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FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 416 CULVERT REPLACEMENT (03X-0724/C1)
NORTH GOWER TOWNSHIP, ONTARIO
ASSIGNMENT NO.: 4023-E-0001
GWP 4202-13-00

GEOCRES NO.: 31G04-007

Location: Lat: 45.149996°, Long: -75.682100°

Client Name: Jacobs Solutions Inc.
Date: February 11, 2025
File: 38447

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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 at North Gower Township for Culvert 03X-0724/C1 on Highway 416 in Ottawa, Ontario. Thurber Engineering Ltd. (Thurber) carried out the foundation investigation as a subconsultant to Jacobs Solutions Inc. (Jacobs) under Ministry of Transportation of Ontario (MTO) Assignment No. 4023-E-0001.

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

Site No. 03X-0724 is located on Highway 416 approximately 0.5 km north of the Roger Stevens Drive (County Road 6) interchange. For project purposes, Highway 416 is herein described as oriented north-south, and the culvert is described as oriented east-west.

At the site, Highway 416 is a four-lane highway with a N-EW Ramp to Roger Stevens Drive, and has a posted speed limit of 110 km/hr. The highway is divided with a grassy median approximately 16 m wide. The shoulders to the highway rounding have a width of approximately 1.5 to 3.0 m and are partially paved. No guiderails were noted along either the northbound or southbound shoulders of the highway in the vicinity of the culvert. Traffic volumes on this section of Highway 416 are understood to be 34,200 AADT in 2016.

The overall culvert at the site consists of two structures:

- 03X-0724/C1 (previously numbered 03X-0724/C0) – a 3.8 m wide, Steel Closed Arch (SCA) constructed under contract 1982-0025 beneath the (now) Highway 416 northbound lanes; and
- 03X-0724/C2 (previously numbered 03X-0725/C0) – double cell concrete box culvert with overall width of about 7.5 m and height of 2.25 m (each cell with internal span of 3.25 m and rise of 1.75 m) constructed under contract 1996-0007 beneath the Highway 416 southbound lanes.

The two culvert sections are understood to abut each other beneath highway median and facilitate water flow from west to east. This report addresses the replacement of the 3.8 m wide SCA beneath the northbound lanes of Highway 416 (03X-0724/C1).

The CSP arch culvert crosses the northbound lanes on an approximate 45° skew to the highway alignment. Embankment side slopes, in the vicinity of the culvert, are inclined at between approximately 3.3H:1V to 3.7H:1V. The existing highway embankment side slopes at the culvert site did not show any visible signs of global instability at the time of the investigation.

The northbound lanes road surface is at approximately elevation 90.2 m and the elevation of the culvert crown is approximately 88.0 m at the inlet (03X-0724/C2) and 87.7 m at the outlet (03X-0724/C1). The water level was measured at an elevation of about 86.1 m on August 28, 2024.

The site is in a rural setting, and the terrain along the ditch line is relatively flat on both sides of the highway. The area directly adjacent to the culvert is mostly farmland with some deciduous trees and shrubs.

Photographs showing the existing conditions in the project area at the time of the field investigation are included in Appendix D for reference.

2.2 Site Geology

Based on the Physiography of Southern Ontario[1] mapping, the site lies within the physiographic landform known as clay plains and more specifically, a physiographic region known as the North

[1] Chapman, L.J., and Putnam, D.F. 2007: Physiography of Southern Ontario; Ontario Geological Survey, Miscellaneous Release--Data 228.

Gower drumlin field which was formed by glacial ice acting on underlying unconsolidated till or ground moraine. The area between the drumlins is overlain by clay and silt deposited with the receding of the Champlain Sea.

Bedrock Geology Map (MRD126)[2] indicates the site is underlain by dolostone and sandstone of the Beekmantown Group.

2.3 Existing Subsurface Information

No existing foundation investigation report was available for this site within the online Geocres Library. However, Geocres Report 31G00-213 for a foundation investigation conducted 500 m south of the culvert was reviewed for regional information only and has not been used further in the report.

3. SITE INVESTIGATION AND FIELD TESTING

The foundation investigation and field-testing program was carried out between April 26 and May 9, 2024, and consisted of three off-road boreholes identified as Boreholes 24-1201, 24-1202 and 24-1205 and two on-road boreholes identified as Boreholes 24-1203 and 24-1204. The on-road boreholes were advanced using a truck mounted CME 55 drill rig equipped with Hollow Stem Auger (HSA), NW casing and NQ coring equipment. Boreholes 24-1202 and 24-1205 were advanced using track mounted CME 55 drill rig equipped with Hollow Stem Auger (HSA), NW casing and NQ coring equipment. Borehole 24-1201 was advanced using portable drilling equipment with a full-weight hammer. Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations.

A summary of the borehole coordinates, elevations, and termination depths is provided in Table 3-1. The locations and elevations of the boreholes were surveyed by Thurber with a Trimble Catalyst DA1 antenna with centimeter accuracy and were measured relative to BM 00820118001 (Elevation 88.395m) and BM 00820118002 (Elevation 93.287m). Horizontal locations were measured by Thurber relative to existing site features. The elevations and borehole coordinates were reviewed and referenced to the survey data provided by MTO. The borehole coordinates and elevations are shown on the Borehole Location and Soil Strata drawing included in Appendix A and on the individual Record of Borehole sheets included in Appendix B. The borehole coordinates are referenced to MTM Zone 9.

[2] *http://www.geologyontario.mndm.gov.on.ca/mines/data/google/mrd126/doc.kml*

Table 3-1 Borehole Summary

BOREHOLE NO.	LOCATION	NORTHING (m)	EASTING (m)	GROUND SURFACE ELEVATION (m)	TERMINATION DEPTH (m)
24-1201	Culvert Inlet	5 001 374.8	369 073.8	86.9	11.2
24-1202	Highway Median	5 001 431.5	369 102.8	89.0	17.2
24-1203	North of Culvert Northbound Lane	5 001 460.3	369 104.0	90.2	14.1
24-1204	South of Culvert Northbound Lane	5 001 450.9	369 113.8	90.2	18.3
24-1205	Culvert Outlet	5 001 485.0	369 121.1	87.0	10.6

Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in general accordance with ASTM D 1586.

In-situ shear vane testing was carried out within the cohesive layers, where possible, using an MTO 'N' sized vane in general accordance with ASTM D 2573. In the portable Borehole 24-1201 the MTO 'N' sized vane could not be used, however a 'B' sized vane was used and the results converted to the standard 'N' vane. Thin-Walled (Shelby) Tube samples were pushed and retrieved in Boreholes 24-1202 to 24-1205 to obtain relatively undisturbed cohesive soil samples.

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 50 mm diameter monitoring well with a 1.5 m slotted screen was installed in Borehole 24-1201 to allow for measurements of the groundwater level and hydraulic conductivity testing after drilling. The well details are illustrated on the respective Record of Borehole sheets provided in Appendix B. The monitoring well will be decommissioned in general accordance with O.Reg. 903 by Thurber personnel.

Following completion of the field investigation, the boreholes without monitoring well installations were decommissioned in general accordance with O.Reg. 903, as amended. Boreholes 24-1203 and 24-1204 were filled with bentonite, cuttings and granular material and capped by cold patch asphalt to reinstate the pavement surface.

4. LABORATORY TESTING

Laboratory testing was selected in general accordance with the April 2022 version of the MTO Guidelines for Foundation Engineering Services (GFES), Section 5. Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all retained soil samples. More than 25% of the recovered soil samples were tested for grain size distribution and, where appropriate, Atterberg Limits, in accordance with MTO and ASTM standards. The rock cores were photographed, and the total core recovery (TCR), solid core recovery (SCR), and rock quality designation (RQD) were measured. Unconfined compressive strength (UCS) testing was carried out on intact bedrock core samples. The results of these tests are summarized on the Record of Borehole sheets included in Appendix B.

Two soil samples were 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 and sampled intervals. Soil classification is in general accordance with ASTM D2487 as amended by the MTO GFES.

In general, the stratigraphy encountered is generally characterized by asphalt pavement, overlying a silty sand with gravel embankment fill, overlying a deposit of clay to clayey silt which is, in turn, underlain by glacial till, and limestone bedrock.

5.1 Asphalt

Asphalt was encountered at the ground surface in the on-road Boreholes 24-1203 and 24-1204. The asphalt was measured to have a thickness of 200 mm.

5.2 Embankment Fill

Granular embankment fill consisting of silty sand with gravel and containing occasional cobbles and boulders was encountered in the boreholes put down through the northbound lane embankment (Boreholes 24-1203 and 24-1204). At Borehole 24-1202, put down in the highway median, fill consisting of sandy clayey silt trace organics was encountered at the ground surface. The granular fill had a thickness ranging from 2.4 m to 3.6 m (base elev. 86.6 m to 86.4 m respectively).

Within the boreholes put down within the highway lanes, SPT N-values ranging from 18 to 63 blows per 300 mm of penetration were recorded, indicating a generally compact to very dense relative density.

The recorded moisture content within the granular embankment fill ranged from 3% to 10% in the silty sand in Boreholes 24-1203 and 24-1204. The results of gradation analyses completed on two samples of the granular embankment fill 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>22 – 27</td></tr>
<tr><td>Sand</td><td>56 – 62</td></tr>
<tr><td>Silt</td><td rowspan="2">16 – 17</td></tr>
<tr><td>Clay</td></tr>
</table>

The recorded moisture content of samples of the sandy silty clay in the median ranged from 18 to 34% in Borehole 24-1202. SPT N-values ranged from 6 to13 blows per 300 mm of penetration, indicating a firm to stiff consistency.

The results of one gradation analyses completed on a sample of the sandy clayey silt embankment fill 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.

SOIL PARTICLE	PERCENTAGE (%)
Gravel	0
Sand	32
Silt	51
Clay	17

Atterberg limit testing was completed on the sample of sandy clayey silt fill from Borehole 24-1202. The results are illustrated in Figure C3 of Appendix C and are summarized below and on the Record of Borehole sheets in Appendix B. The median fill is classified as low plastic (CL).

SOIL PARTICLE	PERCENTAGE (%)
Liquid Limit	33
Plastic Limit	22
Plasticity Index	11

5.3 Clay to Clayey Silt (CH to CL)

A native deposit ranging in composition from clay to clayey silt with localized silt pockets were encountered below the fill. At Boreholes 24-1201 and 24-1205, put down beyond the highway embankments, organics were encountered in the upper 0.2 m to 0.6 m, respectively. The overall clay to clayey silt deposit has a thickness ranging from 5.2 m to 11.5 m (base elev. 81.8 m to 75.1 m). The upper 1.9 m to 2.5 m of the deposit is weathered to a brownish grey crust (base elev. 84.9 m to 84.2 m). In Borehole 24-1202, silt and sand seams were noted below a depth of 10.7 m from ground surface (elev. 78.3 m).

In the weathered crust, SPT N-values ranged from 2 to 6 blows per 0.3 m of penetration, indicating a generally firm consistency. Field vane tests carried out in the underlying unweathered portion of the deposit gave undrained shear strengths ranging from 32 to greater than 100 kPa, but generally between about 40 kPa and 75 kPa, indicating firm to stiff consistency. Remolded vane tests recorded sensitivity values ranging from 2 to 22, but generally between 4 and 9, indicating that the deposit has a low to medium sensitivity (CFEM, 2023[3]). In general, relative to other boreholes, higher sensitivity values were recorded in the boreholes put down beyond the highway embankments (Boreholes 24-1201 and 24-1205).

[3] Canadian Foundation Engineering Manual, 5th Edition (2023).

The recorded moisture content typically ranged from 19 to 74%. A moisture content of 13% was noted in Borehole 24-1202 that can be associated with the presence of silt and sand seams below the depth of 10.7 m from ground surface (elev. 78.3 m). The results of gradation analyses completed on ten samples of the clay to clayey silt layer are illustrated in Figures C4 and C5 of Appendix C. The results of the tests are summarized in the table below and on the Record of Borehole sheet in Appendix B.

SOIL PARTICLE	PERCENTAGE (%)
Gravel	0 – 9
Sand	1 – 13
Silt	36 – 88
Clay	10 – 63

Atterberg limit testing was completed on seven samples of this deposit. The results are illustrated in Figures C6 and C7of Appendix C and are summarized below and on the Record of Borehole sheets in Appendix B. The laboratory results indicate that the clay to clayey silt exhibits high to low plasticity (CH to CL-ML) that generally exhibits decreasing plasticity with greater depth. It should be noted that two results showed non-plastic behavior due to high contents of silt (77 and 88%, respectively) in Boreholes 24-1202 and 24-1205.

SOIL PARTICLE	PERCENTAGE (%)
Liquid Limit	25 – 59
Plastic Limit	17 – 29
Plasticity Index	7 – 31

5.4 Sand with Silt (SM)

A deposit of sand with silt was encountered below the clay to clayey silt layer in Borehole 24-1204 and had a thickness of 0.8 m (base elev. 78.0 m). One SPT N-value weight-of-hammer (WH) was recorded, indicating a very loose relative density; however, may also be an indication of sampling disturbance.

The recorded moisture content within the sand was 14%. The results of gradation analyses completed on one sample of the layer are illustrated in Figure C8 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	1
Sand	90
Silt & Clay	9

5.5 Silty Sand Glacial Till

A native deposit of glacial till consisting of silty sand with varying amounts of gravel and containing cobbles and boulders underlies the clay to clayey silt deposit and was encountered in all boreholes, with the exception of Borehole 24-1202. Boreholes 24-1201 and 24-1203 were terminated in the glacial till deposit at base elevations of 75.7 m and 76.1 m, respectively. Where encountered and fully penetrated, the glacial till layer had a thickness ranging from 1.0 m to 2.9 m (base elev. 80.1 m to 75.1 m).

SPT N-values of 14 blows for 300 mm of penetration to greater than 100 blows for 75 mm were recorded, indicating a compact to very dense relative density. It should be noted that refusal blow counts could be associated with the presence of cobbles and boulders within the layer rather than the density of soil matrix. Coring was required to penetrate portions of the deposit in Borehole 24-1204.

The recorded moisture content of samples of the till ranged from 6 to 13%. The results of gradation analyses completed on two samples of the glacial till layer are illustrated in Figure C8 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	10 – 20
Sand	63 – 67
Silt & Clay	13 – 27

5.6 Bedrock

Bedrock was encountered below the glacial till (where penetrated) in the boreholes 24-1202, 24-1204 and 24-1205. The bedrock surface was encountered at depths of 6.2 m to 15.1 m below the existing ground surface (elev. 80.8 m to 75.1 m) and slopes down to the west between Boreholes 24-1205 and 24-1204. The bedrock is described as slightly weathered to fresh jointed to fresh, fine grained, limestone that is predominantly grey in color. Photographs of the bedrock cores are provided in Appendix C. The rock core quality and strength are summarized below.

PARAMETER	RANGE
Total Core Recovery (TCR), %	30 – 100
Solid Core Recovery (SCR), %	23 – 97
Rock Quality Designation (RQD), %	23 – 97
Fracture Index (fractures per 0.3 m) (1)	0 – >10
Unconfined Compressive Strength (UCS) (2), MPa	69 – 204

Notes: (1) Indicated as "FI" on Borehole Logs
(2) samples tested from Boreholes 24-1202 and 24-1205

The RQD ranged from 23% to 97%, but was generally between 23 and 76%, indicating a bedrock quality classified as very poor to fair (CFEM, 2023). The results of unconfined compressive strength testing were 69 MPa and 204 MPa and is indicative of the bedrock to be strong to very strong (CFEM, 2006).

5.7 Groundwater Level

A monitoring well was installed in Borehole 24-1201 to monitor the groundwater levels after completion of drilling. The measured groundwater levels are summarized in the below.

Table 5-1 Summary of Measured Water Levels

BOREHOLE	DATE OF READING	WATER DEPTH / ELEVATION (m)	COMMENT
24-1201	2024/04/26 2024/07/03 2024/08/15	0.2 / 86.7 0.0 / 86.9 0.2 / 86.7	Monitoring Well (screen in clayey silt)

The surface water level in the culvert system was measured to be at Elevations 86.4 m and 86.3 m at the inlet and outlet, respectively, on August 28, 2024.

It should be noted that the values above are considered short-term readings and may not reflect groundwater levels at the time of construction and that the surface water levels could respond quickly to precipitation events. Seasonal fluctuations of the groundwater are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation and spring snow melts.

A Single Well Response Test (SWRT), or "slug test", was carried out on July 3, 2024, in the monitoring well installed in Borehole 24-1201 by inserting a bailer into the well and removing a volume of water from the monitoring well to induce an 'instantaneous' change and recording the rising of the water level over time with a data logger (i.e., a rising head test). The slug test was analyzed using the Hvorslev method and the plot of the slug test results is included in Appendix B.

The estimated hydraulic conductivity value calculated from the in-situ slug test is summarized in Table 5-2 below.

Table 5-2 Single Well Response Test Results

BOREHOLE	BOTTOM OF SCREEN DEPTH/ ELEVATION (m)	SOIL IN ZONE OF SCREEN	ESTIMATED HYDRAULIC CONDUCTIVITY (m/s)
24-1201	4.6 / 82.3	Clayey Silt	2.4×10^{-8}

5.8 Analytical Testing

Two soil samples were submitted for analytical testing. The analysis results are included in Appendix C and are summarized in the following table.

Table 5-3 Summary of Analytical Test Results

BOREHOLE	24-1202	24-1205
SAMPLE	SS5	SS4A
DEPTH (m)	3 – 3.6	2.3 – 2.6
ELEVATION (m)	85.7	84.6
SOIL TYPE	Clayey Silt	Clayey Silt
CONDUCTIVITY (µS/cm)	1050	722
pH	7.12	7.32
RESISTIVITY (Ohm-cm)	960	1,390
CHLORIDE (µg/g)	524	290
SULPHATE (µg/g)	50	27
SULPHIDE (%)	<0.01	<0.01

6. MISCELLANEOUS

The as-drilled locations and ground surface elevation were measured by Thurber following completion of the field program. George Downing Estate Drilling Ltd. of Hawkesbury, Ontario, supplied and operated the drill rigs used to drill, test, sample, and decommission the truck-mounted and track-mounted boreholes. Limitless Drilling Inc. of Renfrew, Ontario, supplied and operated the drill rigs used to drill, test, sample, and decommission the portable borehole. Traffic control was performed in accordance with Ontario Book 7 and was provided by T.G. Carrol Cartage Ltd. of Carp, Ontario. The field investigation was supervised on a full-time basis by Mr. I. Khan, EIT, Mr. D. Amorim Pereira, Geotechnical Technician and Mr. H. Sitland, Geotechnical Technician. Overall supervision of the field investigation program was provided by Mr. C. Murray, P.Eng.

The Single Well Response Test (SWRT) was conducted by Mr. H. Sitland, Geotechnical Technician, and the analysis performed by Mr. S. Morton, P.Geo.

Routine geotechnical laboratory testing was completed by Thurber's laboratory in Ottawa. UCS testing of rock core was completed by Stantec at their lab in Ottawa. Analytical testing was completed by Paracel Laboratories Ltd. in Ottawa.

Interpretation of the factual data and preparation of this report was completed by D. Amorim Pereira, Geotechnical Technician and Matt Kennedy, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., the Designated Principal Contacts 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 for replacement of the Highway 416 culvert (03X-0724/C1) crossing the highway in Ottawa, Ontario. Thurber carried out the foundation investigation as a subconsultant to Jacobs Solutions Inc. (Jacobs) under Assignment No. 4023-E-0001. The discussion and recommendations presented in this report are based on the information provided by Jacobs 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, Jacobs Solutions Inc., 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 interpretations may affect equipment selection, proposed construction methods, scheduling and the like.

7.1 Existing Structure

The existing culvert system at the site consists of two structures:

- 03X-0724/C1 (previously numbered 03X-0724/C0) – a 3.8 m wide, Steel Closed Arch (SCA) constructed under contract 1982-0025 beneath the (now) Highway 416 northbound lanes; and

- 03X-0724/C2 (previously numbered 03X-0725/C0) – double cell concrete box culvert with overall width of about 7.5 m and height of 2.25 m (each cell with internal span of 3.25 m and rise of 1.75 m)p constructed under contract 1996-0007 beneath the Highway 416 southbound lanes.

It is understood that the culverts cross the highway on an approximately 45° skew to the highway alignment with flow from west to east. The road surface of the northbound lanes is at approximate elevation 90.2 m and the elevation of the culvert crown is approximately 88.0 m at the inlet (03X-0724/C2) and 87.7 m at the outlet (03X-0724/C1). The surface water level was measured at elevation of about 86.4 m on August 28, 2024 and was at about 86.7 m in the monitoring well installed at Borehole 24-1201.

7.2 Proposed Structure

Based on the RFP, it is understood that the existing concrete box culvert beneath the Highway 416 southbound lanes (03X-0724/C2) requires no significant repairs and will remain in place, and the existing Steel Closed Arch culvert beneath the Highway 416 northbound lanes (03X-0724/C1) is to be replaced with a concrete box culvert to complement the hydraulic capacity of the existing concrete culvert.

A General Arrangement drawing for the new structure is not available. However, it has been assumed that the replacement culvert is to be designed with an invert elevation and width similar to that of the existing culvert. It is anticipated that no grade raise will be required and the length of the replacement culvert will be similar to that of the existing box culvert under the southbound lanes (03X-0724/C2), extended as necessary to satisfy requirement to extend a minimum of 14 m from the edge of the through lane. No wingwalls or headwalls are anticipated.

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 surface conditions and in accordance with the Canadian Highway Bridge Design Code (CHBDC) version CSA S6-19.

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

It is understood that the replacement culvert structure is to be designed to the “Major Route” importance category.

It is understood that the replacement culvert would have a consequence level of *Typical*. 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 of the CHBDC, the degree of site prediction model understanding is considered to be *Typical* based on the current information.

The fundamental period of vibration of the replacement culvert is assumed to be less than 0.5 s.

8. SEISMIC CONSIDERATIONS

8.1 CHBDC Seismic Site Designation

In accordance with Section 4.4.3.2 of the CHBDC, the selection of the seismic site classification is based on the nature of soil and bedrock deposit within the upper 30 m of the stratigraphy that underlies the reference foundation level. If the shear wave velocity is not known, as is the case at this site, the seismic site class may be determined by the harmonic mean of the energy-corrected SPT-N values (N_{60}) and/or the undrained shear strength (s_u) encountered below the foundation element(s).

The unweathered portion of the silty clay deposit that underlies the upper weathered crust and will underlie the new culvert ranges from about 2.6 m to 9.6 m thick. Field testing indicated that it had an undrained shear strength between 32 kPa and 75 kPa. The calculated harmonic mean of the undrained shear strength encountered below the anticipated culvert bottom ranged from 49 kPa to 53 kPa at the borehole locations. Considering that the representative shear wave velocity in the glacial till and limestone bedrock is anticipated to be higher than that in the overlying silty clay deposit, a Site Class D defined per Table 4.1 within Section 4.4.3.2 of the CHBDC is considered appropriate for design in the absence of shear wave velocity measurements.

8.2 Spectral and Peak Acceleration Hazard Values

The current CHBDC was developed considering the fifth-generation seismic model developed by the Geological Survey of Canada (GSC)[4] based on the 2015 National Building Code of Canada (NBCC). The GSC has subsequently released the sixth-generation seismic model which is based on the 2020 NBCC. The site-specific seismic hazard values obtained from the 2020 National

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

Building Code of Canada Seismic Hazard tool considering a Site Designation of X_D (Site Class D) are presented below in Table 8-1 .

Table 8-1 Recommended Ground Motion Parameters for Design (Site Designation X_D)

PARAMETER	PROBABILITY OF EXCEEDANCE IN 50 YEAR (RETURN PERIOD)		
	2% (2,475-year)	5% (975-year)	10% (475-year)
Sa(0.2) [g]	0.618	0.404	0.280
Sa(0.5) [g]	0.508	0.339	0.232
Sa(1.0) [g]	0.302	0.190	0.125
Sa(2.0) [g]	0.144	0.0875	0.0553
Sa(5.0) [g]	0.0402	0.0225	0.0133
Sa(10.0) [g]	0.0126	0.00693	0.00407
PGA [g]	0.361	0.248	0.175
PGV [m/s]	0.354	0.219	0.141

8.3 Liquefaction Potential

The susceptibility of the cohesive soils at this site to experience liquefaction/cyclic softening was assessed following the Bray et al. (2004)[5] criteria using index properties and in-situ shear strengths. Based on this assessment, the cohesive foundation soils are not considered susceptible to cyclic mobility under the design earthquake.

Localized silt/sand pockets were encountered at the bottom of the clay to clayey silt layer in Boreholes 24-1202, 24-1204 and 24-1205. SPT ‘N’ blow counts ranging from as low as weight of hammer (WH) to 3 blows per 0.3 m of penetration were recorded within these pockets, indicating a very loose relative density. As such, these discrete zones may be susceptible to liquefaction during the 2,475-year event but are not considered to be indicative of the behavior of the overall deposit.

The glacial till deposit at the site consist of sand with silt and varying amounts of gravel, cobbles and boulders. Auger drilling through the deposit was difficult and required coring techniques to penetrate several portions. The compact to very dense glacial till deposit is not considered susceptible to liquefaction.

[5] Bray, J. D. et al. (2004b). Liquefaction susceptibility of fine-grained soils. Proc., 11th Int. Conf. on Soil Dynamics and Earthquake Engineering and 3rd Int. Conf. on Earthquake Geotechnical Engineering, Berkeley, CA, Jan 7-9, 655–662

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9. DESIGN OPTIONS

9.1 Culvert Type and Foundation Alternatives

Selection of the replacement culvert type must consider the proposed construction procedures, staging requirements, dewatering requirements, geotechnical resistance available in the foundation strata, depth to suitable bearing stratum and post construction settlement. The options that have been considered from a foundation perspective include:

- Pipe Culvert (Concrete, HDPE, Steel)
  From a foundation engineering perspective, a concrete pipe culvert is a technically feasible alternative. The size of the pipe culvert would depend on the required hydraulic capacity. Multiple smaller pipes may be required to carry the flow.

- 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. An effective connection between the existing box culvert and a new box culvert will be important.

- Open Bottom Culvert (Box, Arch)
  The construction of an open-bottom culvert will have greater construction concerns due to the high water table and requirement for greater excavation depths to construct the culvert footings to satisfy frost depth requirements. The use of an open-bottom culvert would require greater dewatering efforts and has the potential for larger settlement following construction when compared to other culvert options.

A comparison of the foundation alternatives, in terms of their respective advantages, disadvantages, risks and consequences, is included in Appendix E.

9.2 Construction Methodology Alternatives

Temporary excavations for construction of the replacement culvert will extend below the groundwater level. An adequate and effective dewatering plan including surface water management, cofferdams, water flow diversion and excavation dewatering will be required to enable excavation to the required founding elevation and construction of the foundations in the dry (see Section 11.3).

It is anticipated that temporary protection systems along the centerline of the existing highway and temporary cofferdams will be required to allow for the staged construction and for dewatering and water diversion during culvert replacement. The foundation recommendations presented herein have been prepared based on the assumption that the construction of the replacement culvert beneath the northbound lanes will be carried out either under full road closure using a detour on to the existing southbound lanes or with the use of temporary roadway protection allowing one lane of traffic through the construction zone.

If staged construction with temporary protection within the northbound lanes is preferred, roadway protection system would be required, as discussed further in Section 11.2, installed near the embankment centerline to maintain a single lane of traffic flow along the current northbound lanes embankment. The Contractor would need to consider the overall height of the protection systems and the potential for encountering obstructions within the fill and the underlying clay to clayey silt deposit during the installation of roadway protection (including the existing buried steel culvert).

10. FOUNDATION DESIGN RECOMMENDATIONS

From a foundation engineering perspective, a concrete, closed-bottom, box culvert is recommended. Relevant elevations obtained from the available preliminary design information are as follows:

- Existing approximate top of pavement northbound lanes — Elev. 90.2 m
- Low point of stream bed in proposed culvert — Elev. 85.7 m
- Assumed elevation of underside of base slab of culvert — Elev. 84.9 m
- Groundwater elevation — Elev. 86.1 m to 86.9 m

10.1 Closed Box Culvert

It is assumed that the dimensions of the existing Highway 416 embankments will be maintained following culvert replacement. It is not anticipated that the subgrade soils within the proposed northbound lanes culvert footprint will be subjected to any additional loads when compared to the existing embankment footprint.

Subgrade preparation should follow the recommendations provided in Section 10.2 in order to provide a suitable competent subgrade for the bedding. Construction will extend below the groundwater level. Surface water diversion and dewatering will be required to place the bedding material and install the culvert in the dry (Section 11.3).

The existing culvert under the southbound lanes (03X-0724/C2) consists of two cells totaling an overall width of about 7.5 m (each cell with internal span of about 3.25 m). For a new box culvert with a total exterior width of 7.5 m founded on a properly prepared and compacted granular bedding layer, the design can be based on factored geotechnical resistance values as follows:

- Factored Geotechnical Resistance at ULS: 150 kPa
- Factored Geotechnical Resistance at SLS: 110 kPa

It is noted that the replacement two-cell concrete box culvert, with each cell having inside rise and span of 2.25 m and 3.25 m, respectively, will be larger than the existing 3.8 m diameter SCA culvert under the existing northbound embankment, thus the result of the construction will be a net unloading.

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 case of eccentric or inclined loading, the bearing resistance must be reduced in accordance with CHBDC Clause 6.10.2. Foundation settlement, based on the supplied SLS resistance, is expected to be up to 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 friction 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 Backfill

"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. Fill should be placed and compacted as per OPSS.PROV 501 and OPSS.PROV 206. The culvert should be constructed following OPSS.PROV 401 and OPSS.PROV 422.

Subgrade preparation for the culvert replacement should include excavation and removal of the existing culvert (assuming replacement along the same alignment) and backfill materials. All organics, existing fill, soft or loose deposits, disturbed soils, alluvial deposits and deleterious materials must be stripped from the footprint of the foundation to expose competent subgrade at or below the desired founding elevations. Granular A or Granular B Type II can be used to backfill any sub-excavations required for subgrade improvements and compacted in accordance with OPSS.PROV 501.

Given the sensitive subgrade clay soils anticipated at the founding level of the culvert, construction equipment should not be permitted to travel on the exposed subgrade. The compaction of granular bedding directly above the subgrade may result in disturbance of the material with pumping of fines into the granular bedding and difficulty achieving the specified degree of compaction. After inspection and approval of the subgrade, protection of the subgrade should include a separation layer consisting of non-woven geotextile placed below the bedding material. The geotextile should meet the specifications of OPSS.PROV 1860 Class II and have an FOS not greater than 150 μm.

The Granular A or Granular B Type II bedding layer should be a minimum of 300 mm thick and covered with a 75 mm levelling course of Granular A. Cover limits should be similar to those shown on OPSD 803.010. Cover material should consist of Granular A or Granular B Type II. Excavated embankment fill material should not be used as culvert backfill since the existing fill may contain rubble and debris. The backfill should be compacted in regular lifts as per OPSS.PROV 501.

Heavy compaction equipment, used adjacent to or directly above the culvert, must be restricted in accordance with OPSS.PROV 501 to protect the replacement culvert from damage. The top of backfill elevation must always be within 500 mm on both sides of the culvert in accordance with OPSS.PROV 902. Care must be exercised when compacting the fill adjacent to and above the culvert in order not to damage the culvert.

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

10.3 Frost Depth

The frost penetration depth at this site is 1.8 m as per OPSD 3090.101. However, it is not necessary to found a closed box culvert below the depth of frost penetration. Frost taper treatment should be provided at this site as per OPSD 803.010 for the box culvert.

10.4 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. 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.

10.4.1 Static Lateral Earth Pressure

Lateral earth pressures acting on vertical structures should be computed in accordance with 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)

Typical earth pressure coefficients for vertical walls for backfill material with a horizontal surface behind the wall are shown in Table 10-1.

Table 10-1 Static Earth Pressure Coefficients

PARAMETER	OPSS GRANULAR A & B TYPE II	SELECT SUBGRADE MATERIAL (SSM)
Soil Unit Weight, kN/m^3, γ	22.8 / 22.0	21.0
Angle of Internal Friction, ϕ	35°	30°
Coefficient of at Rest Earth Pressure, K_o (Restrained Wall)	0.43	0.50
Coefficient of Active Earth Pressure, K_a (Unrestrained Wall)	0.27	0.33
Passive, K_P (Movement towards Soil Mass) in front of wall	3.7	3.0

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. Active earth pressures should be used for unrestrained walls. For rigid structures, at rest horizontal earth pressures would apply for design.

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 soil layers.

Where ground surfaces are sloped behind the walls, Thurber should be contacted for lateral earth pressure coefficients.

10.4.2 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 restrained walls

The coefficients of horizontal earth pressure for seismic loading presented in Table 10-2 may be used for vertical walls and a horizontal backslope. The provided earth pressure coefficients are based on the site-specific seismic hazard values for the Seismic Site Class D, and a 2% probability of exceedance in 50 years (2,475-year).

Table 10-2 Combined Static and Seismic Earth Pressure Coefficients

PARAMETER	OPSS GRANULAR A & B TYPE II	SELECT SUBGRADE MATERIAL (SSM)
Soil Unit Weight, kN/m^3, γ	22.8 / 22.0	21.0
Angle of Internal Friction, ϕ	35°	30°
Restrained Wall		
Dynamic Active Earth Pressure Coefficient, K_{AE}	0.54	0.64
Unrestrained Wall		
Dynamic Active Earth Pressure Coefficient, K_{AE}	0.38	0.46

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

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

where:

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

10.5 Embankment Design and Reinstatement

10.5.1 Embankment Reinstatement

The existing embankment side slopes, in the vicinity of the existing culvert, are inclined between approximately 3.3H:1V to 3.7H:1V and the existing Highway 416 embankment is up to about 3.2 m high above the adjacent lands. In general, the existing embankment consists of silty sand with gravel, overlying the native clay to clayey silt and glacial till deposits. It is understood that no grade raise or widening is anticipated along the Highway 416 alignment and it has been assumed that the embankment side slopes will be reinstated at 3H:1V, or flatter, to match the existing side slopes. In general, no evidence of recent global embankment slope instability or erosion was noted.

Embankment reconstruction after culvert replacement should be carried out in accordance with OPSS.PROV 206. If constructed using Select Subgrade Material (SSM) or Granular B Type I, the embankment may be constructed at 2H:1V, or flatter; and as noted above, it has been assumed that they will be constructed at 3H:1V to match existing. Granular fill should be placed and compacted in accordance with OPSS.PROV 501.

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

10.5.2 Embankment Settlement and Stability

Provided the subgrade is prepared as outlined above and reconstruction of the embankment up to the existing grade is carried out in accordance with recommendations provided within this report, embankment side slopes no steeper than 2H:1V would remain stable for an embankment reinstated with SSM, or Granular B Type I.

Based on the subsurface information collected as part of the current study, less than 25 mm of settlement is expected to occur beneath the existing highway alignment and reconstructed embankment. The magnitude of the embankment compression constructed with granular materials is in the order of 0.5% of the embankment height and is expected to occur during fill placement.

Further assessment of stability and settlement should be carried out where construction staging dictates the requirement for additional loading.

10.6 Cement Type and Corrosion Potential

Analytical tests were completed to determine the pH, water soluble sulphate, sulphide, chloride concentration, resistivity and electrical conductivity of samples of the soil. The analysis results are summarized in Section 5.8 and a copy of the test results is provided in Appendix C.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The tests results provided in Section 5.8 were compared with Table 3.2 of the MTO Gravity Pipe Design Guideline and indicate a severely corrosive environment. The corrosive effects of road de-icing salts should also be considered.

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 ranges from 27 and 50 μg/g, see Section 5.8. The selection for class of concrete should include consideration of the effects of road de-icing salts.

11. CONSTRUCTION CONSIDERATIONS

11.1 Excavation

All excavation must be carried out in accordance with the requirements of the Occupational Health & Safety Act & Regulations (OHSA) for Construction Projects. For the purposes of OHSA, the fill and native soils above groundwater may be classified as Type 3 soil. Native soils below the water table may be classified as Type 4 soil. Unsupported excavations made in Type 3 or Type 4 soils must have side slopes no steeper than 1H:1V or 3H:1V, respectively, from the base of the excavation. 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. Where there are space restrictions or where a slope must be retained, the excavations will need to be carried out within a protection system.

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 the stability of the existing roadway and culvert. The temporary cut slopes may have to be protected from precipitation and runoff to avoid erosion and 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. Further discussion on temporary protection systems is presented in Section 11.2.

Excavation for the culvert replacement must be carried out in accordance with OPSS.PROV 401 OPSS.PROV 422 and will be carried out through the existing embankment fill and into the underlying native deposits. Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor.

Excavation for installation of a closed box culvert will be required to extend to a depth below the culvert invert that is sufficient to accommodate placement of a suitably prepared granular bedding layer (see Section 10.2). Greater excavation depth will introduce additional risk and challenges associated with the deeper excavation protection systems that would be required.

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 and construction of temporary construction access roads are also the Contractor’s responsibility. Placement of construction equipment or temporary stockpiling must not destabilize the embankment slopes (existing, temporary or new). It is recommended that stockpiling or surface surcharge should not be allowed on the embankment or side slopes. The management and disposal of excess material shall be in accordance with OPSS.PROV 180.

11.2 Temporary Protection Systems

Temporary Protection Systems will be required for 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 system 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 is anticipated that temporary protection systems along the centerline of the existing highway and temporary cofferdams will be required to allow for the staged construction and for dewatering and water diversion during culvert replacement. The design of the roadway protection system 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, operations and stockpiles. Interlocking sheet piles are one feasible option for temporary protection.

Table 11-1 Lateral Earth Pressure Coefficients for Temporary Shoring Design

MATERIAL	UNIT(*) WEIGHT (kN/m^3)	K_A (-)	K_p (-)	S_u (kPa)	GROUND SURFACE *BEHIND* WALL
Existing Embankment Fill	20	0.33	3.0	-	Horizontal
Native Clay to Clayey Silt	17	-	-	40	Horizontal
Native Sand with Silt Till	21	0.27	3.7	-	Horizontal

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

Lateral earth pressure coefficients, under fully mobilized conditions, that can be used in design of the protection system installed through new granular fill material are provided in Table 11-1 for static conditions. The lateral earth pressure coefficients for the existing fill and native soils are given 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.

It is recommended that 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

Subgrade preparation and placement, compaction of granular bedding, and construction of the replacement culvert must be carried out in the dry. Based on the existing surface water levels measured at the culvert outlet, it is anticipated that the site will require unwatering/dewatering to lower the groundwater to below the final excavation or founding level. Furthermore, surface runoff will tend to seep into and accumulate in 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.

Subgrade preparation, placement and compaction of granular bedding, and culvert construction must be carried out with a properly designed dewatering system to control groundwater and ditch/surface water and may include cofferdams, ditch diversion, pumping, etc. Where required, a temporary flow passage should convey water flow around the construction site, this may require pumping. 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 dewatering systems in accordance with SP517F01 which amends OPSS.PROV 517. Given the site conditions and anticipated works, the Designer Fill-In Note 2 in SP517F01 Table 1 should be “Yes”; the design Engineer and design-checking Engineer do need a minimum of 5 years of experience in designing similar dewatering systems. A preconstruction survey is not required, thus Designer Fill-In Note 4 in this SP should be “N/A”. Based on the water level elevation at the time of the investigation, it is anticipated that the site will require dewatering to lower the groundwater to below the final excavation or footing level; Note 5 of SP 517F01 Table 1 should be 0.5 m but will need to be confirmed by the designer of the dewatering system.

The dewatering plan should be coordinated with TPS design. The dewatering system will be required to remain operational and effective until the temporary excavations are backfilled and then should be decommissioned and removed.

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.

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 all 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 and well prior to the onset of winter conditions in order to limit surficial erosion and water should be prevented from running down an unprotected slope.

Scour protection should be provided for the culvert inlet and outlet areas. Effective scour and erosion protection should be provided along the waterline, ditches and footings. Design of the erosion protection measure 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 surface subjected to flowing water in accordance with OPSS.PROV 511. Treatment at the outlet should be in accordance with OPSD 810.010.

The surface water flows from west to east through the culvert system at the site. If the two culvert halves are to be discontinuous in the median, a clay seal may be required at the inlet of the new box culvert under the northbound lanes (03X-0724/C1) to minimize the potential for piping and erosion around the inlet of the new culvert. In this case, the clay seal should consist of a geosynthetic clay liner and extend to approximately 300 mm above the high-water level and laterally for the width of the granular backfill around the culvert. The liner requirements should be in accordance with OPSS.PROV 1205. However, if the culverts are to provide a continuous connection, a clay seal in the median would not be required.

12. CONSTRUCTION CONCERNS

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

- Construction will extend below the water table. An adequate and effective surface water management and dewatering plan must be implemented to construct the culvert in the dry.
- The soil that will be exposed at the culvert subgrade level is moisture sensitive and may become disturbed or otherwise negatively impacted when subjected to construction or personal traffic, freeze-thaw actions, ingress, or ponding water. See suggested wording for a Contract Provision in Appendix F.
- Obstructions could be encountered in the existing embankment fill and may limit choice of equipment and methods. See suggested wording for a Contract Provision in Appendix F.
- The Contractor’s selection of construction equipment and methodology must include assessment of the capability of the existing soils to support the proposed construction equipment and supplies.

The 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.

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13. CLOSURE

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

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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.

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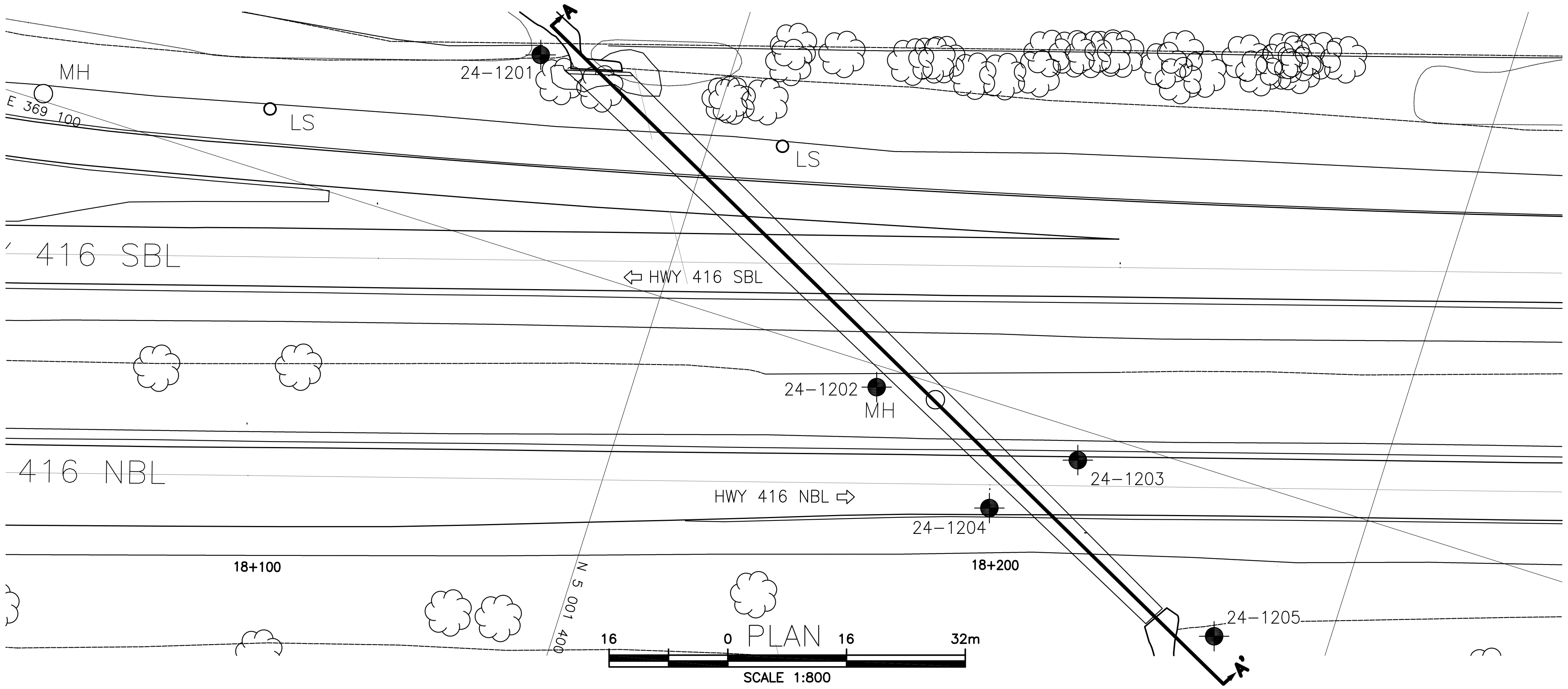
APPENDIX A

Borehole Locations and Strata Drawing



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

CONT No
GWP No 4202-13-00

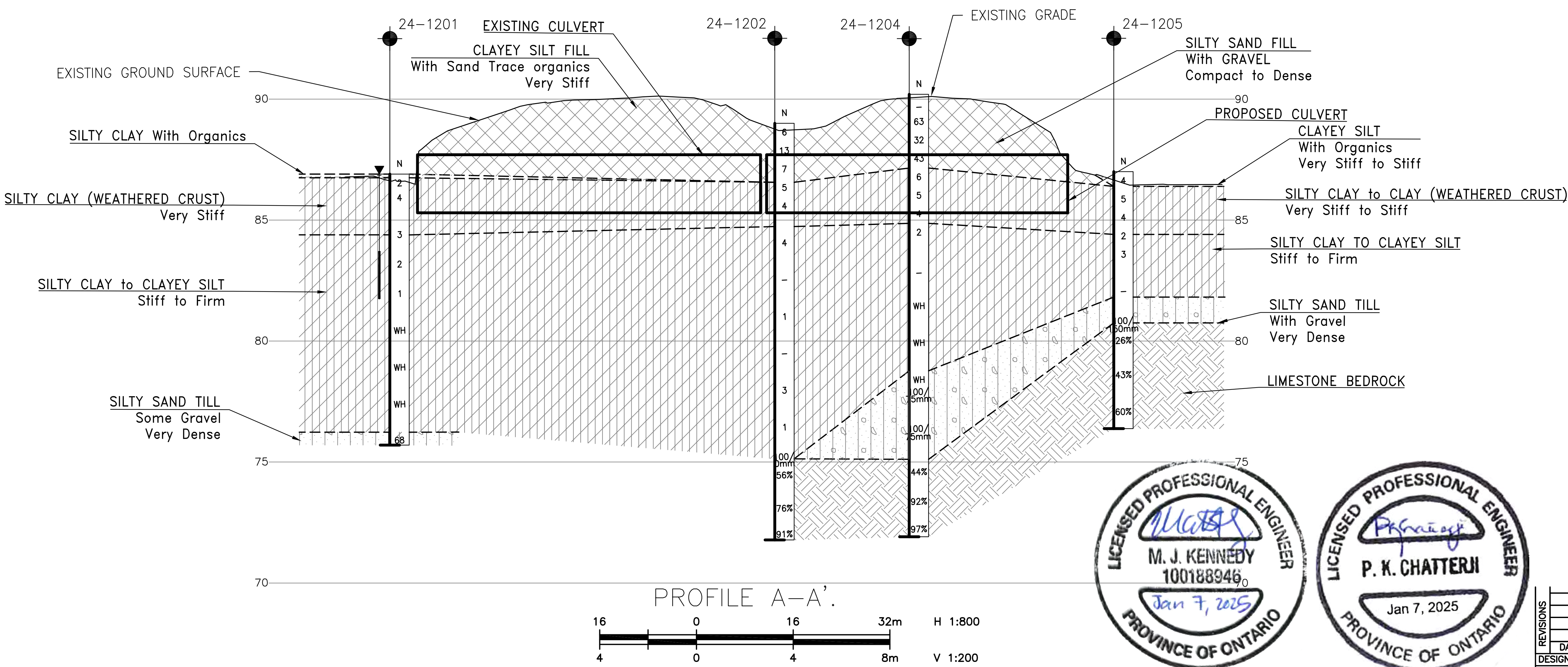
REHABILITATION OF THE HWY 416/417 CULVERT 03X-0724/C1
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

Ontario

THURBER

KEYPLAN



LICENSED PROFESSIONAL ENGINEER
M. J. KENNEDY
100188946
Jan 7, 2025
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Jan 7, 2025
PROVINCE OF ONTARIO

LEGEND

(solid borehole symbol)	Borehole (By Thurber)
(open borehole symbol)	Borehole (Previous Investigation)
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
24-1201	86.9	5 001 374.8	369 073.8
24-1202	89.0	5 001 431.5	369 102.8
24-1203	90.2	5 001 460.3	369 104.0
24-1204	90.2	5 001 450.9	369 113.8
24-1205	87.0	5 001 485.0	369 121.1

-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 9.

GEOCRES No. 31G04-007

REVISIONS | DATE | BY | DESCRIPTION

DESIGN CM | CHK | CODE | LOAD | DATE OCT 2024
DRAWN RH | CHK | SITE | STRUCT | DWG 1

FILENAME: H:\Drafting\38000\38447\99_PROJ\11_BHPP_03X_0724(1200)\TED-38447-0724.dwg
PLOTDATE: 1/6/2025 1:52 PM

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APPENDIX B

Symbols and Terms

Record of Boreholes Sheets

SWRT Results

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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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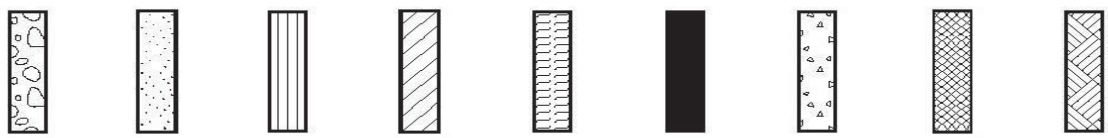
STRATA PLOT:

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

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 (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.

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

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

Note - W_L= Liquid Limit

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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 24-1201

METRIC

GWP# 4202-13-00
LOCATION Lat: 45.149421°, Long: -75.682618° Site 03X-0724, MTM z9: N 5 001 374.8 E 369 073.8
ORIGINATED BY IK

HWY 416
BOREHOLE TYPE Portable / NW Casing
COMPILED BY AO

DATUM Geodetic
DATE 2024.04.26 - 2024.04.26
CHECKED BY CM

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
86.9	Ground Surface				
0.0	**SILTY CLAY (CI)** with organics stiff	1	SS	2	
0.2	**SILTY CLAY (CI)** very stiff brownish grey **[WEATHERED CRUST]**	2	SS	4	
		3	SS	3	0 1 36 63
84.2 / 2.7	**CLAYEY SILT (CL)** stiff to firm grey	4	SS	2	
		5	SS	1	
		6	SS	WH	0 1 71 28
		7	SS	WH	
		8	SS	WH	

Field vane shear strength sensitivities (plotted): 13.0, 10.0, 5.5, 6.7, 5.5, 22.0, 8.0, 7.4, 4.3

Elevation scale: 86, 85, 84, 83, 82, 81, 80, 79, 78, 77

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; (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 24-1201

METRIC

GWP# 4202-13-00	LOCATION Lat: 45.149421°, Long: -75.682618° Site 03X-0724, MTM z9: N 5 001 374.8 E 369 073.8		ORIGINATED BY IK
HWY 416	BOREHOLE TYPE Portable / NW Casing		COMPILED BY AO
DATUM Geodetic	DATE 2024.04.26 - 2024.04.26		CHECKED BY CM

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa / DCPT	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
	Continued From Previous Page											
	CLAYEY SILT (CL) firm to stiff grey					+ 4.7; + 8.0						
76.2 / 10.7	**SILTY SAND** some gravel very dense grey **[GLACIAL TILL]**	9	SS	68	76		o		10	63	27 (SI+CL)	
75.7 / 11.2	**End of Borehole**											

Monitoring Well installed:
Schedule 40 PVC standpipe with 50-mm diameter and 1.5-m slotted screen.

Water Level Readings:

DATE	DEPTH (m)	ELEV. (m)
2024/04/26	0.2	86.7
2024/07/03	0.0	86.9
2024/08/15	0.2	86.7

Legend: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE

+³, ×³: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No 24-1202

 METRIC

GWP# 4202-13-00 | LOCATION Lat: 45.149928°, Long: -75.682242° Site 03X-0724, MTM z9: N 5 001 431.5 E 369 102.8 | ORIGINATED BY DAP

HWY 416 | BOREHOLE TYPE HSA / NW Casing / NQ Coring | COMPILED BY AO

DATUM Geodetic | DATE 2024.05.01 - 2024.05.01 | CHECKED BY CM

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
89.0	Ground Surface				
0.0	SANDY CLAYEY SILT trace organics, very stiff, brownish grey **[FILL]**	1	SS	6	
		2	SS	13	0 32 51 17
		3	SS	7	
86.6 / 2.4	**CLAYEY SILT (CL)** very stiff, brownish grey **[WEATHERED CRUST]**	4	SS	5	
		5	SS	4	
84.7 / 4.3	**CLAYEY SILT (CL)** stiff to firm, grey	6	SS	4	
		7	ST	-	
		8	SS	1	0 1 74 25
		9	ST	-	

Shear strength (field vane) annotations: > 110 kPa; 5.4; 4.0; 5.5; 8.3; 5.5; 6.0; 6.5

Elevation scale: 88, 87, 86, 85, 84, 83, 82, 81, 80, 79

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

RECORD OF BOREHOLE No 24-1202

METRIC

GWP# 4202-13-00
LOCATION Lat: 45.149928°, Long: -75.682242° Site 03X-0724, MTM z9: N 5 001 431.5 E 369 102.8
ORIGINATED BY DAP
HWY 416
BOREHOLE TYPE HSA / NW Casing / NQ Coring
COMPILED BY AO
DATUM Geodetic
DATE 2024.05.01 - 2024.05.01
CHECKED BY CM

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH (kPa) / Sensitivity	WATER CONTENT	UNIT WEIGHT (FI)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	CLAYEY SILT (CL) stiff to firm, grey					Field vane + 8.0; + 2.8			
	- silt and sand seams noted below a depth of 10.7 m	10	SS	3	78		o		0 13 77 10 silt seam, non-plastic
							o		
						Field vane + 5.0; + 4.5			
					77				
		11	SS	1			o		
					76	Field vane + 2.4; + 3.5			
75.1 / 13.9	**LIMESTONE BEDROCK** very strong, slightly weathered to fresh jointed, fine grained, grey	12	SS	100/ 0mm	75		o	FI	
		1	RUN	-	74			>10, 2, 3, 1, 5	RUN #1 TCR=100% SCR=85% RQD=56% UCS=204MPa
		2	RUN	-	73			1, 2, 0	RUN #2 TCR=100% SCR=83% RQD=76%
71.8 / 17.2		3	RUN	-	72			1, 0	RUN #3 TCR=91% SCR=91% RQD=91%

End of Borehole

A representative open-hole groundwater level measurement was not obtained during drilling.

+3, ×3: Numbers refer to Sensitivity

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

THURBER

RECORD OF BOREHOLE No 24-1203

METRIC

GWP# 4202-13-00	LOCATION Lat: 45.150187°, Long: -75.682223° Site 03X-0724, MTM z9: N 5 001 460.3 E 369 104.0	ORIGINATED BY DAP/HS
HWY 416	BOREHOLE TYPE HSA / NW Casing	COMPILED BY AH
DATUM Geodetic	DATE 2024.05.09 - 2024.05.09	CHECKED BY CM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
90.2	Ground Surface				
0.0	**ASPHALT (200 mm)**				
0.2	SILTY SAND with gravel brownish grey compact to dense **[FILL]**	1	GS	-	
		2	SS	49	
		3	SS	26	
		4	SS	31	22 62 16 (SI+CL)
		5	SS	18	
86.4 / 3.8	**CLAY (CH)** very stiff brownish grey **[WEATHERED CRUST]**	6	SS	3	
		7	SS	2	0 1 37 62
84.9 / 5.3	**CLAYEY SILT (CL)** very stiff to stiff grey	8	SS	WH	
		9	SS	WH	0 2 74 24
		10	ST	-	
		11	ST	-	

Elevation scale: 90, 89, 88, 87, 86, 85, 84, 83, 82, 81

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

Field vane sensitivity values plotted: 8.7, 6.0, 6.0, 14.7

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 24-1203

METRIC

GWP# 4202-13-00

LOCATION Lat: 45.150187°, Long: -75.682223° Site 03X-0724, MTM z9: N 5 001 460.3 E 369 104.0

ORIGINATED BY DAP/HS

HWY 416

BOREHOLE TYPE HSA / NW Casing

COMPILED BY AH

DATUM Geodetic

DATE 2024.05.09 - 2024.05.09

CHECKED BY CM

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	CLAYEY SILT (CL) stiff to firm grey				
79.4 / 10.8	**SILTY SAND** with gravel compact to very dense grey **[GLACIAL TILL]**	12	SS	21	
		13	SS	14	20 67 13 (SI+CL)
76.1 / 14.1	**End of Borehole** A representative open-hole groundwater level measurement was not obtained during drilling.	14	SS	100/ 75mm	

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE (80, 79, 78, 77); 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

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 24-1204

METRIC

GWP# 4202-13-00

LOCATION Lat: 45.150101°, Long: -75.682099° Site 03X-0724, MTM z9: N 5 001 450.9 E 369 113.8

ORIGINATED BY DAP

HWY 416

BOREHOLE TYPE HSA / NW Casing / NQ Coring

COMPILED BY AH

DATUM Geodetic

DATE 2024.05.07 - 2024.05.07

CHECKED BY CM

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
90.2	Ground Surface				
0.0	**ASPHALT (200 mm)**				
0.2	SILTY SAND with gravel, occasional cobbles and boulders, very dense to dense, greyish brown **[FILL]**	1	GS	-	27 56 17 (SI+CL)
		2	SS	63	
		3	SS	32	
		4	SS	43	
87.2 / 3.0	**CLAY (CH)** very stiff, brownish grey **[WEATHERED CRUST]**	5	SS	6	
		6	SS	5	9 3 36 52
		7	SS	4	
84.9 / 5.3	**CLAYEY SILT (CL)** to **SILT (ML)** stiff, grey	8	SS	2	
		9	ST	-	
		10	SS	WH	

Field vane sensitivity values plotted: 8.7, 8.0, 6.3, 4.4, 4.3

Continued Next Page

+ 3, × 3 : Numbers refer to Sensitivity

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

DOUBLE LINE 38447 SITE 0724 GINT LOGS.GPJ 2012TEMPLATE(MTO).GDT 1-6-25

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 24-1204

METRIC

GWP# 4202-13-00	LOCATION Lat: 45.150101°, Long: -75.682099° Site 03X-0724, MTM z9: N 5 001 450.9 E 369 113.8		ORIGINATED BY DAP
HWY 416	BOREHOLE TYPE HSA / NW Casing / NQ Coring		COMPILED BY AH
DATUM Geodetic	DATE 2024.05.07 - 2024.05.07		CHECKED BY CM

ELEV / DEPTH	DESCRIPTION (Continued From Previous Page)	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	CLAYEY SILT (CL) to **SILT (ML)** firm grey		11	SS	WH		80	+ 40 (field vane)	o		0 1 85 14
78.8 / 11.4	**SAND** with silt very loose grey		12	SS	WH		79		o		1 90 9 (SI+CL)
78.0 / 12.2	**SILTY SAND** with gravel occasional cobbles and boulders very dense grey **[GLACIAL TILL]**		13	SS	100/ 75mm		78		o		
			14	SS	100/ 75mm		77, 76				
			1	NQ	-					FI	
75.1 / 15.1	**LIMESTONE** strong fresh to fresh jointed fine grained grey		1	RUN	-		75			4, 4, 4, 5	RUN #1 TCR=100% SCR=72% RQD=44%
			2	RUN	-		74, 73			1, 1, 0, 0	RUN #2 TCR=100% SCR=92% RQD=92%
			3	RUN	-		72			1, 0, 1	RUN #3 TCR=100% SCR=97% RQD=97%
71.9 / 18.3	**End of Borehole** A representative open-hole groundwater level measurement was not obtained during drilling.										

+ 3, × 3: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No 24-1205

METRIC

GWP# 4202-13-00
LOCATION Lat: 45.150407°, Long: -75.682002° Site 03X-0724, MTM z9: N 5 001 485.0 E 369 121.1
ORIGINATED BY DAP
HWY 416
BOREHOLE TYPE HSA / NW Casing / NQ Coring
COMPILED BY AH
DATUM Geodetic
DATE 2024.05.02 - 2024.05.02
CHECKED BY CM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa	WATER CONTENT	UNIT WEIGHT / FI	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
87.0	Ground Surface								
0.0	**CLAY SILT (CL)** with organics, stiff, brown	1	SS	4					
86.4 / 0.6	**CLAYEY SILT (CL)**, very stiff, brownish grey **[WEATHERED CRUST]**	2	SS	5	86				
		3	SS	4	85				0 1 63 36
84.4 / 2.6	**CLAYEY SILT (CL)** to **SILT (ML)**, stiff to firm, grey	4	SS	2	84				0 1 88 11 non-plastic
		5	SS	3	83	20.0 (field vane); 12.0 (field vane)			
		6	ST	-	82				
81.8 / 5.2	**SILTY SAND** with gravel, very dense, grey **[GLACIAL TILL]**	7	SS	100/ 150mm	81			FI	
80.8 / 6.2	**LIMESTONE**, strong, slightly weathered to fresh jointed, fine grained, grey, mud seams noted within run 2 and 3	1	RUN		80			>10, >10, 0, 0	RUN #1 TCR=100% SCR=63% RQD=26% UCS=69MPa
		2	RUN		79			-, -, -, -	RUN #2 TCR=30% SCR=23% RQD=23%
		3	RUN		78			-, 0, 0, >10	RUN #3 TCR=69% SCR=60% RQD=60%

Continued Next Page

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

RECORD OF BOREHOLE No 24-1205

METRIC

GWP# 4202-13-00	LOCATION Lat: 45.150407°, Long: -75.682002° Site 03X-0724, MTM z9: N 5 001 485.0 E 369 121.1	ORIGINATED BY DAP	
HWY 416	BOREHOLE TYPE HSA / NW Casing / NQ Coring	COMPILED BY AH	
DATUM Geodetic	DATE 2024.05.02 - 2024.05.02	CHECKED BY CM	

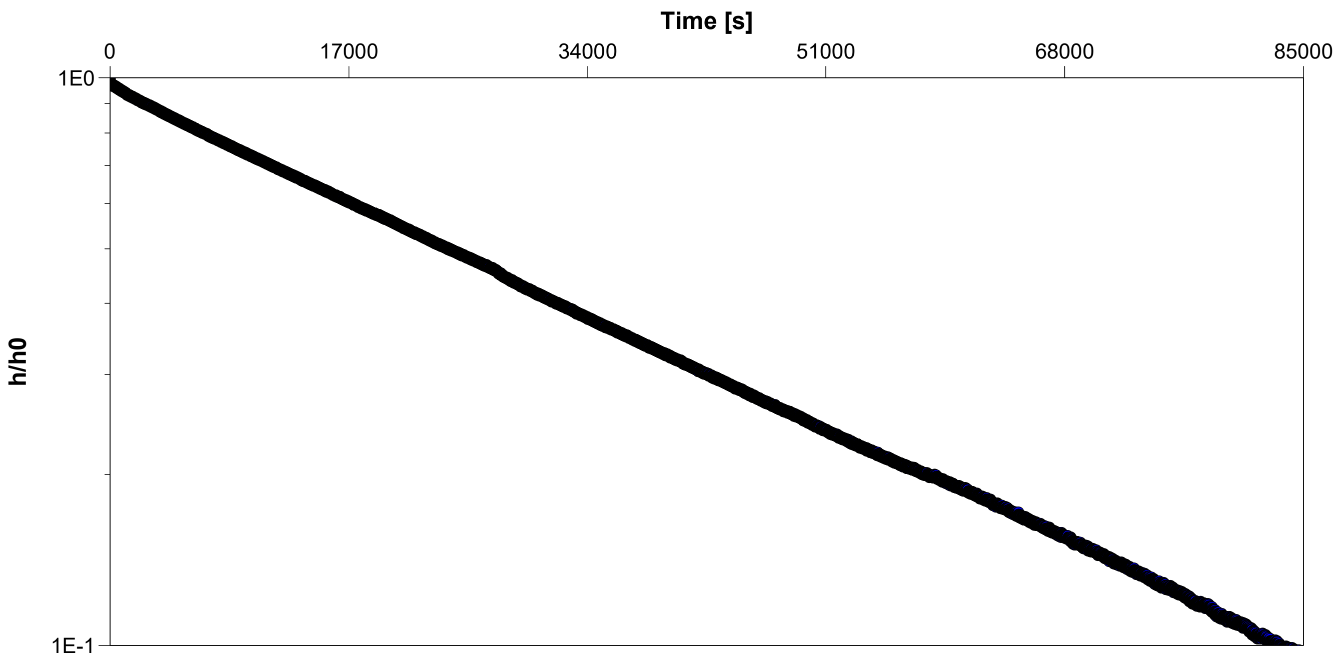
ELEV / DEPTH	SOIL PROFILE: DESCRIPTION (Continued From Previous Page)	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB 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
	LIMESTONE									-	
76.4										0	
10.6	**End of Borehole** A representative open-hole groundwater level measurement was not obtained during drilling.										

+ 3, × 3: Numbers refer to Sensitivity

15 ⊕ 5 (20 above, 10 below): (%) STRAIN AT FAILURE

THURBER ENGINEERING LTD.	**Slug Test Analysis Report**
	Project: Hwy 416 & 417
	Number: 38447
	Client: Jacobs

Location: Hwy 416, ON	Slug Test: 24-1201	Test Well: 24-1201
Test Conducted by: HS		Test Date: 2024-07-03
Analysis Performed by: SM	SWRT Analysis	Analysis Date: 2024-07-08
Aquifer Thickness:		
Checked by: DH	Rising Head Test	



Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]	
24-1201	2.4×10^{-8}	

THURBER ENGINEERING LTD.

APPENDIX C

Particle Size Analysis Figures

Atterberg Limit Figures

Rock Core Photos

UCS Test Results

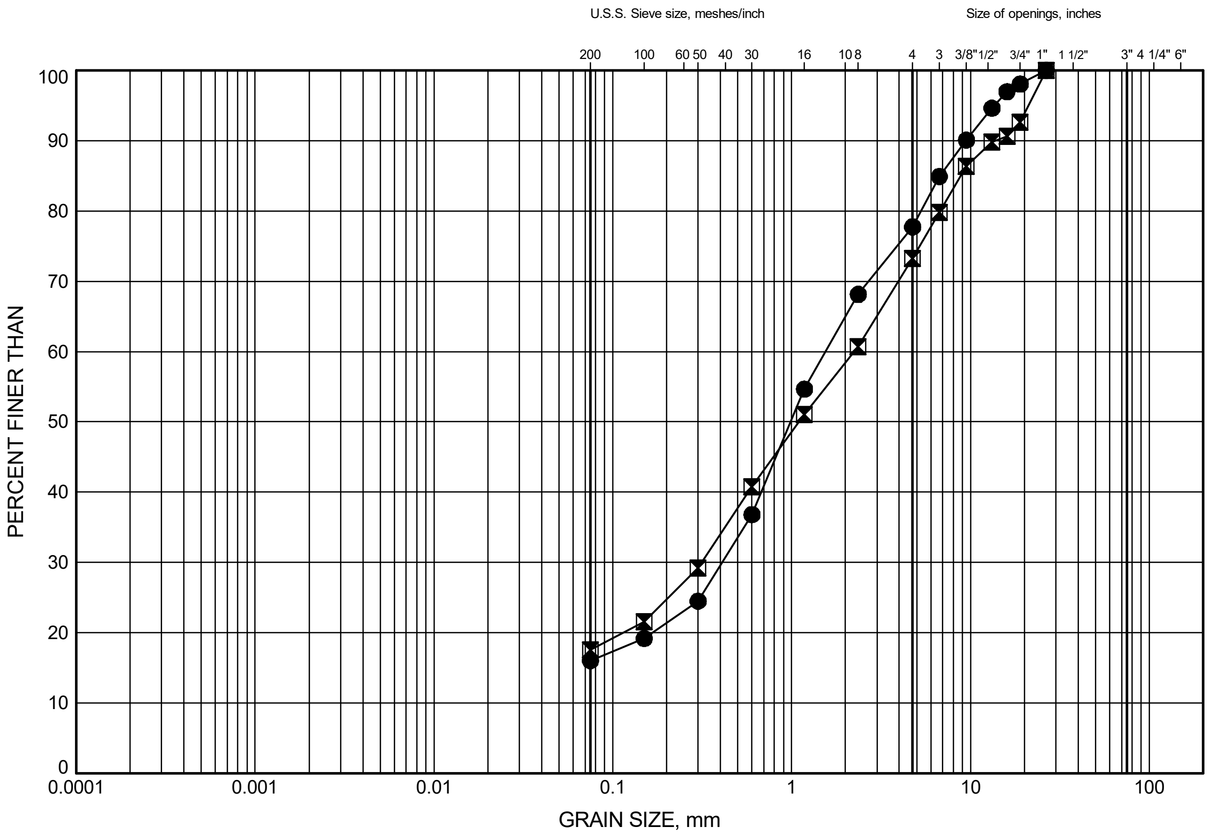
Analytical Testing Results

Highway 416 Culvert 03X-0724/C1

GRAIN SIZE DISTRIBUTION

FIGURE C1

FILL:Silty Sand with Gravel



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	24-1203	2.6	87.6
⧗	24-1204	0.5	89.7

Date August 2024

GWP# 4202-13-00

THURBER

Prep'd RH

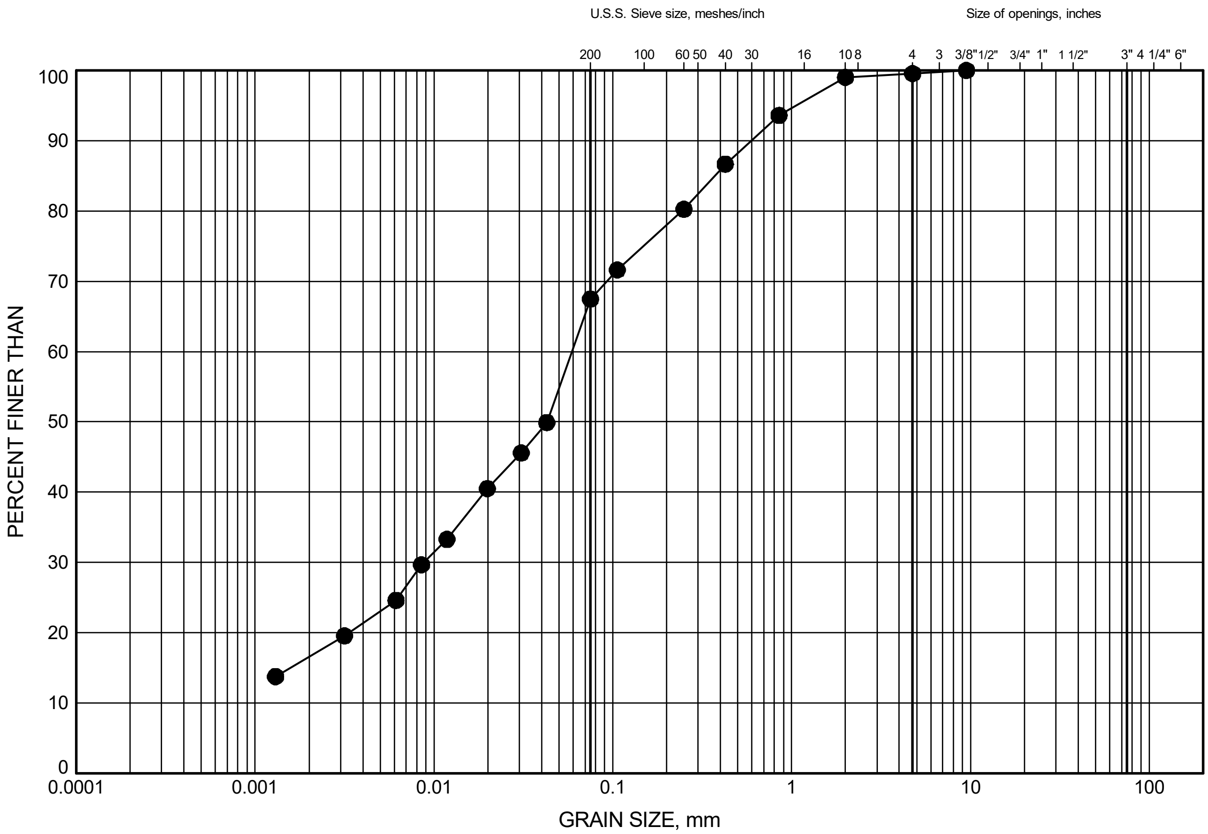
Chkd. CM

Highway 416 Culvert 03X-0724/C1

GRAIN SIZE DISTRIBUTION

FIGURE C2

FILL: Sandy Clayey Silt



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	24-1202	1.1	87.9

Date August 2024

GWP# 4202-13-00

THURBER

Prep'd RH

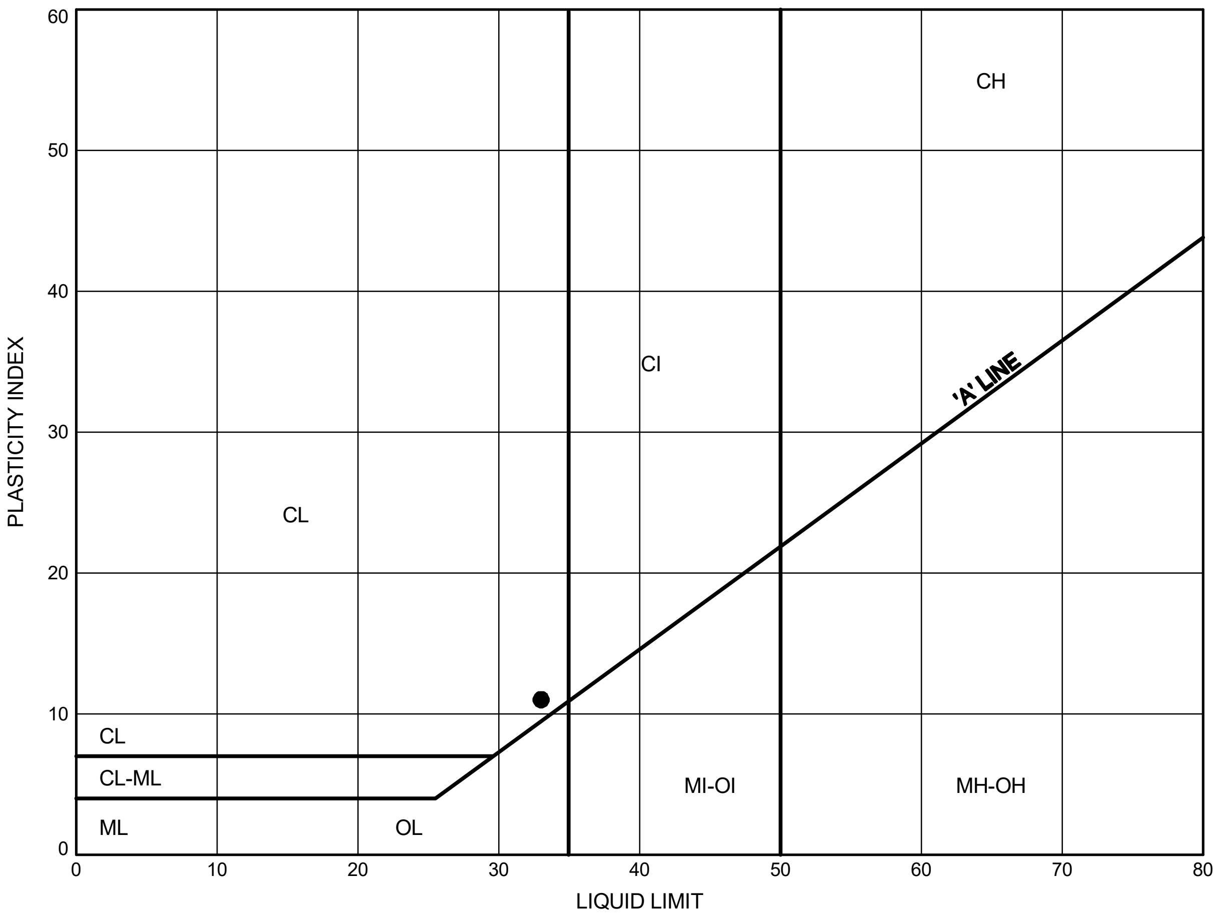
Chkd. CM

Highway 416 Culvert 03X-0724/C1

ATTERBERG LIMITS TEST RESULTS

FIGURE C3

FILL: Sandy Clayey Silt



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	24-1202	1.1	87.9

Date August 2024

GWP# 4202-13-00

THURBER

Prep'd RH

Chkd. CM

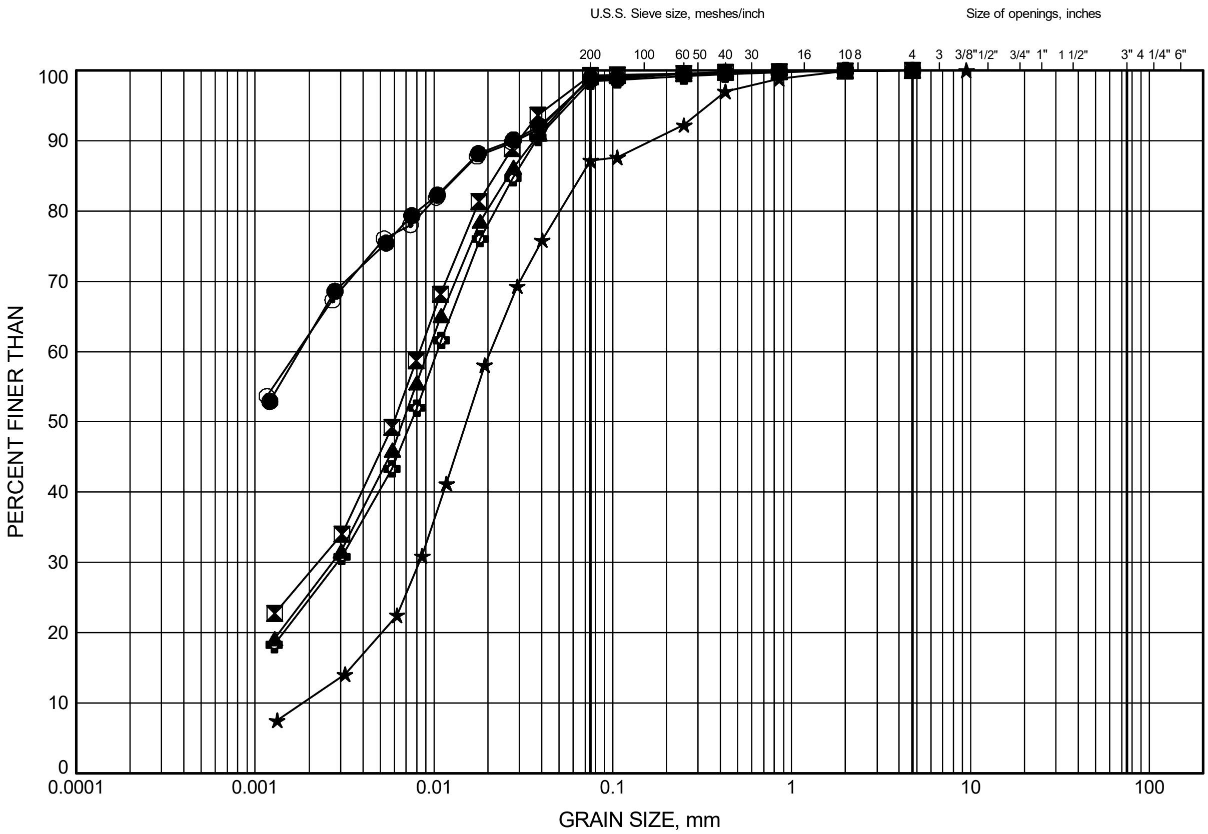
THURBALT 38447 SITE 0724 GINT LOGS.GPJ 8-27-24

Highway 416 Culvert 03X-0724/C1

GRAIN SIZE DISTRIBUTION

FIGURE C4

Clay to Clayey Silt (CH to CL)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	24-1201	2.4	84.5
⧗	24-1201	6.4	80.5
▲	24-1202	7.9	81.1
★	24-1202	10.9	78.1
⊙	24-1203	4.9	85.3
✿	24-1203	7.2	83.0

Date August 2024

GWP# 4202-13-00

THURBER

Prep'd RH

Chkd. CM

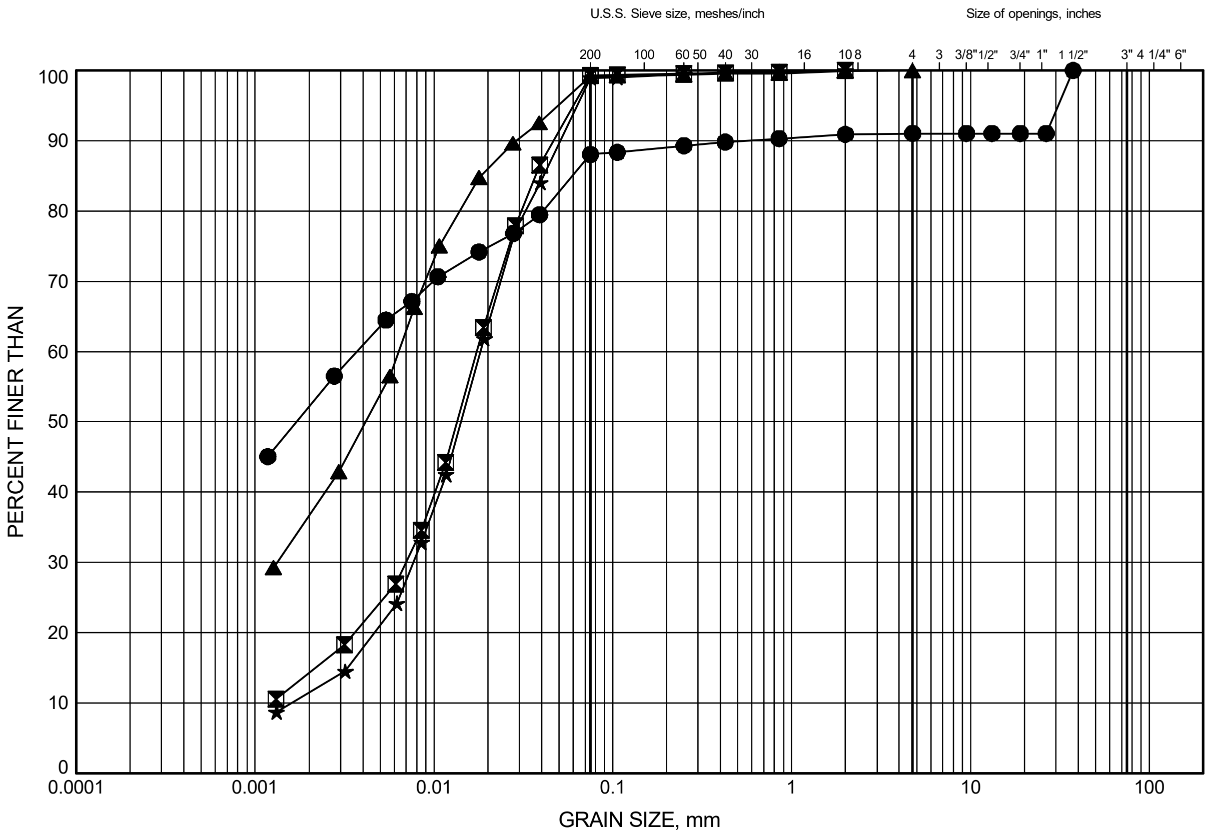
GRAIN SIZE DISTRIBUTION - THURBER 38447 SITE 0724 GINT LOGS.GPJ 8-27-24

Highway 416 Culvert 03X-0724/C1

GRAIN SIZE DISTRIBUTION

FIGURE C5

Clay to Clayey Silt (CH to CL)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	24-1204	4.1	86.1
⊠	24-1204	10.2	80.0
▲	24-1205	1.8	85.2
★	24-1205	2.7	84.3

Date August 2024

GWP# 4202-13-00

THURBER

Prep'd RH

Chkd. CM

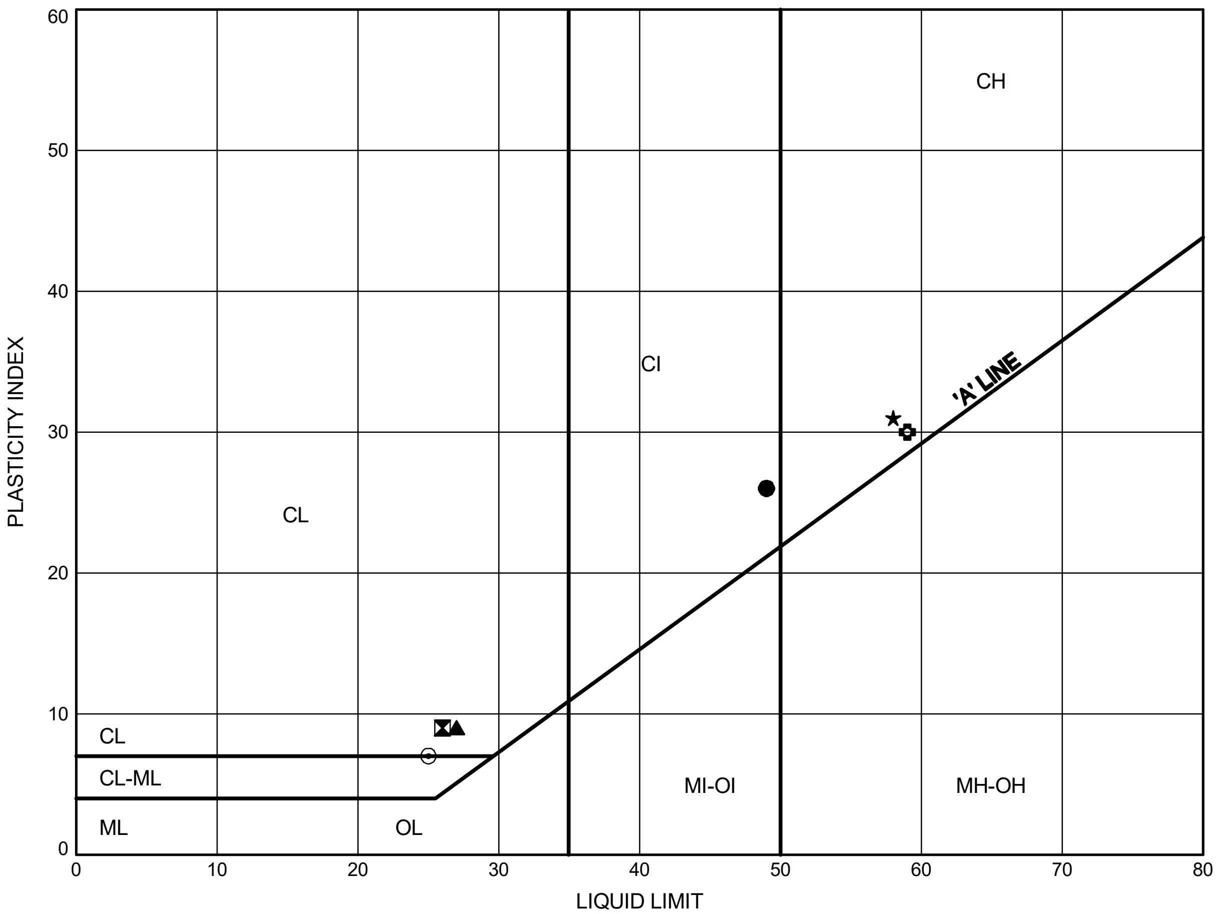
GRAIN SIZE DISTRIBUTION - THURBER 38447 SITE 0724 GINT LOGS.GPJ 8-27-24

Highway 416 Culvert 03X-0724/C1

ATTERBERG LIMITS TEST RESULTS

FIGURE C6

Clay to Clayey Silt (CH to CL)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	24-1201	2.4	84.5
⧗	24-1201	6.4	80.5
▲	24-1202	7.9	81.1
★	24-1203	4.9	85.3
⊙	24-1203	7.2	83.0
✿	24-1204	4.1	86.1

Date August 2024

GWP# 4202-13-00

THURBER

Prep'd RH

Chkd. CM

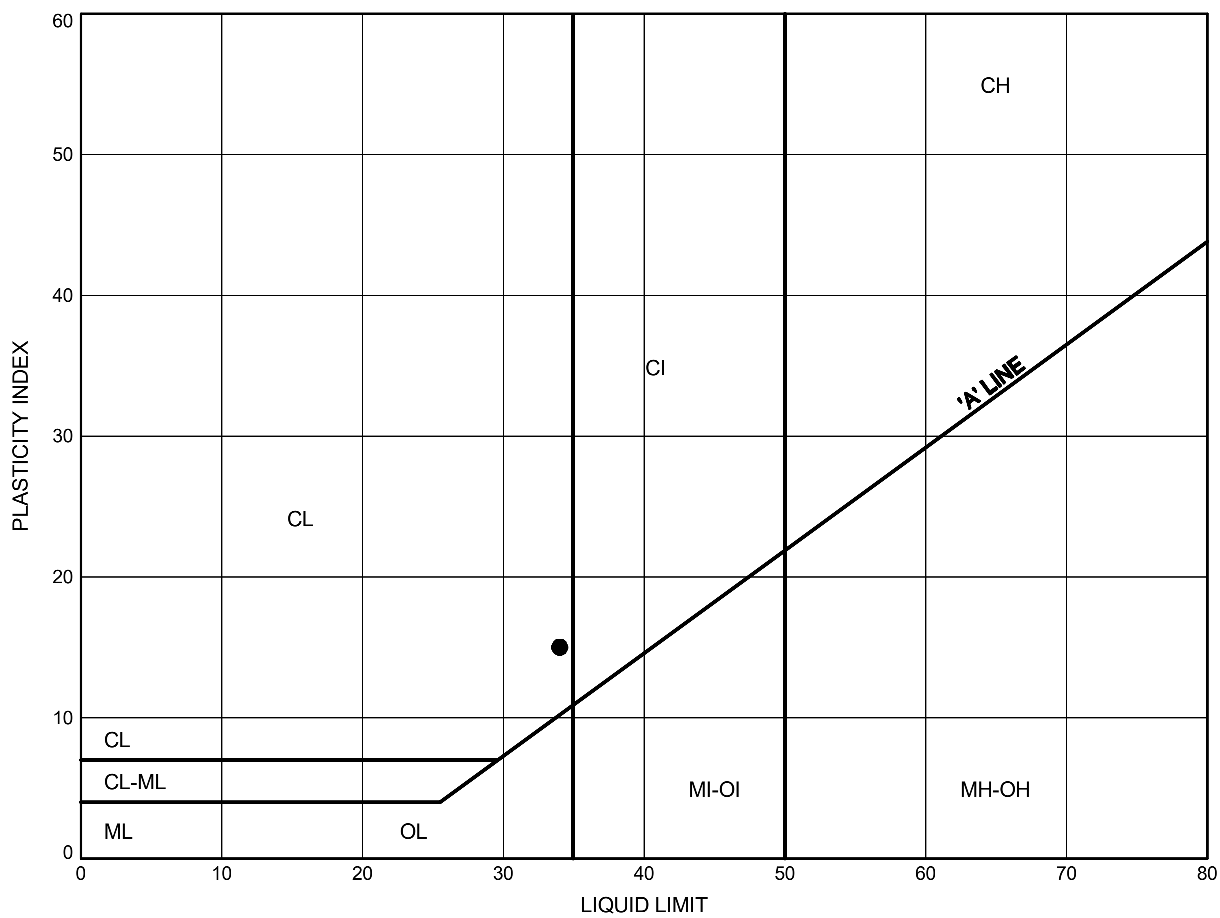
THURBALT 38447 SITE 0724 GINT LOGS.GPJ 8-27-24

Highway 416 Culvert 03X-0724/C1

ATTERBERG LIMITS TEST RESULTS

FIGURE C7

Clay to Clayey Silt (CH to CL)



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	24-1205	1.8	85.2

THURBALT 38447 SITE 0724 GINT LOGS.GPJ 8-27-24

Date August 2024

GWP# 4202-13-00

THURBER

Prep'd RH

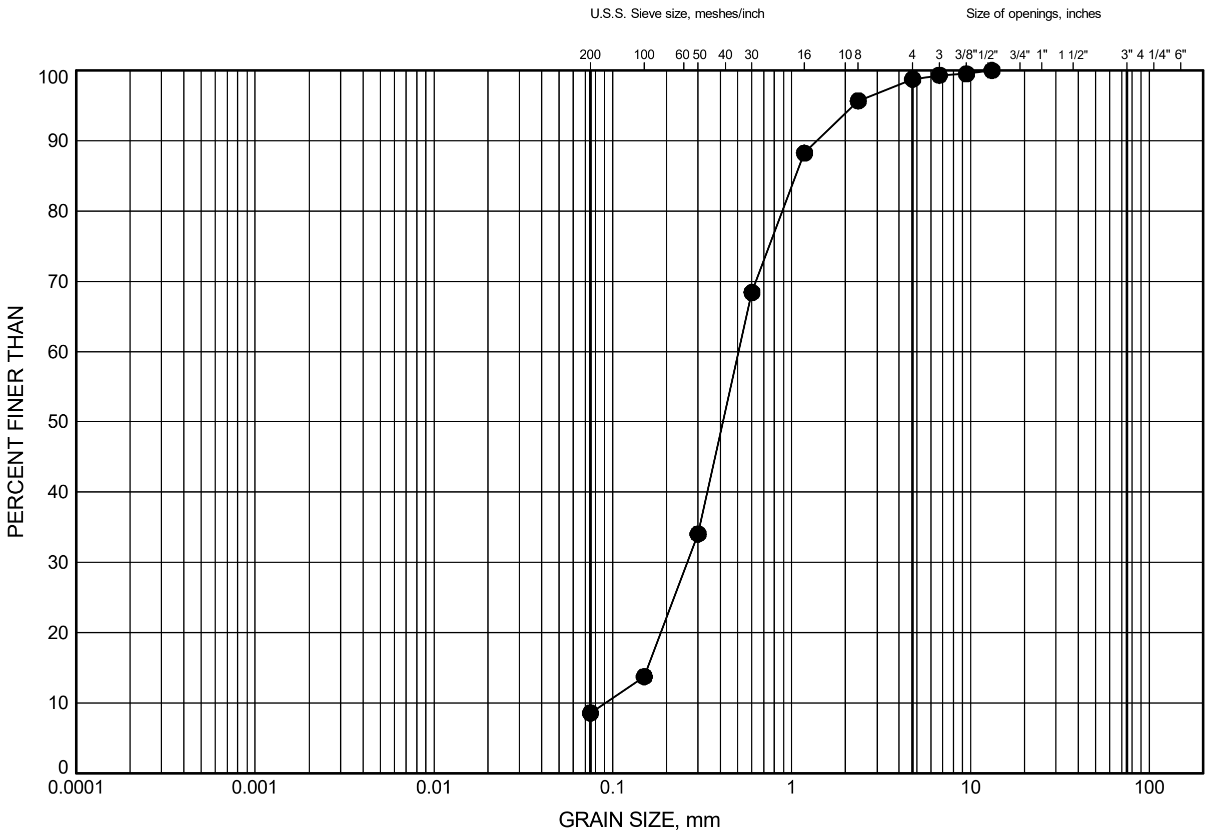
Chkd. CM

Highway 416 Culvert 03X-0724/C1

GRAIN SIZE DISTRIBUTION

FIGURE C8

Sand with Silt (SM)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	24-1204	11.7	78.5

GRAIN SIZE DISTRIBUTION - THURBER 38447 SITE 0724 GINT LOGS.GPJ 8-27-24

Date August 2024

GWP# 4202-13-00

THURBER

Prep'd RH

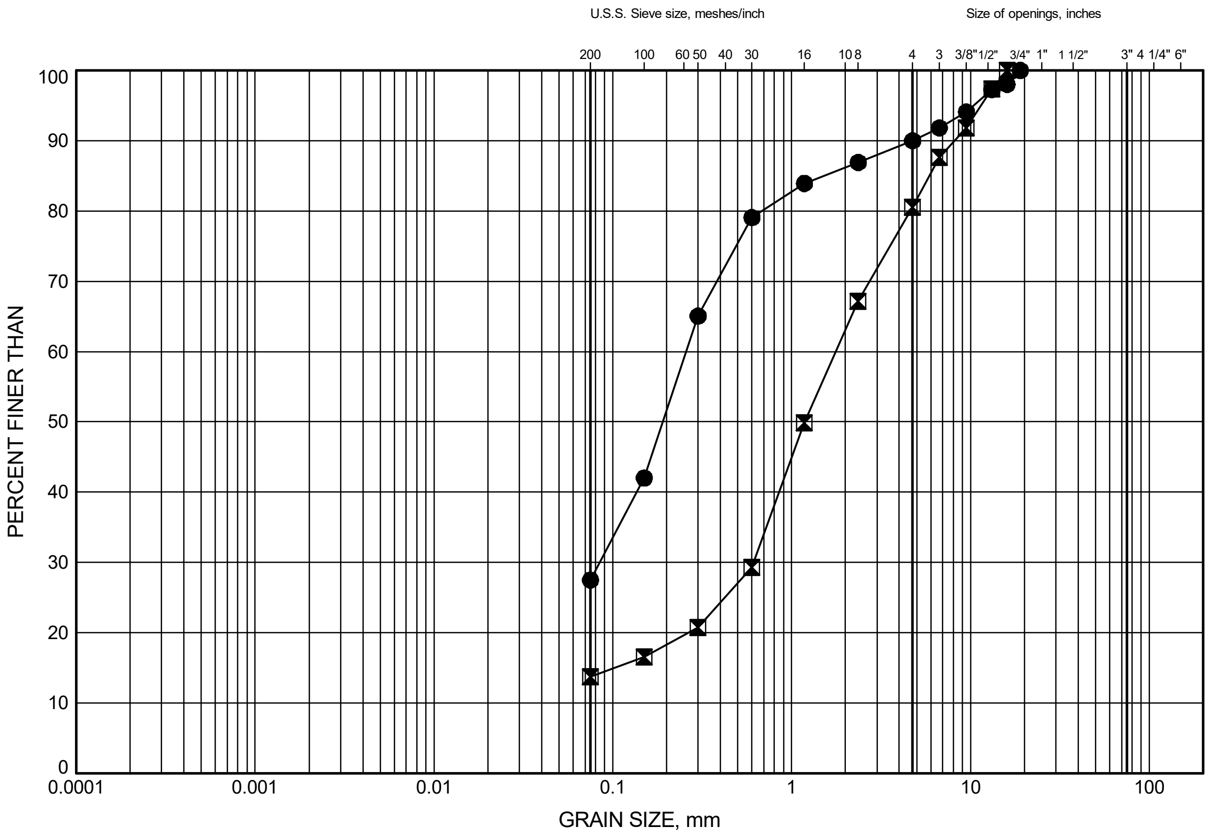
Chkd. CM

Highway 416 Culvert 03X-0724/C1

GRAIN SIZE DISTRIBUTION

FIGURE C9

Silty Sand with Gravel [GLACIAL TILL]



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	24-1201	10.9	76.0
⧗	24-1203	12.5	77.7

Date August 2024

GWP# 4202-13-00

THURBER

Prep'd RH

Chkd. CM

GRAIN SIZE DISTRIBUTION - THURBER 38447 SITE 0724 GINT LOGS.GPJ 8-27-24

Borehole 24-1202

Runs 1 to 3 (of 3)

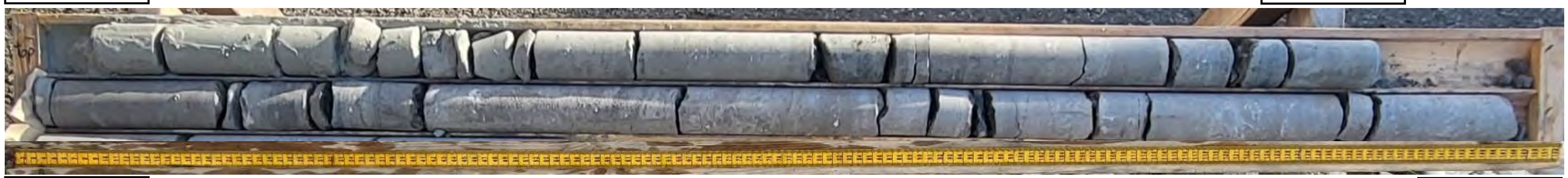
Depth 13.9 to 17.2 m

Elevation 75.1 to 71.8 m

Dry Sample

Run 1 Start
elev. 75.1 m

Run 1 End
elev. 73.9 m



Run 2 Start
elev. 73.9 m

Run 2 End
elev. 72.4 m

Run 3 Start
elev. 72.4 m

Run 3 End
elev. 71.8 m

THURBER ENGINEERING LTD.

THURBER ENGINEERING LTD.	Foundation Investigation Highway 416 Culvert Site No. 03X-0724/C1 Ottawa, Ontario	BH 24-1202 GWP: 4202-13-00 Project No.: 38447

Borehole 24-1202

Runs 1 to 3 (of 3)
Depth 13.9 to 17.2 m
Elevation 75.1 to 71.8 m
Wet Sample

Run 1 Start
elev. 75.1 m

Run 1 End
elev. 73.9 m

Run 2 Start
elev. 73.9 m

Run 2 End
elev. 72.4 m

Run 3 Start
elev. 72.4 m

Run 3 End
elev. 71.8 m

THURBER ENGINEERING LTD.

Foundation Investigation
Highway 416 Culvert
Site No. 03X-0724/C1
Ottawa, Ontario

BH 24-1202
GWP: 4202-13-00
Project No.: 38447

Borehole 23-1204

Run 1 to 3 (of 3)

Depth 15.1 to 18.3 m

Elevation 75.1 to 71.9 m

Dry Sample

NQ 1
elev. 76.0 to 75.1 m

Run 1 Start
elev. 75.1 m

Run 1 End
elev. 74.2 m

Run 2 Start
elev. 74.2 m

Run 2 End
elev. 72.7 m

Run 3 Start
elev. 72.7 m

Run 3 End
elev. 71.9 m

THURBER ENGINEERING LTD.	Foundation Investigation Highway 416 Culvert Site No. 03X-0724/C1 Ottawa, Ontario	BH 24-1204 GWP: 4202-13-00 Project No.: 38447

Borehole 23-1204

Run 1 to 3 (of 3)
Depth 15.1 to 18.3 m
Elevation 75.1 to 71.9 m
Wet Sample

NQ 1
elev. 76.0 to 75.1 m

Run 1 Start
elev. 75.1 m

Run 1 End
elev. 74.2 m

Run 2 Start
elev. 74.2 m

Run 3 Start
elev. 72.7 m

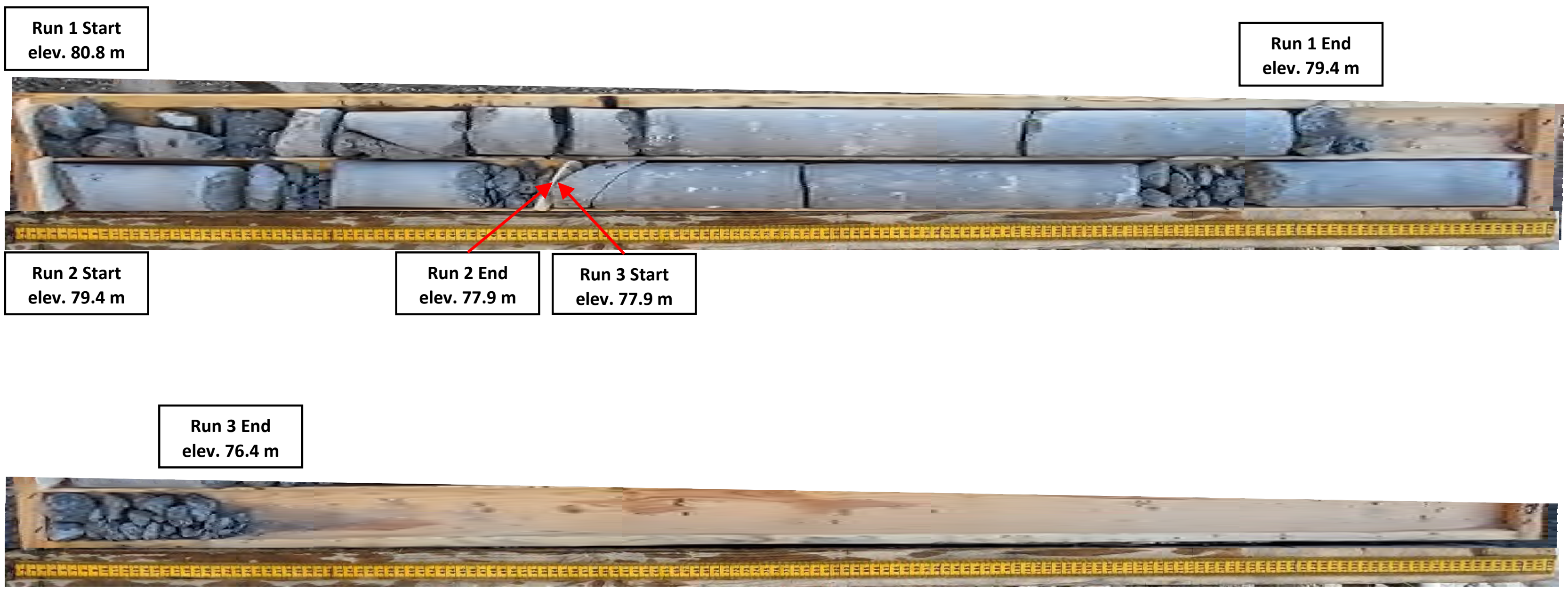
Run 3 End
elev. 71.9 m

THURBER ENGINEERING LTD.

THURBER ENGINEERING LTD.	Foundation Investigation Highway 416 Culvert Site No. 03X-0724/C1 Ottawa, Ontario	BH 24-1204 GWP: 4202-13-00 Project No.: 38447

Borehole 23-1205

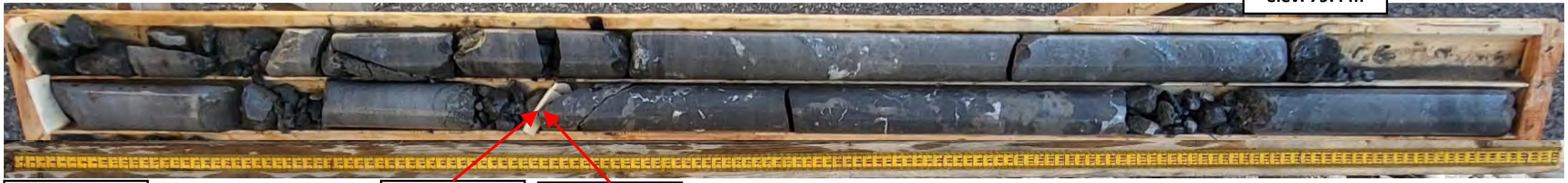
Run 1 to 3 (of 3)
Depth 6.2 to 10.6 m
Elevation 80.8 to 76.4 m
Dry Sample



THURBER ENGINEERING LTD.	Foundation Investigation Highway 416 Culvert Site No. 03X-0724/C1 Ottawa, Ontario	BH 24-1205 GWP: 4202-13-00 Project No.: 38447

Borehole 23-1205

Run 1 to 3 (of 3)
Depth 6.2 to 10.6 m
Elevation 80.8 to 76.4 m
Wet Sample



THURBER ENGINEERING LTD.

Foundation Investigation
Highway 416 Culvert
Site No. 03X-0724/C1
Ottawa, Ontario

BH 24-1205
GWP: 4202-13-00
Project No.: 38447

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

June 10, 2024
File: 121625371

Client: Thurber Engineering, File #38447

Reference: ASTM D7012, Method C, Unconfined Compressive Strength of Intact Rock Core Highway 416 & 417

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

Location	Sample Depth	Compressive Strength (MPa)	Description of Break
[redacted]			
23-1202 Run-1	47’4’’-47’11’’	203.7	Type-2, Well-formed cone on one end
23-1205 Run-1	22’6’’-23’9’’	68.7	Type-2, Well-formed cone on one end
[redacted]			

Sincerely,

Stantec Consulting Ltd.

Brian Prevost

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

PARACEL LABORATORIES LTD.

Order #: 2422508

Certificate of Analysis

Report Date: 07-Jun-2024

Client: **Thurber Engineering Ltd.**

Order Date: 31-May-2024

Client PO:

Project Description: 38447 Task: 1.3

	MDL/Units	23-1202 SS5 (10'-12')	23-1205 SS4A (7'6"-8'6")	[redacted]	-	-
Sample Date:		01-May-24 09:00	02-May-24 09:00			
Sample ID:		2422508-01	2422508-02			
Matrix:		Soil	Soil			
Physical Characteristics						
% Solids	0.1 % by Wt.	71.2	80.0		-	-
General Inorganics						
Conductivity	5 uS/cm	1050 [1]	722 [1]		-	-
pH	0.05 pH Units	7.12 [2]	7.32 [2]		-	-
Resistivity	0.1 Ohm.m	9.6 [1]	13.9 [1]		-	-
Anions						
Chloride	10 ug/g	524 [1]	290 [1]		-	-
Sulphate	10 ug/g	50 [1]	27 [1]		-	-

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

13-June-2024

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. : 04 June 2024
LR Report: **CA13156-JUN24**
Reference: Project#: 2422508

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	Sample Date & Time	Sulphide (Na_2CO_3) %
1: Analysis Start Date		13-Jun-24
2: Analysis Start Time		07:12
3: Analysis Completed Date		13-Jun-24
4: Analysis Completed Time		08:39
5: RL		0.01
6: 23-1202 SS5 (10'-12')	01-May-24 09:00	< 0.01
7: 23-1205 SS4A (7'6"-8'6")	02-May-24 09:00	< 0.01
~~8: 23-1305 SS4 (7'6"-9'6")~~	~~02-May-24 09:00~~	~~< 0.01~~
~~9: 23-1302 SS5 (10'-12')~~	~~25-Apr-24 09:00~~	~~< 0.01~~
~~10: 23-1402 SS5 (10'-12')~~	~~24-Apr-24 09:00~~	~~< 0.01~~
~~11: 23-1405 SS3 (7'6"-9'6")~~	~~23-Apr-24 09:00~~	~~< 0.01~~

RL - SGS Reporting Limit

Note: Results for analysis performed past holding times may be unreliable; samples processed as per client's instructions.

Kimberley Didsbury
Project Specialist,
Environment, Health & Safety

OnLine LIMS

0003744419

THURBER ENGINEERING LTD.

APPENDIX D

Site Photographs

THURBER ENGINEERING LTD.

Photo 1: Culvert inlet looking northeast *(taken April 2024).*

Photo 2: Culvert inlet looking north *(taken April 2024).*

Photo 3: SB embankment looking north *(taken April 2024).*

Photo 4: Looking downstream northeast at culvert outlet *(taken August 2024).*

Photo 5: Looking southeast at culvert outlet *(taken August 2024).*

Photo 6: NB embankment looking north *(taken August 2024).*

APPENDIX E

Comparison of Foundation Alternatives

THURBER ENGINEERING LTD.

Comparison of Alternative Foundation Types

Type	Pipe Culvert	Closed Box Culvert	Open Bottom Culvert
Advantages	• Relatively expedient installation • Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade	• Relatively expedient installation if precast units are used. • A single closed box culvert can likely provide sufficient flow capacity.	• A single open bottom culvert can likely provide sufficient flow capacity. • Typically favourable from an aquatic habitat perspective.
Disadvantages	• Roadway protection systems and lane closures required for open cut. • Feasibility also depends on flow capacity and other hydraulic properties. May need multiple pipes. • Requires compacted granular pad. • May need to provide substrate inside the culvert for aquatic habitat purposes.	• Roadway protection systems and lane closures required for open cut. • Requires compacted granular pad. • May need to provide substrate inside the culvert for aquatic habitat purposes.	• Slower installation due to the cast-in-place footings • Roadway protection systems and lane closures required for open cut. • Requires deeper excavation.
Risks/ Consequences	• Given the excessive deformations experienced by the existing SPCSP culvert, a more rigid pipe such as concrete may be required. • Potential for base disturbance	• Potential for base disturbance	• Increased depth of excavation and dewatering effort required for open bottom culvert construction.
Relative Cost	Moderate	Moderate	High
Recommendation	**Feasible**	**Recommended**	**Feasible, Not Recommended**

THURBER ENGINEERING LTD.

APPENDIX F

List of Referenced Specifications

Non-Standard Special Provisions

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

OPSD 208.010	Benching of Earth Slopes
OPSD 219.110	Light-Duty Silt Fence Barrier
OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less than or Equal to 3.0m
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.101	Foundation Frost Depths for Southern Ontario
OPSS.PROV 180	General Specification for the Management of Excess Materials
OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 401	Trenching, Backfilling, and Compacting
OPSS.PROV 422	Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 511	Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 803	Vegetative Cover
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS.PROV 805	Construction Specification for Temporary Erosion and Sediment Control Measures
OPSS.PROV 902	Construction Specification for Excavating and Backfilling Structures
OPSS.PROV 1010	Material Specification for Aggregates Base, Subbase, Select Subgrade, and Backfill Material
OPSS.PROV 1205	Material Specification for Clay Seal
OPSS.PROV 1860	Material Specification for Geotextiles
SSP 105S09	Amendment to OPSS 539 - Temporary Protection Systems
SSP 110S06	Amendment to OPSS 1010 - Material Specification for Aggregates Base, Subbase, Select Subgrade, and Backfill Material
SSP 517F01	Amendment to OPSS 517 - Construction Specification for Dewatering

2. Suggested wording for Non-Standard Special Provisions

"Presence of Cobbles and Boulders"

Cobbles and boulders should be expected within the existing embankment fill and native glacial till deposit underlying the site. Considerations of these potential obstructions must be made in the selection of appropriate equipment and procedures for excavations, installations of cofferdams and temporary protection systems.

"Protection of Sensitive Foundation Soils"

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