



**THURBER** ENGINEERING LTD.

**PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT  
HIGHWAY 401 WIDENING, HIGHWAY 16 TO MAITLAND ROAD  
HIGHWAY 401 STA. 13+075 CULVERT REHABILITATION  
SITE NO. 16X-0250/C0  
GWP 4024-20-00 / ASSIGNMENT NO. 4019-E-0010.2**

Geocres No.: 31B-101

Report to:

**MTO c/o AECOM Canada Ltd.**

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**PART 1. FACTUAL INFORMATION**

**1 INTRODUCTION**

Thurber Engineering Ltd. (Thurber) has been retained by AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation Ontario (MTO) under Assignment No. 4019-E-0010, Work Item No. 2, to carry out Foundation Investigations to support the Preliminary Design and Environmental Assessment for the widening of Highway 401 from Highway 416 to Maitland Road. The overall scope of work comprises replacement or rehabilitation of 14 existing structures, including 10 bridges and four structural culverts.

This report addresses the proposed rehabilitation of the structural culvert beneath Highway 401 at approximate Station 13+075. The culvert, Site No. 16X-0250/C0, is located approximately 100 m west of the W-N Ramp bridge connecting traffic coming from the west on Highway 401 to traffic traveling north on Highway 416, near the town of Prescott, Ontario.

This section of the report presents the factual findings obtained from a preliminary foundation investigation completed at the site, as well as existing subsurface information pertinent to the site, obtained from the MTO's Foundation Library which included:

- Report prepared by Jacques, Whitford Limited titled, "*Report on Foundation Investigation, W.P. 374-89-00, Concrete Culvert, Site 16-259, Ramp W-N, Sta. 21+338.8, Site 16-260, Ramp N-W, Sta. 11+400, Hwy. 401-416 Interchange, District 9, Ottawa*", dated August 17, 1992 (Geocres No. 31B-67), including addendum dated January 7, 1998.

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

The site is in the central area of the Highway 401 and Highway 416 Interchange. Johnstown Creek flows roughly from west to east beneath interchange ramps and Highway 401 to its outlet into the St. Lawrence River at Johnstown. The culvert addressed in this report is located beneath Highway 401, at Station 13+075. For project purposes, Highway 401 and the culvert are described herein as oriented east-west and north-south, respectively.

The land adjacent to the site typically consists of forests, wet ground, and agricultural fields. The terrain is relatively flat apart from the existing highway and interchange embankments and associated drainage ditches. Highway 401 in this area consists of a four-lane divided freeway with paved shoulders and a median stormwater system. Guiderails are present along the outside shoulders and a concrete median barrier wall bounds the inside shoulders.

A site visit was carried out on March 29, 2021 to observe the existing site conditions. Within the vicinity of the culvert, the Highway 401 embankment side slopes are sloped at approximately 2H:1V to the flooded ground to the south and flatter to the flooded ground to the north. The embankment side slopes are generally grass-covered, with bushes and small trees growing along the Johnstown Creek. At that time, the embankments did not show any visible signs of distress or other performance issues. Large blocks of bedrock have been stacked to form wingwalls and a head wall at the inlet and outlet. A subsequent site visit was carried out on May 5, 2021 to survey the top of the existing culvert and the water level in Johnstown Creek.

Based on the available project background documents including the photos and recent documented inspection records, the culvert consists of a cast-in-place, single span concrete culvert with open footings, constructed in 1961. The culvert is approximately 53.1 m long, has a total internal span width of 6.0 m, and an overall approximate internal height of 1.8 m above the stream bed. Structural culvert (Site No. 16-259) is located approximately 10 m downstream from the culvert outlet.

Based on published geological information in *The Physiography of Southern Ontario* by Chapman and Putnam (1984), the site lies on the border of the physiographic regions known as the Smith's Falls Limestone Plain and the Glengarry Till Plain.

The Smith's Falls Limestone Plain is characterized by typically shallow bedrock but including a few localized deep areas of highly variable soils consisting of clays, sands, and gravels. The Glengarry Till Plain is characterized by an undulating surface consisting of morainic ridges and intervening clay flats and swamps, overlying till and similar glaciofluvial deposits containing many cobbles and boulders. Both areas are known to be underlain by limestone/dolostone and sandstone bedrock.

Photographs showing the existing conditions at the site at the time of the initial site visit and subsequent field work are included in Appendix D for reference.



### 3 SITE INVESTIGATIONS AND FIELD TESTING

The original foundation investigation for Culvert 16X-0250/C0 was not available at the time of writing this report. During subsequent design of the Highway 401 and Highway 416 Interchange, Borehole 92-3 was put down between the outlet of existing Culvert 16X-0250/C0 and the inlet of proposed Culvert 16-259/C. Borehole 92-3 will be used to discuss the subsurface conditions at the site. The current investigation was carried out in April 2021 to collect additional subsurface information near the existing culvert inlet. Summaries of the investigations are provided in the following sections.

#### 3.1 Previous Investigation (1992)

Several field investigations were carried out as part of the planning and design of the then-proposed Highway 401 and Highway 416 interchange. As reported in Geocres Report 31B-67, Borehole 92-3 was put down during the investigation for Culvert 16-259/C in May 1992, between the existing outlet of Culvert 16X-0250/C0 and the proposed inlet of Culvert 16-259/C. The investigation employed a track-mounted CME 55 drill rig to advance the borehole. The location of the borehole was surveyed by others as part of the 1992 field program.

The northing, easting and elevation of the borehole referenced in this investigation are shown on the Borehole Location and Soil Strata Drawing No. 1 in Appendix A and in Table 3-1, below. The site is located within MTM Zone 9. Note that the borehole location was originally surveyed relative to NAD27 horizontal datum and has been converted relative to NAD83 in the drawing, on the Record of Borehole Sheet (where appropriate), and in Table 3-1, below.

**Table 3-1: Borehole Summary**

Borehole No.	Drilled Location	Northing <sup>1</sup> (Latitude)	Easting <sup>1</sup> (Longitude)	Ground Surface <sup>2</sup> Elevation (m)	Termination Depth (m)
92-3	Outlet (South)	4 956 816.3 (44.746868)	384 857.7 (-75.488981)	84.1	4.0

Notes: 1) Borehole was surveyed relative to NAD27; coordinates listed above were converted relative to NAD83.

2) Borehole was put down prior to construction of the existing ramp and culvert.

Soil samples were obtained at selected intervals using split spoon samplers in conjunction with Standard Penetration Testing (SPT) during the investigation. In Borehole 92-3, the bedrock was cored approximately 1.6 m with NQ sized coring equipment.

A standpipe piezometer was installed in Borehole 92-3 prior to backfilling. It has been assumed that the standpipe piezometer was removed or abandoned prior to construction of the ramp and culvert.

#### 3.2 Current Investigation

The current site investigation was carried out in the Spring of 2021. One borehole (Borehole 250-21-1) was put down at the inlet (north end) of the 16X-0250/C0 culvert site on April 23, 2021. The



borehole was put down with a CME 55 track-mounted drill rig equipped with hollow stem augers and rotary diamond drilling equipment.

The location of the 2021 borehole was surveyed by Thurber in plan and elevation with a Trimble Catalyst DA1 antenna with centimeter accuracy. The northing, easting and elevation of the borehole is shown on the Borehole Location and Soil Strata Drawing No. 1 in Appendix A, the individual Record of Borehole sheets in Appendix B, and in Table 3-2 below.

**Table 3-2: Borehole Summary**

<b>Borehole No.</b>	<b>Drilled Location</b>	<b>Northing (Latitude)</b>	<b>Easting (Longitude)</b>	<b>Ground Surface Elevation (m)</b>	<b>Termination Depth (m)</b>
250-21-1	Inlet (North)	4 956 870.6 (44.747366)	384 828.8 (-75.489340)	85.1	10.2

Soil samples were obtained using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Borehole 250-21-1 was advanced approximately 3 m into bedrock, with NQ sized coring equipment. The borehole was then backfilled in accordance with MOE requirements (O.Reg 903, as amended).

The drilling and sampling operations were supervised on a full-time basis by a member of Thurber's geotechnical staff. The drilling supervisor logged the boreholes and processed the recovered soil and bedrock samples for transport to Thurber's Ottawa geotechnical laboratory for further examination and testing.

#### **4 LABORATORY TESTING**

Geotechnical laboratory testing carried out as part of the current investigation consisted of natural moisture content determination, grain size distribution, and Atterberg limit testing of soil samples. All rock cores collected as part of the current investigation were photographed and their total core recovery (TCR), solid core recovery (SCR), and rock quality designation (RQD) were measured. Unconfined compressive strength (UCS) testing was carried out on a selected bedrock sample. The 1992 investigation included natural moisture content determination and an Atterberg Limit test carried out on soil samples.

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

#### **5 GENERAL DESCRIPTION OF SUBSURFACE CONDITIONS**

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix B and the Borehole Location and Soil Strata Drawing included in Appendix A. A general description of the stratigraphy based on the conditions encountered in the boreholes is given in the following sections. However, the factual data presented on the Borehole Records takes precedence over the Soil Strata Drawing and the general description. It must be recognized that the soil and groundwater conditions may vary between and beyond borehole



locations. Soil classification for the 2021 investigation is in accordance with ASTM D2487. Description of cohesive soils and secondary components of all deposits from the 2021 borehole are described as outlined in the MTO Guideline for Foundation Engineering Services manual (October 2020). Terminology from the historic Geocres information may vary from current practice.

In general, the site is underlain by a deposit of silty clay to clay, overlying a deposit of silt which is, in turn, underlain by bedrock consisting of interbedded dolostone and sandstone bedrock.

The sections below describe subsurface conditions encountered at the time the boreholes were advanced. Since the boreholes were put down up to several metres away from the culvert, it should be noted that surficial deposits at the culvert may differ from that described below. Furthermore, the deposits described in Borehole 92-3 would likely have been disturbed, altered, or completely removed during the construction of the W-N Ramp and Culvert 16-259/C.

## **5.1 Surficial Deposits**

At the time of the 1992 investigation, about 30 mm of topsoil was encountered at the ground surface in Borehole 92-3, near the south end of the culvert.

## **5.2 Clay and Sand**

A deposit of clay and sand, approximately 0.6 m thick with a base Elevation of 83.5 m, was encountered beneath the topsoil in Borehole 92-3. One Standard Penetration Test (SPT) conducted within the clay and sand layer gave an N-value of 1 blow for 0.3 m of penetration; the material was described as having a very soft consistency.

## **5.3 Silty Clay to Clay**

A native, cohesive deposit ranging in composition from silty clay to clay was encountered at ground surface in Borehole 250-21-1 and beneath the clay and sand deposit in Borehole 92-3. The silty clay deposit has a thickness ranging from 5.3 m to 1.7 m (base Elevations of 79.8 m and 81.8 m) near the north and south culvert ends, respectively.

The upper portion of the clay layer has generally been weathered to a grey-brown crust. SPTs conducted in the grey-brown weathered crust gave N-values ranging from 5 to 14 blows for 0.3 m of penetration, indicating a very stiff consistency. Unweathered grey silty clay was encountered beneath the weathered crust in Borehole 250-21-1. SPTs conducted in the grey silty clay gave N-values of 9 and 14 blows for 0.3 m of penetration, indicating a very stiff consistency.

Recorded moisture contents of the clay layer ranged from 22 to 45%. The results of two grain size analysis tests are summarized below and are illustrated on Figure C1 in Appendix C.1.



#### Summary of Grain Size Distribution Testing – Silty Clay to Clay

Soil Particle	Percentage (%)
Gravel	0 – 1
Sand	1 – 2
Silt	41 – 50
Clay	47 – 58

The results of the Atterberg Limits testing carried out on two samples of the silty clay from the current investigation, and one sample from the 1992 investigation are summarized below and are illustrated on Figures C2 and C4 in Appendix C, respectively. The laboratory results indicate that the material is generally a clay of intermediate plasticity (CI) to high plasticity (CH).

#### Summary of Atterberg Limit Testing – Silty Clay to Clay

Parameter	Value
Liquid Limit	43 – 54
Plastic Limit	20 – 27
Plasticity Index	23 – 28

### 5.4 Silt to Sandy Silt

A thin deposit of grey, non-plastic silt to sandy silt was encountered beneath the silty clay to clay in both boreholes. The silt deposit had a thickness of 1.6 m and 0.1 m with base depths of 6.9 m and 2.4 m (Elevation 78.2 and 81.7) near the north and south culvert ends, respectively. Two SPTs conducted in this layer gave N-values of 29 and 47 blows for 0.3 m of penetration, indicating a compact to dense relative density.

Recorded moisture contents of two samples of the silt were 13 and 15%. The results of one grain size analysis test conducted on a sample of the silt in Borehole 250-21-1 is summarized below and are illustrated on Figure C3 in Appendix C.1.

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

Soil Particle	Percentage (%)
Gravel	1
Sand	5
Silt	82
Clay	12

### 5.5 Bedrock

The bedrock surface was proven by coring at Boreholes 250-21-1 and 92-3 from Elevations of 78.2 m and 81.7 m, respectively. The bedrock surface slopes or steps up to the south. The bedrock encountered in the 1992 investigation was described as limey dolostone with shaley partings. The bedrock was reported to be of excellent quality with a Rock Quality Designation (RQD) value of 100%.

The bedrock encountered in the current investigation consisted of fresh, very strong, grey interbedded dolostone and sandstone. The RQD ranged from 58% to 82%, the Solid Core Recovery (SCR) ranged from 96% to 100%, and the Total Core Recovery (TCR) ranged from 96% to 100%. Photographs of the bedrock cores are provided in Appendix C. Unconfined compressive strength (UCS) testing was carried out on one sample of the bedrock from Borehole 250-21-1. The result of 182 MPa indicates a very strong rock; test details are in Appendix C.

## 5.6 Groundwater

The groundwater level measured in the standpipe piezometers installed during the 1992 field investigation is presented in Table 5-1. The Johnstown Creek level was measured during a recent site visit carried out on May 5, 2021 and is also presented in Table 5-1.

**Table 5-1: Summary of Groundwater Levels**

<b>Borehole No.</b>	<b>Bottom of Screen Elevation (m)</b>	<b>Screened Unit</b>	<b>Depth (mbgs)</b>	<b>Groundwater Elevation (m)</b>	<b>Date of Measurement</b>
92-3	80.1	Bedrock	0.1	84.0	1992/05/15
Johnstown Creek Surface Level (Existing Inlet)				84.3	2021/05/05
Johnstown Creek Surface Level (Existing Outlet)				84.3	2021/05/05

These observations are considered short term and it should be noted that the groundwater and creek water level at other times of the year may be different and seasonal fluctuations of the levels are to be expected. In particular, the groundwater and creek level may be at a higher elevation after periods of significant and/or prolonged precipitation.



## 6 MISCELLANEOUS

It is noted that the information provided herein is partially based on investigations completed prior to construction of the Highway 401/416 Interchange. It is likely that conditions have changed on site during the intervening years.

The 2021 borehole location was selected by Thurber relative to existing site features. The 2021 elevation survey of the borehole, Johnstown Creek and the culvert was carried out by Thurber with reference to geodetic elevation benchmarks provided by the MTO.

Eastern Ontario Diamond Drilling of Hawkesbury, Ontario supplied and operated the drilling equipment and carried out the 2021 drilling, soil sampling, in-situ testing, piezometer installation and borehole decommissioning. The field investigation was supervised on a full-time basis by Jamil Pirani, EIT, of Thurber.

Routine geotechnical laboratory testing was completed by Thurber's laboratory in Ottawa, Ontario. Unconfined Compressive Strength Testing of the bedrock was carried out by Stantec's laboratory in Ottawa.

Overall project management and direction of the field investigation was provided by Matt Kennedy, P.Eng. Interpretation of the factual data and preparation of this report was carried out by Sarah Harrold, EIT and Matt Kennedy, P.Eng. The report was reviewed by Paul Carnaffan, P.Eng. and Fred Griffiths, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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**PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**7 INTRODUCTION**

This report presents the interpretation of the factual subsurface data collected as part of the foundation investigation completed at the site and desktop study conducted by Thurber for the rehabilitation of the existing structural culvert at Site 16X-0250/C0.

The site is located near the southern limit of the Highway 401 and Highway 416 Interchange. Johnstown Creek flows roughly from west to east beneath interchange ramps and Highway 401 to its outlet into the St. Lawrence River at Johnstown. The culvert addressed in this report is located beneath Highway 401 at approximate Station 13+075, approximately 100 m west of the ramp bridge connecting traffic coming from Highway 401 west to Highway 416 north. For project purposes, Highway 401 and the culvert are herein described as oriented east-west and north-south, respectively.

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

The following sections provide preliminary geotechnical recommendations for the design of the foundation elements as part of the structural assessment and rehabilitation. The discussions and recommendations presented in this report are based on the information provided by AECOM and the Ministry of Transportation of Ontario (MTO), the foundation investigation completed at the site, and on the factual data obtained from MTO's Geocres Foundations Library as part of the current study. It is noted that the information provided herein is partially based on investigations completed prior to construction of the Highway 401/416 Interchange. It is likely that conditions have changed on site during the intervening years.

## **7.1 Existing Structure**

The existing culvert conveys Johnstown Creek roughly north-south beneath the travelled lanes of Highway 401. The culvert, constructed in 1961, is approximately 53.1 m long, has an internal height above the stream bed of 1.8 m, and an overall internal span width of 6.0 m. The contract drawings from initial construction are not available for review. The 2018 OSIM report describes a structure as an open-footing, reinforced cast-in-place single-span concrete culvert. At the time of the structural inspections outlined in the 2018 OSIM inspection report, the culvert had a water depth ranging from about 0.75 m to 1.0 m.

During a site visit carried out on May 5, 2021, the top of the culvert at the inlet was determined to be at elevation 85.3 m and the creek level was at elevation 84.3 m. It is estimated that the elevation of Highway 401 is approximately 86.7 m and the current stream bed is at approximate elevation 83.2 m. Although unconfirmed, the undersides of the footings are anticipated to be at approximate elevation 81.5 m. The elevations of the highway, stream bed, and underside of the footings have been estimated for discussion purposes and should be confirmed by others for design.

The OSIM inspection report suggests that the culvert comprises two open-footed structures: one rigid frame, and one non-rigid frame. The bearing elevations of the open footings are not indicated in the available structural information and have been assumed to be within the very stiff silty clay (anticipated at the north end of the culvert) and/or at the bedrock surface (anticipated at the south end of the culvert).

## **7.2 Proposed Work**

It is understood that the existing culvert is to undergo structural rehabilitation and that the details of the works are yet to be determined. Preliminary foundation recommendations are required concerning seismic design, foundation bearing resistance, and lateral earth pressure to allow structural assessment of the culvert and the need for rehabilitation treatments. Additional investigation and analysis will be required in any subsequent detail design phase of the project.

## **7.3 Applicable Codes and Design Considerations**

The geotechnical assessment presented below has been prepared based on the available data regarding the existing foundations and ground conditions and in accordance with the Canadian Highway Bridge Design Code, version CSA S6:19 (CHBDC).

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

It is understood that the culvert structure is being assigned to the “Major Route” importance category (to be confirmed).



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

As per Section 6.5.3.2 of the CHBDC, the degree of site prediction model understanding is considered to be *Typical* based on acquisition of additional information during subsequent design stages.

## 8 SEISMIC CONSIDERATIONS

### 8.1 Spectral and Peak Acceleration Hazard Values

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

The site coefficients used to determine the design spectral acceleration and displacement values are a function of the Site Class, the peak ground acceleration (PGA) and  $S_a(0.2)$ . The PGA for this location for a *reference* Site Class C with a 2% probability of exceedance in 50 years is 0.25g (1 in 2475 year). This value is to be scaled by the  $F(PGA)$  based on the site-specific Site Class as per Section 4.4.3.3 (Table 4.8) of the CHBDC (see Section 8.2).

### 8.2 CHBDC Seismic Site Classification

In accordance with the CHBDC, the selection of the seismic site classification is based on the soil and bedrock conditions encountered in the upper 30 m of the stratigraphy beneath the underside the foundations. As outlined in Section 4.4.3.2 of the CHBDC, if the shear wave velocity of the site soil and bedrock is not known, the seismic site class must strictly 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.

At the site, a silty clay to clay deposit overlies a silt deposit, which is underlain by interbedded dolostone and sandstone bedrock (present at 2.4 m to 6.9 m depths). As noted in Section 7.1, the culvert has been assumed to be founded within the very stiff silty clay and/or at the bedrock surface. Based on the recorded SPT N-values, the silty clay was classified as very stiff with an assumed relative average shear strength of 100 kPa or greater, which correlates to Seismic Site Class C. The average of the two SPT N-values recorded in the underlying silt at the north end of the culvert was 38 blows per 0.3 m of penetration, which correlates to a Seismic Site Class D. Though no shear wave velocity data is available, the good to excellent quality interbedded dolostone and sandstone bedrock is anticipated to fall within Seismic Site Class B.



For preliminary design of the rehabilitation of the structure at the site, a Site Class C may be used. The site classification must be confirmed with measurement of the shear wave velocity in the upper 30 m of the site at subsequent design stages.

### 8.3 Seismic Performance Category

In consideration of the Site Class C spectral values for the site, an assumed designated *Major Route* importance category, and assuming the culvert structure has a fundamental period less than 0.5 seconds the site is within Seismic Performance Category 3, as per Section 4.4.4 (Table 4.10) of the CHBDC.

### 8.4 Liquefaction Potential

The susceptibility of the cohesive soils at this site to experience liquefaction/cyclic softening was assessed following the Boulanger and Idriss (2007)<sup>i</sup> criteria using estimated undrained shear strengths (very stiff based on SPT N-value). The results of the analysis indicate the cohesive material is not susceptible to cyclic mobility.

The susceptibility of the cohesionless soils at the site to experience liquefaction was assessed using the SPT data following the simplified method for cohesionless soil as outlined in Boulanger and Idriss (2014)<sup>ii</sup>. The cohesionless soils at the site are not considered to be susceptible to liquefaction.

## 9 FOUNDATION DESIGN RECOMMENDATIONS

Foundation design aspects for the structural assessment of the culvert include subgrade conditions, geotechnical resistances, and imposed loading pressures. The culvert must be designed to resist loading including, but not limited to, lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loading and any surcharge due to construction equipment and activities.

### 9.1 Foundation Bearing Resistances

The culvert is approximately 53.1 m long, has an internal height of about 1.8 m above the stream bed, and an overall internal span width of 6.0 m and an external width of approximately 6.8 m. The culvert is understood to be founded on open footings bearing on either the silty clay and/or directly on the bedrock. Assuming that the footings founded within the silty clay are up to 2 m wide, the factored geotechnical resistance of the foundation soil may be taken as follows.

- Factored Geotechnical Resistance at ULS of 300 kPa
- Factored Geotechnical Resistance at SLS of 250 kPa

Where the culvert is founded directly on bedrock, the factored geotechnical resistances at ULS and SLS would be greater.





The factored geotechnical resistances include the following factors:

- Consequence factor ( $\Psi$ ) of 1.0 (as per CHBDC Table 6.1)
- Geotechnical resistance factors (as per CHBDC Table 6.2):
  - $\phi_{gu} = 0.50$  (static analysis; *typical* degree of understanding)
  - $\phi_{gs} = 0.80$  (static analysis; *typical* degree of understanding)

The bearing resistance values are for vertical, concentric loading. In the case of eccentric or inclined loading, the bearing resistance must be reduced in accordance with CHBDC Clause 6.10.5. The bearing resistances provided above are based on the assumption that all fill or otherwise deleterious material was removed from the silty clay bearing surface prior to construction of the footings.

Resistance to lateral forces/sliding resistance between concrete and the underlying silty clay and/or bedrock should be evaluated in accordance with the CHBDC assuming unfactored coefficients of 0.35 for silty clay and 0.7 for clean bedrock in contact with mass concrete. A geotechnical resistance factor of 0.8 ( $\phi_{gu}$ ), as per Table 6.2 of the CHBDC (static analysis – typical understanding) should be applied to the sliding frictional capacity between concrete and the underlying silty clay or bedrock.

## 9.2 Backfill and Lateral Earth Pressures

The available subsurface information at the site was collected up to about 10 m away from the constructed culvert and did not penetrate the backfill material that would have been placed directly adjacent to the culvert walls. As such, the composition of the backfill placed during construction is unknown. For analysis purposes of existing conditions, backfill conforming to OPSS Granular B Type I or Select Subgrade Material (SSM) may be assumed.

Lateral earth pressure parameters provided in Table 9-1 and Table 9-2 in the sections below are based on the assumptions that the wall is vertical and the backfill is fully drained so that there are no unbalanced hydrostatic pressures above the permanent groundwater level. If adequate drainage cannot be confirmed, the potential for buildup of unbalanced hydrostatic pressures should be considered in design. Where back slopes are horizontal (i.e. existing culvert walls), the corresponding coefficients provided in Table 9-1 and Table 9-2 should be used. For other backfill and wall geometries (such as behind wing walls or headwalls), Thurber will need to calculate the appropriate earth pressure coefficients once the final geometry is confirmed.

### 9.2.1 Static Lateral Earth Pressure

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

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



where:

$\sigma_h$	=	horizontal pressure on the wall at depth h (kPa)
K	=	earth pressure coefficient (see table below) ( $K_a$ for yielding walls, $K_o$ for non-yielding walls)
$\gamma$	=	unit weight of retained soil (see table below), use submerged unit weight below groundwater level
h	=	depth below top of fill where pressure is computed (m)
q	=	value of any surcharge (kPa)

A lateral earth pressure due to backfill compaction should be added to the calculated lateral earth pressure in accordance with Clause 6.12.3 of the CHBDC. Typical earth pressure coefficients for vertical walls with horizontal backslopes, and with the assumed backfill are shown in Table 9-1.

**Table 9-1 Static Earth Pressure Coefficients**

Condition	OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21 \text{ kN/m}^3$	Select Subgrade Fill $\phi = 30^\circ, \gamma = 20 \text{ kN/m}^3$
Active, $K_A$ (Yielding Wall)	0.31	0.33
At Rest, $K_o$ (Non-Yielding Wall)	0.47	0.5
Passive, $K_P$ (Movement towards Soil Mass) in front of wall	3.3	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. The movement required can be assessed from Table C6.12 of the Commentary to the CHBDC. Active earth pressures should be used for unrestrained (non-rigid) elements of the culvert and foundation walls.

### 9.2.2 Combined Static and Seismic Lateral Earth Pressure

In accordance with Clause 6.14.7.2 of the CHBDC, retaining structures should be designed using dynamic earth pressure coefficients that incorporate the effects of earthquake loading. The following recommendations are per Section C6.14.7.2 of the Commentary of the CHBDC which states that seismically induced lateral soil pressures may be calculated using the Mononobe-Okabe Method with:

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

**Table 9-2 Combined Static and Seismic Earth Pressure Coefficients**

Condition	OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21 \text{ kN/m}^3$	Select Subgrade Fill $\phi = 30^\circ, \gamma = 20 \text{ kN/m}^3$
Active, $K_{AE}$ Yielding Wall	0.38	0.41
Active, $K_{AE}$ Non-Yielding Wall	0.48	0.52

The coefficients of horizontal earth pressure for combined static and seismic loading presented in Table 9-2 may be used for vertical walls with horizontal back slopes. The provided earth pressure coefficients are based on a Seismic Site Class C (see Section 8.2) and a PGA with a 2% probability of exceedance in 50 years of 0.25g (Geological Survey of Canada – Fifth Generation).

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

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

where:

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

### 9.3 Frost Depth

The depth of frost penetration at this site is estimated to be 1.6 m (as per OPSD 3090.101).

## 10 RECOMMENDED SCOPE FOR DETAIL DESIGN

The recommendations provided above are in support of the preliminary design of the proposed rehabilitation of the Highway 401 culvert at Sta. 13+075 (Site No. 16X-0250/C0) as part of the overall Preliminary Design and Environmental Assessment for the widening of Highway 401 from Highway 416 to Maitland Road. Depending on the scope of the design rehabilitation works, additional foundation investigation may be required following the selection of the Technically



Preferred Alternative (TPA). Additional field investigation should be carried out to provide additional foundation design input to the following:

- Shear wave velocity measurements in the 30 m below the foundation elements to confirm Seismic Site Classification
- Characterization of embankment and structural backfill materials
- Construction staging (requirement for Temporary Protection Systems)
- Embankment widening (permanent and temporary)
- Cofferdams (to support culvert dewatering and or creek diversion)
- Feasibility of tunnelled creek diversion pipe installation
- Culvert extension(s)
- Erosion and scour protection
- Testing of soil and/or groundwater at the site to determine degree of corrosiveness of the sub-surface environment and potential for sulphate attack on steel and concrete elements in contact with the soil and groundwater at the site

The required supplementary foundation field investigation scope should be reviewed following the selection of the TPA.

## 11 CLOSURE

Engineering analysis and preparation of this report was carried out by Mr. Matt Kennedy, P.Eng. The report was reviewed by Paul Carnaffan, P.Eng. and Fred Griffiths, P.Eng., a Designated Principal Contact for MTO Foundations Projects.



Matt Kennedy, M.Sc.(Eng.), P.Eng.  
Senior Geotechnical Engineer



Paul Carnaffan, P.Eng.  
Principal  
Senior Geotechnical Engineer



Fred Griffiths, Ph.D., P.Eng.  
MTO Review Principal,  
Senior Geotechnical Engineer



## REFERENCES

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

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

## STATEMENT OF LIMITATIONS AND CONDITIONS

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- 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.
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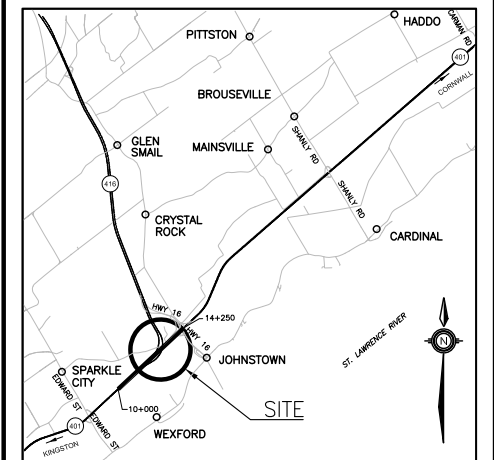
## **Appendix A.**

### **Borehole Location Plan and Stratigraphic Drawing**






A circular professional engineer seal for the Province of Ontario. The outer ring contains the text "LICENSED PROFESSIONAL ENGINEER" at the top and "PROVINCE OF ONTARIO" at the bottom. In the center, the name "M. J. KENNEDY" is printed above the license number "100188946". A handwritten signature "M. J. Kennedy" is written across the top half of the seal. Below the license number, the date "Jan 23, 2023" is handwritten.

SHEET

**THURBER** ENGINEERING LTD.



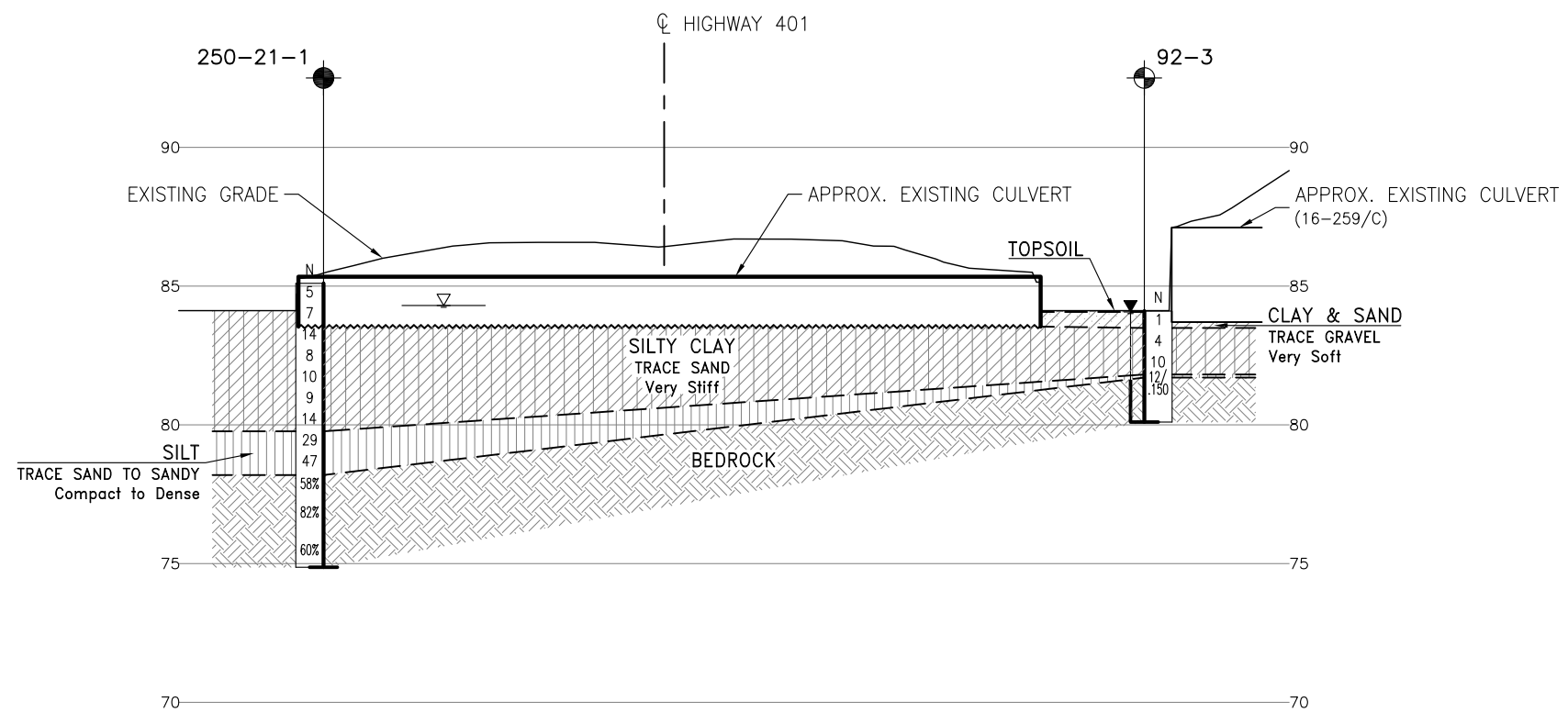
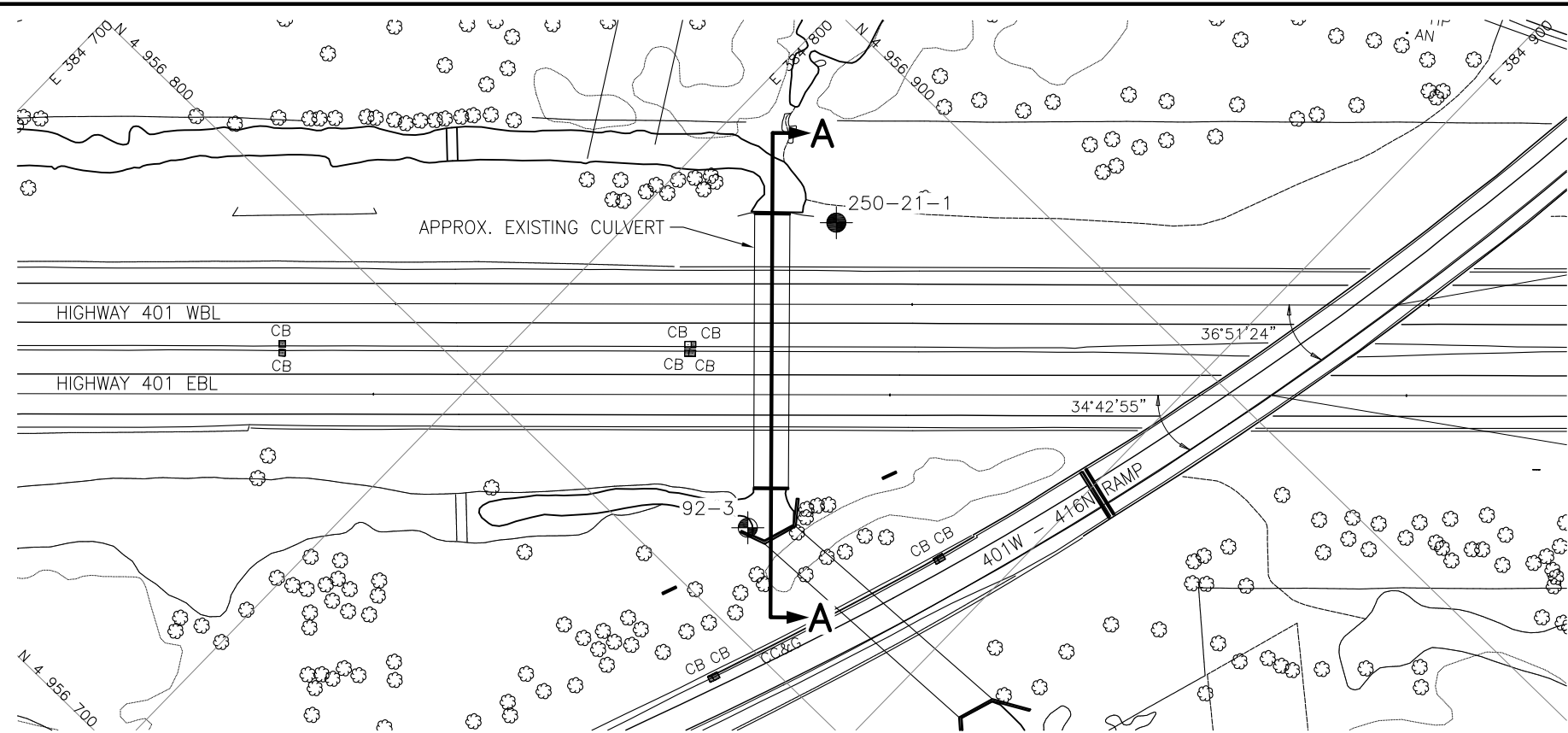
## LEGEND

	Borehole (Current Investigation)
	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
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
250-21-1	85.1	4 956 870.6	384 828.8
92-3	84.1	4 956 816.3	384 857.7

- 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. 31B-101**



A horizontal scale bar representing a distance of 20 meters. The bar is divided into four equal segments by three vertical tick marks. Above the bar, the markings are labeled 10, 0, 10, and 20m from left to right. Below the bar, the markings are labeled 5, 0, 5, and 10m from left to right.

V 1:250

REVISIONS										
	DATE	BY	DESCRIPTION							
DESIGN	MJK	CHK -	CODE	LOAD				DATE	JAN 2023	
DRAWN	MFA	CHK MK	SITE 16-250/C	STRUCT				DWG	1	





## **Appendix B.**

### **Record of Borehole Sheets (Current and 1992 Investigations)**



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

### TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

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

### TERMINOLOGY DESCRIBING SOIL STRUCTURE:

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

### RECOVERY:

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

### N-VALUE:

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

### DYNAMIC CONE PENETRATION TEST (DCPT):

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



### STRATA PLOT:

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



Boulders  
Cobbles  
Gravel      Sand      Silt      Clay      Organics      Asphalt      Concrete      Fill      Bedrock

### TEXTURING CLASSIFICATION OF SOILS

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

### TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

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

### SAMPLE TYPES

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

### TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

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

### MODIFIED UNIFIED SOIL CLASSIFICATION

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

Note -  $W_L$  = Liquid Limit



## EXPLANATION OF ROCK LOGGING TERMS

### ROCK WEATHERING CLASSIFICATION

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

### TERMS

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

### DISCONTINUITY SPACING

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

### STRENGTH CLASSIFICATION

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

# RECORD OF BOREHOLE No 250-21-1

1 OF 2

METRIC

GWP# 4024-20-00 LOCATION Lat: 44.747366°, Long: -75.48934° N 4 956 870.6 E 384 828.8 ORIGINATED BY JP  
 HWY 401 BOREHOLE TYPE CME 55 Trackmount, HSA/NQ Coring COMPILED BY SH  
 DATUM Geodetic DATE 2021.04.23 - 2021.04.24 CHECKED BY MJK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT		NATURAL MOISTURE CONTENT		LIQUID LIMIT		UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W P		W		W L				
								○ UNCONFINED	+ FIELD VANE	○ UNCONFINED	+ FIELD VANE	○ UNCONFINED	+ FIELD VANE	○ UNCONFINED	+ FIELD VANE			
85.1	<b>SILTY CLAY to CLAY</b> Trace sand Contains organics Grey-brown Very stiff <b>WEATHERED CRUST</b>		1	SS	5												GR SA SI CL	
0.0																		
			2	SS	7													
			3	SS	14													
			4	SS	8													
			5	SS	10													
81.3	<b>SILTY CLAY</b> Trace sand Grey Very stiff		6	SS	9												1 2 50 47	
3.8																		
			7	SS	14													
79.8	<b>SILT</b> Trace sand Grey Compact to dense		8	SS	29												1 5 82 12	
5.3																		
			9	SS	47													
78.2	Interbedded <b>DOLOSTONE</b> and <b>SANDSTONE</b> Grey Smooth Fine grained to coarse grained Fresh Very strong		1	RUN													RUN #1 TCR=100% SCR=100% RQD=58%  UCS = 182 MPa  RUN #2 TCR=96% SCR=96% RQD=82%  RUN #3 TCR=100% SCR=96% RQD=60%	
6.9																		
			2	RUN														
			3	RUN														
	Vertical fracture 9.6 to 9.9 m																	

Continued Next Page

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

DOUBLE LINE 29381 BOREHOLE LOGS REHAB SITES.GPJ 2012TEMPLATE(MTO).GDT 12-23-22

RECORD OF BOREHOLE No 250-21-1

2 OF 2

METRIC

GWP# 4024-20-00 LOCATION Lat: 44.747366°, Long: -75.48934°  
N 4 956 870.6 E 384 828.8 ORIGINATED BY JP  
HWY 401 BOREHOLE TYPE CME 55 Trackmount, HSA/NQ Coring COMPILED BY SH  
DATUM Geodetic DATE 2021.04.23 - 2021.04.24 CHECKED BY MJK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
74.9	Continued From Previous Page						75										
10.2	End of Borehole																

DOUBLE LINE 29381 BOREHOLE LOGS REHAB SITES.GPJ 2012TEMPLATE(MTO).GDT 12-23-22

# RECORD OF BOREHOLE No 92-3

METRIC

W P 374-89-00 LOCATION Co-ords N: 4 956 816.3 E: 384 857.7  
 DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem, N-Casing, Rock Coring  
 DATUM Geodetic DATE May 13, 1992

ORIGINATED BY Y.L.  
 COMPILED BY F.J.G.  
 CHECKED BY CKK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	VALUES			20	40	60	80	100					
84.1	Ground Surface																
83.5	Topsoil		1	SS	1		84 May 15, 1992										
83.5	Clay, sand, trace gravel, Brown, very Soft		2	SS	4		83 Native Backfill										
81.8	Silty Clay Brown to Grey Firm to Hard		3	SS	10		82										
81.8	Sandy silt Grey, compact		4	SB	2/15mm		81										
80.1	Bedrock Limey Dolostone with shaley partings Excellent		5	NQ	REC 100%												RQD 100%
80.1	End of Borehole																

OFFICE REPORT ON SOIL EXPLORATION



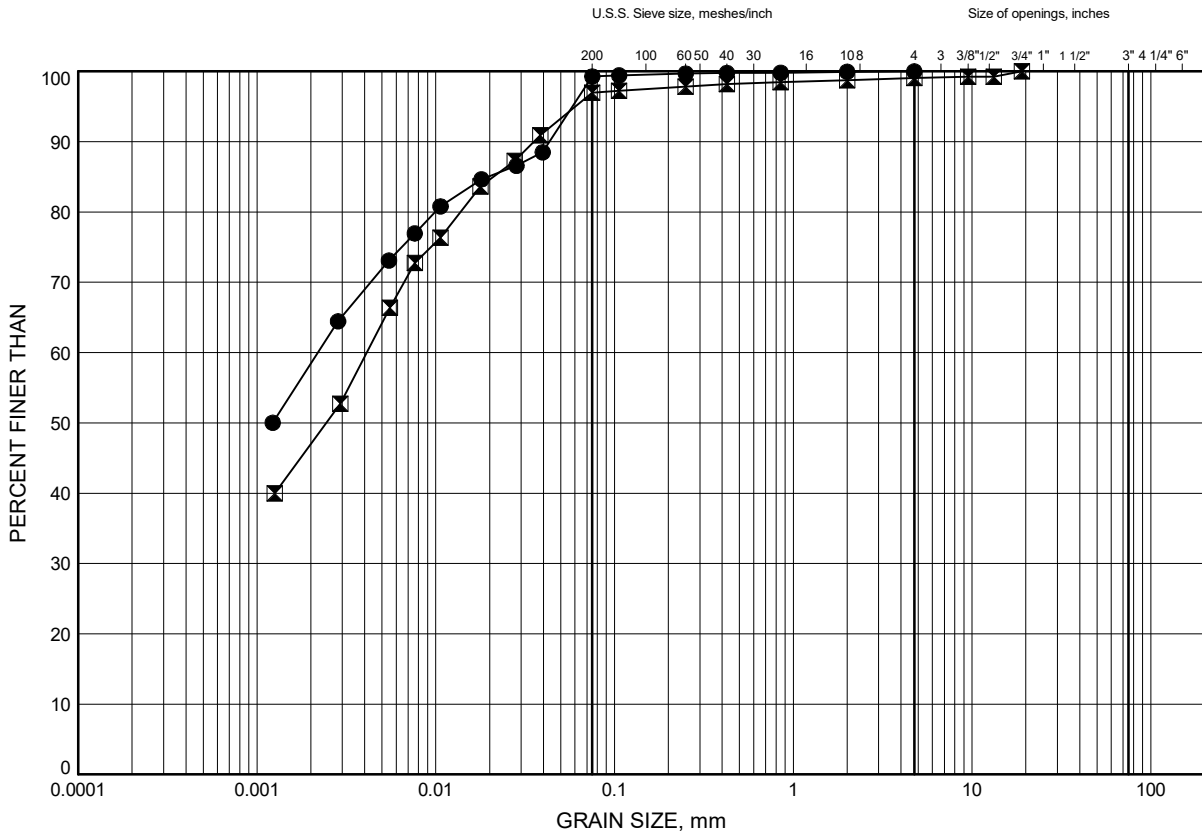


## **Appendix C.**

### **Laboratory Test Results (Current and 1992 Investigations)**

# GRAIN SIZE DISTRIBUTION

## SILTY CLAY to CLAY



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	250-21-1	1.1	84.1
⊠	250-21-1	4.1	81.0

Date December 2021

WP# 4024-20-00



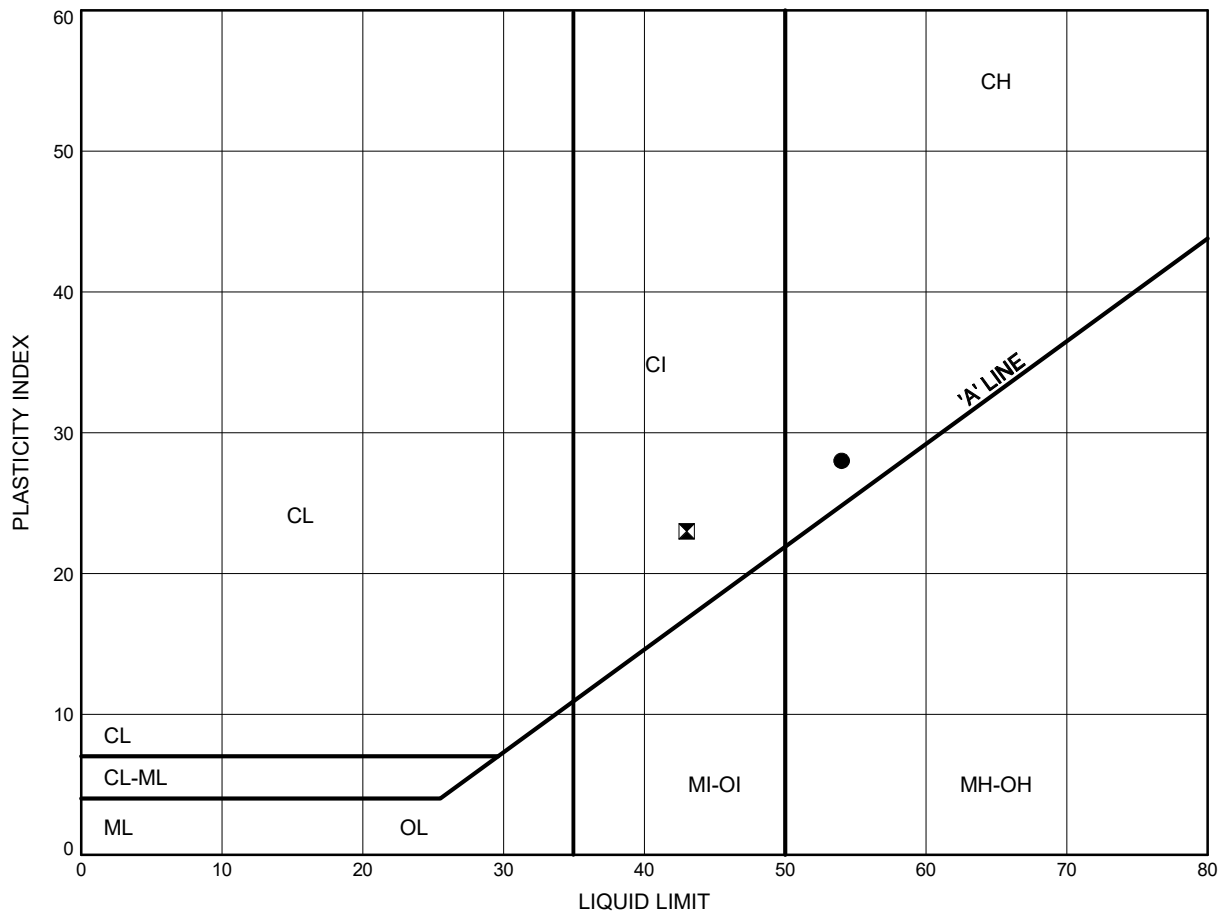
Prep'd SH

Chkd. MJK

Highway 401 Sta. 13+075 Culvert (Site 16X-0250/C0)  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE C2

**SILTY CLAY to CLAY**



**LEGEND**

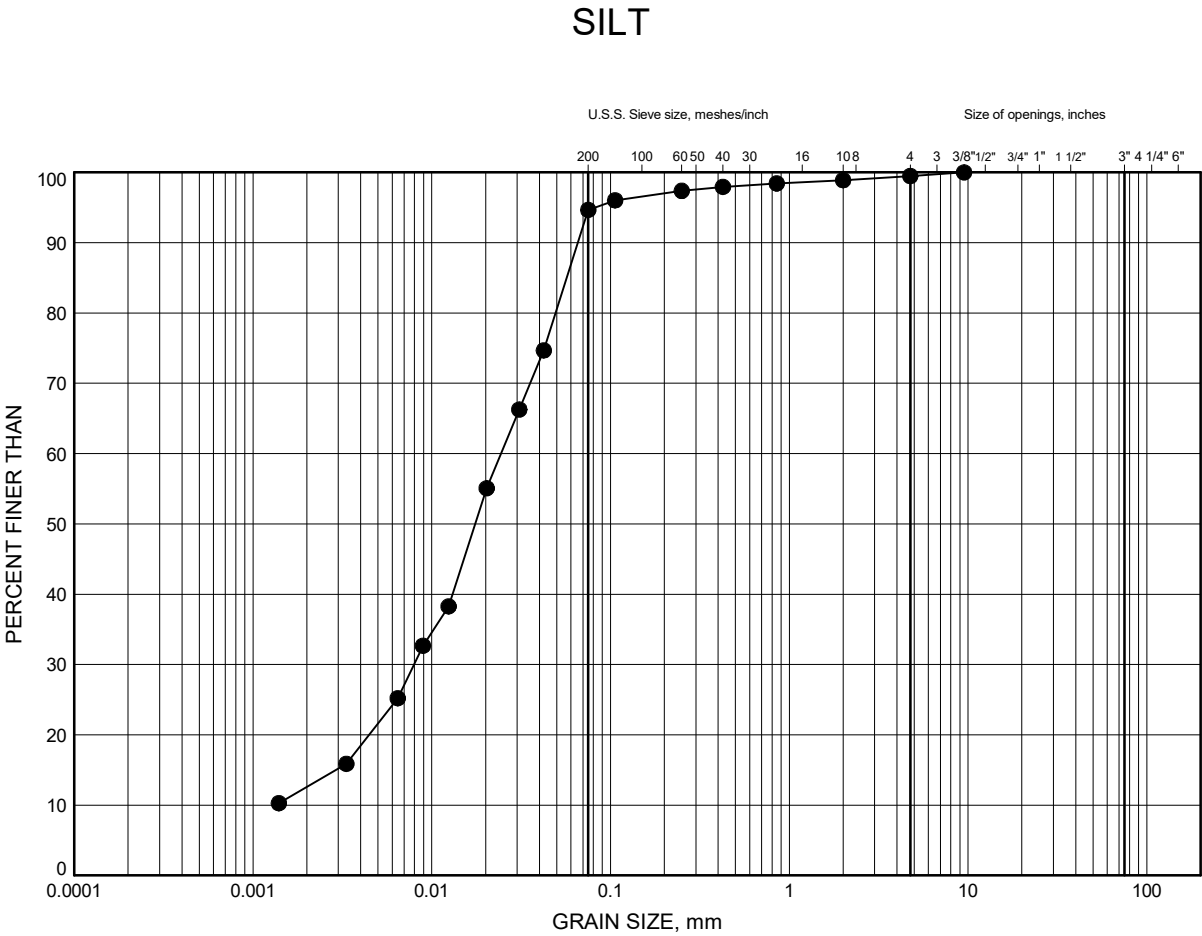
SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	250-21-1	1.1	84.1
⊠	250-21-1	4.1	81.0

Date December 2021  
 WP# 4024-20-00



Prep'd SH  
 Chkd. MJK

GRAIN SIZE DISTRIBUTION



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

LEGEND

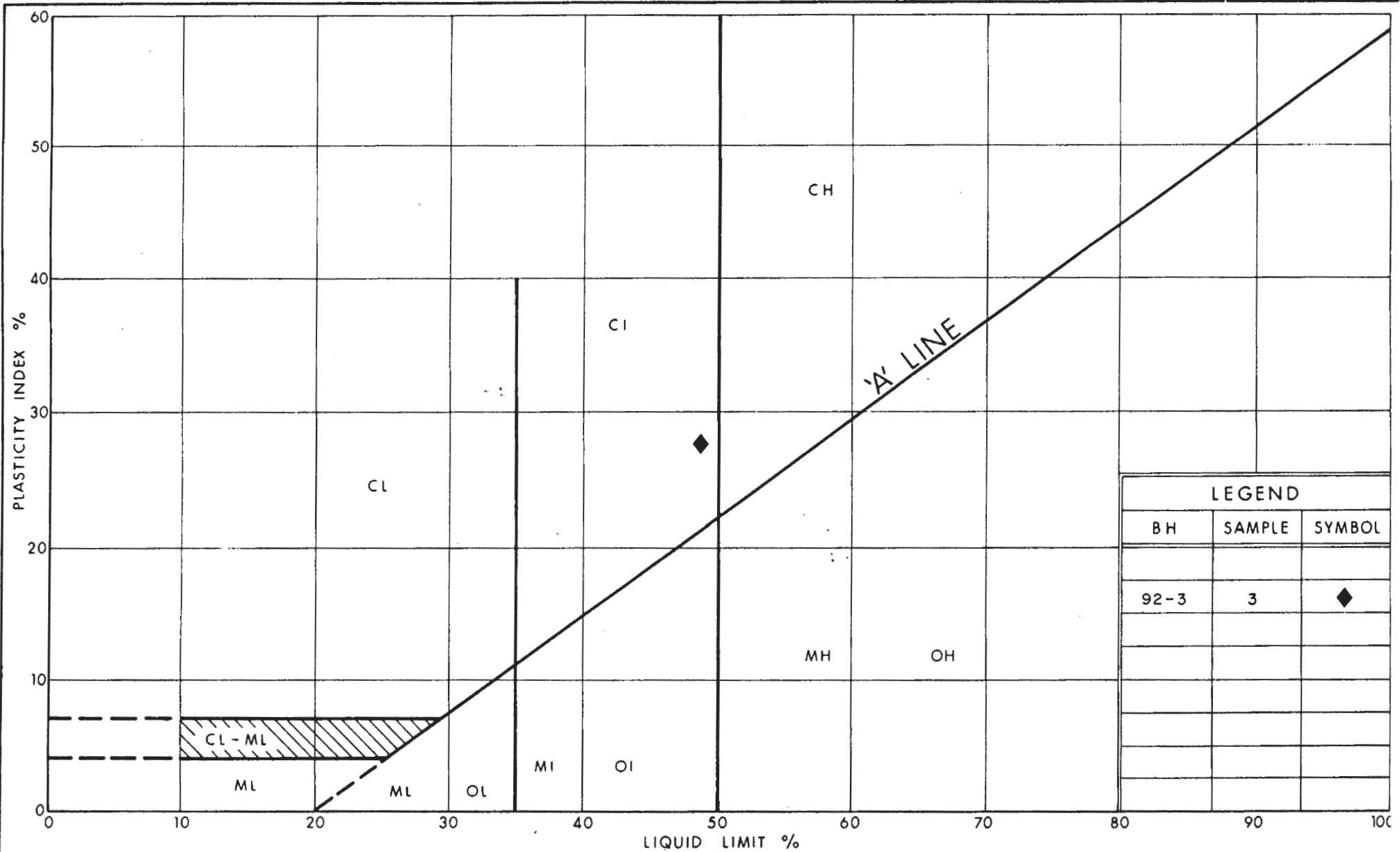
SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	250-21-1	5.6	79.5

GRAIN SIZE DISTRIBUTION - THURBER 29381 BOREHOLE LOGS.GPJ 3/6/21

Date December 2021  
WP# 4024-20-00



Prep'd SH  
Chkd. MJK



Ministry of  
Transportation

## PLASTICITY CHART SILTY CLAY

FIG No C4

W P 374-89-00



**Stantec**

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

May 25, 2021  
File: 122410864

**Attention:** Thurber Engineering, File #29381

**Reference:** ASTM D7012, Method C, Unconfined Compressive Strength of Intact Rock Core  
Highway 401/416 Interchange

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

Location	Sample Depth	Compressive Strength (MPa)	Description of Break
259-21-1 Run-2	8'6"-9'1"	205.3	Well-formed cone at both ends
306-21-2 Run-1	77'2"-77'9"	219.8	Well-formed cone at both ends
307-21-1 Run-1	55'-55'7"	162.4	Well-formed cone at both ends
308-21-1 Run-2	72'6"-73'3"	216.9	Vertical cracking throughout, no well-formed cones.
250-21-21 Run-2	24'8"-25'3"	181.6	Well-formed cone at both ends

Sincerely,

**Stantec Consulting Ltd**

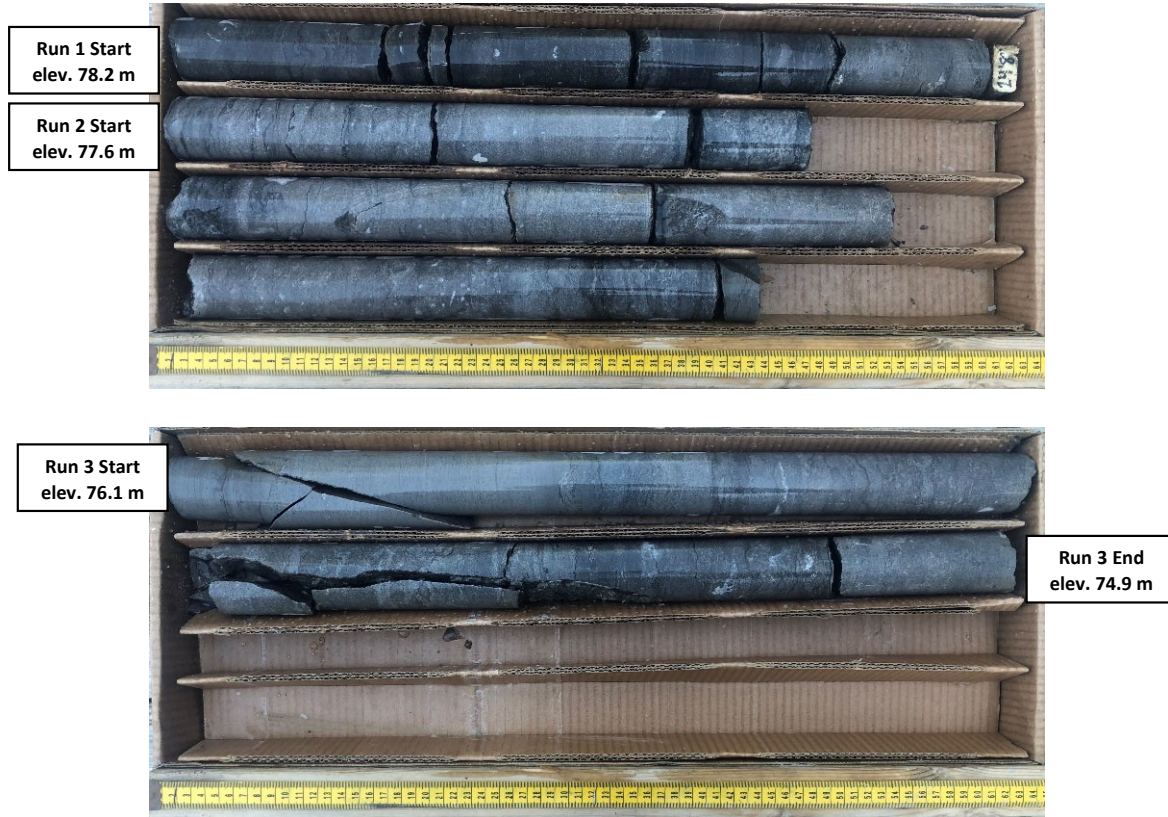
*Brian Prevost*

Brian Prevost  
Laboratory Supervisor  
Tel: 613-738-6075  
[brian.prevost@stantec.com](mailto:brian.prevost@stantec.com)

**Borehole 250-21-1**  
**Run 1 to 3 (of 3)**  
**Elevation 78.2 m to 74.9 m**  
**Dry**



**Borehole 250-21-1**  
**Run 1 to 3 (of 3)**  
**Elevation 78.2 m to 74.9 m**  
**Wet**







## **Appendix D.**

### **Site Photographs**



**Photo 1. Looking south at culvert inlet (2021/03/29).**



**Photo 2. Looking southwest at culvert inlet (2021/03/29).**





**Photo 3. Looking northwest at culvert inlet (2021/04/23).**



## **Appendix E.**

### **GSC Seismic Hazard Calculation**

# 2015 National Building Code Seismic Hazard Calculation

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

Site: 44.747N 75.489W

User File Reference: Culvert Site 16-250/C

2021-06-29 19:13 UT

Requested by: Sarah Harrold, EIT, Thurber Engineering Ltd.

Probability of exceedance per annum	0.000404	0.001	0.0021	0.01
Probability of exceedance in 50 years	2 %	5 %	10 %	40 %
Sa (0.05)	0.384	0.216	0.129	0.037
Sa (0.1)	0.453	0.265	0.165	0.052
Sa (0.2)	0.382	0.227	0.145	0.048
Sa (0.3)	0.292	0.175	0.113	0.039
Sa (0.5)	0.209	0.126	0.081	0.028
Sa (1.0)	0.106	0.064	0.042	0.014
Sa (2.0)	0.051	0.030	0.019	0.006
Sa (5.0)	0.013	0.007	0.004	0.001
Sa (10.0)	0.005	0.003	0.002	0.001
PGA (g)	0.245	0.145	0.090	0.028
PGV (m/s)	0.173	0.100	0.062	0.019

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

## References

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

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

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

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



Natural Resources  
Canada

Ressources naturelles  
Canada

Canada



## **Appendix F.**

### **OSIM Structure Inspection Report (2018)**

# STRUCTURE INSPECTION REPORT

Culvert

SITE NUMBER: 16X-0250/C0

INSPECTION DATE: 2018-07-19





## STRUCTURE INSPECTION REPORT

Site Number: 16X-0250/C0

LOCATION			
Main Highway:	401	Location:	
Region:	Eastern	Latitude:	44.7473705
District:		Longitude:	-75.4888399
Township:	EDWARDSBURGH	LHRS:	47322
Current County:		LHRS Offset:	0.0652105844612123
Old County:		Owner/Custodian:	Provincial
		Inspected by:	MTO
Regional Engineer:		Admin. System:	MTO

No Service On/Under records found





# STRUCTURE INSPECTION REPORT

Site Number: 16X-0250/C0

## STRUCTURE INFORMATION

Year built:	1961	Interchange number:	
Year Superstruct. Built:		Interchange structure #:	
Structure category:	Open Culvert	Structure Material 1:	Reinforced Cast-In-Place Concrete
Structure Type 1:	Open Footing (Rigid Frame)	Structure Material 2:	Reinforced Cast-In-Place Concrete
Structure Type 2:	Open Footing (Non-Rigid Frame)		
Apron:	No		
Headwall:		Culvert length, m:	53.10
Cut-off Wall:		Direction of structure:	
WingWall:			
Retaining Wall:		Skew angle, degree:	
Rock fill:		Fill on structure, m:	
No. of Cell:		Load Limit, tonnes:	
Span length, m:	Total=6 (1)=6;		

## TRAFFIC INFORMATION ON STRUCTURE

No. of lanes	Traffic directional bound
Highway class	AADT
Posted speed, km/h	% trucks
Operational Status	Detour distance, m

## CAPTIAL WORK HISTORY

Contract No.	Contract Year	Structure completion year	Work category	Scope of works
--------------	---------------	---------------------------	---------------	----------------

## ADDITIONAL INVESTIGATION HISTORY

Date	Additional Investigation	Comments
------	--------------------------	----------

## APPRAISAL INDICES AND COMMENTS

Fatigue		
Seismic		
Scour		
Flood		
Barrier		
Curb		
Load Capacity		

# STRUCTURE INSPECTION REPORT

Site Number: 16X-0250/C0

INSPECTION HISTORY				
Type	Date	BCI	Special Notes	BCI Justification
Regular OSIM	2005-09-16	73.70		
Regular OSIM	2007-02-12	73.10	Low clearance difficult to inspect. Ice inspection completed in 2007.--Others in PartyR. Jundis, J. Wang	
Regular OSIM	2010-06-16	72.70		
Regular OSIM	2014-12-04	72.0		
Regular OSIM	2018-07-19			

INSPECTION INFORMATION			
Reg. OSIM Freq, yrs	4 year		
Enh. OSIM Freq, yrs	N/A	Inspection year	Even
Inspector	Joel Covert	Inspection duration, hr	
Supervising Engineer		Start date	2018-07-19
Others in party	Mike Colton	End date	2018-07-19
Firm	McIntosh Perry Consulting Engineers Ltd.	Weather	Sunny
Enhanced access equipment used		Temperature, deg C	25
Inspection BCI		Next Inspection date	2022-07-19
BCI Justification			
Special notes			

OVERALL STRUCTURE NOTES			
Overall Comments:			
Recommended Work on Structures:			

STRUCTURE ELEMENT AND CONDITION DATA						
Element group	Decks		Dimensions		Condition Data	
Element name	Decks > Wearing surface		Units	m	Units	Sq.m
Element type			Length		Excellent	0
Material			Width		Good	90
Location			Height		Fair	6
Environment			Count		Poor	0
Protection system			Inspected	Yes	Total Quantity	96
Maintenance needs			Timing:	Performance Deficiencies:		

## STRUCTURE INSPECTION REPORT

Site Number: 16X-0250/C0

Recommended work		Timing:	
Comments	Fair - Some fair long and trans. cracks		
Photo Reference	5		

# STRUCTURE INSPECTION REPORT

Site Number: 16X-0250/C0

# STRUCTURE INSPECTION REPORT

Site Number: 16X-0250/C0

Element group	Embankments & Streams		Dimensions		Condition Data	
Element name	Streams and Waterways> ( N-S )		Units	m	Units	All
Element type			Length		Excellent	0
Material			Width		Good	1
Location	N-S		Height		Fair	0
Environment			Count		Poor	0
Protection system			Inspected	Yes	Total Quantity	1
Maintenance needs			Timing:	Performance Deficiencies:		
Recommended work			Timing:			
Comments	Good - Water depth: 1.0m					
Photo Reference						

# STRUCTURE INSPECTION REPORT

Site Number: 16X-0250/C0

Element group	Foundations		Dimensions		Condition Data	
Element name	Foundations > Foundation (below ground level)		Units	m	Units	N/A
Element type	Spread		Length		Excellent	0
Material	Cast-in-place concrete		Width		Good	106
Location			Height		Fair	0
Environment			Count		Poor	0
Protection system			Inspected	No	Total Quantity	106
Maintenance needs			Timing:	Performance Deficiencies:		
Recommended work			Timing:			
Comments						
Photo Reference						

# STRUCTURE INSPECTION REPORT

Site Number: 16X-0250/C0

Element group	Culverts		Dimensions		Condition Data	
Element name	Barrels> ( N-S )		Units	m	Units	Sq.m
Element type	Frames - Rigid		Length	53.100	Excellent	0
Material	Cast-in-place concrete		Width	6.000	Good	466
Location	N-S		Height	1.800	Fair	35
Environment	Moderate		Count	1	Poor	9
Protection system			Inspected	Yes	Total Quantity	510
Maintenance needs			Timing:	Performance Deficiencies:		
Recommended work			Timing:			
Comments	Fair - Efflorescence along top of walls. West wall narrow vertical crack with efflorescence. Poor - Soffit has two spalls with exposed rebar and efflorescence. Median CB drains through wall. Scaling throughout - Fair to poor. Soffit delam at inlet, soffit delam/spall at outlet. Delam/spalls at interface, around ditch inlet. Inspected -					
Photo Reference	8, 11, 9, 10, 12, 6, 13, 7					



# STRUCTURE INSPECTION REPORT

Site Number: 16X-0250/C0

Photo #: 1

Outlet



Photo #: 2

Downstream



Photo #: 3

Upstream



Photo #: 5

Wearing Surface



Photo #: 6

East Wall, Spall and Efflorescence



Photo #: 7

Soffit, Delam (2)





# STRUCTURE INSPECTION REPORT

Site Number: 16X-0250/C0

Photo #: 8

Soffit, Delam (3)



Photo #: 9

Soffit, Delam at Inlet



Photo #: 10

Soffit, Shallow Spall (2)



Photo #: 11

Soffit, Spall at Outlet



Photo #: 12

Soffit, Spalls and Delams at Ditch Inlet



Photo #: 13

West Wall, Scaling

