



THURBER ENGINEERING LTD.

**PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 401 WIDENING, HIGHWAY 16 TO MAITLAND ROAD
401W-416N RAMP CULVERT REHABILITATION, SITE NO. 16X-0259/C0
GWP 4024-20-00 / ASSIGNMENT NO. 4019-E-0010.2**

Geocres No.: 31B-102

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 16 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 the W-N Ramp which connects the eastbound lanes on Highway 401 to the northbound lanes on Highway 416. The culvert, Site No. 16-259/C, is located beneath the ramp approximately 45 m south of the south abutment of the Highway 401 Underpass below the W-N Ramp, 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 data from 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); and,
- Letter report prepared by Jacques, Whitford Limited titled, "*Addendum to Jacques Whitford Report No. 10212 dated August 17, 1992, W.P. 374-89-00, Site 16-259 and Site 16-260, Concrete Culverts, Ramps W-N and N-W, Hwy 401/416 Interchange*", dated January 7, 1998 (Geocres No. 31B-67).

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 located near the southern limit of the Highway 401 and Highway 416 Interchange. Johnstown Creek flows roughly from west to east beneath the interchange ramps and Highway 401 to its outlet into the St. Lawrence River at Johnstown. The culvert addressed in this report is located beneath the W-N Ramp connecting Highway 401 eastbound lanes to the Highway 416 northbound lanes. The culvert is approximately 45 m south of the south abutment of the Highway 401 Underpass below the W-N Ramp. For project purposes, the W-N Ramp and culvert are herein described as oriented north-south and east-west, 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. The areas near the culvert inlet and outlet were noted to be poorly drained.

Highway 401 in this area consists of a four-lane divided freeway with paved shoulders and a median barrier and median stormwater system. A guiderail is present along the south side of the highway. The W-N Ramp consists of one travelled lane with partially paved shoulders and guiderails on both sides.

A site visit was carried out on March 29, 2021 to observe the existing conditions. Within the vicinity of the culvert, the embankment side slopes are at approximately 2H:1V and are generally grass-covered, with bushes and small trees growing around the culvert ends. At the time of the site visit, the embankments did not show any visible signs of distress or other performance issues. 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 concrete, twin barrel, rigid frame, closed bottom, box culvert, constructed in 1998. The culvert is approximately 51.2 m long, has a total internal span of 6.0 m, and an approximate internal height of 2.5 m above the stream bed. The culvert structure includes a headwall at each end as well as wing walls in all four quadrants.

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 site visit are included in Appendix D for reference.

3 SITE INVESTIGATIONS AND FIELD TESTING

The original foundation investigation for design of Culvert 16-259/C was carried out in May 1992. An additional field investigation took place in September 1997 following a change in the preferred alignment of the culvert. The current investigation was carried out in April 2021 to collect additional subsurface information near the existing culvert outlet. Summaries of the investigations are provided in the following sections.

3.1 Previous Investigations (1992 & 1997)

Field investigations were carried out as part of the planning and design of the then-proposed Highway 401 and Highway 416 interchange. Borehole 92-3 was put down in May 1992 as part of the first investigation for the subject culvert (Geocres No. 31B-67). Following a realignment of the design of the culvert, Borehole 97-1 was put down as part of a subsequent investigation carried out in September 1997. Both investigations employed a track-mounted CME 55 drill rig to advance the boreholes.

The locations of the boreholes were surveyed by others prior to the initiation of the field work, unless they were subsequently relocated due to site constraints, in which case the as-drilled borehole location was then surveyed.

The northing, easting and elevation of the boreholes 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 locations were originally surveyed relative to NAD27 horizontal datum and have been converted relative to NAD83 in the drawing, on the Record of Borehole Sheets (where appropriate), and in Table 3-1, below.

Table 3-1: Borehole Summary

Borehole No.	Drilled Location	Northing ¹ (Latitude)	Easting ¹ (Longitude)	Ground Surface ² Elevation (m)	Termination Depth (m)
92-3	Inlet (West)	4 956 816.3 (44.746868)	384 857.7 (-75.488981)	84.1	4.0
97-1	Outlet (East)	4 956 831.3 (44.746996)	384 917.7 (-75.488221)	84.3	1.2

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

2) Boreholes were 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 investigations. 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 (2021) Investigation

The current site investigation was carried out in the Spring of 2021. One borehole (Borehole 259-21-1) was put down at the outlet (east side) of the 16-259/C culvert site between April 19 and 20, 2021. The borehole was put down with a Hilti D250 Portable drill rig equipped with tri-cone and rotary diamond drilling equipment.

The location of the 2021 borehole was surveyed by Thurber for both location 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

Borehole No.	Drilled Location	Northing (Latitude)	Easting (Longitude)	Ground Surface Elevation (m)	Termination Depth (m)
259-21-1	Outlet (East)	4 956 812.1 (44.746829)	384 919.7 (-75.488202)	84.6	4.0

Soil samples were obtained using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). As part of the portable rig equipment, a half-weight hammer (32 kg) was used for split spoon sampling. SPT “N” values shown on the Record of Borehole log were adjusted to reflect values that would have been obtained using a hammer of standard weight. Borehole 259-21-1 was advanced approximately 3 m into bedrock, with NQ sized coring equipment. The borehole was backfilled in accordance with MOE requirements (O.Reg 903, as amended).

The drilling and sampling operations were supervised on a full-time basis by a member of Thurber’s 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 and grain size distribution testing of soil samples. All rock cores 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 clay to silty clay on the west side the culvert, overlying a deposit of sandy silt to silty sand which is, in turn, underlain by bedrock consisting of interbedded dolostone and limestone 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 Boreholes 92-3 and 97-1 would likely have been disturbed, altered, or completely removed during the construction of the W-N Ramp and culvert structure.

5.1 Surficial Deposits

At the time of the 1992 investigation, about 300 mm of topsoil was encountered at the ground surface in Borehole 92-3 near the culvert inlet.

5.2 Clay and Sand

A deposit of clay and sand with a trace of gravel was reported beneath the topsoil on the log for Borehole 92-3. The layer was approximately 600 mm thick with a base elevation of 83.5 m. One SPT conducted within this layer gave a value of 1 blow per 0.3 m of penetration indicating a very soft consistency.

5.3 Silty Clay

A native silty clay deposit was encountered beneath the clay and sand deposit in Borehole 92-3. The layer was approximately 1.7 m thick with the bottom of the deposit at Elevation of 81.8 m.

SPT tests conducted within this layer gave N-values ranging from 4 to 10 blows per 0.3 m of penetration. Pocket penetrometer tests carried out on split spoon samples as part of the 1992 investigation indicated a shear strength of about 200 kPa. The silty clay was described as having a firm to hard consistency.

The moisture contents of the two samples tested were 35 and 45%. The results of Atterberg Limits testing carried out on one sample from Borehole 92-3 are summarized below and are illustrated

on Figure C2 Appendix C. The laboratory results indicate that the material is a silty clay of intermediate plasticity (CI).

Summary of Atterberg Limit Testing – Silty Clay

Parameter	Value
Liquid Limit	49
Plastic Limit	21
Plasticity Index	28

5.4 Sandy Silt to Silty Sand

A thin deposit of grey sandy silt was encountered beneath the silty clay in Borehole 92-3. A deposit of brown sand to silty sand, some gravel was encountered at ground surface near the culvert outlet in Borehole 97-1 and Borehole 259-21-1. The thickness of the deposit ranged from 0.2 to 1.2 m with a base elevation ranging from 83.7 to 81.7 m.

An SPT conducted within this layer gave an N-value 21 blows for 0.3 m of penetration, indicating a compact relative density. The deposit was described as loose on the Record of Borehole for 97-1 and compact on the log for Borehole 92-3.

The moisture content of the two samples tested were about 23%. The results of a grain size analysis conducted on a sample of this material from Borehole 259-21-1 are summarized below and are illustrated on Figure C1 in Appendix C.

Summary of Grain Size Distribution Testing – Silty Sand

Soil Particle	Percentage (%)
Gravel	14
Sand	58
Silt	19
Clay	9

5.5 Bedrock

Bedrock was proven by coring at Boreholes 92-3 and 259-21-1 at Elevations of 81.7 m and 83.7 m, respectively. Borehole 97-1 encountered the assumed bedrock surface (inferred based on auger refusal) at Elevation 83.1 m. Based on the subsurface information, the bedrock surface slopes or steps up to the east. The bedrock encountered in the 1992 investigation was described as limy 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 slightly weathered, very strong, grey interbedded sandstone and dolostone. The RQD ranged from 31% to 51%, the Solid Core Recovery (SCR) ranged from 90% to 100%, and the Total Core Recovery (TCR) ranged from 90% to 100%. Photographs of the bedrock cores are provided in Appendix C.



5.6 Groundwater

The groundwater level measured in the standpipe piezometer 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

Borehole No.	Bottom of Screen Elevation (m)	Screened Unit	Depth (mbgs)	Groundwater Elevation (m)	Date of Measurement
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. Marathon Underground of Greely, Ontario supplied and operated the drilling equipment and carried out the drilling, soil sampling, in-situ testing, and borehole decommissioning.

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.

Sarah Harrold, B.A.Sc.
Geotechnical EIT



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



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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-0259/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 the interchange ramps and Highway 401 to its outlet into the St. Lawrence River at Johnstown. The culvert addressed in this report is located beneath the W-N Ramp connecting Highway 401 eastbound lanes to the Highway 416 northbound lanes. The culvert is approximately 45 m south of the south abutment of the Highway 401 Underpass below the W-N Ramp. For project purposes, the ramp and culvert are herein described as oriented north-south and east-west, 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 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 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. 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 original General Arrangement drawing (dated March 1997 and included in Appendix F) shows a culvert consisting of a rigid frame, open-footing, box culvert founded on bedrock. However, based on the recent site visit and the details included in the 2018 OSIM report, the culvert is understood to be a pre-cast concrete, twin-barrel, closed box culvert.

The culvert, constructed in 1998, is approximately 51.2 m long, has an internal height of 2.5 m, and an overall internal span width of 6.0 m (2 x 3.0 m wide barrels). The culvert is constructed at a 20 degree skew from perpendicular to the ramp alignment. Both the inlet and outlet headwalls are roughly parallel to the ramp. Cast-in-place concrete wingwalls are present on both sides of the culvert inlet and outlet and range in length from 5.2 m to 8.5 m.

At the time of the structural inspection outlined in the 2018 OSIM inspection report, the culvert had an internal vertical clearance from creek bottom of about 2.5 m, the water depth was about 0.3 m, and a high-water mark was observed corresponding with a water depth of 1.2 m. During a site visit carried out on May 5, 2021, the creek level was surveyed at Elevation 84.3 m, which was consistent with the historical water level readings. Based on the information above, the creek bed within the culvert is at about Elevation 84.0 m. Considering a nominal stream bed substrate thickness of 0.3 m and a bottom slab with a thickness of 0.5 m, the underside of the closed box culvert would be within 1.5 m of the bedrock surface at the inlet, and at the bedrock surface at the outlet.

It is noted that the 2018 OSIM indicates that the precast units are poorly aligned and that there is evidence of leakage. This special note was first recorded in the 2016 inspection.

7.2 Proposed Work

It is understood that the existing culvert is to undergo structural rehabilitation. It is understood that the details of the works are yet to be decided at this time. 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 likely 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.

It is also 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 (Ψ) of 1.0, as per Table 6.1 of the CHBDC, has been used in assessing factored geotechnical resistances. If this consequence classification changes, the geotechnical assessment and recommendations provided within this report will need to be reviewed and revised.

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

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. At the site, dolostone to sandstone bedrock is present within several metres of the underside the closed box culvert.

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.

Due to the limited thickness of overburden below the foundation, which is assumed to range from about 1.5 m at the inlet to less than 0.1 m at the outlet and the good to excellent quality interbedded dolostone and sandstone bedrock under the footing, as per Table 4.1 of the CHBDC, a Site Class B may be used for preliminary design at the site.



The site classification should be confirmed with measurement of the shear wave velocity in the upper 30 m of the site at a subsequent design stage.

8.3 Seismic Performance Category

In consideration of the Site Class B spectral values for the site and the designated *Major Route* importance category, the culvert structure would fall into either seismic performance category 2, if the culvert has a fundamental period less than 0.5 seconds, or seismic performance category 1, if the culvert has a fundamental period greater than or equal to 0.5 seconds, as per Section 4.4.4 (Table 4.10) of the CHBDC. Assuming that the culvert will have a fundamental period of less than 0.5 seconds and for preliminary design purposes, force-based design (FBD) will be required, as per Section 4.4.5.3.1 (Table 4.11) 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)ⁱ criteria using measured undrained shear strengths. 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)ⁱⁱ. The cohesionless soils anticipated to be below the culvert foundation 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 51.2 m long, has an internal height of 2.5 m, and an overall internal span width of 6.0 m (2 x 3.0 m wide barrels) and an external width of 7.2 m. The underside of the base slab of the closed box culvert would be within 1.5 m of the bedrock surface at the inlet, and at the bedrock surface at the outlet. Given the box culvert is founded on 7.2 m wide footing on up to 1.5 m of firm to hard silty clay overlaying bedrock, 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 (Ψ) 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 native silty clay or bedrock surface prior to construction of the existing culvert.

Resistance to lateral forces/sliding resistance between concrete and underlying material should be evaluated in accordance with the CHBDC assuming an unfactored coefficient of 0.5 or 0.4 for mass concrete on a granular fill leveling pad or the native silty clay, respectively. 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 the underlying material.

Differential culvert settlement has been considered as a cause for the poor alignment of the precast units and associated leakage reported in the 2018 OSIM. Typically, such movements would occur very soon after culvert and embankment placement; they most likely reflect poor subgrade preparation or construction practices (such as excess vibration from compaction or sheet pile extraction).

9.2 Backfill and Lateral Earth Pressures

The available subsurface information at the site from previous investigations was collected prior to construction of the culvert and the 401W-416N ramp. The surficial deposit in Borehole 259-21-1 from the current investigation may represent the embankment fill or the native material. The composition of the backfill placed adjacent to the culvert and headwalls during construction is unknown. However, based on typical practice at the time of construction in 1998 and the recommendations included in the associated Foundation Investigation and Design Report (Geocres No. 31B-67), backfill conforming to OPSS Granular A or Granular B (Type I) has been 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, the corresponding coefficients provided in Table 9-1 and Table 9-2 should be used. Where back slopes are inclined at



approximately 2H:1V (i.e. behind the headwalls and wingwalls) the corresponding coefficients provided in Table 9-1 and Table 9-2 should be used. For other backfill and wall geometries, Thurber will need to calculate the appropriate earth pressure coefficients once the final geometry is confirmed.

9.2.1 Static Lateral Earth Pressure

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

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

where:

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

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

Table 9-1 Static Earth Pressure Coefficients

Condition	OPSS Granular A $\phi = 35^\circ, \gamma = 22 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21 \text{ kN/m}^3$	
	Horizontal Back Slope	2H:1V Back Slope	Horizontal Back Slope	2H:1V Back Slope
Active, K_A (Yielding Wall)	0.27	0.39	0.31	0.47
At Rest, K_o (Non-Yielding Wall)	0.43	0.62	0.47	0.68
Passive, K_P (Movement towards Soil Mass) in front of wall	3.7	10.8	3.3	8.6

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 elements of the headwalls. The box culvert may be assumed to be a rigid structure for calculation of the design earth pressures.

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:

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

The coefficients of horizontal earth pressure for combined static and seismic loading presented in Table 9-2 may be used. The provided earth pressure coefficients are based on a Seismic Site Class B (see Section 8.2) and a PGA with a 2% probability of exceedance in 50 years of 0.21g (Geological Survey of Canada – Fifth Generation) and a $F(PGA)$ of 0.87 as per Table 4.8 of the CHBDC.

Table 9-2 Combined Static and Seismic Earth Pressure Coefficients

Condition	OPSS Granular A $\phi = 35^\circ, \gamma = 22 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21 \text{ kN/m}^3$	
	Horizontal Back Slope	2H:1V Back Slope	Horizontal Back Slope	2H:1V Back Slope
Active, K_{AE} Yielding Wall	0.33	0.57	0.37	0.68
Active, K_{AE} Non-Yielding Wall	0.41	0.82	0.45	0.98

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:

σ_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)
γ	=	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 401W – 416N ramp culvert (Site No. 16X-0259/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 will 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)
- Cofferdams (to support culvert dewatering and or creek diversion)
- Culvert extension(s)
- 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 Sarah Harold, 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 Foundation Projects.

Thurber Engineering Ltd.
Report Prepared By:

Sarah Harrold, B.A.Sc
Geotechnical EIT



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

Paul Carnaffan, P.Eng.
Principal | Branch Manager
Senior Geotechnical Engineer



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



REFERENCES

ⁱ 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.

ⁱⁱ 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.

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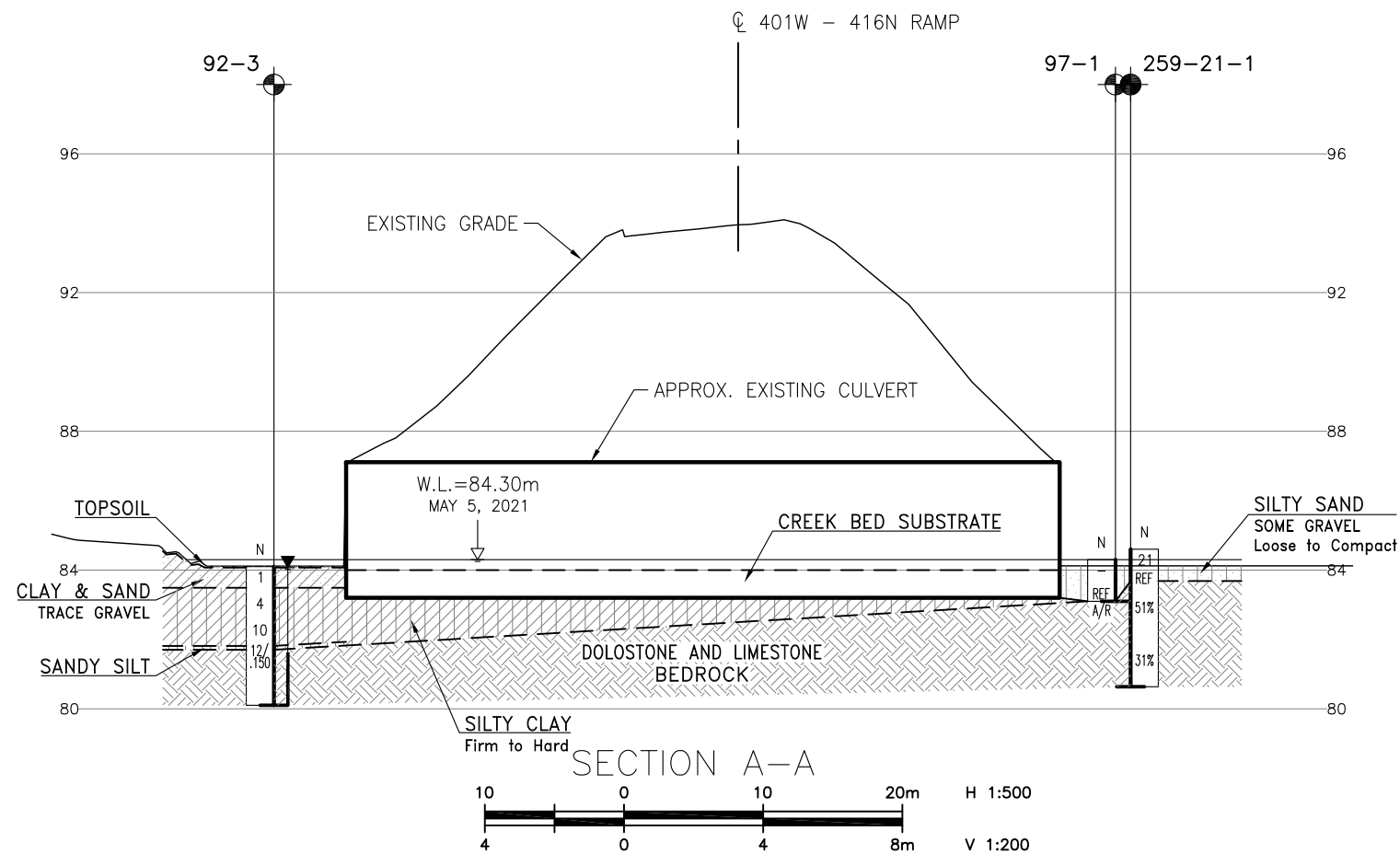
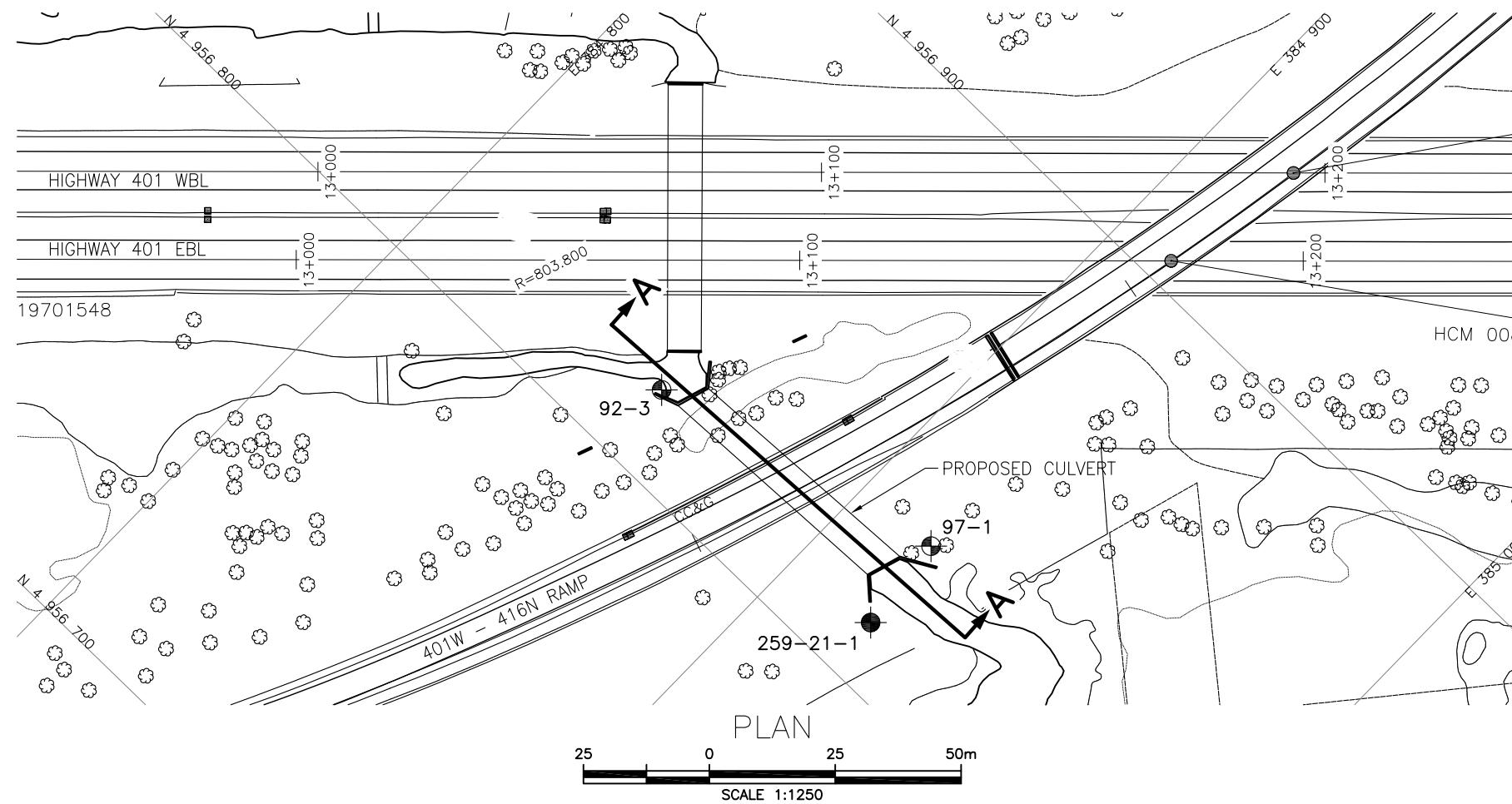
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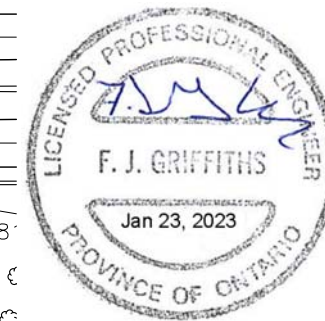


Appendix A.

Borehole Location Plan and Stratigraphic Drawing



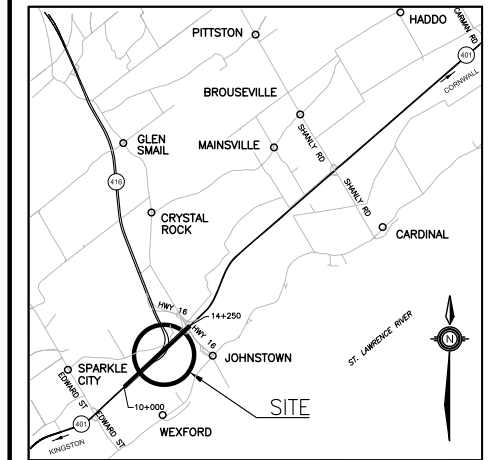
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

HIGHWAY 401
401W - 416N RAMP
CULVERT REHABILITATION
BOREHOLE LOCATIONS AND SOIL STRATA

Ontario 



KEYPLAN

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

[illegible]

-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. 31B-102

REVISIONS							
	DATE	BY	DESCRIPTION				
DESIGN	MJK	CHK -	CODE	LOAD	DATE	JAN 2023	
DRAWN	MFA	CHK MK	SITE 16-259/C	STRUCT	DWG	1	



Appendix B.

Record of Borehole Sheets (Current and 1992/1997 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 259-21-1

1 OF 1

METRIC

GWP# 4024-20-00 LOCATION Lat: 44.746829°, Long: -75.488202° N 4 956 812.1 E 384 919.7 ORIGINATED BY JP
 HWY 401 BOREHOLE TYPE Hilti D250 Portable, Tri-Cone/NQ Coring COMPILED BY SH
 DATUM Geodetic DATE 2021.04.19 - 2021.04.20 CHECKED BY MJK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						
								20 40 60 80 100						
84.6														
0.0	SILTY SAND , some gravel Compact Brown Moist to wet		1	SS	21		84							14 58 19 9
83.7			2	SS	REF								FI	
0.9	Interbedded DOLOSTONE and LIMESTONE Slightly weathered Thinly bedded Grey Fine to medium grained Vertical fracture 3.4 to 3.7 m Very strong		1	RUN			83						2	RUN #1 TCR=90% SCR=90% RQD=51%
													4	
													6	
													4	
													2	
							82						4	UCS = 205 MPa
			2	RUN									3	RUN #2 TCR=100% SCR=100% RQD=31%
													9	
													8	
80.6							81						6	
4.0	End of Borehole Note: 1) A half-weight hammer was used for split spoon sampling. SPT "N" values shown have been adjusted to reflect values that would have been obtained using a hammer of standard weight.													

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

RECORD OF BOREHOLE No 97-1

1 OF 1

METRIC

W.P. 374-89-00 LOCATION Hwy 401/416 Interchange, Johnstown Creek Culvert ORIGINATED BY CL
 DIST 9 HWY 401/416 BOREHOLE TYPE Hollow Stem Auger COMPILED BY CL
 DATUM Geodetic DATE 97.09.18 & CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W _P	W	W _L		
84.3	I		1	BS													
0.0	Loose, brown, SAND, some silt		2	SS		ref											
83.1																	
1.2	End of Borehole Auger Refusal on Inferred Bedrock ref = >50 blows for 150mm																

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 _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	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

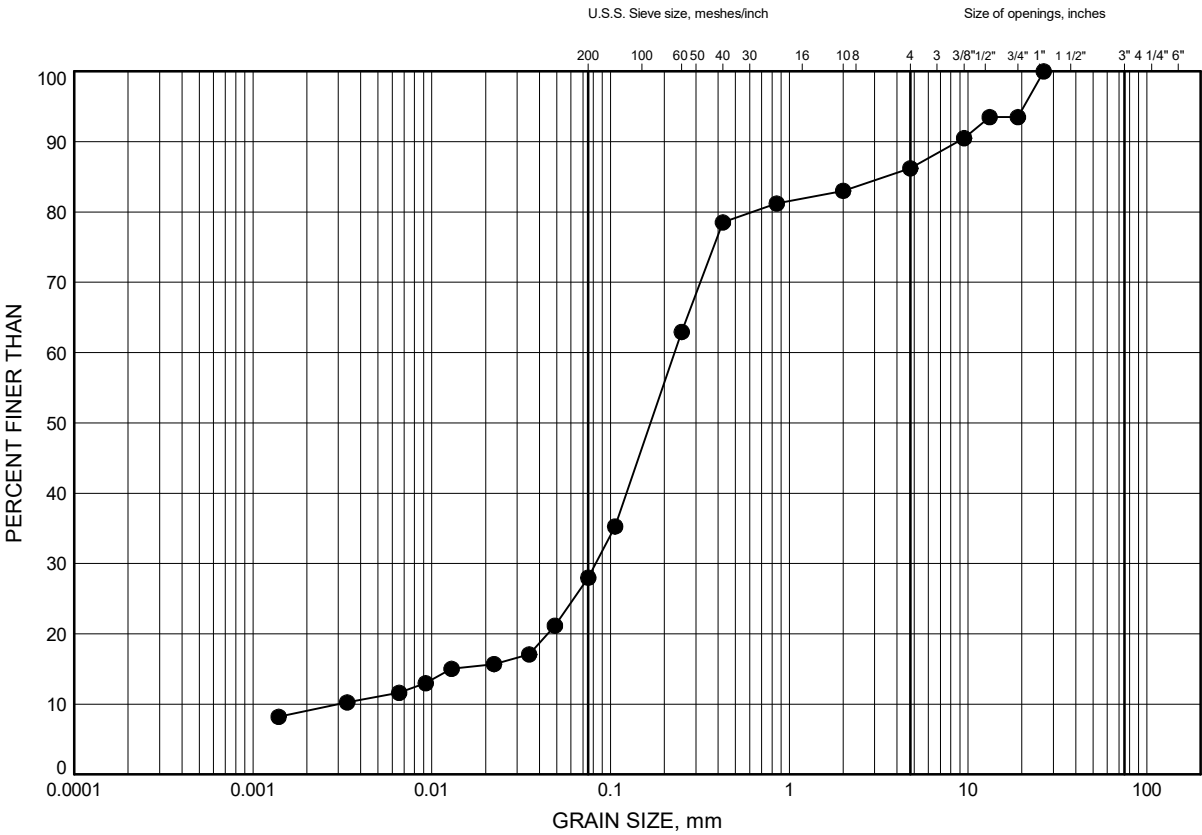


Appendix C.

Laboratory Test Results (Current and 1992/1997 Investigations)

GRAIN SIZE DISTRIBUTION

SILTY SAND, some gravel



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

LEGEND

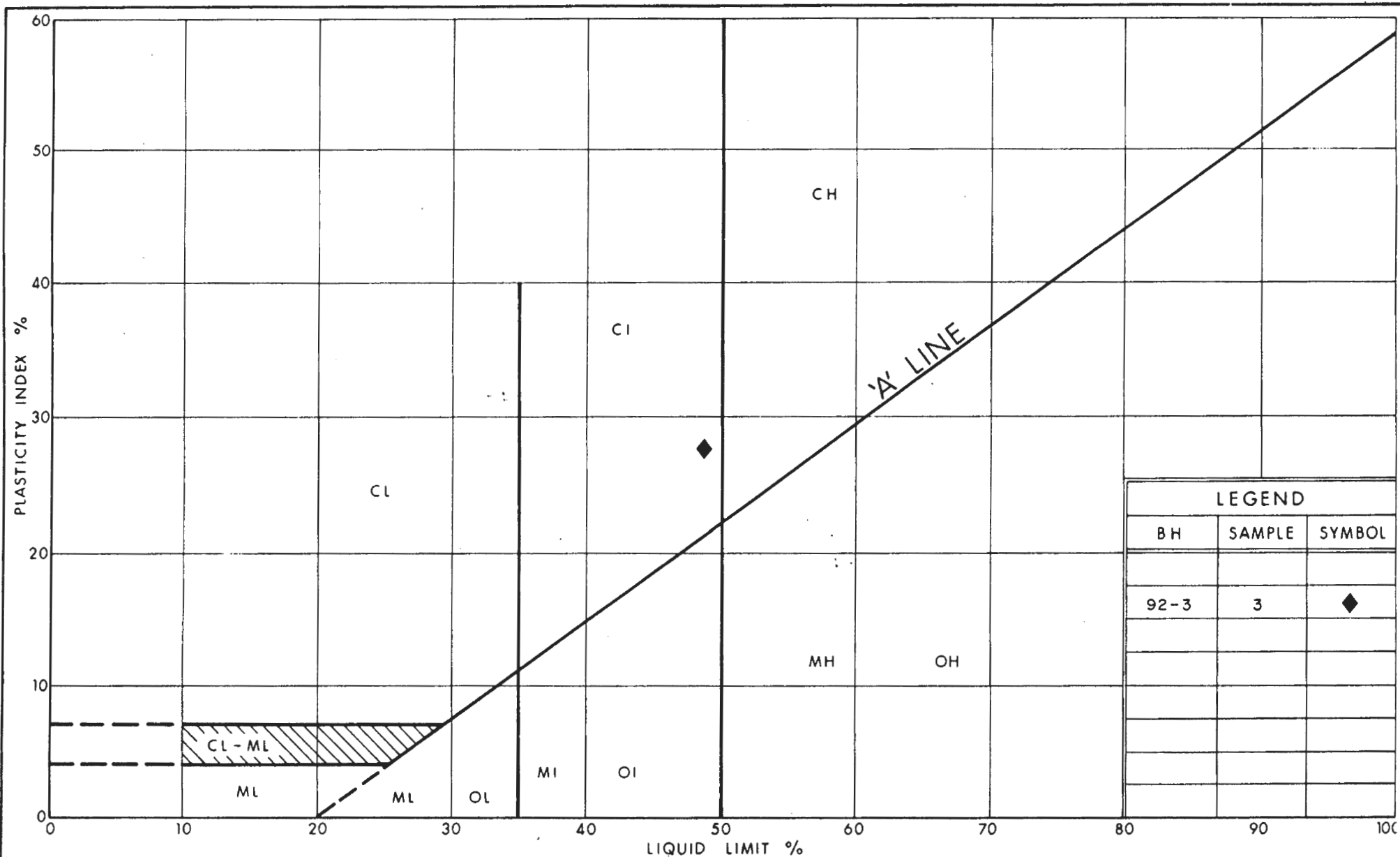
SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	259-21-1	0.3	84.3

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. 2

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

Borehole 259-21-1
Run 1 to 2 (of 2)
Elevation 83.7 m to 80.6 m
Dry



THURBER ENGINEERING LTD.

Highway 401/416 Interchange
Hwy 401W – 416N Ramp Culvert
(Site No. 16X-0259/C0)
Assignment No. 4019-E-0010.2, GWP 4024-20-00

BH 259-21-1
Project No.: 29381

Borehole 259-21-1
Run 1 to 2 (of 2)
Elevation 83.7 m to 80.6 m
Wet



THURBER ENGINEERING LTD.

Highway 401/416 Interchange
Hwy 401W – 416N Ramp Culvert
(Site No. 16X-0259/C0)
Assignment No. 4019-E-0010.2, GWP 4024-20-00

BH 259-21-1
Project No.: 29381



Appendix D.

Site Photographs



Photo 1. Looking southwest at the poorly drained ground and Hwy 401 Underpass of the W-N Ramp (2021/03/29).



Photo 2. Looking south at east (outlet) culvert wingwalls (2021/03/29).



Photo 3. Looking west at east (outlet) culvert headwall (2021/03/29).



Photo 4. Looking north at east (outlet) culvert headwall (2021/03/29).



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 16-259/C

2021-06-08 14:08 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 m/s^2). Peak ground velocity is given in m/s . Values are for "firm ground" (NBCC2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are highlighted in yellow. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. **These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.**

References

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

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

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

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



Natural Resources
Canada

Ressources naturelles
Canada

Canada



Appendix F.

General Arrangement Drawing (1997)

OSIM Structure Inspection Report (2018)

DRAWING FRAME: 790mm X 534mm

STRUCTURE INSPECTION REPORT

401 W - 416 N Ramp Culvert

SITE NUMBER: 16X-0259/C0

INSPECTION DATE: 2018-07-19



STRUCTURE INSPECTION REPORT

Site Number: 16X-0259/C0

LOCATION

Main Highway:	401	Location:	
Region:	Eastern	Latitude:	44.7470656
District:		Longitude:	-75.4885286
Township:	EDWARDSBURGH	LHRS:	47322
Current County:		LHRS Offset:	0.0703277722043225
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-0259/C0

STRUCTURE INFORMATION

Year built:	1998	Interchange number:	
Year Superstruct. Built:		Interchange structure #:	
Structure category:	Closed Culvert	Structure Material 1:	Reinforced Precast Concrete
Structure Type 1:	Box Culvert (Rigid Frame)	Structure Material 2:	
Structure Type 2:			
Apron:			
Headwall:	Yes	Culvert length, m:	51.20
Cut-off Wall:		Direction of structure:	
WingWall:	Yes		
Retaining Wall:		Skew angle, degree:	
Rock fill:		Fill on structure, m:	
No. of Cell:		Load Limit, tonnes:	
Span length, m:	Total=6 (1)=3;(2)=3;		

TRAFFIC INFORMATION ON STRUCTURE

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

CAPTIAL WORK HISTORY

Contract No.	Contract Year	Structure completion year	Work category	Scope of works
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ADDITIONAL INVESTIGATION HISTORY

Date	Additional Investigation	Comments
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APPRAISAL INDICES AND COMMENTS

Fatigue		
Seismic		
Scour		
Flood		
Barrier		
Curb		
Load Capacity		

STRUCTURE INSPECTION REPORT

Site Number: 16X-0259/C0

INSPECTION HISTORY				
Type	Date	BCI	Special Notes	BCI Justification
Regular OSIM	2006-12-12	96.30	limited inspection from ends due to flood--Others in PartyR.S., S.H.	
Regular OSIM	2008-08-06	73.80		
Regular OSIM	2010-06-16	73.50		
Regular OSIM	2012-08-15	71.10		
Regular OSIM	2014-12-08	79.60		Culvert new in 1998 and environment is benign Excellent Condition data increased from 0% to 36%.
Regular OSIM	2016-06-29	77.7	Precast units poorly aligned, evidence of leakage.--Others in PartyMike Colton	
Regular OSIM	2018-07-19		Precast units poorly aligned, evidence of leakage.	

INSPECTION INFORMATION			
Reg. OSIM Freq, yrs	2 year		
Enh. OSIM Freq, yrs	N/A	Inspection year	Even
Inspector	Joel Covert	Inspection duration, hr	0.75
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	2020-07-19
BCI Justification			
Special notes			

OVERALL STRUCTURE NOTES			
Overall Comments:	Precast units poorly aligned, evidence of leakage.		
Recommended Work on Structures:			

STRUCTURE ELEMENT AND CONDITION DATA					
Element group	Embankments & Streams		Dimensions		Condition Data
Element name	Embankments & Streams > Embankments		Units	m	Units Each
Element type			Length		Excellent 0
Material			Width		Good 2

STRUCTURE INSPECTION REPORT

Site Number: 16X-0259/C0

Location		Height		Fair	0
Environment		Count		Poor	0
Protection system		Inspected	Yes	Total Quantity	2
Maintenance needs		Timing:	Performance Deficiencies:		
Recommended work		Timing:			
Comments					
Photo Reference					

STRUCTURE INSPECTION REPORT

Site Number: 16X-0259/C0

Element group	Culverts		Dimensions		Condition Data	
Element name	Inlet Components> (North Headwall)		Units	m	Units	Sq.m
Element type			Length		Excellent	1
Material	Cast-in-place concrete		Width		Good	5
Location	North Headwall		Height		Fair	0
Environment	Benign		Count	1	Poor	0
Protection system			Inspected	Yes	Total Quantity	6
Maintenance needs			Timing:	Performance Deficiencies:		
Recommended work			Timing:			
Comments						
Photo Reference						

STRUCTURE INSPECTION REPORT

Site Number: 16X-0259/C0

Element group	Culverts		Dimensions		Condition Data	
Element name	Barrels> (Twin Barrel)		Units	m	Units	Sq.m
Element type	Frames - Rigid		Length	51.200	Excellent	0
Material	Precast concrete		Width	3.000	Good	1066
Location	Twin Barrel		Height	2.500	Fair	60
Environment	Benign		Count	2	Poor	0
Protection system			Inspected	Yes	Total Quantity	1126
Maintenance needs			Timing:	Performance Deficiencies:		
Recommended work			Timing:			
Comments	Fair - Precast units poorly aligned, evidence of leakage (past report indicated 31 joints leaking) with efflorescence. Poor - Inspected -					
Photo Reference	4, 7, 6, 8, 9, 5					

STRUCTURE INSPECTION REPORT

Site Number: 16X-0259/C0

Element group	Abutments		Dimensions		Condition Data	
Element name	Wingwalls> (Inlet, North)		Units	m	Units	Sq.m
Element type			Length		Excellent	6
Material	Cast-in-place concrete		Width		Good	24
Location	Inlet, North		Height		Fair	0
Environment	Benign		Count		Poor	0
Protection system			Inspected	Yes	Total Quantity	30
Maintenance needs			Timing:	Performance Deficiencies:		
Recommended work			Timing:			
Comments	Good - Poor alignment with east barrel.					
Photo Reference						

STRUCTURE INSPECTION REPORT

Site Number: 16X-0259/C0

Element group	Culverts		Dimensions		Condition Data	
Element name	Outlet Components> (South Headwall)		Units	m	Units	Sq.m
Element type			Length		Excellent	1
Material	Cast-in-place concrete		Width		Good	5
Location	South Headwall		Height		Fair	0
Environment	Benign		Count	1	Poor	0
Protection system			Inspected	Yes	Total Quantity	6
Maintenance needs			Timing:	Performance Deficiencies:		
Recommended work			Timing:			
Comments						
Photo Reference						

STRUCTURE INSPECTION REPORT

Site Number: 16X-0259/C0

Element group	Decks		Dimensions		Condition Data	
Element name	Wearing Surface> (Off Ramp)		Units	m	Units	Sq.m
Element type			Length	8.000	Excellent	0
Material	Asphalt		Width	6.000	Good	48
Location	Off Ramp		Height		Fair	0
Environment	Severe		Count		Poor	0
Protection system			Inspected	Yes	Total Quantity	48
Maintenance needs			Timing:	Performance Deficiencies:		
Recommended work			Timing:			
Comments	Good - Narrow cracks.					
Photo Reference						

STRUCTURE INSPECTION REPORT

Site Number: 16X-0259/C0

Element group	Abutments		Dimensions		Condition Data	
Element name	Wingwalls> (Outlet, South)		Units	m	Units	Sq.m
Element type			Length		Excellent	6
Material	Cast-in-place concrete		Width		Good	24
Location	Outlet, South		Height		Fair	0
Environment	Benign		Count		Poor	0
Protection system			Inspected	Yes	Total Quantity	30
Maintenance needs			Timing:	Performance Deficiencies:		
Recommended work			Timing:			
Comments	Good - Poor alignment with west barrel.					
Photo Reference						

STRUCTURE INSPECTION REPORT

Site Number: 16X-0259/C0

Element group	Embankments & Streams		Dimensions		Condition Data	
Element name	Embankments & Streams > Streams and Waterways		Units	m	Units	All
Element type			Length		Excellent	0
Material			Width		Good	1
Location			Height		Fair	0
Environment			Count		Poor	0
Protection system			Inspected	Yes	Total Quantity	1
Maintenance needs			Timing:	Performance Deficiencies:		
Recommended work			Timing:			
Comments	Good - Debris at Inlet Water depth = 300 mm. High water mark at 1.2 m. Inspected -					
Photo Reference	10					

STRUCTURE INSPECTION REPORT

Site Number: 16X-0259/C0

Photo #: 1

Inlet



Photo #: 2

Outlet



Photo #: 3

Downstream



Photo #: 4

East Cell, Looking South



Photo #: 5

East Cell, Poor Alignment



Photo #: 6

East Cell, Soffit Efflorescence



STRUCTURE INSPECTION REPORT

Site Number: 16X-0259/C0

Photo #: 7

West Cell, Looking South



Photo #: 8

West Cell, East Wall, Shallow Spall



Photo #: 9

West Cell, Soffit, Efflorescence



Photo #: 10

Debris at Inlet

