THURBER ENGINEERING LTD.

DRAFT
FOUNDATION INVESTIGATION AND DESIGN REPORT
PUMPHOUSE CREEK CULVERT, HART TOWNSHIP
HIGHWAY 7044, 7.1 KM SOUTH OF HIGHWAY 144 JUNCTION,
ASSIGNMENT NO. 5019-E-0010.2
GWP 5097-18-00

GEOCRES NO.: TBD

Report to:

MTO Northeastern Region

Latitude: 46.65217°
Longitude: -81.58528°

March 2021
Thurber File No.: 30357

104, 2460 Lancaster Road, Ottawa ON K1B 4S5 T. 613 247 2121 F. 613 247 2185
thurber.ca

THURBER

TABLE OF CONTENTS

PART 1. FACTUAL INFORMATION

PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

APPENDICES

THURBER

DRAFT
FOUNDATION INVESTIGATION AND DESIGN REPORT
PUMPHOUSE CREEK CULVERT, HART TOWNSHIP
HIGHWAY 7044, 7.1 KM SOUTH OF HIGHWAY 144 JUNCTION,
ASSIGNMENT NO. 5019-E-0010.2
GWP 5097-18-00
GEOCRES NO.: TBD

PART 1. FACTUAL INFORMATION

1 INTRODUCTION

This section of the report presents the factual findings obtained from a foundation investigation completed at the Pumphouse Creek Culvert crossing Highway 7044 (Old Carter Road), Site No. 46-0389-C0, in the geographic Township of Hart. Thurber Engineering Limited (Thurber) carried out the current field investigation as a sub-consultant to McIntosh Perry Consulting Engineers (MPCE) under Retainer Agreement No. 5019-E-0010, Work Item No. 2.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, 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 was developed based on the current investigation.

No historical foundation investigation reports were available for this site from the online Geocres Library. However, a Foundation Investigation and Design Report prepared by LVM-Merlex (Geocres No. 41I-336, dated December 22, 2015) for a similar culvert crossing approximately 400 m to the north was retrieved and reviewed as part of the current assignment.

2 SITE DESCRIPTION

Pumphouse Creek follows a meandering alignment roughly parallel to Highway 7044, south of the community of Cartier, Ontario. The creek crosses Highway 7044 several times between its junction with Highway 144 to the north, and its junction with Fox Lake Road approximately 10 km to the south. The existing culvert at the site conveys Pumphouse Creek beneath Highway 7044 approximately 7.1 km south of its junction with Highway 144 in Cartier.

MTO Work Item No. 2 describes the existing culvert as a triple-barrel corrugated steel pipe(s) (CSP) with diameters of 1.2 m, 1.6 m, and 1.2 m. The CSPs have lengths ranging from about 12.0 m to 15.1 m. The culvert alignment is generally east-west, with CSP skew angles of about 3 to 6 degrees from perpendicular, and creek flow toward the west. During the investigation, the ground surface at the existing inverts were measured to be approximately 194.3 m and 194.2 m at the inlet and outlet, respectively.

At the location of the culvert, Highway 7044 is a two-lane, undivided highway. Based on available historical site photographs, it has been assumed that the current asphaltic surface treatment was placed sometime between 2012 and 2016, before which a gravel surface was present. Gravel shoulders are present on both sides of the highway. The embankments are open with no barriers in the vicinity of the creek crossing.

The embankment fill height above the existing CSPs ranges from about 0.7 to 1.0 m. The elevation of the road surface ranges from about 196.7 m at the centreline to about 196.3 m and 196.5 m at the east and west edges, respectively. The existing east and west embankment slopes in the vicinity of the culvert are sloped at about 2.6H:1V and 1.8H:1V, respectively.

Rockfill was observed along portions of the embankment side slopes, along with sparse vegetation. In general, no evidence of significant global or slope instability of the embankments were observed on the exposed slope faces; however, two localized voids within the existing embankment were observed during the investigation on December 11th, 2020. The first void discovered was located near the east edge of the roadway, between the north and central pipes. It extended down and to the west (into the embankment) approximately 1.7 m. Upon further examination of the roadway and embankments, a second void was discovered near the west edge of the roadway, immediately south of the south pipe, and extended down and to the east (into the embankment) approximately 3.7 m.

At the time of discovery of the voids, the field work was halted, and the area management company (Emcon Services Company Inc.) was contacted to repair the voids and resurface the roadway. Field work was resumed on site on January 18th, 2021.

The land adjacent to the highway is generally forested, with bedrock outcrops visible in available aerial photography. From the site, a significant bedrock outcrop is visible some 75 m to 100 m to the east.

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

3 SITE INVESTIGATIONS AND FIELD TESTING

The site investigation and field-testing program was carried out between December 8th and 11th, 2020, and January 18th and 22nd, 2021. The field work consisted of advancing four on-road foundation boreholes identified as 20-01, 20-02, 20-03, and 20-04. The drilling was carried out using a truck mounted CME 55 drill rig.

Borehole 20-03 and the upper 9.1 m of Borehole 20-04 were completed between December 8th and 11th, at which time the embankment voids were discovered, and the field investigation put on hold. The drilling recommenced on January 18th to complete the remaining lower 3.7 m of Borehole 20-04 as well as Boreholes 20-01 and 20-02.

A borehole summary is provided in Table 3-1. The borehole elevations were surveyed with a Leica N3 Close Focus level, with a reported accuracy of +/- 0.2 mm, relative to benchmark No. 1075 provided by the MTO. Horizontal locations were measured relative to existing site features. The site is within MTM Zone 12; however, the coordinates presented in in Table 3-1, on Drawing 1 included in Appendix A, and on the Record of Borehole sheets included in Appendix B are based on horizontal measurements relative to site features and should be interpreted as relative only. Similarly, the elevations presented in in Table 3-1, on Drawing 1 included in Appendix A, and on the Record of Borehole sheets included in Appendix B are relative to a local datum.

Table 3-1 Borehole Summary

Borehole ID.	Location	Northing (m)	Easting (m)	Existing Ground Surface Elevation (m)	Termination Depth Below Existing Ground Surface (m)
Foundation					
20-01	Southbound Lane, North of Existing Culvert	5 168 237.7	259 992.0	196.6	12.8
20-02	Southbound Lane, South of Existing Culvert	5 168 225.2	259 993.6	196.6	12.8
20-03	Northbound Lane, North of Existing Culvert	5 168 227.9	259 998.7	196.6	12.8
20-04	Northbound Lane, South of Existing Culvert	5 168 235.9	259 997.8	196.6	12.8
Survey Benchmark					
No. 1075	Vertical Control Point in Tree Root	5 168 332.3	260 002.1	196.0	N/A

* **Note**: Borehole coordinates and ground surface elevations are relative to a local MTO benchmark No. 1075.

Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations. In all boreholes, soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in accordance with ASTM D 1586. The boreholes where advanced to sampled depths of about 12.8 m below the existing ground surface. All boreholes were terminated in the overburden.

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

Following completion of the field investigation, the boreholes were decommissioned in general accordance with MOE requirements (O.Reg. 903 as amended). The boreholes were capped with granular cuttings and cold patch to reinstate the pavement surface. The boreholes were observed prior to demobilizing from site and no borehole settlement was observed.

The approximate borehole locations are shown on the Borehole Locations and Soil Strata Drawing included in Appendix A. The locations in plan, based on Station and Offset from centreline and elevation of the boreholes are provided on this drawing, Table 3-1, and on the Record of Borehole sheets and on the Pavement Logs included in Appendix B.

4 LABORATORY TESTING

The recovered soil samples were subjected to visual identification and to natural moisture content determination. Selected samples were also subjected to gradation analysis (by sieve). The results of these tests are summarized on the Record of Borehole sheets included in Appendix B. Two samples were selected and submitted for analytical testing of corrosivity parameters and sulphate content. All laboratory test results from the field investigation are provided in Appendix C.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix B and 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 report sections. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description for interpretation of the site conditions. It must be recognized that the soil and groundwater conditions will vary between and beyond the borehole locations.

In general terms, the encountered stratigraphy consisted of roadway embankment fill, underlain by native sand deposits.

Soil classification is in accordance with ASTM D2487 as modified by Section 6.1.2 of the MTO Guideline for Foundation Engineering Services, Version 2.0, October 2020.

5.1 Pavement Structure and Embankment Fill

Prime Surface Treatment

A prime surface treatment (PST) with a thickness of about 25 mm was encountered in boreholes 20-01, 20-03, and 20-04. Borehole 20-02 was put down at the crest of the roadway embankment and did not encounter a prime surface treatment.

Fill: Sand and Gravel

Fill consisting of gravelly sand to sandy gravel with trace to some fines was encountered below the prime surface treatment at Boreholes 20-01, 20-3, and 20-04, and at ground surface at Borehole 20-02. The granular fill contained cobbles in Borehole 20-01 and occasional wood pieces in Boreholes 20-02 and 20-03.

The granular fill was generally 3.0 m to 3.2 m thick, with the exception of at Borehole 20-04 where 4.6 m of granular fill was encountered. The base of the granular fill ranged in Elevation from 193.6 m to 192.0 m.

SPT N-Values in the fill ranged from 12 to greater than 100 blows per 0.3 m of penetration, indicating a compact to very dense relative density. The higher blow counts are likely indicative of sampler refusal on cobbles or boulders. Recorded moisture contents ranged from 1% to 19% in this layer, with one sample that contained wood pieces recording a moisture content of 82%.

The results of gradation analyses completed on one sample of this layer from Borehole 20-04 are illustrated in Figure C1 included in Appendix C. The results are summarized below and are presented on the corresponding Record of Borehole sheet in Appendix B.

<table>
<tr><th>Soil Particle</th><th>Percentage (%)</th></tr>
<tr><td>Gravel</td><td>61</td></tr>
<tr><td>Sand</td><td>37</td></tr>
<tr><td>Silt</td><td rowspan="2">2</td></tr>
<tr><td>Clay</td></tr>
</table>

5.2 Sand with Silt and Gravel

A layer of native sand with varying amounts of fines and gravel was encountered beneath the granular fill in three boreholes. The composition of this upper layer of native sand varied from silty sand with gravel in Borehole 20-01, to sand with silt and gravel in Borehole 20-02, to gravelly sand with silt in Borehole 20-03. This layer seems to transition with depth into the underlying sand deposit, but where encountered the thickness of this layer ranges from 1.6 m to 4.4 m. The base of this layer ranged in Elevation from 192.0 m to 189.0 m.

SPT N-Values recorded within this deposit ranged from 9 to 45 blows per 0.3 m of penetration, indicating a loose to dense relative density. The recorded moisture contents ranged from 4% to 15%.

The results of gradation analyses completed on five samples of the layer are illustrated in Figure C2 included in Appendix C. The results are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B.

<table>
<tr><th>Soil Particle</th><th>Percentage (%)</th></tr>
<tr><td>Gravel</td><td>15 to 42</td></tr>
<tr><td>Sand</td><td>53 to 83</td></tr>
<tr><td>Silt</td><td rowspan="2">3 to 19</td></tr>
<tr><td>Clay</td></tr>
</table>

5.3 Sand

A deposit of sand with only trace amounts of fines and gravel was encountered below the upper sand layer, or below the granular embankment fill (Borehole 20-04). This deposit was encountered at elevations ranging from about 192.0 m to 189.0 m and extended to the termination depth of all boreholes.

SPT N-Values recorded within this deposit ranged from 9 to 57 blows per 0.3 m of penetration but were generally between 10 and 25 indicating a compact relative density. The recorded moisture contents ranged from 5% to 27%.

The results of gradation analyses completed on six samples of the deposit are illustrated in Figure C3 included in Appendix C. The results are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B.

<table>
<tr><th>Soil Particle</th><th>Percentage (%)</th></tr>
<tr><td>Gravel</td><td>0 to 5</td></tr>
<tr><td>Sand</td><td>93 to 99</td></tr>
<tr><td>Silt</td><td rowspan="2">1 to 3</td></tr>
<tr><td>Clay</td></tr>
</table>

5.4 Water Level

Piezometers were not required to be installed to monitor the groundwater level at this site. Since water was introduced into the borehole as part of the drilling/coring process, the water level present in the creek at the culvert inlet and outlet was measured during the field investigation. The measured groundwater levels are summarized in the table below.

Table 5-1 Measured Water Surface Levels

Location	Depth Below Road Grade (m)	Height Above Creek Bottom (m)	Elevation (m)	Date
Culvert Inlet	1.7	0.6	194.9	December 10, 2020
Culvert Outlet	1.8	0.6	194.8	December 10, 2020

It should be noted that fluctuations of the creek and groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation and spring snow melt.

5.5 Results of Analytical Tests

Two soil samples were submitted for analysis of pH, water soluble sulphate and chloride concentrations, resistivity and conductivity. The analysis results are included in Appendix C and are summarized in the following table.

Table 5-2 Analytical Testing

Borehole	20-02	20-04
Sample	SS4	SS4
Depth (m)	2.3 to 2.9	2.3 to 2.9
Elevation (m)	193.7 to 194.3	193.7 to 194.3
Material	Gravelly Sand	Sandy Gravel
Conductivity (µS/cm)	54	234
pH	5.39	6.23
Resistivity (Ohm-cm)	18,600	42,800
Chloride (µg/g)	19	13
Sulphate (µg/g)	31	33

6 MISCELLANEOUS

Borehole locations were selected relative to the existing site features including the existing triple-barrel culvert and anticipated foundation locations. Ground surface elevations at the investigated locations were recorded relative to a benchmark provided by MTO.

Marathon Drillling Ltd. from Greely, Ontario supplied and operated the drill rig to carry out the drilling, sampling, in-situ testing for the borehole drilling and decommissioning. The field investigations were supervised by Nick Weil of Thurber. Overall supervision of the investigation program was conducted by Paul Carnaffan, P.Eng.

Routine geotechnical laboratory testing was carried out by Thurber's geotechnical laboratory in Ottawa, Ontario. Analytical testing was carried out by Paracel Laboratories Ltd. in Ottawa, Ontario. Interpretation of the data and preparation of this report were carried out by Matt Kennedy, P.Eng. The report was reviewed by Dr. Fred Griffiths, P.Eng., a Designated Principal Contact for MTO Foundation Projects.

Thurber Engineering Ltd.
Report Prepared By:

Matt Kennedy, P.Eng.
Senior Geotechnical Engineer

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

DRAFT
FOUNDATION INVESTIGATION AND DESIGN REPORT
PUMPHOUSE CREEK CULVERT, HART TOWNSHIP
HIGHWAY 7044, 7.1 KM SOUTH OF HIGHWAY 144 JUNCTION,
ASSIGNMENT NO. 5019-E-0010.2
GWP 5097-18-00
GEOCRES NO.: TBD

PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This section of the report provides an interpretation of the factual data from Part 1 of this report and presents foundation design recommendations to assist the project team in the design of the proposed culvert replacement on Highway 7044, approximately 7.1 km south of the Highway 144 junction in Cartier, Ontario, in the Township of Hart. The discussion and recommendations presented in this report are based on the information provided by the Ministry of Transportation Northeastern Region (MTO) and on the factual data obtained during the investigation. Thurber Engineering Limited (Thurber) carried out the current field investigation as a sub-consultant to McIntosh Perry Consulting Engineers (MPCE) under Agreement No. 5019-E-0010, Work Item No. 2.

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. The construction or design-build contractor 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.

In general terms, the encountered stratigraphy consisted of granular roadway embankment fill overlying native sand deposits. Bedrock was not encountered with the depth of investigation. The water level in the creek was recorded at about 0.6 m above the existing culvert invert (measured at the middle CSP) on December 10, 2020.

The existing culvert comprises three corrugated steel pipes (CSP) with diameters of 1.2 m (north and south pipes) and 1.6 m (middle pipe). The north, middle, and south pipes are approximately 13.0 m, 15.1 m, and 12.0 m long, respectively. The culvert alignment is generally east-west with the flow through the culvert towards the west. During the investigation, the existing creek bottom elevation, which was roughly level with the invert of the middle pipe, was measured to be at approximate Elevations 194.3 m and 194.2 m at the inlet and outlet, respectively.

At the location of the culvert, Highway 7044 is a two-lane, undivided highway. The embankments are open with no barriers in the vicinity of the creek crossing. The embankment fill height above the existing CSPs ranges from about 0.7 to 1.0 m. The elevation of the road surface ranges from about 196.7 m at the centreline to about 196.3 m and 196.5 m at the east and west edges, respectively. The existing east and west embankment slopes in the vicinity of the culvert are sloped at about 2.6H:1V and 1.8H:1V, respectively.

Previous foundation investigation and design information for the subject culvert was not available from the online Geocres library. However, a Foundation Investigation and Design Report prepared by LVM-Merlex (Geocres No. 41I-336, dated December 22, 2015) for a similar culvert crossing approximately 400 m north was retrieved and reviewed as part of the current assignment.

7.1 Proposed Replacement

Based on correspondence with the designers, it is understood that the triple barrel CSP culvert is to be replaced near the existing culvert alignment and with a similar or lower invert level as the existing triple-barrel CSP culvert (approximate invert elevations to range from 194.0 m to 193.8 m). The existing highway grade and cross-section are to be reinstated. It is also understood that pipe culverts are not preferred at this site as they could pose fishery concerns.

7.2 Applicable Codes and Design Considerations

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

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

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

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 (Sa(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 values are a function of the Site Class, PGA and Sa(0.2). The PGA value at this site provided by GSC for a *reference* Site Class C with a 2% probability of exceedance in 50 years (2475-year event) is 0.06 g. This value is to be scaled by the F(PGA) based on the site-specific Site Class, as discussed below.

8.2 CHBDC Seismic Site Classification and Performance Category

In accordance with the CHBDC, the selection of the seismic site classification is based on the soil within the upper 30 m of the stratigraphy. As per Table 4.1 of the CHBDC, this site has been classified as a Seismic Site Class D based on the harmonic mean of the SPT-N values encountered below the proposed culvert invert. Since the boreholes were terminated at depths of about 12.8 m below the existing road grade, an average SPT-N value of 20 blows per 0.3 m of penetration was assumed in the underlying soil between 12.8 m and 30.0 m depth for assessment of the Seismic Site Class. The Site Class D PGA was calculated to be 0.07 g based on an F(PGA) of 1.29.

It is understood this culvert has an importance category of *Other*. As per Section 4.4.4 of the CHBDC, a seismic performance category 1 is applicable at this site for all structural periods (T).

8.3 Liquefaction Potential

The susceptibility of the cohesionless soils at the site to experience liquefaction was assessed following the simplified method for cohesionless soil as outlined in Boulanger and Idriss (2014)[1]. The soils at this site are not considered susceptible to liquefaction for the design PGA.

9 DESIGN OPTIONS

9.1 Culvert Type and Foundation Alternatives

It is anticipated that the replacement structure selected will have a similar or greater hydraulic capacity as the existing culvert and will lower the creek bed elevation to between 194.0 m and 193.8 m. Selection of the replacement culvert type must consider the proposed construction procedures, staging requirements, geotechnical resistance available in the foundation soils, depth to suitable bearing stratum, and post-construction settlement criteria. From a geotechnical perspective, the following replacement culvert types were considered:

- <u>Closed Pipes (Concrete, HDPE, Steel)</u>
  Pipe culverts are a technically feasible alternative from a foundation engineering perspective. However, multiple circular pipes would be required to provide the same hydraulic capacity as the existing triple-barrel culvert and it is understood that this type of replacement culvert would pose fishery concerns, thus this option is not considered further.

- Closed Bottom Culvert (Box)

  A precast segmental box culvert is considered a feasible option from a foundation engineering perspective. Precast sections, rather than cast-in-place construction, can be installed expediently with less potential for disturbance of the founding soils during installation, requires less excavation depth and more manageable dewatering conditions.

- Open Bottom Culvert (Box, Arch)

  An open bottom culvert is considered feasible at this site from a foundation engineering perspective based on the native soils to be encountered at the footing depth. However, this will require greater excavation to depths below elevation 191.8 m to satisfy frost protection requirements and greater dewatering efforts to construct the culvert in the dry as excavations will be below the creek level. Larger differential settlements should be expected from an open bottom culvert when compared to those from a pipe or closed bottom culverts.

A comparison of these alternatives, based on their respective advantages and disadvantages, is included in Appendix F. It is not considered to be economical or practical to support a culvert on deep foundations, including sheet piles, at this site and therefore this option is not presented in this report.

9.2 Construction Methodology Alternative

For the proposed culvert replacement, the following construction methods were considered.

- Open Cut with Full Road Closure with Traffic Detour

  Installation of a new culvert using open cut techniques and a full road closure would allow for an expedited construction schedule and could reduce costs associated with roadway protection and water control. Highway 7044 is a low volume road so a full road closure could be a feasible alternative provided there is an appropriate detour route available. It is noted that cobbles and boulders were encountered in the embankment fill so excavation equipment should be selected appropriately.

- Open Cut with Staged Temporary Widening

  Widening of the existing highway and/or construction of a temporary detour embankment to accommodate traffic passage during construction is considered feasible from a geotechnical perspective. Widening to the east may be preferred due to the narrower creek bed on the outlet side. However, placement of new fill adjacent to the existing embankment could generate settlement under the footprint of the embankment widening as well as the existing embankment. A review of the environmental acceptability for placing fill near the creek, the requirement for property acquisition and alteration to highway geometry would also be needed to assess this option.

- Open Cut with Staged Replacement and Temporary Protection System

  The use of open cut techniques in conjunction with staged culvert replacement is a feasible construction option from a geotechnical perspective. This option will require roadway protection installed along the embankment centerline to maintain a single lane of traffic flow along the current highway alignment. The Contractor will need to consider the potential for encountering cobbles/obstructions in the embankment fill during the design and installation of roadway protection.

- Trenchless Installation

  Given the presence of cobbles and boulders in the embankment, relatively shallow cover and high water level in cohesionless soils, additional challenges would be met for a trenchless installation at this site. A trenchless installation is therefore not recommended and will not be discussed further in this report.

9.3 Recommended Approach for the Culvert Replacement

From a foundation engineering perspective, the alternative of replacing the existing culvert with a precast segmental closed box culvert using open cut techniques is the recommended culvert replacement option. It is understood that this could be completed with a full road closure or as a staged construction with a temporary protection system.

10 FOUNDATION DESIGN RECOMMENDATIONS

Foundation design aspects for the replacement culvert include subgrade conditions, geotechnical resistances, settlement of the founding soils, imposed loading pressures, erosion control, protection system design, groundwater control, and stability of staged construction. 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.

10.1 Foundation Bearing Resistances

10.1.1 Closed Bottom Box Culvert

A pre-cast segmental closed box culvert should be founded on a bedding layer (see Section 10.2). Subgrade preparation should follow the recommendations provided in Section 10.2 to provide a suitable subgrade for the bedding layer.

Assuming an invert elevation between 194.0 m and 193.8 m, a base slab thickness of 300 mm and a 300 mm bedding layer, the existing soils observed in the foundation boreholes consist of to be fill consisting of dense sand and gravel fill and compact to dense native sand with varying amounts of gravel and silt. A closed box culvert would not need to be founded below the depth of frost (see Section 10.3). For a box culvert with a 5 m width, the design can be based on the factored geotechnical resistance values as follows.

- Factored Geotechnical Resistance at ULS of 450 kPa
- Factored Geotechnical Resistance at SLS of 200 kPa

THURBER

The factored geotechnical resistances include the following factors:

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

The bearing resistance values are for vertical, concentric loading. In the case of eccentric or inclined loading, the bearing resistance must be reduced in accordance with CHBDC Clause 6.10.5. Foundation settlement, based on the supplied SLS resistance, is expected to be up to 25 mm. The bearing resistances provided above are based on the assumption that organic material is not encountered at the subgrade layer. If organic or otherwise deleterious materials are encountered, it will need to be removed down to competent inorganic soils and replaced with well compacted granular fill (see Section 10.2).

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

It is noted that construction will extend below the observed water level. Surface water diversion and dewatering will be required to place the bedding material and install the culvert in the dry. This is discussed further in Section 11.3.

10.1.2 Open Bottom Culvert

An open footed (box or arch) culvert should be founded at or below the depth of frost at the site (Elevation 191.8 m). The existing soils at this depth were observed in the foundation boreholes to consist of compact to dense native sand with varying amounts of gravel and silt. An open footed box culvert with cast-in-place footings with a minimum width of 2 m, can be designed based on the factored geotechnical resistance values as follows.

- Factored Geotechnical Resistance at ULS of 225 kPa
- Factored Geotechnical Resistance at SLS of 150 kPa

The factored geotechnical resistances above are for vertical, concentric loading and include the consequence and geotechnical resistance factors outlined in Section 10.1.1.

Resistance to lateral forces/sliding resistance between cast-in-place concrete and the underlying native soils should be evaluated in accordance with the CHBDC assuming an unfactored coefficient of 0.50 for cast-in-place concrete.

Construction for open bottom culvert footings will extend below the observed water level and surface water diversion and dewatering will be required to place the bedding material and install the culvert in the dry (see Section 11.3).

10.2 Subgrade Preparation, Bedding, Cover and Backfilling

Subgrade preparation for the culvert replacement should include excavation and removal of the existing culvert (assuming replacement along the same alignment) and backfill materials. All organics, existing fill, soft or loose deposits, disturbed soils, alluvial deposits and deleterious materials must be stripped from the footprint of the foundation to expose competent subgrade at or below the desired founding elevations. If winter construction is carried out, the subgrade should be protected from frost.

As soon as practical, the excavation should be backfilled with granular fill consisting of OPSS.PROV 1010 Granular A or Granular B Type II material to protect the subgrade from disturbance during construction and weather. Construction equipment should not travel on the exposed subgrade. The granular fill should be compacted as per OPSS.PROV 501.

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

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

It is anticipated that excavated embankment fill materials free of organics and deleterious materials may be used as culvert backfill. The excavated soils should be properly stored and handled to prevent moisture changes. If winter construction is carried out, snow and/or ice should not be allowed to accumulate. The backfill soils should be compacted in regular lifts as per OPSS.PROV 501.

Heavy compaction equipment used adjacent to and directly above the culvert must be restricted in accordance with OPSS.PROV 501. Care must be exercised when compacting the fill adjacent to and above the culvert in order not to damage the culvert.

10.3 Frost Depth

The frost penetration depth at this site is 2.2 m as per OPSD 3090.100 which is based on MTC Report RR225: Aspects of Prolonged Exposure of Pavements to Sub-Zero Temperatures. It is not necessary to found a pipe or a closed box culvert below the depth of frost penetration. For other footings, if any, a minimum of 2.2 m of earth cover, or thermal equivalent, must be provided above the base of the footing.

10.4 Backfill and Earth Pressure

The lateral earth pressures provided by the equations in the sections below are based on the assumption that the backfill is fully drained so that there are no unbalanced hydrostatic pressures.

If adequate drainage cannot be confirmed, the potential for buildup of hydrostatic pressures should be considered in design.

10.4.1 Static Lateral Earth Pressure

Lateral earth pressures acting on vertical walls should be computed in accordance with the CHBDC and under drained conditions are generally given by the following expression:

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

where:

σ_h	=	static lateral earth pressure on the wall at depth d (kPa)
K	=	static earth pressure coefficient (see table below)
γ	=	unit weight of retained soil (see table below), adjusted below water level
d	=	depth below top of fill where pressure is computed (m)
q	=	value of any surcharge (kPa)

A lateral earth pressure due to backfill compaction should be added to the calculated lateral earth pressure in accordance with Clause 6.12.3 of the CHBDC. Typical earth pressure coefficients for vertical walls for backfill material are shown in Table 10-1.

Table 10-1 Static Earth Pressure Coefficients

Condition	**Earth Pressure Coefficient (K)** **OPSS Granular A or Granular B Type II** **ϕ = 35°, γ = 22.8 kN/m³** **Horizontal Surface Behind Wall**
Active, K_A (Yielding Wall)	0.27
At Rest, K_O (Non-Yielding Wall)	0.43
Passive, K_P (Movement towards Soil Mass)	3.69
Soil Group(*)	"medium dense sand"

Note: (*) For use with figure C6.27 of the Commentary to the CHBDC.

A geotechnical resistance factor of 0.5 (ϕ_{gu}) should be applied in static design to the passive earth pressures in accordance with Table 6.2 of the CHBDC (static analysis - *typical* understanding).

The 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 values to be used in design can be assessed from Figure C6.27 of the Commentary to the CHBDC using the soil group designation as outlined in Table 10-1. Active earth pressures should be used for any head walls or unrestrained walls. For rigid structures such as a concrete box culvert, it is recommended that at-rest horizontal earth pressures be used for design.

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

10.4.2 Combined Static and Seismic Lateral Earth Pressure

In accordance with Clause 6.14.7.2 of the CHBDC (S6-19), structures should be designed using dynamic earth pressure coefficients that incorporate the effects of earthquake loading. The following recommendations are per Section C6.14.7.2 of the Commentary of the CHBDC which states that seismically induced lateral soil pressures may be calculated using Mononobe-Okabe Method with:

- k_h = ½ * F(PGA) * PGA, for structures that allow 25 to 50 mm of movement, and
- k_h = F(PGA) * PGA, for non-yielding walls

The coefficients of horizontal earth pressure for seismic loading are presented in Table 10-2 may be used for vertical walls. The provided earth pressure coefficients are based on a site-adjusted PGA with a 2% probability of exceedance in 50 years of 0.07g using an F(PGA) of 1.29 for Site Class D, as per Table 4.8 of the CHBDC (S6-19).

Table 10-2 Combined Static and Seismic Earth Pressure Coefficients

Condition	Earth Pressure Coefficient (K) – OPSS Granular A or Granular B Type II, $\phi = 35^o$, $\gamma = 22.8\ kN/m^3$ – Horizontal Surface Behind Wall
Active, K_{AE} (Yielding Wall)	0.29
Active, K_{AE} (Non-Yielding Wall)	0.31

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

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

where:

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

10.5 Approach Embankments

10.5.1 Embankment Reinstatement

It is understood that no significant fingrade raise or widening is anticipated along the alignment of Highway 7044, either permanent or temporary. The existing slopes at the location of the culvert were measured during the investigation to range between 1.8H:1V to 2.6H:1V. Rock particles were observed along portions of the embankment side slopes, along with sparse vegetation. In general, the embankment consists of gravelly sand to sandy gravel with occasional to frequent cobbles.

No evidence of recent global embankment slope instability or erosion were noted. However, two voids within the existing embankments were encountered from the road surface during the drilling operations, as described previously in Section 2.

Embankment reinstatement after construction of the replacement culvert should be carried out in accordance with OPSS.PROV 206. If the existing embankment fill is re-used the embankment could be reinstated with side slopes of 2H:1V (or flatter). If constructed using Select Subgrade Material (SSM) or Granular B Type I, the embankment should be reinstated with side slopes of 2H:1V (or flatter). This could result in a larger embankment footprint in some areas. The fill should be placed and compacted in accordance with OPSS.PROV 501. Rock protection lining the side slopes should also be reinstated.

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

10.5.2 Embankment Stability and Settlement

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

As the embankment is to be reconstructed to match the existing pavement elevation, negligible foundation settlement is expected to occur for an embankment to be reconstructed to existing grades. Less than 25 mm of settlement is expected to occur from the construction of the embankment with slopes widened to 2H:1V.

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

10.5.3 Embankment Widening

A foundation investigation was not completed for a temporary detour embankment or embankment widening as part of the current assignment. Further assessment of the existing conditions adjacent to the Highway 7044 embankment should be carried out where construction staging dictates that a embankment widening is needed and additional field investigations with recommendations should be provided.

10.6 Cement Type and Corrosion Potential

Chemical analysis for determination of pH, water soluble sulphate, sulphides, chloride concentrations, resistivity, and electrical conductivity was carried out on samples of the native materials. The analysis results are summarized in Section 5.5 and a copy of the test results is provided in Appendix C.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The test results provided in Table 5-2 were compared with Table 3.2 of the MTO Gravity Pipe Design Guideline and indicate a very low to low corrosive environment. The test results provided in Section 5.5 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with the soil and groundwater at the site. The sulphate results in Table 5-2 were compared with Table 3 of Canadian Standards Association Standards A23.1-19 (CSA A23.1) and indicate a low degree of sulphate attack potential on concrete structures at this site.

The corrosive effects of road de-icing salts should also be considered.

THURBER

11 CONSTRUCTION

11.1 Excavation

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of OHSA, the fill and native cohesionless soils above the water table may be classified as Type 3 soil. The native cohesionless soil below the groundwater level may be classified as Type 4 soil. Where an excavation is within more than one soil type, the entire excavation must meet the requirements of the higher soil type. Unsupported excavations in Type 4 soil must have side slopes no steeper than 3H:1V. Unsupported excavations made in Type 3 soils must have side slopes no steeper than 1H:1V from the base of the excavation.

Excavation for the culvert replacement must be carried out in accordance with OPSS.PROV 401, 421 and 422 and will be carried out through the existing embankment fill and into the underlying native deposits. Please refer to Section 10.4 for backfill recommendations. Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor.

Excavation for installation of a closed box culvert would be required to extend to a depth below the culvert invert that is sufficient to accommodate placement of a suitably prepared granular bedding layer. Excavation for installation of an open footed culvert would be required to extend a significantly greater depth to accommodate frost protection. Greater excavation depth will introduce additional risk and challenges associated with the deeper excavation protection systems that would be required.

Material stockpiling above the existing grades is a temporary construction measure and the associated stability implications are the responsibility of the Contractor. It is recommended that stockpiling or surface surcharge should not be allowed on the embankment or side slopes. The management and disposal of excess material shall be in accordance with OPSS.PROV 180.

11.2 Temporary Protection Systems

Temporary protection systems may be required during various stages of construction and must be implemented in accordance with OPSS.PROV 539 as amended by SP 105S09 and designed for Performance Level 2 (maximum 25 mm horizontal deflection). The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when designing the shoring system.

The design of roadway protection is the responsibility of the Contractor. All protection systems should be designed by a licensed Professional Engineer experienced in such designs and retained by the Contractor. The design of the roadway protection system must incorporate traffic loading and surcharge loading due to construction equipment and operations.

It is recommended that an NSSP be included in the tender documents to alert the Contractor to the rockfill, cobbles, boulders and obstructions within the fill. Nonetheless, sheet piles are considered a feasible option at this site from a geotechnical perspective. A suitable anchoring and/or bracing system may need to be incorporated into the temporary protection design to resist lateral earth pressure loadings.

Lateral earth pressure coefficients, under fully mobilized conditions, that can be used in design of the protection system installed through Granular A material are provided in Table 10 1. The lateral earth pressure coefficients for the existing non-cohesive soils are given below:

Existing embankment fill:

γ = 20 (kN/m^3 bulk unit weight of soil, to be adjusted below water)

K_A = 0.33

K_P = 3.0

Native compact non-cohesive soils:

γ = 20 (kN/m^3 bulk unit weight of soil, to be adjusted below water)

K_A = 0.33

K_P = 3.0

The use of vibration during temporary protection system installation and removal should not be precluded.

11.3 Surface and Groundwater Control

The depth of excavation will extend below the water level observed in the culvert at the time of investigation. Water from surface flow and/or groundwater must be diverted away from excavation(s) at all times. Groundwater perched within the embankment and surface water will tend to seep into and accumulate in excavations. The Contractor must be prepared to control the groundwater and surface water at the site. The water level must be lowered below the base of the excavation to allow placement of the bedding in the dry.

Excavation below the groundwater level to place the bedding layer for a closed box culvert or footings of an open culvert in an open cut without prior dewatering is not recommended since the inflow of creek water and groundwater will make it difficult to maintain a dry, sound base on which to work. Disturbance of the subgrade soils is considered to be a significant risk without proper consideration of groundwater lowering. The groundwater level should be lowered to 0.5 m below the planned base of excavation for each stage of excavation.

Construction of cofferdams will be required to divert flow away from the area of the new culvert. A sand bag cofferdam and sump pumps may be sufficient for the installation of a closed box culvert, depending on the creek flow at the time of construction. A more robust system including steel sheet piles could be considered for a closed box culvert, and would be recommended for construction of an open footed culvert. If sheet piles are selected, it should be noted that the presence of cobbles and boulders in the granular fill may impeded their penetration.

The dewatering system is to be designed in accordance with OPSS.PROV 517 and SP517F01. The Designer Fill-In ***** in SP517F01 Table A should be “No”. A preconstruction survey is not required, thus Designer Fill-In ****** in Table A should be “N/A”.

The water level will fluctuate and the minimum groundwater elevation for the site at the time of the proposed culvert installation should be taken as the expected high water level defined in SP 517F01.

The need for a Permit to take Water (PTTW) should be determined by specialists experienced in this field.

11.4 Scour Protection and Erosion Control

The Contractor should provide silt fences and erosion control blankets as per OPSS.PROV 805 throughout the duration of construction to prevent transport of silt/sediment.

Scour and erosion protection should be provided for the culvert inlet and outlet areas. Design of the scour and erosion protection measures must consider hydrologic and hydraulic concerns and should be carried out by specialists experienced in this field.

Typically, rock protection should be provided over all earth surfaces subjected to flowing water in accordance with OPSS.PROV 511. Treatment at the outlet should be in accordance with OPSD 810.010. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 804.

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

12 CONSTRUCTION CONCERNS

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

- Disturbance of the soil subgrade. Where saturated soils are exposed at the subgrade, these areas will become loosened and may become heavily disturbed when subjected to construction traffic. Site and subgrade drainage will be critical to maintain subgrade condition. Construction traffic must not be allowed on the subgrade. The final subgrade should be protected with bedding granular materials as soon as practicable.
- Large rockfill pieces may be encountered during construction and interfere with excavations. Appropriate equipment should be selected.
- Water levels will fluctuate. A suitable dewatering / unwatering system must be employed to enable control of the groundwater seepage. The Contractor should be prepared to take

appropriate measures to construct the bedding and backfill in a dry and stable environment.

- The Contractor's selection of construction equipment and methodology must include assessment of the capability of the existing soils to support the proposed construction equipment and supplies.

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

THURBER

13 CLOSURE

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

Thurber Engineering Ltd.
Report Prepared By:

Matt Kennedy, P.Eng.
Senior Geotechnical Engineer

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

THURBER

14 REFERENCES

[1] 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.

THURBER

Appendix A.

Drawings

METRIC

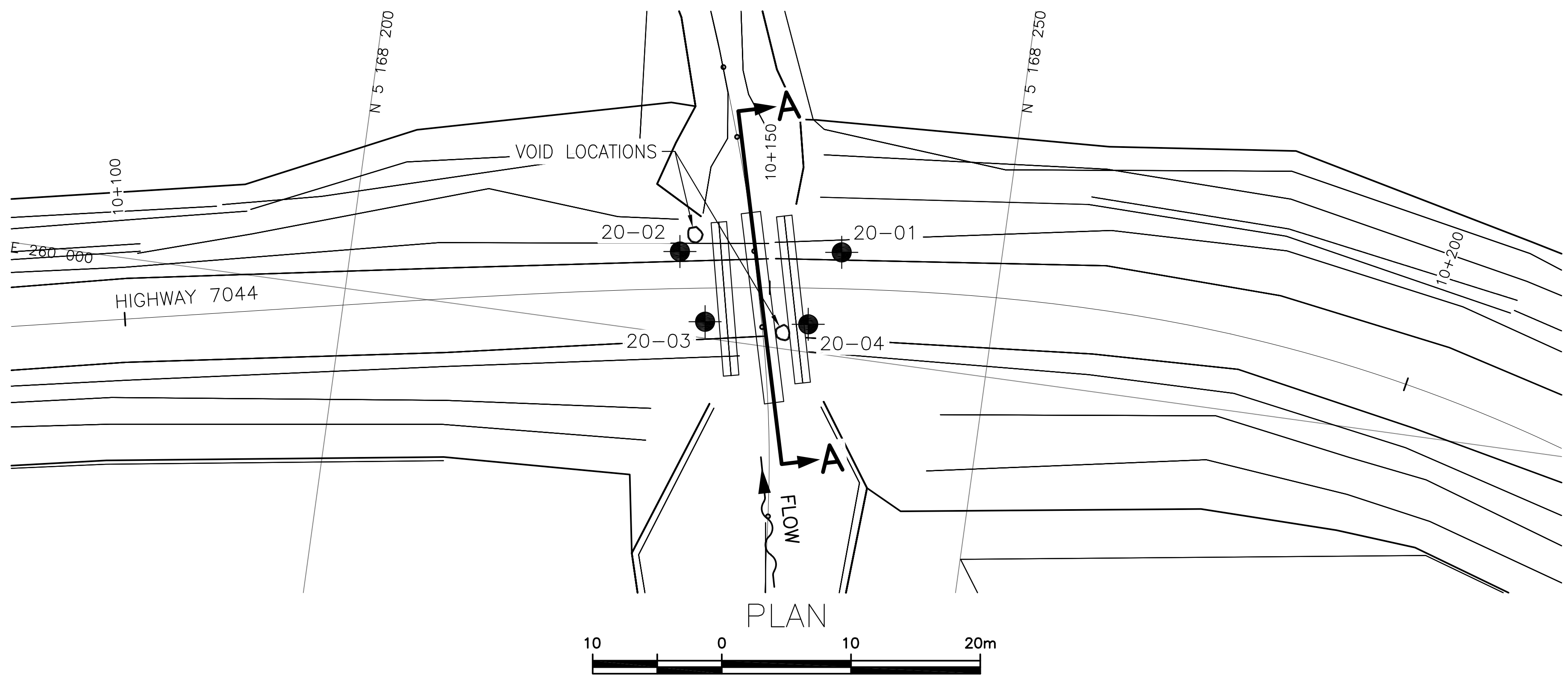
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No
GWP No 5097–18–00

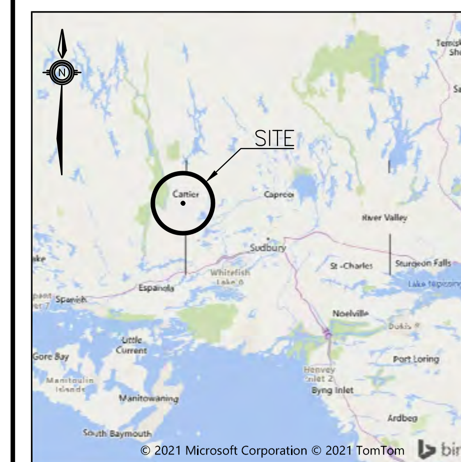
HIGHWAY 7044
PUMPHOUSE CREEK
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

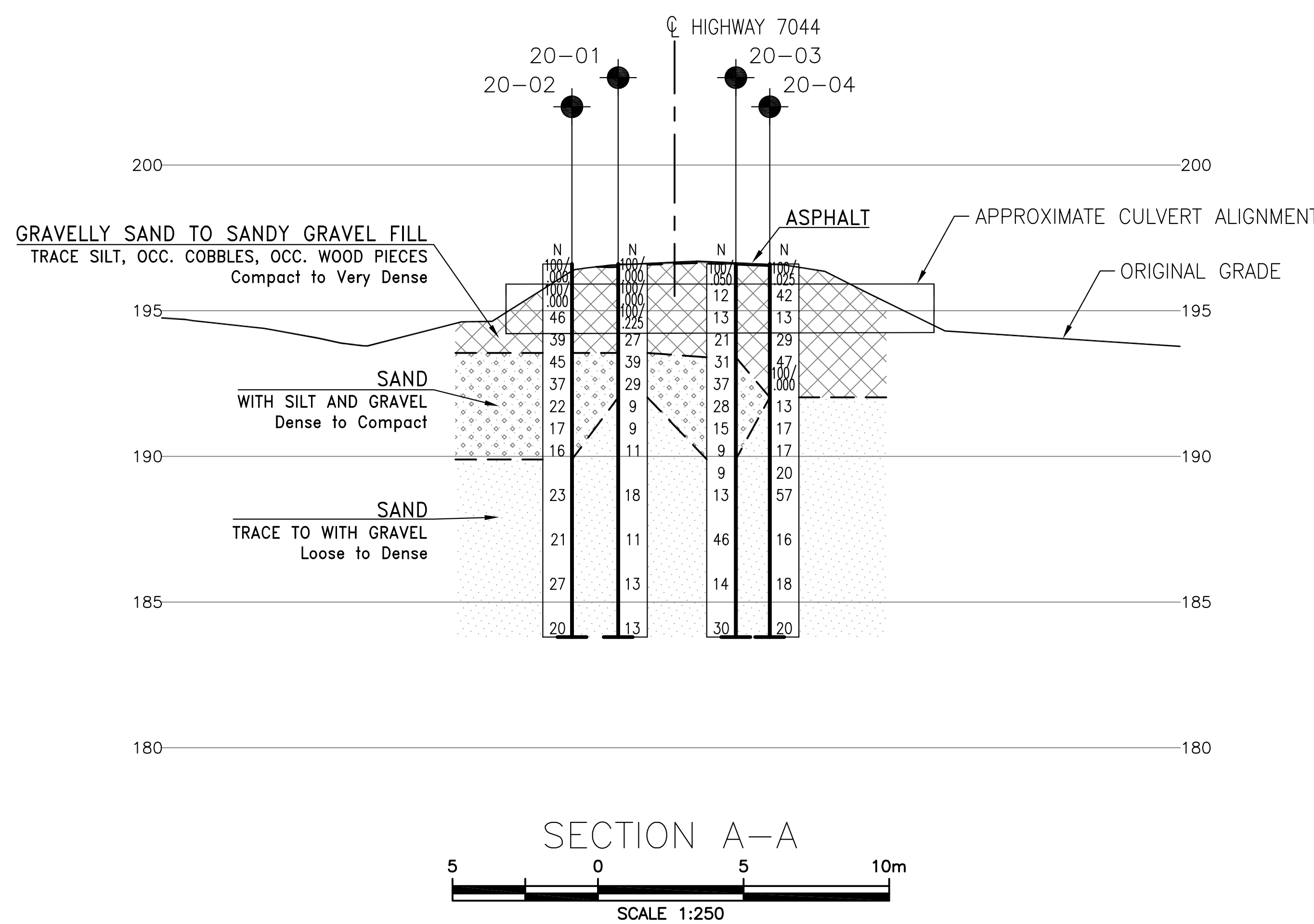
THURBER ENGINEERING LTD.



PLAN



KEYPLAN



SECTION A–A

L E G E N D

●	Borehole
⊕	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
▼	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
20–01	196.6	5 168 237.7	259 992.0
20–02	196.6	5 168 225.3	259 993.6
20–03	196.6	5 168 227.9	259 998.7
20–04	196.6	5 168 235.9	259 997.8

-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) Borehole locations in plan were measured relative to site features and coordinates are approximate only.
4) Coordinate system is MTM NAD 83 Zone 12.

GEOCRES No.

REVISIONS	DATE	BY	DESCRIPTION

DESIGN MJK	CHK –	CODE	LOAD	DATE FEB 2021
DRAWN MFA	CHK MJK	SITE	STRUCT	DWG 1

MINISTRY OF TRANSPORTATION, ONTARIO

FILENAME: H:\Drafting\30000\30357\TED-30357-BHPP.dwg
PLOTDATE: 2/25/2021 4:06 PM

THURBER

Appendix B.

Record of Borehole Sheets

THURBER

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:

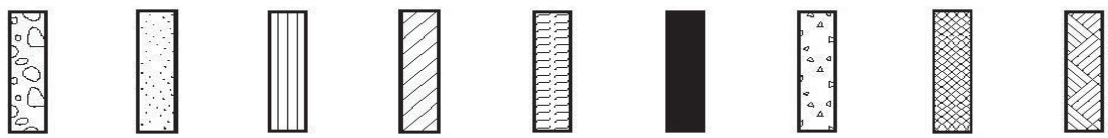
Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 63.5 kg hammer falling 0.76 m, required to drive a 50 mm O.D. split spoon sampler 0.3 m into undisturbed soil. For samples where insufficient penetration was achieved and N-value cannot be presented,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

THURBER

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.



TEXTURING CLASSIFICATION OF SOILS

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

SAMPLE TYPES

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

TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

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

TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

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

THURBER

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

THURBER

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

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

TERMS

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

DISCONTINUITY SPACING

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

STRENGTH CLASSIFICATION

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 20-01

METRIC

GWP# 5097-18-00 | LOCATION Lat: °, Long: ° Hwy 7044 Pumphouse Creek Culvert | ORIGINATED BY NW

HWY 7044 | BOREHOLE TYPE CME55, HSA, Casing w/ Tricone Casing Advancer | COMPILED BY AO

DATUM Local | DATE 2021.01.18 - 2021.01.19 | CHECKED BY MJK

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
196.6	Pavement Surface					
0.0	**ASPHALT SURFACE TREATMENT (25 mm)**	1	SS	100/0"		
	GRAVELLY SAND Trace silt, Brown, Compact, Moist, Contains cobbles (FILL)	2	SS	100/0"	196	
		3	SS	100/13"	195	
		4	SS	27	194	
193.6 / 3.0	**SILTY SAND** With gravel, Grey to brown, Dense to compact, Moist	5	SS	39	193	22 59 19 (SI+CL)
		6	SS	29		
192.0 / 4.6	**SAND** Trace gravel, Brown, Loose, Moist	7	SS	9	192	
191.3 / 5.3	**SAND** Brown, Compact, Wet	8	SS	9	191	2 96 2 (SI+CL)
		9	SS	11	190	
		10	SS	18	189	1 96 3 (SI+CL)
		11	SS	11	188, 187	

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

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

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

DRAFT

DOUBLE LINE 30357 GINT.GPJ 2012TEMPLATE(MTO).GDT 21/2/25

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 20-01

METRIC

GWP# 5097-18-00 | LOCATION Lat: °, Long: ° Hwy 7044 Pumphouse Creek Culvert | ORIGINATED BY NW

HWY 7044 | BOREHOLE TYPE CME55, HSA, Casing w/ Tricone Casing Advancer | COMPILED BY AO

DATUM Local | DATE 2021.01.18 - 2021.01.19 | CHECKED BY MJK

ELEV / DEPTH	DESCRIPTION (Continued From Previous Page)	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND Brown Compact Wet						186				
			12	SS	13				~20		
							185				
			13	SS	13		184		~20		
183.8 / 12.8	End of Borehole										

+3, ×3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 20-02

METRIC

GWP# 5097-18-00
LOCATION Lat: °, Long: ° Hwy 7044 Pumphouse Creek Culvert
ORIGINATED BY NW

HWY 7044
BOREHOLE TYPE CME55, HSA, Casing w/ Tricone Casing Advancer
COMPILED BY AO

DATUM Local
DATE 2021.01.21 - 2021.01.22
CHECKED BY MJK

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
196.6	Pavement Surface					
0.0	**GRAVELLY SAND** Brown Dense Moist Contains wood pieces (FILL)	1	SS	100/0"		
		2	SS	100/0"	○	
		3	SS	46	○	
		4	SS	39		
193.6 / 3.0	**SAND** With silt and gravel Brown Dense to compact Wet	5	SS	45	○	
		6	SS	37	○	
		7	SS	22	○	16 78 6 (SI+CL)
		8	SS	17		
190.5 / 6.1	**SAND** With gravel Brown Compact Wet	9	SS	16	○	15 83 2 (SI+CL)
189.9 / 6.7	**SAND** Brown Compact Wet					
		10	SS	23	○	
		11	SS	21	○	

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (196, 195, 194, 193, 192, 191, 190, 189, 188, 187); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L, WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m^3

Continued Next Page

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 20-02

METRIC

GWP# 5097-18-00	LOCATION Lat: °, Long: ° Hwy 7044 Pumphouse Creek Culvert		ORIGINATED BY NW
HWY 7044	BOREHOLE TYPE CME55, HSA, Casing w/ Tricone Casing Advancer		COMPILED BY AO
DATUM Local	DATE 2021.01.21 - 2021.01.22		CHECKED BY MJK

ELEV / DEPTH	DESCRIPTION (Continued From Previous Page)	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
	SAND Brown Dense to compact Wet						186							
			12	SS	27				o		0	97	3 (SI+CL)	
							185							
			13	SS	20		184		o					
183.8 / 12.8	End of Borehole													

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

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 20-03

METRIC

GWP# 5097-18-00	LOCATION Lat: °, Long: ° Hwy 7044 Pumphouse Creek Culvert		ORIGINATED BY NW
HWY 7044	BOREHOLE TYPE CME55, HSA, Casing w/ Tricone Casing Advancer		COMPILED BY AO
DATUM Local	DATE 2020.12.08 - 2020.12.08		CHECKED BY MJK

Column headings: SOIL PROFILE (ELEV / DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20, 40, 60); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) (GR, SA, SI, CL)

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
196.6	Pavement Surface									
0.0	**ASPHALT SURFACE TREATMENT** (25 mm)	1	SS	100/2"						
	SANDY GRAVEL Compact Brown Moist to wet Contains wood pieces (FILL)	1	GS			○				
					196					
		2	SS	12		○				
					195					
		3	SS	13		○				
		4	SS	21	194	○ 82				
193.4 / 3.2	**GRAVELLY SAND** With silt Compact to dense Grey Wet					○				
		5	SS	31		○				
					193					
		6	SS	37		○				
					192					
		7	SS	28		○	42	52	6 (SI+CL)	
		8	SS	15	191	○				
		9	SS	9		○				
					190					
		10	SS	9		○	35	60	5 (SI+CL)	
189.0 / 7.6	**SAND** Trace gravel Compact to dense Grey to brown Wet				189					
		11	SS	13		○				
					188					
		12	SS	46						
					187					

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

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

DOUBLE LINE 30357 GINT.GPJ 2012TEMPLATE(MTO).GDT 21/2/25

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 20-03

METRIC

GWP#	5097-18-00	LOCATION	Lat: °, Long: ° Hwy 7044 Pumphouse Creek Culvert	ORIGINATED BY	NW
HWY	7044	BOREHOLE TYPE	CME55, HSA, Casing w/ Tricone Casing Advancer	COMPILED BY	AO
DATUM	Local	DATE	2020.12.08 - 2020.12.08	CHECKED BY	MJK

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE)	WATER CONTENT (%) (PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	SAND Trace gravel Compact to dense Grey to brown Wet										
							186				
			13	SS	14				○		3 94 3 (SI+CL)
							185				
			14	SS	30				○		
							184				
183.8 / 12.8	End of Borehole										

DRAFT

DOUBLE LINE 30357 GINT.GPJ 2012TEMPLATE(MTO).GDT 21/2/25

+ 3, × 3: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 20-04

METRIC

GWP# 5097-18-00	LOCATION Lat: °, Long: ° Hwy 7044 Pumphouse Creek Culvert		ORIGINATED BY NW
HWY 7044	BOREHOLE TYPE CME55, HSA, Casing w/ Tricone Casing Advancer		COMPILED BY AO
DATUM Local	DATE 2020.12.09 - 2021.01.18		CHECKED BY MJK

SOIL PROFILE | SAMPLES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100) | SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20, 40, 60, 80, 100) | PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L — WATER CONTENT (%) (20, 40, 60) | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%)

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	GR	SA	SI	CL
196.6	Pavement Surface									
0.0 / 0.0	**ASPHALT SURFACE TREATMENT (25 mm)**		1	SS	100/1"					
	SANDY GRAVEL Dense Brown Moist to wet (FILL)					196				
			2	SS	42					
						195				
			3	SS	13		61	37	2 (SI+CL)	
			4	SS	29	194				
			5	SS	47					
						193				
			6	SS	100/0"					
192.0 / 4.6	**SAND** Trace gravel Compact Grey to brown Wet					192				
			7	SS	13					
			8	SS	17	191	5	93	2 (SI+CL)	
			9	SS	17	190				
			10	SS	20					
						189				
			11	SS	57					
						188				
			12	SS	16	187	0	99	1 (SI+CL)	

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 20-04

METRIC

GWP# 5097-18-00 | LOCATION Lat: °, Long: ° Hwy 7044 Pumphouse Creek Culvert | ORIGINATED BY NW

HWY 7044 | BOREHOLE TYPE CME55, HSA, Casing w/ Tricone Casing Advancer | COMPILED BY AO

DATUM Local | DATE 2020.12.09 - 2021.01.18 | CHECKED BY MJK

ELEV / DEPTH	DESCRIPTION (Continued From Previous Page)	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND Some to trace gravel Compact Grey to brown Wet						186				
			13	SS	18				○ (approx. 22)		
							185				
			14	SS	20		184		○ (approx. 22)		
183.8 / 12.8	End of Borehole										

+ ³, × ³: Numbers refer to Sensitivity

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

Appendix C.

Laboratory Testing

THURBER

Appendix C.1

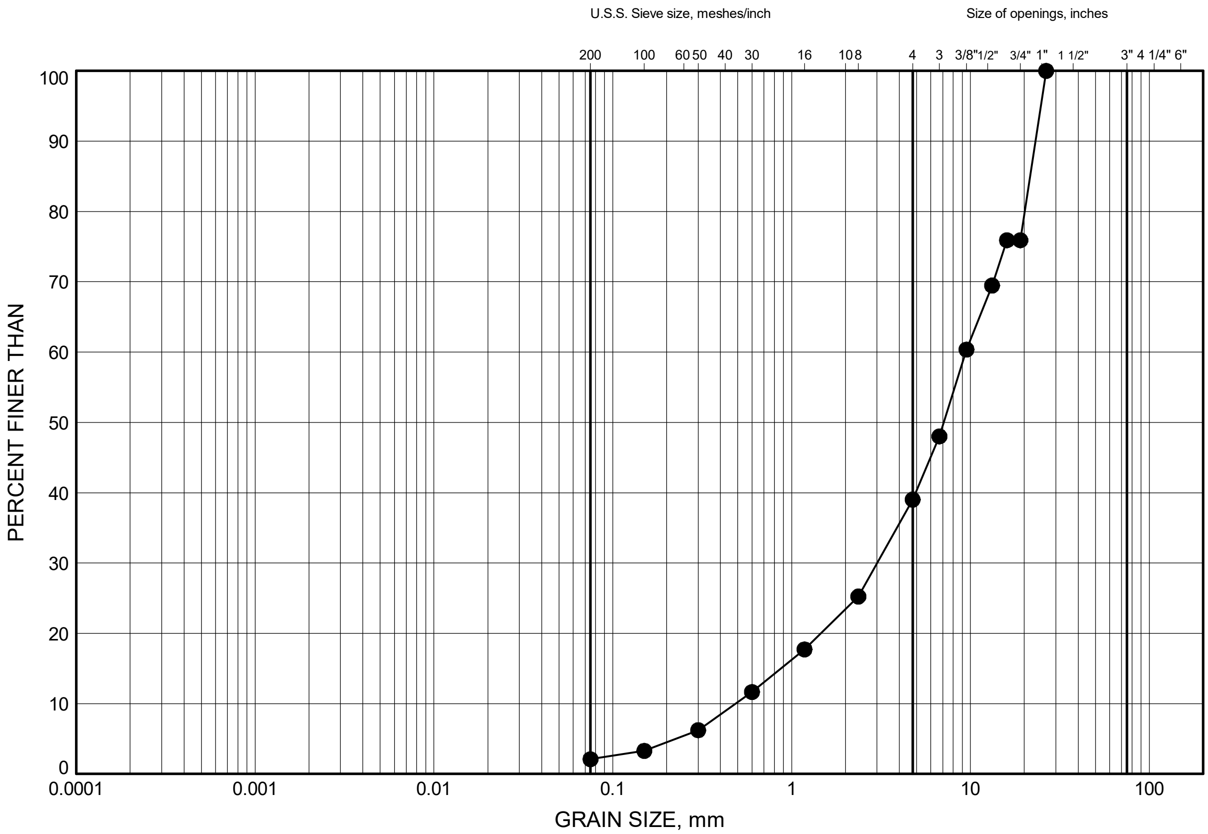
Particle Size Analysis

Hwy 7044 Pumphouse Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE C1

GRANULAR FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	20-04	1.8	194.8

GRAIN SIZE DISTRIBUTION - THURBER 30357 GINT.GPJ 25/2/21

Date February 2021

GWP# 5097-18-00

THURBER

Prep'd SH

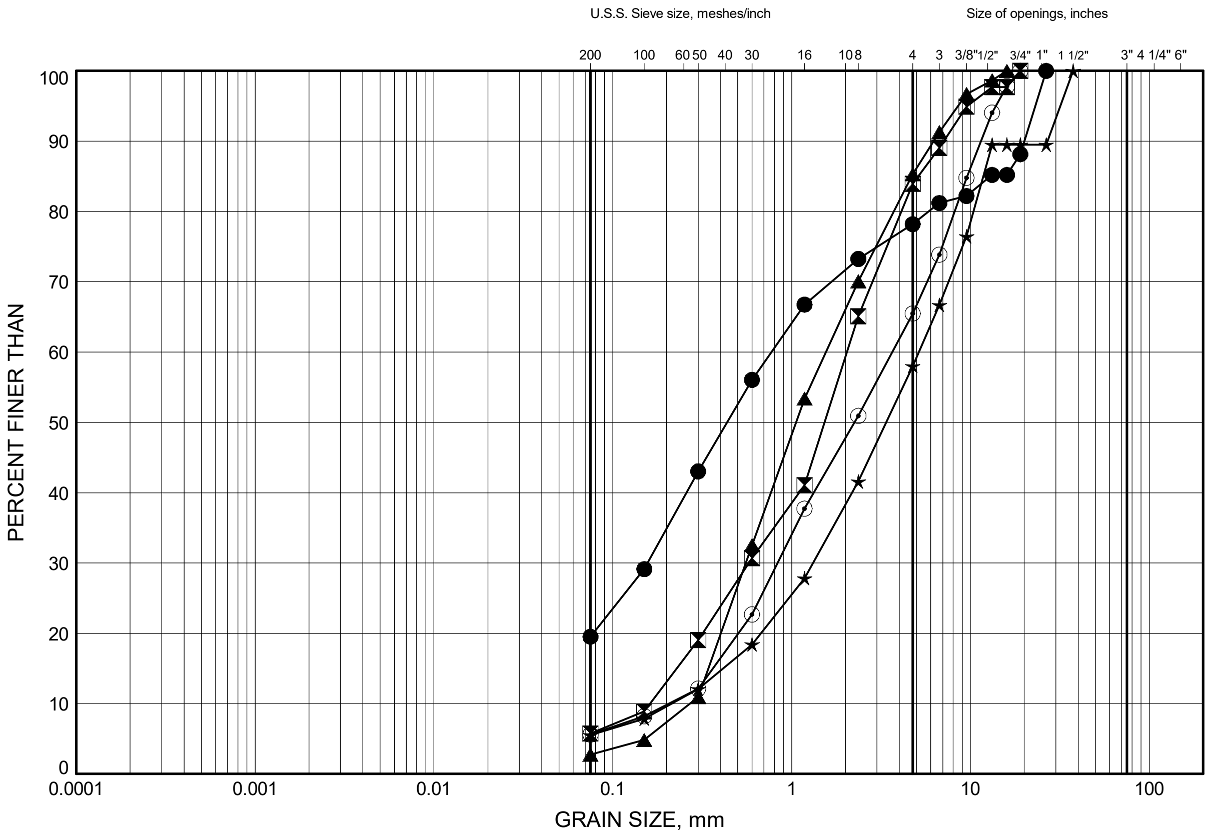
Chkd. MJK

Hwy 7044 Pumphouse Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE C2

SAND WITH SILT AND GRAVEL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	20-01	3.4	193.3
⧗	20-02	4.9	191.8
▲	20-02	6.4	190.2
★	20-03	4.9	191.8
⊙	20-03	7.2	189.5

Date February 2021

GWP# 5097-18-00

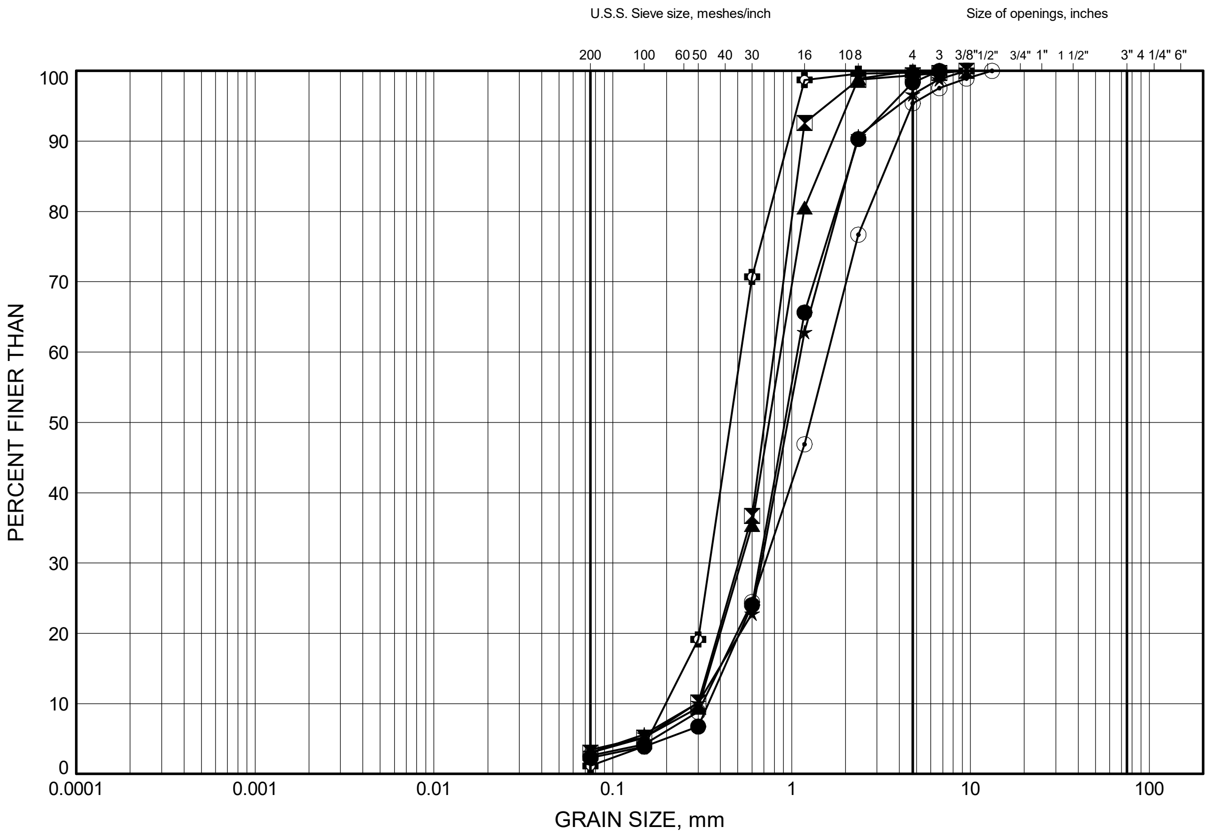
THURBER

Prep'd SH

Chkd. MJK

Hwy 7044 Pumphouse Creek Culvert GRAIN SIZE DISTRIBUTION	FIGURE C3

SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	20-01	5.6	191.0
⧗	20-01	7.9	188.7
▲	20-02	11.0	185.7
★	20-03	11.0	185.7
⊙	20-04	5.6	191.0
✿	20-04	9.4	187.2

Date February 2021

GWP# 5097-18-00

THURBER

Prep'd SH

Chkd. MJK

THURBER

Appendix C.2

Analytical Testing Results

PARACEL LABORATORIES LTD.
TRUSTED. RESPONSIVE. RELIABLE.

300 - 2319 St. Laurent Blvd
Ottawa, ON, K1G 4J8
1-800-749-1947
www.paracellabs.com

Certificate of Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Suite 104
Ottawa, ON K1B4S5
Attn: Matt Kennedy

Client PO:
Project: 30357
Custody: 48667

Report Date: 12-Feb-2021
Order Date: 5-Feb-2021

Order #: 2106574

This Certificate of Analysis contains analytical data applicable to the following samples as submitted:

Paracel ID	Client ID
2106574-01	20-2 SS4 7'6-9'6
2106574-02	20-4 SS4 7'6-9'6

Approved By: Mark Foto

Mark Foto, M.Sc.
Lab Supervisor

PARACEL LABORATORIES LTD.

Order #: 2106574

Certificate of Analysis

Client: Thurber Engineering Ltd.

Client PO:

Report Date: 12-Feb-2021

Order Date: 5-Feb-2021

Project Description: 30357

	Client ID:	20-2 SS4 7'6-9'6	20-4 SS4 7'6-9'6	-	-
	Sample Date:	21-Jan-21 09:00	09-Dec-20 09:00	-	-
	Sample ID:	2106574-01	2106574-02	-	-
	MDL/Units	Soil	Soil	-	-
Physical Characteristics					
% Solids	0.1 % by Wt.	81.2	97.4	-	-
General Inorganics					
Conductivity	5 uS/cm	54 [1]	234 [2]	-	-
pH	0.05 pH Units	5.39 [1]	6.23 [2]	-	-
Resistivity	0.10 Ohm.m	186 [1]	42.8	-	-
Anions					
Chloride	5 ug/g dry	19 [1]	13 [2]	-	-
Sulphate	5 ug/g dry	31 [1]	33 [2]	-	-

PARACEL LABORATORIES LTD.
TRUSTED. RESPONSIVE. RELIABLE.

300 - 2319 St. Laurent Blvd
Ottawa, ON, K1G 4J8
1-800-749-1947
www.paracellabs.com

Subcontracted Analysis

Thurber Engineering Ltd.
2460 Lancaster Rd, Suite 104
Ottawa, ON K1B4S5
Attn: Matt Kennedy

Tel: (613) 247-2121
Fax: (613) 247-2185

Paracel Report No **2106574**
Client Project(s): **30357**
Client PO:
Reference: **Standing Offer**
CoC Number: **48667**

Order Date: 05-Feb-21
Report Date: 12-Feb-21

Sample(s) from this project were subcontracted for the listed parameters. A copy of the subcontractor's report is attached

Paracel ID	Client ID	Analysis
2106574-01	20-2 SS4 7'6-9'6	Sulphide, solid

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

22-February-2021

Paracel Laboratories
Attn : Dale Robertson

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

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

Date Rec. : 09 February 2021
LR Report: **CA15511-FEB21**
Reference: Project#: 2106574

Copy: #1

CERTIFICATE OF ANALYSIS
Final Report

Sample ID	Sample Date & Time	Sulphide (Na2CO3) %
1: Analysis Start Date		16-Feb-21
2: Analysis Start Time		15:10
3: Analysis Completed Date		16-Feb-21
4: Analysis Completed Time		14:22
5: QC - Blank		< 0.04
6: QC - STD % Recovery		106%
7: QC - DUP % RPD		NV
8: RL		0.02
9: 20-2 SS4 7'6-9'6	21-Jan-21	< 0.04
10: 20-4 SS4 7'6-9'6	09-Dec-21	<0.04 UAL

RL - SGS Reporting Limit
NV - No Value
UAL - Unreliable: Sample Age Exceeds Normal Limit
Processed past holding time as per client's instructions.

Kimberley Didsbury,
Project Specialist,
Environment, Health & Safety

OnLine LIMS

0002410073

THURBER

Appendix D.

Site Photographs

THURBER

Photo 1. Looking north on Highway 7044 towards the culvert [December 10, 2020].

Photo 2. Looking south on Highway 7044 towards the culvert [December 10, 2020].

THURBER

Photo 3. Looking west at inlet side of site [December 9, 2020].

Photo 4. Looking south at east embankment slope [December 10, 2020].

Photo 5. Looking south at west embankment slope [December 10, 2020].

Photo 6. Culvert inlet, looking northeast [December 10, 2020].

Photo 7. Culvert outlet, looking west [December 10, 2020].

THURBER

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: 46.652N 81.585W **User File Reference:** Hwy 7044, Pumphouse Cr Culvert (46-0389-C0) 2021-01-27 15:14 UT

Requested by: Matt Kennedy, P.Eng., 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)	0.069	0.041	0.025	0.008
Sa (0.1)	0.096	0.059	0.038	0.013
Sa (0.2)	0.094	0.061	0.040	0.015
Sa (0.3)	0.081	0.053	0.036	0.013
Sa (0.5)	0.067	0.044	0.030	0.010
Sa (1.0)	0.041	0.027	0.018	0.005
Sa (2.0)	0.021	0.013	0.008	0.002
Sa (5.0)	0.005	0.003	0.002	0.000
Sa (10.0)	0.002	0.001	0.001	0.000
PGA (g)	0.055	0.034	0.022	0.007
PGV (m/s)	0.054	0.033	0.021	0.006

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

References

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

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

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

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

THURBER

Appendix F.

Foundation Comparison

THURBER

Comparison of Alternative Foundation Types

Circular Pipe Culvert	Closed Box Culvert	Open Bottom Culvert
Advantages		
- Readily available materials and simpler installation methods - Can tolerate larger magnitude of settlement than rigid culverts	- Relatively expedient installation if precast units are used - smaller magnitude of settlement than open footing culvert	- Relatively expedient installation if precast units are used - Can span existing culvert if needed to stay out of the existing water course
Disadvantages		
- Requires large excavation - Requires protection systems or road closure - Requires compacted granular pad - Would require multiple barrels to match existing flow capacity	- Requires large excavation - Requires protection systems or road closure - Requires compacted granular pad	- Requires deeper excavation - Greater dewatering concern - Potential for post construction settlements and differential settlements
Risk/Consequences		
- Potential for base disturbance	- Potential for base disturbance - Groundwater control may require sheet pile enclosed excavation	- Groundwater control may require sheet pile enclosed excavation - Increased risk of basal instability of footing excavation due to depth of excavation below water level
Relative Cost		
Moderate	Moderate	Moderate
Recommendation		
Recommended	**Recommended**	**Not Recommended**

THURBER

Appendix G.

List of Referenced Specifications

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

OPSD 208.010	Benching of Earth Slopes
OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less than or Equal to 3.0m
OPSD 803.031	Frost Treatment – Pipe Culverts Frost Penetration Line Between Top of Pipe and Bedding Grade
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.100	Foundation Frost Depths for Northern Ontario
OPSS.PROV 180	Construction Specification for the Management of Excess Materials
OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 511	Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting
OPSS.PROV 517	Construction Specification for Dewatering
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS.PROV 805	Construction Specification for Temporary Erosion and Sediment Control Measures
OPSS.PROV 401	Construction Specification for Trenching, Backfilling and Compacting
OPSS.PROV 421	Pipe Culvert Installation in Open Cut
OPSS.PROV 422	Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cut
OPSS.PROV 902	Construction Specification for Excavating and Backfilling Structures
OPSS.PROV 1010	Material Specification for Aggregates Base, Subbase, Select Subgrade, and Backfill Material
OPSS.PROV 1205	Material Specification for Clay Seal
OPSS.PROV 1860	Material Specification for Geotextiles
SP 517F01	Amendment to OPSS 517 - Construction Specification for Dewatering

2. Suggested text for a NSSP on “Buried Obstructions”

“The contractor is advised that rockfill was encountered on the embankment side slopes and within the embankment fill and will be encountered during excavation. Such obstructions may impede the work from reaching design depth of installation. The constructor shall be prepared to remove/dislodge, drill through and/or penetrate these obstructions and extend the work to the design depths."