankment as part of the current assignment. Further assessment of the existing highway embankment should be carried out where construction stages dictates that a temporary detour embankment is needed. A temporary culvert extension may also be required in the area of the embankment widening as well as a review of any drainage impacts. Additional field investigation may be required.

11. CONSTRUCTION CONSIDERATIONS

11.1 Excavation

All excavation must be conducted in accordance with the requirements of the Occupational Health & Safety Act & Regulations (OHSA) for Construction Projects. The fill materials and native soils above the groundwater level may be classified as Type 3 soil and native soils below the groundwater level are classified as Type 4 soils. *If an excavation penetrates more than one soil type, the entire excavation must be completed in accordance with the more stringent requirement as per the requirements of the regulation.*

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 the 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. Temporary embankment and cut slope stability is the responsibility of the Contractor.

Excavation for culvert replacement must be carried out in accordance with OPSS.PROV 401, OPSS.PROV 421 and OPSS 422 and will be carried out through existing embankment fill and into the underlying native soils. 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.

At locations where there are space restrictions or where a slope has to 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

Temporary Protection Systems may be required during various stages of construction and must be implemented in accordance with OPSS.PROV 539 as amended by SP 105S09. Performance Level 2 (maximum 25 mm horizontal deflection) is considered appropriate where the protection supports the existing highway. 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.

It will be difficult to drive sheet piles at this site due to the presence of rockfill, native sandy gravel with cobbles and undulating shallow bedrock. A suggested contract provision concerning obstructions is provided in Appendix G. Drilled in soldier piles with lagging are considered suitable at this site. However, the selection and design of roadway protection is 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. An anchoring and/or internal bracing system may need to be incorporated into the temporary protection design to resist lateral earth pressure loadings.

Lateral earth pressure coefficients, under fully mobilized conditions, that can be used in design of the protection system installed through new granular fill material consisting of Granular A or Granular B Type II are provided in Table 10-1 for static conditions. The lateral earth pressure coefficients for the existing fill and native soils are given below for a vertical wall and a horizontal backslope. Unit weights provided herein are to be adjusted for applications below the groundwater level. Unbalanced hydrostatic pressures should be considered in the design of the protection systems.

Table 11-1 Static Earth Pressure Coefficients for Existing Soils

MATERIAL	UNIT(*) WEIGHT (kN/m^3)	K_A (-)	K_p (-)	S_u (kPa)	GROUND SURFACE *BEHIND* WALL
Existing Gravelly Sand to Sand Fill	20	0.33	3.0	-	Horizontal
Existing Rockfill	19	0.24	4.2	-	Horizontal
Native Organic Silt	19	0.36	2.8	-	Horizontal
Native Sand to Sandy Silt to Silty Sand	19	0.33	3.0	-	Horizontal
Native Sandy Gravel	21	0.31	3.3	-	Horizontal

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

It is recommended that the protection systems in the vicinity of the culvert (within 3 m from the edge of the culvert) should be left in place and cut off in accordance with OPSS.PROV 539.

11.3 Surface and Groundwater Control

Excavations that extend below the groundwater level without prior dewatering are not recommended since the inflow of groundwater will make it difficult to maintain a dry, sound base on which to work. Disturbance of the subgrade soils is considered to be a risk without groundwater lowering. The presence of rockfill and cohesionless subgrade soils could allow for increased seepage.

Typically, subgrade preparation, placement and compaction of granular bedding, and culvert construction must be carried out in the dry. Based on the groundwater elevation at the time of the investigation, the site will require dewatering to lower the groundwater (see Section 10.2). Furthermore, surface runoff will tend to seep into and accumulate into the excavations. The Contractor must control groundwater, perched groundwater, and surface water flow at the site to permit construction in a dry and stable excavation. Typically, the groundwater level within the work zone should be lowered to a minimum of 0.5 m below the underside of the planned excavation base prior to each stage of excavation.

A properly designed dewatering system to control groundwater and ditch/surface water is required and may include cofferdams, ditch diversion, pumping etc. If required, the temporary flow diversion pipe should be placed outside the construction area. If the replacement culvert is installed on a new alignment the existing culvert could be used for ditch flow diversion until the new culvert is completed. Alternatively, an existing culvert located approximately 90 m south of the site could be utilized as a flow diversion pipe if the flow can be diverted/pumped. The design of flow passage systems is the responsibility of the Contractor. Given the site conditions and anticipated works, the Designer Fill-In ***** in SP 517F01 Table A for flow passage systems should be "Yes"; the design Engineer and design-checking Engineer do need a minimum of 5 years of experience in designing similar flow passage systems.

The dewatering system will be required to remain operational and effective until the temporary excavations are backfilled and then should be decommissioned and removed. The design of dewatering systems is the responsibility of the Contractor. The Contract Documents must alert the Contractor to this responsibility and to design the system in accordance with SP FOUN0003 which amends OPSS.PROV 902 and SP517F01 which amends OPSS.PROV 517. Given the site conditions and anticipated works, the Designer Fill-In ***** in SP517F01 Table A should be "No" for dewatering systems; the design Engineer and design-checking Engineer do not need a minimum of 5 years of experience in designing similar dewatering systems. A preconstruction survey is not recommended, thus Designer Fill-In ** in this SP should be "N/A".

The water level will fluctuate and the minimum groundwater elevation for the site at the time of the excavation should be taken as the expected highwater level defined in SP517F01 and SP FOUN0003. It is likely that the beaver dam is impacting the surface water levels.

The dewatering plan should be coordinated with the TPS design. It is anticipated that sump pumps will likely be sufficient to extract water from an excavation carried out within a watertight sheet pile enclosure to cut off the groundwater flow. Where applicable, sheet piled enclosure can be designed following the recommendations provided in Section 11.2 however, it should be noted that rockfill is present and the native deposits contained cobbles and inferred boulders as well as undulating shallow bedrock which may limit the sheet pile penetration depths. Alternatively, a clear stone pad constructed in the wet (see Section 10.2) should be considered. Pumping from behind sandbag coffer dams should continue until control of inflow is achieved and the Granular bedding and culvert can be placed and backfilled in a dry stable environment.

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.

11.4 Scour and Erosion Protection

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 materials indicate that the soils have a low to medium potential for soil erodibility (Wischmeier Nomograph factor, K). The native soils have a low to medium potential for soil erodibility.

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

12. CONSTRUCTION CONCERNS

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

- Obstructions
  Buried obstructions (i.e., rockfill, cobbles, boulders, shallow bedrock, wood) may be encountered during construction and will interfere with excavations and installation of temporary protection/dewatering systems. 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.
- Dewatering & Temporary Flow Passage Systems
  It will be necessary to divert the ditch flow around the excavation to place the bedding and construct the culvert in the dry. Excavations and placement of bedding material must be completed in the dry. The presence of cohesionless fills and native soils may increase seepage rates. Suitable diversion and dewatering systems must be employed. The diversion scheme will be critical for culvert construction at this site. The Contractor should be prepared to take appropriate measures to construct the bedding layer and place the culvert in a dry and stable environment.

The successful performance of the project will depend largely upon good workmanship and quality control during construction. Subgrade examination and field density testing should be carried out by qualified personnel during construction to confirm that foundation recommendations are correctly implemented and material specifications are met.

13. CLOSURE

Engineering analysis and preparation of this report were carried out by Mr. S. Peters, P.Eng. The report was reviewed by Dr. F. Griffiths, P.Eng., a Designated Principal Contact for MTO Foundation Projects.

Thurber Engineering Ltd.
Report Prepared By:

Stephen Peters, M.A.Sc., P.Eng.
Associate
Geotechnical Engineer

Fred Griffiths, Ph.D., P.Eng.
Senior Associate
Senior Geotechnical Engineer

THURBER

STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report, which is of a summary nature and is not intended to stand alone without reference to the instructions given to Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. THURBER IS NOT RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT THURBER'S WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS THURBER MAY EXPRESSLY APPROVE. Ownership in and copyright for the contents of the Report belong to Thurber. Any use which a third party makes of the Report, is the sole responsibility of such third party. Thurber accepts no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without Thurber's express written permission.

5. INTERPRETATION OF THE REPORT

a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.

c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.

d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

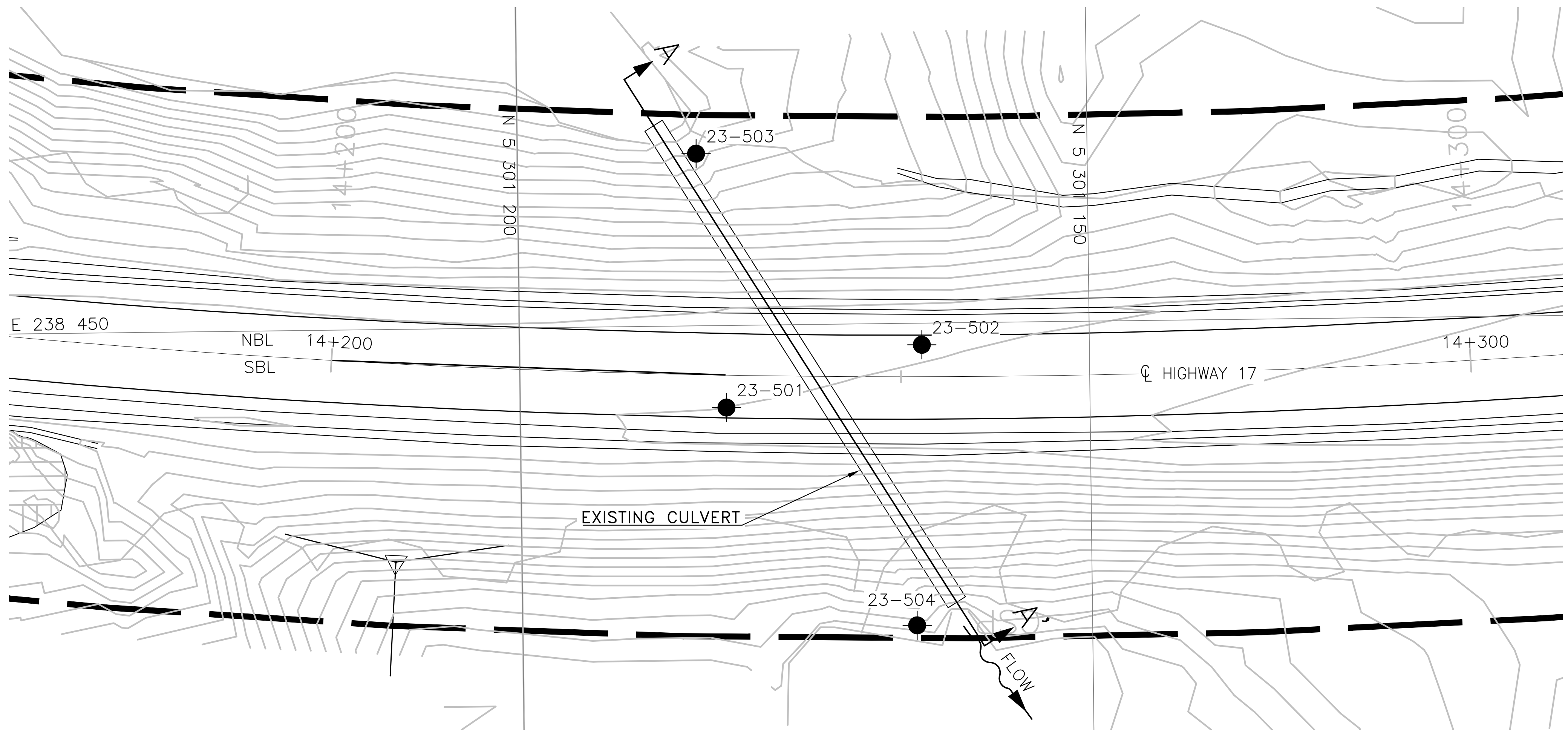
7. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

APPENDIX A

Borehole Locations and Strata Drawing

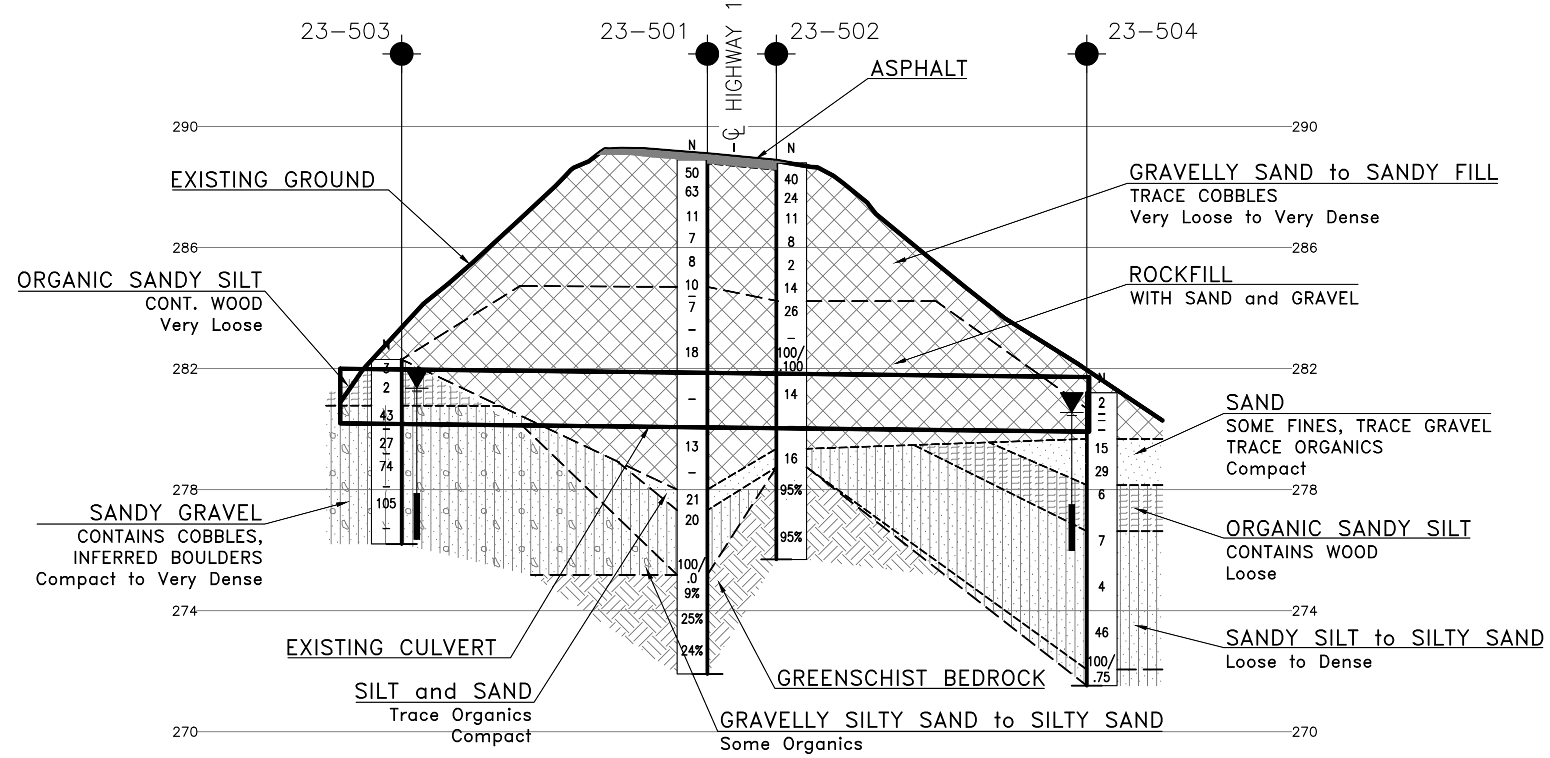
MINISTRY OF TRANSPORTATION, ONTARIO



PLAN

10 0 10 20m

SCALE 1:500



SECTION (A–A')

10 0 10 20m H 1:500

5 0 5 10m V 1:250

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No

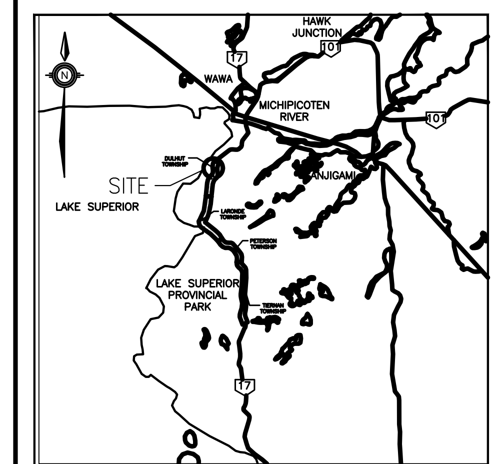
GWP No 5207–18–00

HIGHWAY 17
DULHUT TOWNSHIP
CULVERT 14+242
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

Ontario

THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

●	Borehole
◐	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	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
23–501	288.9	5 301 181.9	238 442.8
23–502	288.8	5 301 164.7	238 448.1
23–503	282.3	5 301 184.3	238 465.1
23–504	281.2	5 301 165.4	238 423.5

LICENSED PROFESSIONAL ENGINEER
F. J. GRIFFITHS
90360280
2023/11/23
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
S. PETERS
100194478
2023/11/23
PROVINCE OF ONTARIO

-NOTES-

1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
3) Coordinate system is MTM NAD 83 Zone 13.

GEOCRES No. 41N00-037

REVISIONS

DATE	BY	DESCRIPTION

DESIGN	CHK	CODE	LOAD	DATE NOV 2023	
DRAWN MC	CHK	SITE	STRUCT	DWG 1	

FILENAME: T:\Drafting\31000\31653\TED-31653-500.dwg
PLOTDATE: 11/24/2023 10:12 AM

THURBER ENGINEERING LTD.

APPENDIX B

Symbols and Terms

Record of Boreholes Sheets

Single Well Response Test

Client: AECOM Canada Ltd.

File No.: 31653

November 23, 2023

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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.

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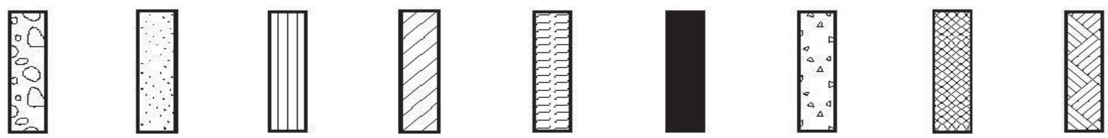
STRATA PLOT:

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

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MODIFIED UNIFIED SOIL CLASSIFICATION

<table>
<tr><th colspan="2">Major Divisions</th><th>Group Symbol</th><th>Typical Description</th></tr>
<tr><td rowspan="8">COARSE GRAINED SOIL</td><td rowspan="4">GRAVEL AND GRAVELLY SOILS</td><td>GW</td><td>Well-graded gravels or gravel-sand mixtures, little or no fines.</td></tr>
<tr><td>GP</td><td>Poorly-graded gravels or gravel-sand mixtures, little or no fines.</td></tr>
<tr><td>GM</td><td>Silty gravels, gravel-sand-silt mixtures.</td></tr>
<tr><td>GC</td><td>Clayey gravels, gravel-sand-clay mixtures.</td></tr>
<tr><td rowspan="4">SAND AND SANDY SOILS</td><td>SW</td><td>Well-graded sands or gravelly sands, little or no fines.</td></tr>
<tr><td>SP</td><td>Poorly-graded sands or gravelly sands, little or no fines.</td></tr>
<tr><td>SM</td><td>Silty sands, sand-silt mixtures.</td></tr>
<tr><td>SC</td><td>Clayey sands, sand-clay mixtures.</td></tr>
<tr><td rowspan="9">FINE GRAINED SOILS</td><td rowspan="3">SILT AND CLAY SOILS
$W_L < 35\%$</td><td>ML</td><td>Inorganic silts, very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.</td></tr>
<tr><td>CL</td><td>Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.</td></tr>
<tr><td>OL</td><td>Organic silts and organic silty-clays of low plasticity.</td></tr>
<tr><td rowspan="3">SILT AND CLAY SOILS
$35\% < W_L < 50\%$</td><td>MI</td><td>Inorganic compressible fine sandy silt with clay of medium plasticity, clayey silts.</td></tr>
<tr><td>CI</td><td>Inorganic clays of medium plasticity, silty clays.</td></tr>
<tr><td>OI</td><td>Organic silty clays of medium plasticity.</td></tr>
<tr><td rowspan="3">SILT AND CLAY SOILS
$W_L > 50\%$</td><td>MH</td><td>Inorganic silts, micaceous or diatomaceous fine sandy of silty soils, elastic silts.</td></tr>
<tr><td>CH</td><td>Inorganic clays of high plasticity, fat clays.</td></tr>
<tr><td>OH</td><td>Organic clays of high plasticity, organic silts.</td></tr>
<tr><td colspan="2">HIGHLY ORGANIC SOILS</td><td>Pt</td><td>Peat and other organic soils.</td></tr>
</table>

Note - W_L= Liquid Limit

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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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 23-501

METRIC

GWP# 5207-18-00 | LOCATION Lat: 47.846242°, Long: -84.886665° Sta. 14+242 - Dulhut Township, MTM z13: N 5 301 181.9 E 238 442.8 | ORIGINATED BY APS

HWY 17 | BOREHOLE TYPE CME 75 Truck Mount / NW Casing / NQ Coring | COMPILED BY RH

DATUM Geodetic | DATE 2023.05.08 - 2023.05.09 | CHECKED BY AO

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
288.9	Ground Surface					
0.0	**ASPHALT (115 mm)**					
0.1	GRAVELLY SAND, trace fines, very dense, greyish brown to light brown **FILL**	1	SS	50		
		2	SS	63	288	38 54 8 (SI+CL)
287.4 / 1.5	SAND, some gravel, trace cobbles, loose to compact, light brown **FILL**	3	SS	11	287	16 81 3 (SI+CL)
		4	SS	7	286	
		5	SS	8		
		6	SS	10	285	
284.5 / 4.4	COBBLES with gravel and sand **ROCKFILL**	1	NQ	-		
		7	SS	7	284	
		2	NQ	-	283	
		8	SS	18	282	
		3	NQ	-	281, 280	
		9	SS	13	279	

Column headings: SOIL PROFILE; SAMPLES; STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 23-501

METRIC

GWP# 5207-18-00
LOCATION Lat: 47.846242°, Long: -84.886665° Sta. 14+242 - Dulhut Township, MTM z13: N 5 301 181.9 E 238 442.8
ORIGINATED BY APS

HWY 17
BOREHOLE TYPE CME 75 Truck Mount / NW Casing / NQ Coring
COMPILED BY RH

DATUM Geodetic
DATE 2023.05.08 - 2023.05.09
CHECKED BY AO

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT (kN/m³) / FI	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	COBBLES with gravel and sand **ROCKFILL**	4	NQ	-				
278.0 / 10.9	**SILT** and **SAND**, trace organics, compact, dark brown	10	SS	21	278			1 49 45 5
277.3 / 11.6	**SANDY SILT**, some gravel, compact, light grey	11	SS	20	277			14 25 56 5 Non-plastic
					276			
275.2 / 13.7	**GREENSCHIST BEDROCK** contains calcite inclusions, highly weathered, fine grained, dark greenish grey, strong	12	SS	100/ 0 mm	275		FI 4, >10, >10	
		1	RUN	-			>10	RUN #1 TCR=52% SCR=9% RQD=9%
		2	RUN	-	274		5, 7	RUN #2 TCR=100% SCR=25% RQD=25%
		3	RUN	-	273		>10, >10, >10, 2	RUN #3 TCR=70% SCR=13% RQD=24%
271.9 / 17.0	**End of Borehole**				272		5	

Note: Water was introduced into the borehole as part of the drilling procedure. An open-hole water level may not be representative of groundwater conditions.

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100
PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

+³, ×³: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 23-502

METRIC

GWP# 5207-18-00 | LOCATION Lat: 47.846087°, Long: -84.886592° Sta. 14+242 - Dulhut Township, MTM z13: N 5 301 164.7 E 238 448.1 | ORIGINATED BY APS

HWY 17 | BOREHOLE TYPE CME 75 Truck Mount / NW Casing / NQ Coring | COMPILED BY RH

DATUM Geodetic | DATE 2023.05.12 - 2023.05.13 | CHECKED BY AO

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	UNIT WEIGHT kN/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
288.8	Ground Surface						
0.0	**ASPHALT (140 mm)**						
0.1	**SAND (25 mm)**						
0.2	**ASPHALT (65 mm)**						
0.2	SAND and GRAVEL, dense, greyish brown **FILL**	1	SS	40	o		38 56 6 (SI+CL)
288.0 / 0.8	GRAVELLY SAND, trace to some gravel, very loose to compact, light brown **FILL**	2	SS	24	o		
		3	SS	11	o		
		4	SS	8	o		
		5	SS	2	o		
		6	SS	14	o		22 75 3 (SI+CL)
284.2 / 4.6	**COBBLES** some boulders with gravel and sand **ROCKFILL**	7	SS	26	o		
		8	NQ	-			
		9	SS	100/ 100 mm	o		
		10	NQ	-			
		11	SS	14			
		12	NQ	-			
279.4 / 9.4	**SILTY SAND**, some gravel, compact, light grey	13	SS	16	o	FI 1	14 48 35 3

Elevation scale: 288, 287, 286, 285, 284, 283, 282, 281, 280, 279

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100

PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

15 20 5 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 23-502

METRIC

GWP# 5207-18-00
LOCATION Lat: 47.846087°, Long: -84.886592° Sta. 14+242 - Dulhut Township, MTM z13: N 5 301 164.7 E 238 448.1
ORIGINATED BY APS
HWY 17
BOREHOLE TYPE CME 75 Truck Mount / NW Casing / NQ Coring
COMPILED BY RH
DATUM Geodetic
DATE 2023.05.12 - 2023.05.13
CHECKED BY AO

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
278.7 10.1	**SILTY SAND**, some gravel compact light grey									3	
	GREENSCHIST BEDROCK contains calcite inclusions fresh fine grained dark greenish grey very strong									0	RUN #1 TCR=97% SCR=77% RQD=95%
			1	RUN	-		278			1	
										1	
										0	
							277			1	
										1	
			2	RUN	-					2	RUN #2 TCR=100% SCR=88% RQD=95%
							276			0	
275.7										0	
13.1	**End of Borehole**										

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

DOUBLE LINE 31653 -500.GPJ 2012TEMPLATE(MTO).GDT 11-24-23

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 23-503

METRIC

GWP# 5207-18-00
LOCATION Lat: 47.846266°, Long: -84.886368° Sta. 14+242 - Dulhut Township, MTM z13: N 5 301 184.3 E 238 465.1
ORIGINATED BY APS

HWY 17
BOREHOLE TYPE Portable / NW Casing / NQ Coring
COMPILED BY RH

DATUM Geodetic
DATE 2023.05.10 - 2023.05.13
CHECKED BY AO

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20, 40, 60, 80, 100
SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE: 20, 40, 60, 80, 100
PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L
WATER CONTENT (%): 20, 40, 60
UNIT WEIGHT γ kN/m³
REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

ELEV / DEPTH	DESCRIPTION
282.3	Ground Surface
0.0	**ORGANIC SANDY SILT** contains wood, loose to very loose, dark brown
280.8 / 1.5	**SANDY GRAVEL**, some fines, with cobbles, inferred boulders, compact to very dense, light grey
276.2 / 6.1	**End of Borehole**

NUMBER	TYPE	"N" VALUES	REMARKS / GRAIN SIZE (GR SA SI CL)
1	SS	3	
2	SS	2	4 28 57 11
3	SS	43	
4	NQ	-	
5	SS	27	
6	NQ	-	
7	SS	74	56 34 10 (SI+CL)
8	NQ	-	
9	SS	105	
10	NQ	-	

Elevation scale: 282, 281, 280, 279, 278, 277

Monitoring well Installed:
Schedule 40 PVC standpipe with 32-mm diameter and 1.5-m slotted screen.

Water Level Readings:

DATE	DEPTH (m)	ELEV. (m)
2023/05/13	0.9	281.4
2023/06/09	0.9	281.4
2023/07/11	1.0	281.3
2023/07/12	1.0	281.3
2023/07/13	1.0	281.3

$+^3, \times^3$: Numbers refer to Sensitivity

15 20 5 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 23-504

METRIC

GWP# 5207-18-00

LOCATION Lat: 47.846091°, Long: -84.886921°
Sta. 14+242 - Dulhut Township, MTM z13: N 5 301 165.4 E 238 423.5

ORIGINATED BY APS

HWY 17

BOREHOLE TYPE Portable / NW Casing / NQ Coring

COMPILED BY RH

DATUM Geodetic

DATE 2023.05.09 - 2023.05.10

CHECKED BY AO

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
281.2	Ground Surface				
0.0	**TOPSOIL (100 mm)**				
0.1	GRAVELLY SILTY SAND trace organics very loose brown **FILL**	1	SS	2	26 54 20 (SI+CL)
280.6 / 0.6	Cobbles and Boulders **ROCK FILL**	2	NQ	-	
		3	NQ	-	
		4	NQ	-	
279.7 / 1.5	**SAND**, some fines trace gravel and organics trace gravel and organics compact dark brownish grey	5	SS	15	5 83 12 (SI+CL)
		6	SS	29	
278.2 / 3.0	**ORGANIC SANDY SILT** loose dark brownish grey	7	SS	6	0 22 73 5 Non-plastic
276.6 / 4.6	**SANDY SILT** to **SILTY SAND** loose to dense light grey stratified structure	8	SS	7	0 23 68 9
		9	SS	4	
		10	SS	46	0 66 32 2
272.1 / 9.1	**GRAVELLY SILTY SAND** compact light grey	11	SS	100/ 75 mm	20 59 21 (SI+CL)
271.5 / 9.7	**End of Borehole**				

Elevation scale: 281, 280, 279, 278, 277, 276, 275, 274, 273, 272

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 ⌖ 5 / 10 (%) STRAIN AT FAILURE

DOUBLE LINE 31653-500.GPJ 2012TEMPLATE(MTO).GDT 11-24-23

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 23-504

METRIC

GWP#	5207-18-00	LOCATION	Lat: 47.846091°, Long: -84.886921° Sta. 14+242 - Dulhut Township, MTM z13: N 5 301 165.4 E 238 423.5	ORIGINATED BY	APS
HWY	17	BOREHOLE TYPE	Portable / NW Casing / NQ Coring	COMPILED BY	RH
DATUM	Geodetic	DATE	2023.05.09 - 2023.05.10	CHECKED BY	AO

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

Monitoring well Installed:
Schedule 40 PVC standpipe with 32-mm diameter and 1.5-m slotted screen.

Water Level Readings:

DATE	DEPTH (m)	ELEV. (m)
2023/05/10	0.3	280.9
2023/05/11	0.6	280.6
2023/05/12	0.5	280.7
2023/05/13	0.5	280.7
2023/06/09	0.5	280.7
2023/07/12	0.5	280.7
2023/07/13	0.5	280.7

Note: A third-weight hammer was used to advance the split-spoon sampler. The "N" values presented above have been adjusted to provide an estimate of the "N" value that would have been obtained with a standard hammer.

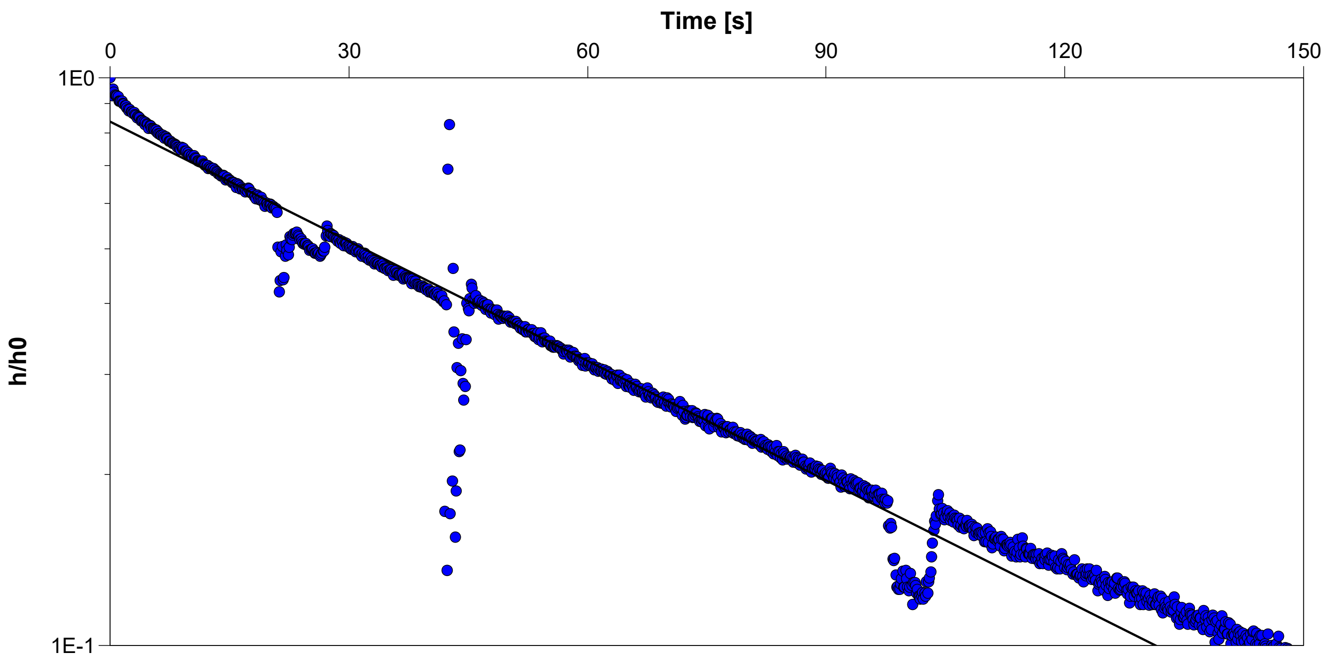
+ ^{3}, × ^{3}: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

DOUBLE LINE 31653 -500.GPJ 2012TEMPLATE(MTO).GDT 11-24-23

THURBER ENGINEERING LTD.	**Slug Test Analysis Report**
	Project: Highway 17 and Old Woman River Bridge
	Number: 31653
	Client: AECOM

Location: Laronde Township, Ontario	Slug Test: 23-504	Test Well: 23-504
Test Conducted by: SM & IK		Test Date: 2023-07-15
Analysis Performed by: SM	SWRT Analysis	Analysis Date: 2023-07-19
Aquifer Thickness:		
Checked by: AH		



Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]	
23-504	1.4×10^{-5}	

THURBER ENGINEERING LTD.

APPENDIX C

Particle Size Analysis Figures

Atterberg Limits Figures

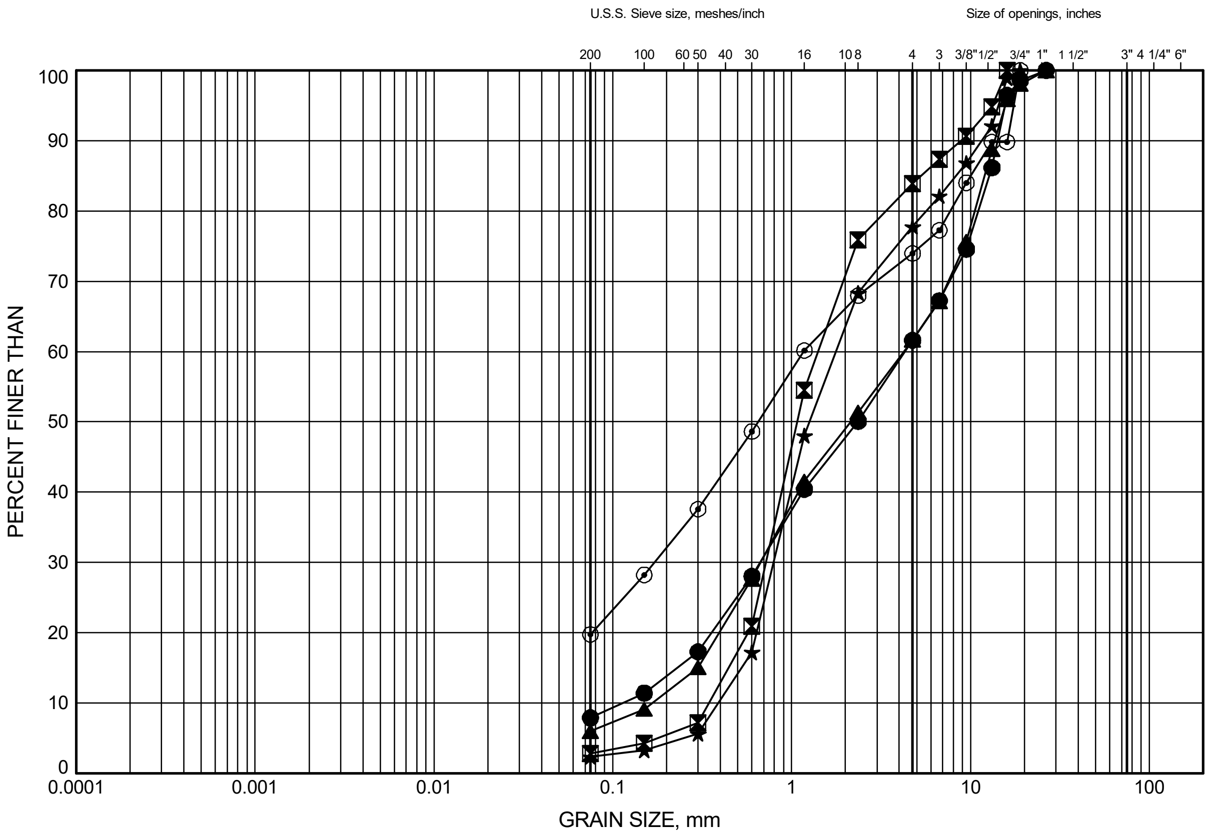
Unconfined Compressive Strength Testing Results

Bedrock Core Photographs

Analytical Testing Results

Highway 17 Old Woman River GRAIN SIZE DISTRIBUTION	FIGURE C1

GRAVELLY SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	23-501	1.1	287.8
⧗	23-501	1.8	287.1
▲	23-502	0.3	288.5
★	23-502	4.1	284.7
⊙	23-504	0.4	280.8

Date August 2023

GWP# 5207-18-00

THURBER

Prep'd RH

Chkd. SP

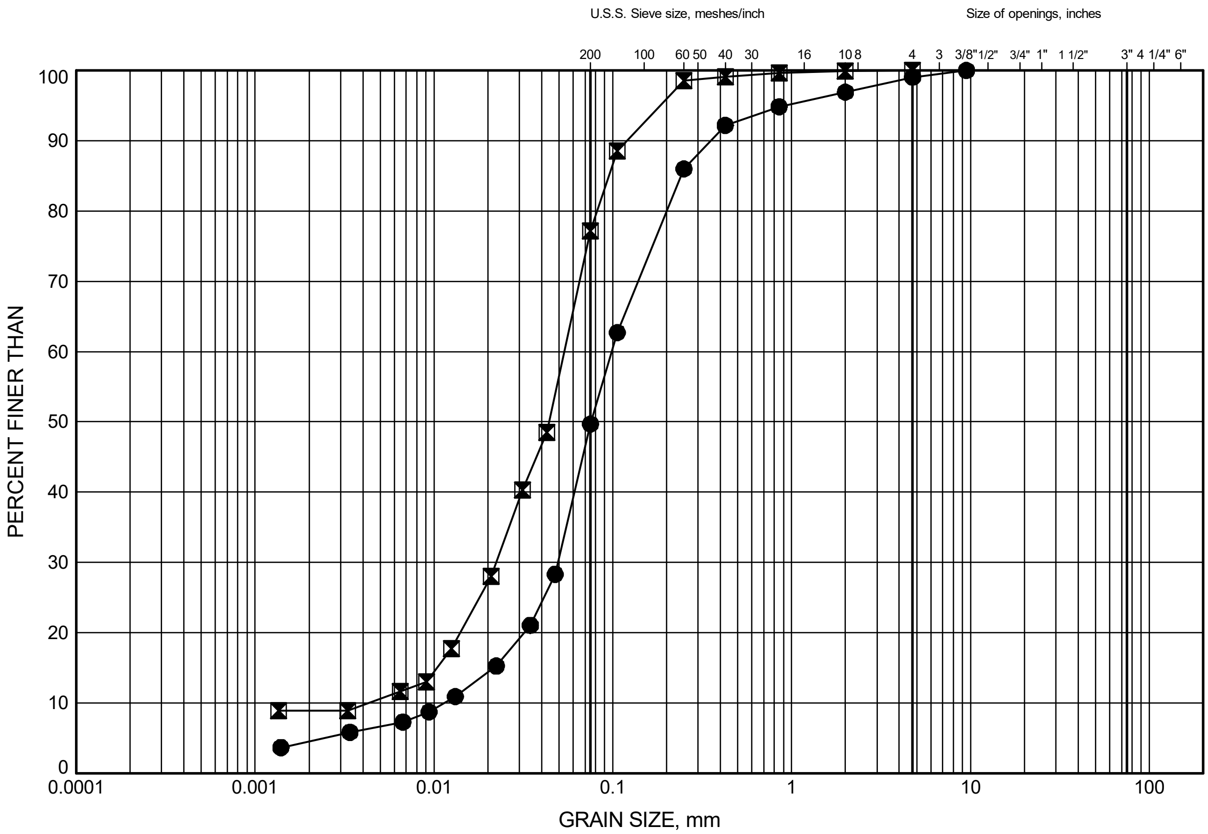
GRAIN SIZE DISTRIBUTION - THURBER 31653 -500.GPJ 8-3-23

Highway 17 Old Woman River

GRAIN SIZE DISTRIBUTION

FIGURE C2

SILT and SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	23-501	11.2	277.7
⧗	23-504	4.9	276.3

Date August 2023

GWP# 5207-18-00

THURBER

Prep'd RH

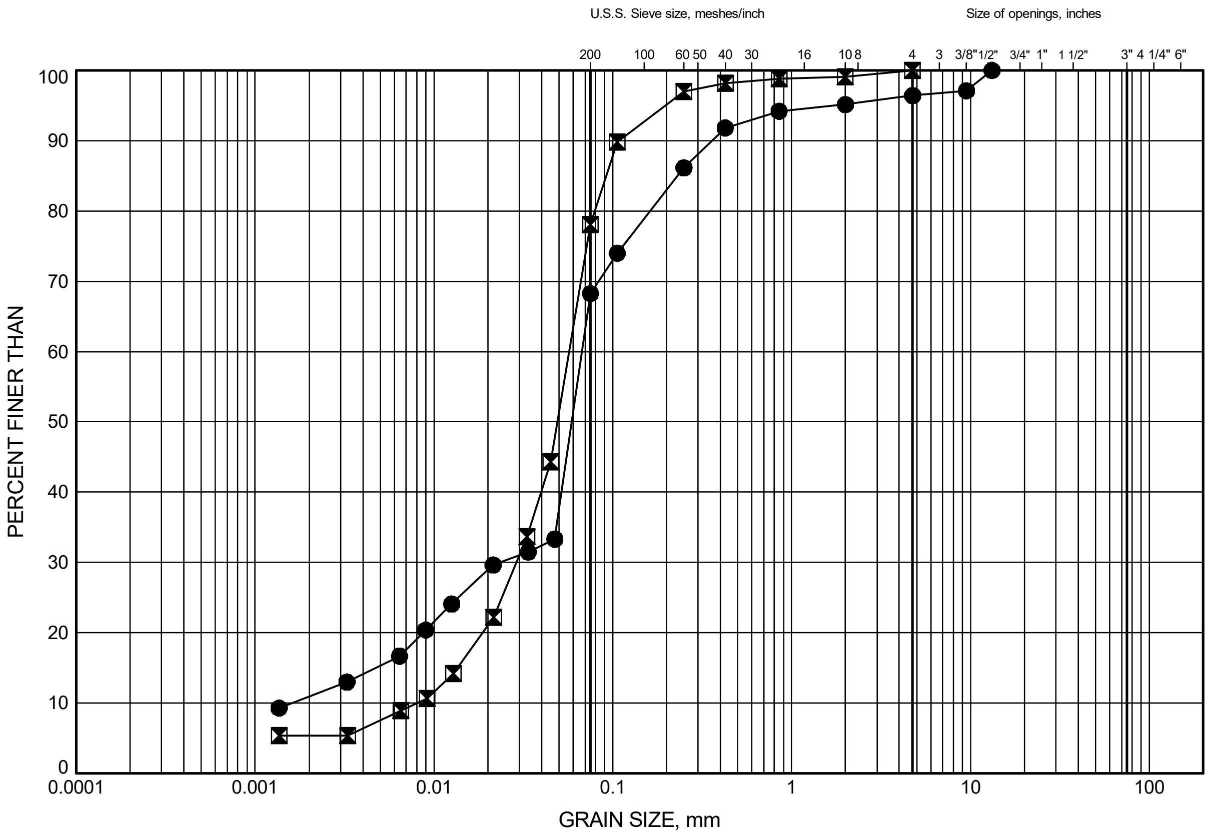
Chkd. SP

GRAIN SIZE DISTRIBUTION - THURBER 31653 -500.GPJ 8-3-23

Highway 17 Old Woman River
GRAIN SIZE DISTRIBUTION

FIGURE C3

ORGANIC SANDY SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	23-503	0.9	281.4
⧗	23-504	3.2	278.0

Date August 2023

GWP# 5207-18-00

THURBER

Prep'd RH

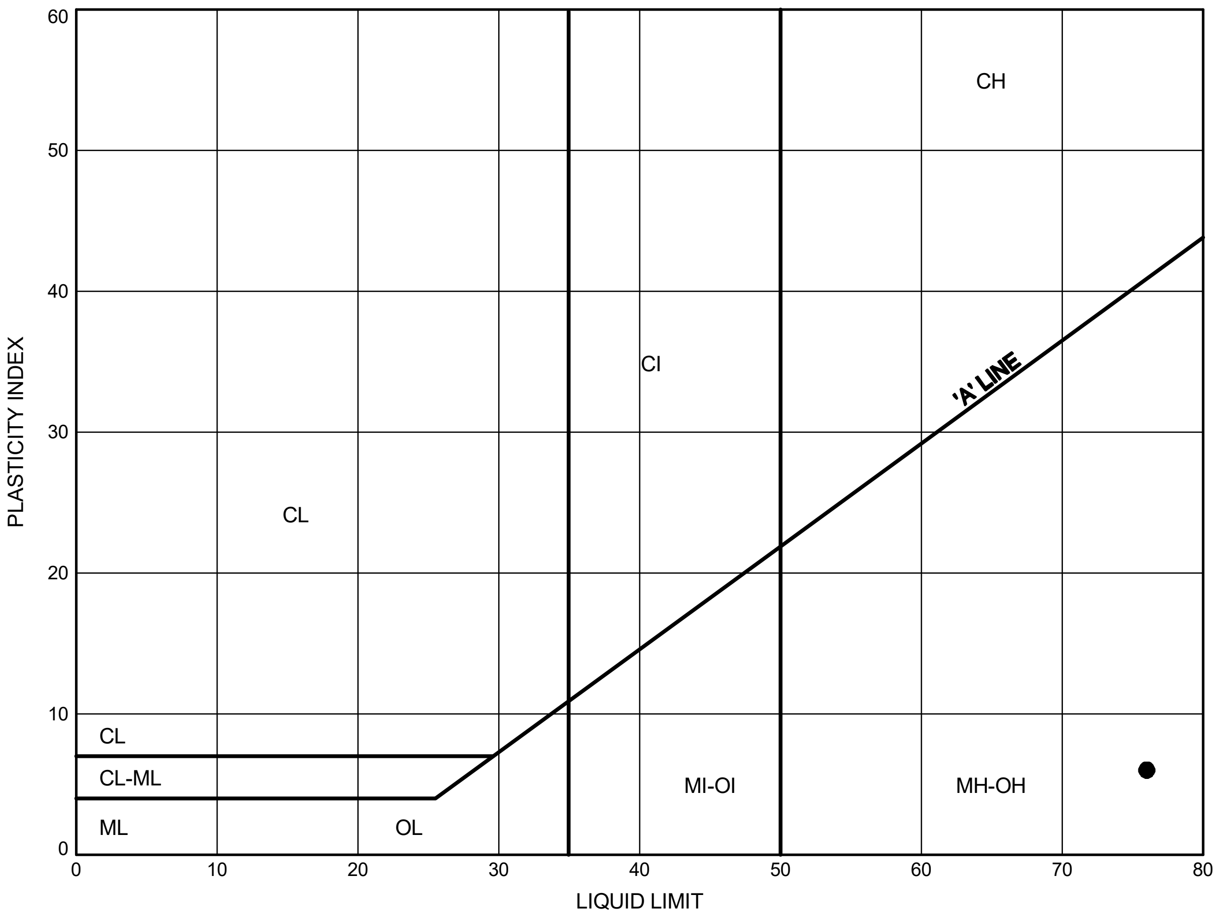
Chkd. SP

Highway 17 Old Woman River

ATTERBERG LIMITS TEST RESULTS

FIGURE C4

ORGANICS SANDY SILT



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	23-503	0.9	281.4

Date August 2023

GWP# 5207-18-00

THURBER

Prep'd RH

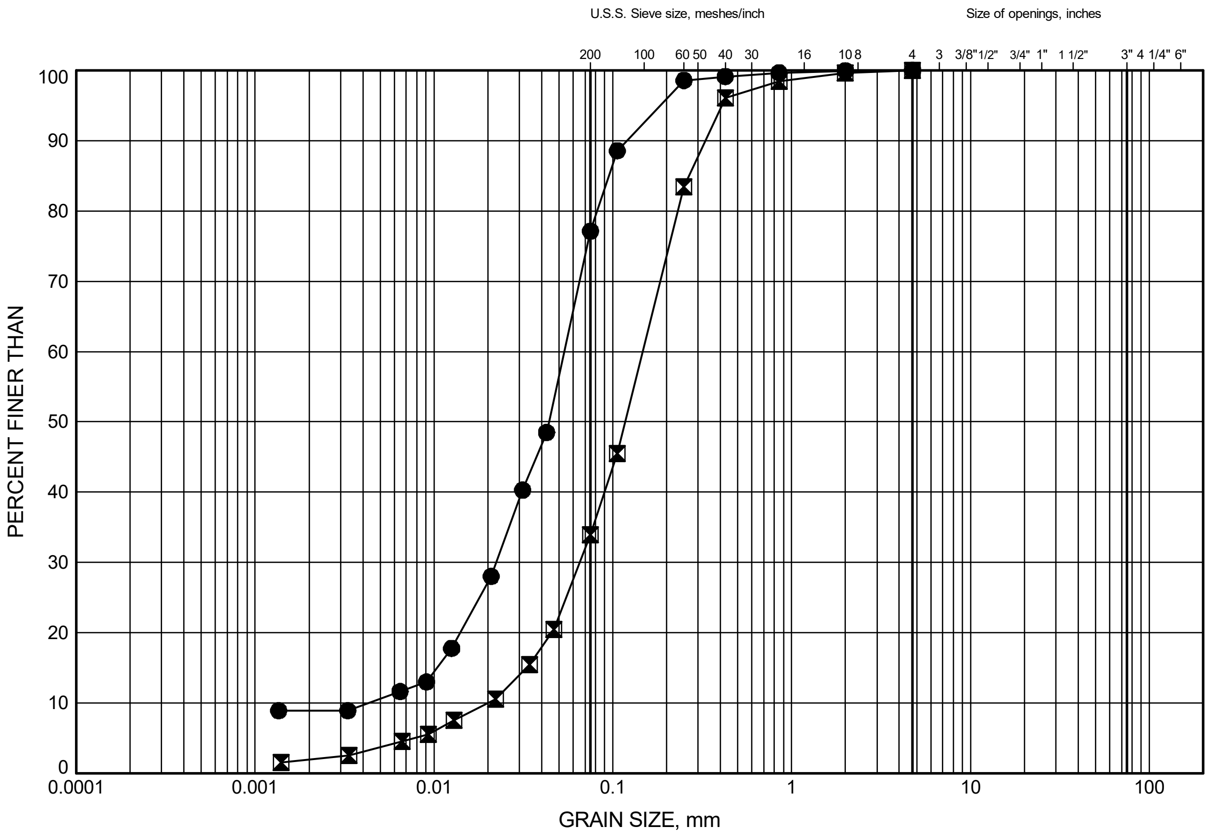
Chkd. SP

Highway 17 Old Woman River

GRAIN SIZE DISTRIBUTION

FIGURE C5

SANDY SILT to SILTY SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	23-504	4.9	276.3
⧗	23-504	7.9	273.3

Date August 2023

GWP# 5207-18-00

THURBER

Prep'd RH

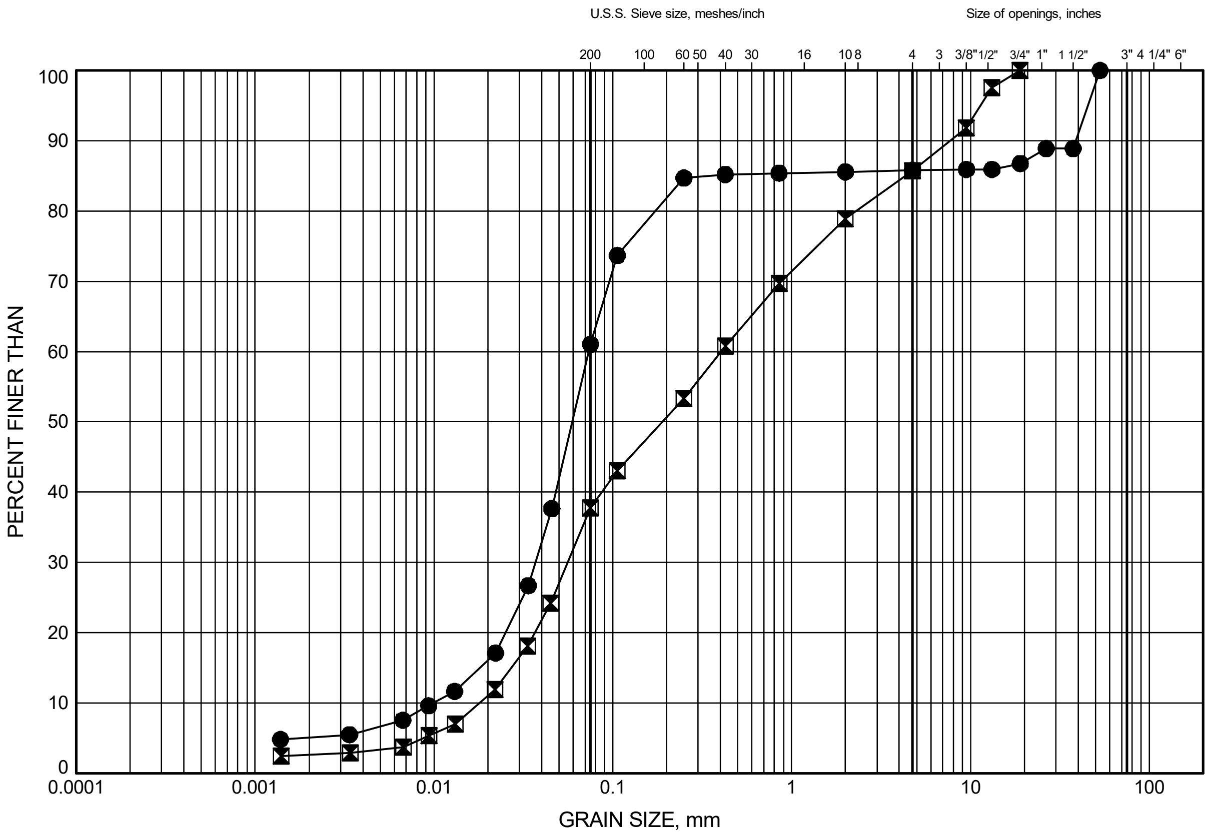
Chkd. SP

Highway 17 Old Woman River

GRAIN SIZE DISTRIBUTION

FIGURE C6

SANDY SILT to SILTY SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	23-501	11.9	277.0
⧗	23-502	9.8	279.0

Date August 2023

GWP# 5207-18-00

THURBER

Prep'd RH

Chkd. SP

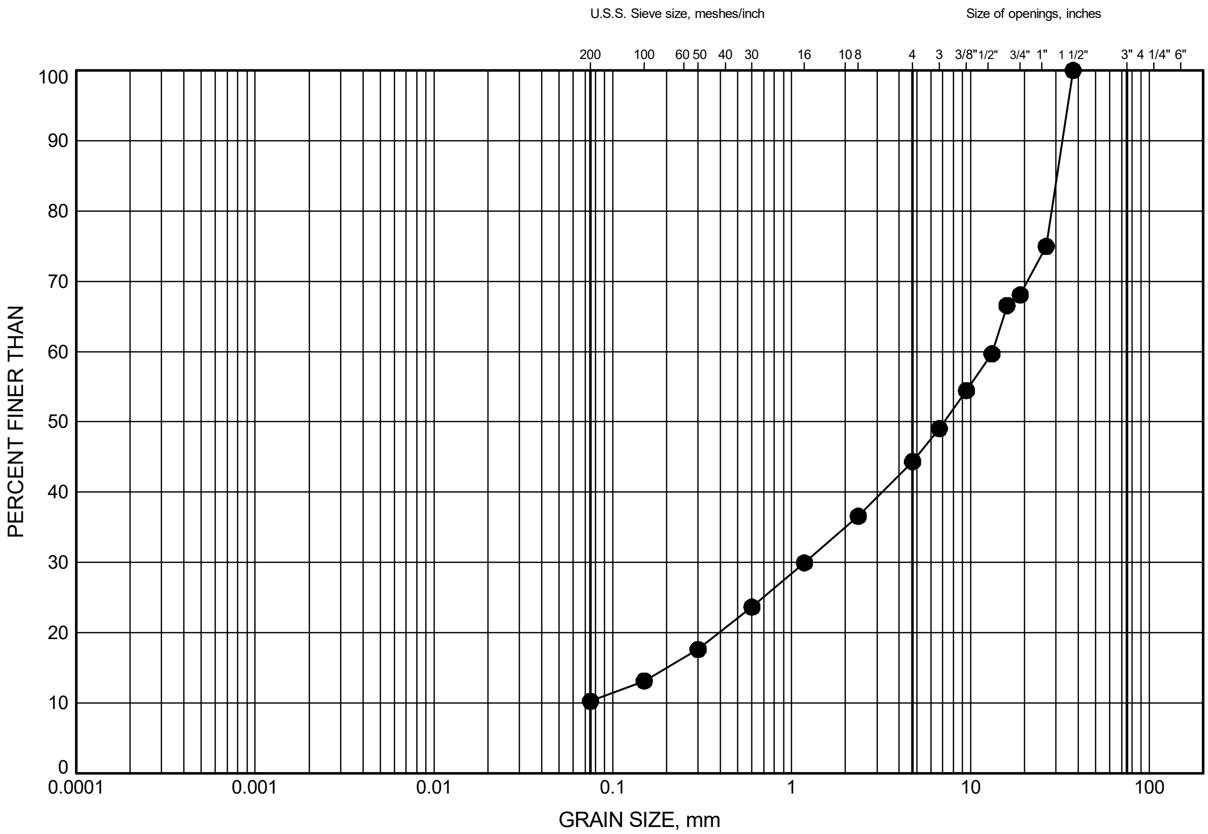
GRAIN SIZE DISTRIBUTION - THURBER 31653 -500.GPJ 8-3-23

Highway 17 Old Woman River

GRAIN SIZE DISTRIBUTION

FIGURE C7

SANDY GRAVEL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	23-503	3.5	278.8

GRAIN SIZE DISTRIBUTION - THURBER 31653 -500.GPJ 8-3-23

Date August 2023

GWP# 5207-18-00

THURBER

Prep'd RH

Chkd. SP

Stantec Consulting Ltd.
2781 Lancaster Rd, Suite 100 A&B, Ottawa ON K1B 1A7

August 8, 2023
File: 122410864

Client: Thurber Engineering, File #31653.60

Reference: ASTM D7012, Method C, Unconfined Compressive Strength of Intact Rock Core
Hwy 17-Old Woman River

The following table summarizes unconfined compressive strength results for three intact rock cores.

Location	Sample Depth	Compressive Strength (MPa)	Description of Break
~~23-102 Run-2~~	~~35'-35'9"~~	~~161.8~~	~~Well-formed cones at both ends.~~
~~23-403 Run-1~~	~~4'8"-5'5"~~	~~152.3~~	~~Vertical cracking~~
23-502 Run-1	37'4"-38'	93.7	Diagonal fracture

Sincerely,

Stantec Consulting Ltd.

Brian Prevost

Brian Prevost
Laboratory Supervisor
Tel: 613-738-6075
Fax: 613-722-2799
brian.prevost@stantec.com

Borehole 23-501

Runs 1 to 3
Depth 13.7 m to 17.0 m
Elevation 275.2 m to 271.9 m
Dry Sample

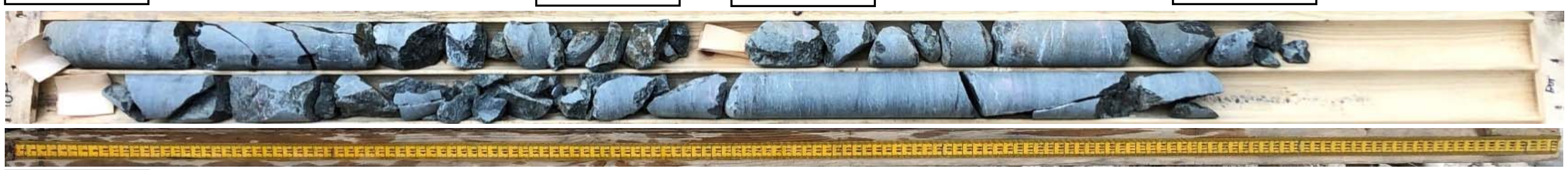
NQ 1, 2, 3 and 4
Gravel and Cobbles

Run 1 Start
elev. 275.2 m

Run 1 End
elev. 274.0 m

Run 2 Start
elev. 274.0 m

Run 2 End
elev. 273.5 m



Run 3 Start
elev. 273.5 m

Run 3 End
elev. 271.9 m

THURBER ENGINEERING LTD.

Geotechnical Investigation
Highway 17 Old Woman River Bridge
Sta. 14+242, Dulhut Township

BH 23-501
Project No.: 31653

Borehole 23-501

Runs 1 to 3
Depth 13.7 m to 17.0 m
Elevation 275.2 m to 271.9 m
Wet Sample

NQ 1, 2, 3 and 4
Gravel and Cobbles

Run 1 Start
elev. 275.2 m

Run 1 End
elev. 274.0 m

Run 2 Start
elev. 274.0 m

Run 2 End
elev. 273.5 m

Run 3 Start
elev. 273.5 m

Run 3 End
elev. 271.9 m

THURBER ENGINEERING LTD.

Geotechnical Investigation
Highway 17 Old Woman River Bridge
Sta. 14+242, Dulhut Township

BH 23-501
Project No.: 31653

Borehole 23-502

Runs 1 to 3

Depth 10.1 m to 13.1 m

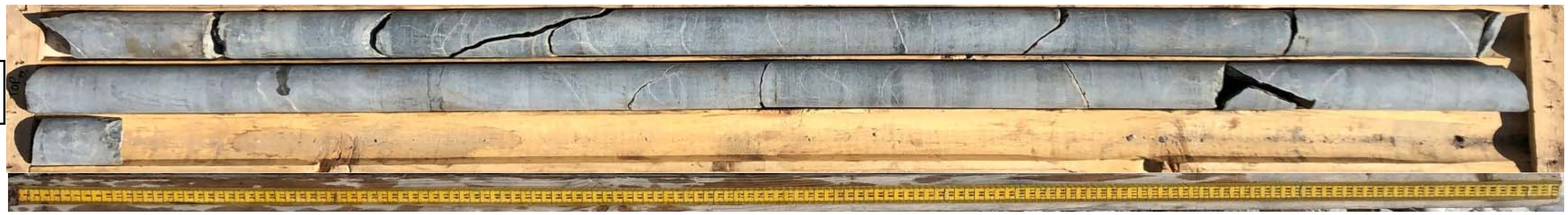
Elevation 278.8 m to 275.7 m

Dry Sample

Run 1 Start
elev. 278.8 m

Run 1 End
elev. 277.3 m

Run 2 Start
elev. 277.3 m



Run 2 End
elev. 275.7 m

THURBER ENGINEERING LTD.

THURBER ENGINEERING LTD.	Geotechnical Investigation Highway 17 Old Woman River Bridge Sta. 14+242, Dulhut Township	BH 23-502 Project No.: 31653

Borehole 23-502

Runs 1 to 3
Depth 10.1 m to 13.1 m
Elevation 278.8 m to 275.7 m
Wet Sample

Run 1 Start
elev. 278.8 m

Run 1 End
elev. 277.3 m

Run 2 Start
elev. 277.3 m

Run 2 End
elev. 275.7 m

THURBER ENGINEERING LTD.

Geotechnical Investigation
Highway 17 Old Woman River Bridge
Sta. 14+242, Dulhut Township

BH 23-502
Project No.: 31653

Certificate of Analysis

Client: Thurber Engineering Ltd.

Client PO:

Report Date: 29-May-2023

Order Date: 17-May-2023

Project Description: 31653 Hwy 17 Old Woman River

	Client ID:	23-504 SS6 (7'6"-9'6")	-	-	-
	Sample Date:	09-May-23 09:00	-	-	-
	Sample ID:	2320268-01	-	-	-
	MDL/Units	Soil	-	-	-
Physical Characteristics					
% Solids	0.1 % by Wt.	80.6	-	-	-
General Inorganics					
Conductivity	5 uS/cm	172	-	-	-
pH	0.05 pH Units	6.85	-	-	-
Resistivity	0.1 Ohm.m	58.2	-	-	-
Anions					
Chloride	10 ug/g dry	59	-	-	-
Sulphate	10 ug/g dry	69	-	-	-

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

02-June-2023

Paracel Laboratories
Attn : Dale Robertson

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

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

Date Rec. : 19 May 2023
LR Report: **CA12947-MAY23**
Reference: Project#: 2320268

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	Sample Date & Time	Sulphide (Na2CO3) %
1: Analysis Start Date		01-Jun-23
2: Analysis Start Time		10:39
3: Analysis Completed Date		01-Jun-23
4: Analysis Completed Time		16:16
5: QC - Blank		< 0.04
6: QC - STD % Recovery		101%
7: QC - DUP % RPD		ND
8: RL		0.02
9: 23-504 SS6 (7'6"-9'6")	09-May-23	< 0.04

RL - SGS Reporting Limit
ND - Not Detected

Kimberley Didsbury,
Project Specialist,
Environment, Health & Safety

OnLine LIMS

0003352835

APPENDIX D

Site Photographs

Photo 1: Culvert inlet. (Photo taken May 2023)

Photo 2: Culvert outlet (Photo taken May 2023)

Photo 3: Highway 17 north of the culvert alignment (Photo taken May 2023)

Photo 4: Highway 17 south of the culvert alignment (Photo taken May 2023)

Photo 5: Looking south at the northbound embankment (Photo taken May 2023)

Photo 6: Looking south at the southbound embankment (Photo taken May 2023)

Photo 7: Water ponding near the inlet (Photo taken May 2023)

Photo 8: Water ponding near the outlet (Photo taken May 2023)

THURBER ENGINEERING LTD.

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: 47.846N 84.887W **User File Reference:** Highway 17 STA 14+242 Dulhut Township 2023-07-20 18:25 UT

Requested by: Thurber Engineering

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)	0.046	0.023	0.013	0.004
Sa (0.1)	0.064	0.035	0.021	0.006
Sa (0.2)	0.061	0.036	0.023	0.007
Sa (0.3)	0.052	0.032	0.021	0.007
Sa (0.5)	0.042	0.027	0.018	0.005
Sa (1.0)	0.026	0.016	0.010	0.003
Sa (2.0)	0.013	0.007	0.004	0.001
Sa (5.0)	0.003	0.002	0.001	0.000
Sa (10.0)	0.001	0.001	0.001	0.000
PGA (g)	0.035	0.020	0.012	0.004
PGV (m/s)	0.032	0.019	0.012	0.003

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

References

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

Structural Commentaries (User's Guide - NBC 2015: Part 4 of Division B)
Commentary J: Design for Seismic Effects

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

See the websites www.EarthquakesCanada.ca and www.nationalcodes.ca for more information

APPENDIX F

Foundation Comparisons

Client: AECOM Canada Ltd.

File No.: 31653

November 23, 2023

THURBER ENGINEERING LTD.

CONCRETE PIPE	OPEN BOTTOM CULVERT	CLOSED BOTTOM CULVERT	TRENCHLESS
Advantages			
- Readily available materials and simple installation methods	- Relatively expedient installation if precast units are used - 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.	- Relatively expedient installation if precast units are used	- Avoids open cut and reduces need for roadway protection systems - Allows for two directions of traffic to be maintained throughout construction
Disadvantages			
- Requires moderate excavation - Protection system will require bracing, anchors and/or rakers - May require temporary by-pass pumping system	- Requires largest and deepest excavation - Protection system is higher so will require additional bracing, anchors and/or rakers - Dewatering to greater depth - May require temporary by-pass pumping system	- Requires moderate excavation - Protection system will require bracing, anchors and/or rakers - May require temporary by-pass pumping system	- Requires specialized construction equipment and Contractor - Requires construction of entry and exit pits and access to the toes of the slope - slow progress in rockfill
Risks			
- Potential for base disturbance	- Increased risk of basal instability	- Potential for base disturbance	- Obstructions present - Entry and exit pits could require sheet pile enclosure excavation and risk of basal instability - A mixed face is anticipated.
Recommendation			
Recommended	Not recommended	Recommended	Not recommended

THURBER ENGINEERING LTD.

APPENDIX G

List of Referenced Specifications and Contract Provisions

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

- OPSS.PROV 206
- OPSS.PROV 401
- OPSS.PROV 421
- OPSS.PROV 422
- OPSS.PROV 501
- OPSS.PROV 511
- OPSS.PROV 517
- OPSS.PROV 539
- OPSS.PROV 803
- OPSS.PROV 804
- OPSS.PROV 805
- OPSS.PROV 902
- OPSS.PROV 1004
- OPSS.PROV 1010
- OPSS.PROV 1205
- OPSS.PROV 1860
- SP 105S09
- SP 110S06
- SP 517F01
- SP FOUN0003
- OPSD 208.010
- OPSD 219.110
- OPSD 802.031
- OPSD 803.010
- OPSD 803.031
- OPSD 810.010
- OPSD 3090.100

2. Contract Provision – Obstructions

Installation of roadway protection systems and coffer dams will encounter obstructions such as rockfill, cobbles and boulders and wood. Such obstructions may impede the work from reaching the design depth of installation. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions and extend the work to the design depths. The work must not destabilize the culvert(s) or embankment.

3. Contract Provision – Dewatering and Temporary Flow Passage

It will be necessary to divert the ditch flow around the excavation to place the bedding and construct the culvert in the dry. Excavations and placement of bedding material must be completed in the dry. The presence of cohesionless native soils may increase seepage rates. Suitable diversion and dewatering systems must be employed. The diversion scheme will be critical for culvert construction at this site. The Contractor should be prepared to take appropriate measures to construct the bedding layer and place the culvert in a dry and stable environment.