



**THURBER** ENGINEERING LTD.

**FINAL**  
**FOUNDATION INVESTIGATION AND DESIGN REPORT**  
**HIGHWAY 118 CULVERT STA. 18+874, DRAPER TOWNSHIP**  
**ASSIGNMENT NO. 5017-E-0003**

**G.W.P. 5287-14-00**

Geocres No.: 31E-401

Report to:

**McIntosh Perry Consulting Engineers Limited**

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**PART 1. FACTUAL INFORMATION**

**1 INTRODUCTION**

This section of the report presents the factual findings obtained from a foundation investigation completed for a culvert at Sta. 18+874 on Highway 118. The culvert crossing is located approximately 150 m east of River Road within Draper Township in the District of Muskoka. Thurber Engineering Limited (Thurber) carried out the current field investigation as a sub-consultant to McIntosh Perry Consulting Engineers Ltd. (MPCE) under Assignment No. 5017-E-0003.

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 was developed in the course of the current investigation.

No previous foundation investigation information was available for the subject culvert site within the online Geocres Library. A Project Assessment Report (PAR) and a historical base plan survey drawing were provided by MPCE.

**2 SITE DESCRIPTION**

For project purposes, Highway 118 will be considered to be oriented east-west with chainage increasing to the east. The existing culvert conveys (unnamed) creek flow from the south to the north under a high fill embankment supporting Highway 118. As described on the historical base plan drawings provided by MCPE, the existing culvert is a non-structural corrugated steel pipe (CSP) culvert with a diameter of 0.8 m and a length of 27.2 m. The invert of the culvert is at approximate elevation 299.8 and 297.5 m at the inlet (south) and the outlet (north), respectively. No signs of erosion or slope instability were noted on the existing highway embankments during the field investigation. The roadway surface over the culvert was generally in good condition with no dips or bumps noted during the field investigation. The existing culvert, as assessed by MPCE, showed some signs of corrosion

and the exposed south end of the culvert had substantial sediment and overgrowth.

At the location of the culvert, Highway 118 is a two-lane highway with paved shoulders. The Highway 118 fill height above the culvert varies along its length and ranges from approximately 4.8 to 7.1 m with the road surface at approximate elevation 305.6 m. The existing embankment slopes are inclined at approximately 1.8H:1V and 1.5H:1V to the north and south, respectively. Cobbles and boulders were observed on the embankment slopes. Cable guiderails with wooden posts are present on both sides of the highway in the vicinity of the culvert. The water level in the Muskoka River, which is located 50 m northwest of the culvert outlet, is controlled by a dam at Matthiasville Falls. The land adjacent to the highway and creek alignment is densely vegetated with shrubs and predominately coniferous trees. Single family dwellings are located approximately 150 m west of the culvert on River Road. Bedrock outcrops and rock cuts are present within close proximity to the culvert site. Overhead utility lines run parallel to the south side of the highway. Traffic volumes on this section of Highway 118 are understood to be 4,300 AADT (2016).

Select photographs showing the existing conditions in the area of the culvert at the time of the field investigation are included in Appendix D for reference.

### **3 SITE INVESTIGATION AND FIELD TESTING**

The site investigation and field testing program was carried out between September 18<sup>th</sup> and 20<sup>th</sup>, 2018. The field investigation consisted of advancing four boreholes identified as 18-1 through 18-4. The drilling was carried out using portable equipment for off-road boreholes 18-1 and 18-4 and a truck mounted CME 75 drill rig for the on-road boreholes 18-2 and 18-3. Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations.

The northing, easting and elevation of the boreholes are 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 3-1. The termination depth of each of the boreholes is also provided, below. The site is within MTM Zone 10. The borehole elevations were surveyed with a Nikon-AP-8 with an accuracy of +/- 1.5 mm. The survey referenced the top of the south end of the culvert which has an elev. 300.792 m, as provided by MPCE. Horizontal locations were measured relative to existing site features.

**Table 3-1: Borehole Summary**

<b>Borehole No.</b>	<b>Drilled Location</b>	<b>Northing (*) (m)</b>	<b>Easting (*) (m)</b>	<b>Ground Surface Elevation (m)</b>	<b>Termination Depth below the Existing Ground Surface (m)</b>
18-1	Near Culvert Outlet	4 983 722.8	328 868.7	295.3	4.1
18-2	Westbound Lane HWY 118	4 983 707.6	328 878.9	305.6	10.8
18-3	Eastbound Lane HWY 118	4 983 704.8	328 886.2	305.6	13.0
18-4	Near Culvert Intlet	4 983 693.8	328 888.6	300.5	4.3

Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) following ASTM D1586. A half-weight (32 kg) hammer was used during SPT testing in Boreholes 18-1 and 18-4, which were drilled with portable equipment. The N-values reported herein for these off-road boreholes have been adjusted to an equivalent standard weight hammer (64 kg). A standard weight hammer was used during SPT testing for the on-road boreholes and no correction was necessary. All boreholes were advanced into bedrock with either NW or NWT casing in conjunction with coring techniques

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

A 19 mm diameter standpipe piezometer was installed in Borehole 18-4 to allow for measurements of the groundwater level after completion of drilling. The piezometer installation details are illustrated on the respective Record of Borehole sheet provided in Appendix B. The boreholes were backfilled in accordance with MOE requirements (O.Reg. 903, as amended). Boreholes 18-2 and 18-3 were backfilled with granulars within the depth of pavement structure and capped with 150 mm of cold patch asphalt to reinstate the traveling surface.

## **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 (hydrometer and/or sieve) and Atterberg Limit testing. The results of these tests are summarized on the Record of Borehole sheets included in Appendix B. One sample of soil recovered from within each of Boreholes 18-2 and 18-4 was selected and submitted for analytical testing of corrosivity parameters. Select rock core samples underwent unconfined compression strength testing. Laboratory test results are provided 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 paragraphs. However, the factual data presented on the Record of Borehole sheets 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.

In general terms, the site was found to be underlain by a pavement structure over sand and silt fill layers overlying deposits of organic silt over glacial till. Granite bedrock was encountered at varying elevations within the depth of investigation in all boreholes.

### **5.1 Embankment**

#### **5.1.1 Asphalt**

Boreholes 18-2 and 18-3 were drilled through the existing Highway 118 embankment and encountered a layer of asphalt with a thickness of 100 mm at ground surface.

#### **5.1.2 Silty Sand with Gravel (Fill)**

Below the asphalt in Boreholes 18-2 and 18-3 was a pavement granular layer consisting of silty sand with gravel. The thickness of this fill was at 0.5 m with a base elevation of 305.0 m.

The SPT tests conducted in the fill gave N-values of 23 and 54 blows, indicating a relative density of compact to very dense. Recorded moisture contents were 5 and 6%.

#### **5.1.3 Sand with Silt (Fill)**

Below the silty sand with gravel fill in Boreholes 18-2 and 18-3 was a fill layer consisting of sand with silt. Cobbles and boulders were encountered below a depth of 2.1 m in Borehole 18-3. Coring was required to get through this layer containing cobbles and boulders. The thickness of the fill ranged from 3.1 to 3.4 m with an underside depth of 3.7 to 4.0 m below

the existing roadway surface (elev. 301.9 to 301.6 m) in Boreholes 18-2 and 18-3, respectively.

The SPT tests conducted in the sand with silt fill gave N-values of 8 to 59 blows, indicating a relative density of loose to very dense.

Recorded moisture contents ranged from 12 to 19%. The results of a grain size analysis conducted on one sample of the sand fill indicated this material to consist of 1% gravel, 93% sand and 6% fines. These results are illustrated on Figure C1 in Appendix C.

#### **5.1.4 Silt with Sand (Fill)**

A layer of fill consisting of silt with sand with trace to some organics was encountered below the sand fill in Boreholes 18-2 and 18-3. The silt fill was 2.4 to 1.3 m thick with an underside depth at 6.1 and 5.3 m below the existing roadway surface (elev. 299.5 and 300.3 m) in Boreholes 18-2 and 18-3, respectively.

The SPT tests conducted in the silt with sand fill gave N-values ranging from 7 to 23 blows, indicating a relative density of loose to compact.

Recorded moisture contents ranged from 12 to 35%. The results of a grain size analysis conducted on one sample of the silt fill indicated this material to consist of 1% gravel, 28% sand, 68% silt and 3% clay. These results are also illustrated on Figure C1 in Appendix C.

An Atterberg Limit test was completed on one sample of the silt with sand fill and indicated that the material is non-plastic.

## **5.2 Organic Sandy Silt (OL)**

A native deposit of organic sandy silt was encountered below the silt fill in Boreholes 18-2 and 18-3. The organic sandy silt deposit was 0.9 to 1.4 m thick with an underside depth at 7.0 and 6.7 m below the existing roadway surface (elev. 298.6 and 298.9 m) in Boreholes 18-2 and 18-3, respectively.

SPT tests conducted in the organic sandy silt gave N-values ranging from 5 to 6 blows, indicating a loose relative density.

Recorded moisture contents of the organic sandy silt ranged from 33 to 54%. The results of a grain size analysis conducted on one sample of the organic silt indicated this material to consist of 1% gravel, 34% sand, 58% silt and 7% clay. These results are illustrated on Figure C2 in Appendix C.

An Atterberg Limit test was completed on one sample of the organic sandy silt deposit and indicated that the material is non-plastic. Organic contents were measured at 10.5 and 10.8%.

### 5.3 Gravel (GP) with Sand to Gravel (GW-GM) with Silt and Sand

A deposit of gravel with sand and varying amounts of silt was encountered at surface in off-road Boreholes 18-1 and 18-4. The gravel deposit was 1.0 m thick with underside elevations of 294.3 and 299.5 m below the ground surface in Boreholes 18-1 and 18-4, respectively.

The SPT tests conducted in this layer gave N-values of 11 and 30 blows, indicating a relative density of compact. Blow counts of over 100 were encountered just above the bedrock surface.

The moisture content of the samples tested ranged from 7 to 11%. The results of grain size analyses conducted on two samples of the gravel are summarized in the table below and are illustrated on Figure C3 in Appendix C.

Soil Particle	Percentage (%)
Gravel	53 – 57
Sand	37 – 44
Silt	3 – 6
Clay	

### 5.4 Silty Sand (SM) with Gravel – (Glacial Till)

A deposit of glacial till consisting of silty sand with gravel was encountered below the organic silt in Borehole 18-3. Frequent cobbles and boulders were encountered throughout the till deposit and coring techniques were required to advance through the layer. The thickness of this layer was 2.7 m with an underside elevation at 296.2 m.

A SPT test conducted in the till deposit gave an N-value of 45 blows, indicating a dense relative density.

Recorded moisture contents ranged from 6 to 13%. The results of a grain size analysis conducted on one sample of the till indicated this material to consist of 13% gravel, 55% sand and 32% fines. An additional grain size analysis conducted on sample of the lower till indicated the lower material to consist of 62% gravel, 33% sand, 5% fines, however, it has been assumed that part of the fines and sand have been washed away with the introduction of water through coring techniques. These results are illustrated on Figure C4 in Appendix C.

## 5.5 Bedrock

Bedrock was proven by coring in all boreholes. A summary of the bedrock surface is summarized in Table 5-1.

**Table 5-1: Summary of Bedrock Elevations**

Borehole No.	Depth to Bedrock (m) below existing ground surface	Bedrock Elevation (m)
18-1	1.0	294.3
18-2	7.0	298.6
18-3	9.4	296.2
18-4	1.0	299.5

The bedrock was slightly weathered to fresh granite. The Total Core Recovery (TCR) measured on the recovered bedrock core ranged from 74 to 100%, the Solid Core Recovery (SCR) ranged from 64 to 100% and the Rock Quality Designation (RQD) ranged from 66 to 100%. Based on the measured RQD values, the bedrock is classified as fair to excellent in quality (Table 3.10, Canadian Foundation and Engineering Manual 006).

Unconfined Compressive Strength (UCS) testing was carried out on two samples of the intact bedrock. The results of UCS testing carried out on the rock core ranged from 76 to 128 MPa, indicating the intact granite bedrock to be strong to very strong. Photographs of the bedrock core are provided in Appendix C.

## 5.6 Groundwater

Representative water levels could not be recorded in the open boreholes due to water being introduced as part of the coring operations. The groundwater water level measured in the standpipe piezometer installed in Borehole 18-4 was recorded at a depth of 0.1 m below the ground surface (elev. 300.4 m) 9 day after completion of installation on September 29, 2018. The culvert was dry at the time of the drilling investigation.

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

## 5.7 Analytical Testing

Two samples of the native soils encountered at the site were submitted for analysis of pH, water soluble sulphate and chloride concentrations, resistivity, and sulphide content. The

analysis results are summarized in the Table 5-2. A copy of the test results is provided in Appendix C.

**Table 5-2: Results of Chemical Analysis**

Borehole (Sample)	Depth <sup>(*)</sup> (mbgs)	Sulphate (µg/g)	pH ( - )	Resistivity (Ohm-cm)	Conductivity (uS/cm)	Chloride (µg/g)	Sulphide (%)
18-2 (SS8)	5.3 – 5.9	70	4.82	745	1,340	1,260	< 0.02
18-4 (SS1)	0.0 – 0.6	6	6.26	8,090	124	19	< 0.02





## 6 MISCELLANEOUS

Borehole locations were selected by Thurber relative to existing site features and the anticipated culvert location. The as-drilled locations and ground surface elevation of the boreholes were measured by Thurber following completion of the field program. Elevation benchmarks were provided by MPCE.

George Downing Estate Drilling Ltd. and Forage M3 Drilling Services Inc., both of Hawksbury, Ontario, supplied and operated the drilling equipment to conduct the drilling, soil sampling, in-situ testing, standpipe installation and decommissioning of the boreholes. NC Traffic Management Inc. of Kirkland Lake, Ontario supplied the traffic control for lane and shoulder closures required for the field work. The field investigation was supervised on a full-time basis by Miss Allison Chow, EIT and Mr. Sean O'Bryan, C.E.T. of Thurber. Overall supervision of the investigation was provided by Miss Katya Edney, P.Eng.

Routine geotechnical laboratory testing was completed by Thurber's laboratory in Ottawa, Ontario. Organic content and UCS testing was completed by Stantec's laboratory in Ottawa, Ontario. Analytical testing was completed by Paracel Laboratories in Ottawa, Ontario. Interpretation of the factual data and preparation of this report were carried out by, Miss Allison Chow, EIT, and Mr. Stephen Peters P.Eng. The report was reviewed by Dr. Fred Griffiths, P.Eng. and Dr. P.K. Chatterji, P.Eng. a Designated Principal Contact for MTO Foundation Projects.

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**PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**7 INTRODUCTION**

This section of the report provides an interpretation of the factual data from Part 1 of this report and presents geotechnical recommendations to assist the project team in designing a suitable replacement of the culvert crossing Highway 118 at Station 18+874. The discussion and recommendations presented in this report are based on the information provided by McIntosh Perry Consulting Engineers Ltd. (MPCE) and on the factual data obtained during the course of the investigation.

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 in order 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 existing culvert conveys creek flow from the south to the north under a high fill embankment supporting Highway 118. As shown on the historical base plan drawings, the existing culvert is a non-structural corrugated steel pipe (CSP) culvert with a diameter of 0.8 m and a length of 27.2 m. The invert of the culvert is at approximate elevation 299.8 and 297.5 m at the inlet (south) and the outlet (north), respectively. The Highway 118 fill height above the culvert varies along its length and ranges from approximately 4.8 to 7.1 m with the road surface at approximate elevation 305.6 m. The existing embankment slopes are inclined at approximately 1.8H:1V and 1.5H:1V to the north and south, respectively. The groundwater was measured in the standpipe piezometer to be at an approximate elevation of 300.4 m on September 29, 2018.



No previous foundation investigation information for the subject culvert was available on the online Geocres Library.

### **7.1 Proposed Structure**

At the time of preparation of this Foundation Investigation and Design Report, it is expected that the existing culvert will be replaced with a non-structural culvert of similar size, length and alignment. It has also been assumed the invert elevations will be similar to that of the existing culvert. This culvert is located at a high fill embankment site, where the fill height above the culvert is approximately 6.1 m. As per the Culvert Reinstatement Typical Drawing of the 30% Drawing Package, received on May 28, 2019 from MPCE, the replacement will be carried out utilizing grade lowering.

### **7.2 Applicable Codes and Design Considerations**

The geotechnical assessment presented 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 S6-14.

It is understood that a structural culvert replacement would have a consequence classification of *Typical Consequence*, in accordance with Section 6.5.1 of the CHBDC. Accordingly, a consequence factor ( $\Psi$ ) of 1.0, as per Table 6.1 of the CHBDC, would be used in assessing factored geotechnical resistances.

## **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). The seismic hazard for this site has been obtained from the GSC calculator. The data includes a peak ground acceleration (PGA), peak ground velocity (PGV) and the 5% 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 475-year, 975-year and 2475-year events. The GSC seismic hazard calculated data sheet for this site is included in Appendix F

The site coefficients used to determine the design spectral acceleration and displacement values are a function of the Site Class and the peak ground acceleration (PGA). The PGA at this site for a *reference* Site Class C with a 2% probability of exceedance in 50 years (2475-year event) is 0.068g. This value is to be scaled by the  $F(PGA)$  based on the site-specific Site Class, as discussed below.

### **8.2 Seismic Liquefaction**

Based on the low reference PGA, the subsurface conditions encountered at the drilled locations at this site and using the Seed & Idriss Simplified Method for liquefaction

assessment, the foundation soils are considered not susceptible to liquefaction during the design seismic event.

### **8.3 CHBDC Seismic Site Classification**

In accordance with the CHBDC, the selection of the seismic site classification is based on the energy corrected penetration resistance of the soil and rock encountered in the upper 30 m of the stratigraphy. This site has been classified as a Site Class D in accordance with Section 4.4.3.2 of the CHBDC (S6-14) utilizing the harmonic mean of the recorded SPT N-values.

## **9 DESIGN OPTIONS**

### **9.1 Culvert Type and Foundation Alternatives**

Selection of the culvert type must consider the proposed construction procedures, staging requirements, geotechnical resistance available in the foundation soils, the depth to suitable bearing stratum and post-construction settlement criteria. From a geotechnical perspective, the following culvert types were considered:

- Circular Pipes (Concrete, HDPE, Steel)  
From a foundation engineering perspective, a pipe culvert is a technically feasible alternative. It is assumed that an internal pipe diameter of similar size or slightly greater than the existing (0.8 m) will be required.
- Open Bottom Culvert (Box, Arch)  
An open bottom culvert is not recommended for this site from a foundation engineering perspective due to the expected size of the replacement culvert, the requirement for greater excavation depths and dewatering efforts during construction and potential for differential settlement following construction taking into consideration the varying bedrock profile.
- 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.

A comparison of these alternatives, based on their respective advantages and disadvantages, is included in Appendix E. It is not considered to be economical or practical to support a culvert on deep foundations at this site and therefore this option is not presented in this report. Likewise, contiguous sheet pile walls supporting a precast concrete slab is also not practicable due to the bedrock profile.

## 9.1 Construction Methodology Alternative

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

- Open Cut with Full Road Closure and 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 flow diversion. However, it is understood that an acceptable detour is not available and therefore this option is not considered feasible.
- Open Cut with Staged Temporary Widening and/or Temporary Detour Embankment  
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 but is not considered practical. Widening to the north side of Highway 118 would require significant fill to be placed due to the lower grades on this side of the highway. Widening to the south would likely require utility relocation. Excavations of bedrock outcrops would likely be required to maintain highway geometry. Additionally, a review of the requirement for property acquisition and highway geometry is also needed to assess this option. An additional borehole investigation would likely be required to determine the subsurface conditions along a temporary detour alignment.
- Open Cut and Temporary Protection System (TPS)  
The use of open cut techniques in conjunction with staged culvert replacement is a feasible construction option from a geotechnical perspective. This option includes a temporary protection system (TPS), as discussed further in Section 11.2, installed along the embankment centerline to maintain a single lane of traffic along the current highway alignment. The Contractor will need to consider the potential for obstructions in the embankment fill during the design and installation of the roadway protection. To reduce lateral deflections of the protection system, the roadway protection may need to include anchoring and/or bracing system. The TPS would need to support a temporary cut height in the order of 7 to 8 m. The height of the TPS could be reduced if a temporary grade lowering was also included.

The existing embankment fill above the culvert is up to approximately 7.1 m high. Temporary grade lowering can be incorporated into the design to reduce the overall height of embankment above the base of the proposed excavation while maintaining traffic within the existing embankment footprint. However, the vertical road alignment and traffic speed constraints will need to be reviewed from a highway design perspective. The project pavement engineer should also be consulted if the grade lowering approach is to be carried forward.

- Temporary Modular Bridge

A temporary modular bridge (TMB) could provide a single lane of traffic passage while allowing for full excavation and replacement of the culvert without staged excavations. A reduced quantity of roadway protection is also anticipated. Additional boreholes would be required at the temporary abutment locations for the TMB for foundation design. The design length of the TMB must include consideration of the need to maintain stable temporary excavation slopes and a horizontal offset between the TMB footings and the crests of the slopes.

- Trenchless Techniques

The presence of a highly variable bedrock surface, cobbles, boulders and mixed soils including organic material will result in challenges. Due to the risks, this option is not recommended for this site.

## **9.2 Recommended Approach for the Culvert Replacement**

From a foundation engineering perspective, the preferred approach is to replace the existing culvert with either a circular or a closed box culvert using open cut techniques. TPS would be needed to facilitate construction. Obstructions are likely to be encountered in the embankment fill and glacial till. Bedrock is at shallow depth. Design of the TPS will need to account for the lateral capacity and depth available in the native soils at this site and the need to anchor or brace the TPS. Grade lowering should be considered to reduce the height of the TPS.

## **10 FOUNDATION DESIGN RECOMMENDATIONS**

Foundation design aspects for the replacement culvert includes subgrade conditions, geotechnical resistances, settlement of the founding soils, imposed loading pressures, erosion control, protection system design, groundwater control and design of staged construction. The culvert must be designed to resist loadings including lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loading and any surcharge due to construction equipment and activities under static and seismic conditions.

### **10.1 Culvert Foundation Bearing Resistances**

It is assumed that the existing culvert will be replaced on the same alignment and that the embankment will be reconstructed with no grade raise or widening (temporary or permanent). Therefore, it is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading.

#### **10.1.1 Box Culvert**

Pre-cast box culverts should be constructed in accordance with OPSS 422. The recommended geotechnical resistances at roadway centreline for a pre-cast box culvert up to 2 m wide with a 0.2 m thick base slab installed with an invert elevation similar to the

current culvert (approximate elev. 297.7 m at the outlet) on an undisturbed native gravel and silty sand till subgrade are as follows:

- Factored Geotechnical Resistance at ULS of 300 kPa
- Factored Geotechnical Resistance at SLS of 200 kPa

Lower resistance values are available near the inlet and outlet due to the reduced footing depth, however, the loads at these locations are also significantly lower and will not govern the design.

The resistances provided are based on full removal of the organic silt below the footprint of the culvert. There exists a possibility of encountering bedrock near the founding elevation along the culvert alignment. Further recommendations are provided in Section 10.2 for subgrade preparation.

The factored geotechnical resistances include the following factors:

- Consequence factor ( $\Psi$ ) of 1.0 (as per CHBDC Table 6.1)
- Geotechnical resistance factors (as per CHBDC Table 6.2):
  - $\phi_{gu} = 0.5$  (static analysis; typical degree of understanding)
  - $\phi_{gs} = 0.8$  (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 6.10.3 and Clause 6.10.4. Foundation settlement, based on the above SLS resistance, is expected to be less than 25 mm for subgrades prepared with good workmanship.

Resistance to lateral forces/sliding resistance between the precast concrete and the underlying Granular 'A' bedding (Section 10.2) should be evaluated in accordance with the CHBDC assuming an unfactored coefficient of friction of 0.45. A geotechnical resistance factor against sliding ( $\phi_{gu}$ ) of 0.8 (CHBDC, Table 6.2) may be used.

Surface water diversion and dewatering (Section 11.3) should be provided as required to place the bedding material and install the culvert in the dry.

#### 10.1.2 Pipe Culvert

Pipe culverts should be constructed in accordance with OPSS.PROV 421. Geotechnical resistance values are not typically required for pipe culverts. A modulus of subgrade reaction of 40 MN/m<sup>3</sup> can be used for a pipe culvert installed on the gravel and silty sand till, if required.



## **10.2 Subgrade Preparation, Bedding and Backfilling**

The organic sandy silt layer observed in Boreholes 18-2 and 18-3 at elevations of 299.5 and 300.3 m is not considered suitable to remain beneath the culvert footprint and should be removed where encountered. After excavation and removal of the existing culvert and existing fill, any organics, soft or loose deposits, disturbed soils, loose alluvial deposits and deleterious materials must be stripped from the footprint of the new culvert to expose competent native undisturbed subgrade material at or below the desired founding elevations. Given the varying conditions of the subgrade anticipated at the founding level in the areas under the embankment, construction equipment should not travel on the exposed final subgrade.

The exposed final subgrade must be inspected to confirm that the subgrade is suitable and uniformly competent. Any deleterious materials at the subgrade level, such as the organic sandy silt, should be sub-excavated and backfilled with granular fill consisting of OPSS.PROV 1010 Granular A material as soon as practical to protect the subgrade from disturbance during construction. The granular fill should be compacted as per OPSS.PROV 501. In order to provide a more uniform foundation subgrade condition for the culvert, a minimum 300 mm thick layer of bedding material conforming to OPSS.PROV 1010 Granular A requirements must be provided under the base of the culvert as per OPSD 803.010 (box culvert) and OPSD 802.010 (pipe culvert).

It is noted that the bedrock surface may be encountered at or in close proximity to the anticipated culvert founding level. To provide better culvert performance and reduce differential settlements, it is not recommended to found the culvert on both bedrock and soil. If bedrock is encountered within 0.3 m of the underside of the culvert, bedrock removal will be required to provide a more uniform foundation performance.

It is noted that construction will extend below the ditch and creek elevation. Water diversion and dewatering will be required to prepare the subgrade in the dry. Please refer to Section 11.3 for additional comments on groundwater and surface water control.

For box culverts, it is recommended that culvert cover be in accordance with OPSD. 803.010 and OPSS 902 and consist of Granular A material meeting the requirements of OPSS.PROV 1010. Culvert backfill above the granular cover should be in accordance with OPSS 902 and consist of material meeting the requirements of OPSS Granular A, Granular B Type I, Granular B Type II or Select Subgrade Material (SSM) and should be compacted as per OPSS.PROV 501. Care must be exercised when compacting the fill adjacent to and above the culvert in order not to damage the culvert. Heavy compaction equipment, used near the culvert, must be restricted in accordance with OPSS.PROV 501.

For flexible pipe culverts it is recommended that culvert embedment and cover be in accordance with OPSD 802.010 and OPSS.PROV 401 and consist of OPSS Granular A



material. Culvert backfill should meet the requirements of OPSS Granular A, Granular B Type I, Granular B Type II or SSM and constructed in accordance with OPSS.PROV. 401.

### 10.3 Frost Depth

The depth of frost penetration at this site is 1.8 m (as per OPSD 3090.101). It is not necessary to found a closed box or pipe culvert at a depth below frost penetration. However, if frost taper treatment is required it should be as directed within the Pavement Design Report. The inclusion of wing walls would require a foundation founded below frost depth.

### 10.4 Lateral Earth Pressures

The Lateral Earth Pressure parameters provided in Table 10-1 and Table 10-2 assume that the wall is vertical and 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. Where ground surfaces are horizontal or sloped at 2H:1V behind vertical walls, the corresponding coefficients provided in Table 10-1 and Table 10-2 should be used.

#### 10.4.1 Static Lateral Earth Pressure Coefficients

Lateral earth pressures acting on structures should be computed in accordance with the CHBDC but under fully drained conditions are given by the following general expression:

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

where:

$\sigma_h$	=	static lateral earth pressure on the wall at depth d (kPa)
K	=	static earth pressure coefficient (see table below) ( $K_A$ for yielding walls, $K_o$ for non-yielding walls)
$\gamma$	=	unit weight of retained soil (see table below), use submerged unit weight below groundwater level
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 backfill on vertical structures are shown in Table 10-1.

**Table 10-1. Earth Pressure Coefficients**

Condition	Earth Pressure Coefficient					
	OPSS Granular A or Granular B Type II $\phi = 35^\circ$ $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ$ $\gamma = 21.2 \text{ kN/m}^3$		OPSS SSM and Existing Sand to Silty Sand Fill $\phi = 30^\circ$ $\gamma = 20.0 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active, $K_A$ (Yielding Wall)	0.27	0.39	0.31	0.47	0.33	0.54
At Rest, $K_O$ (Non-Yielding Wall)	0.43	-	0.47	-	0.50	-
Passive, $K_P$ (Movement towards Soil Mass)	3.7	-	3.3	-	3.0	-
Soil Group(*)	"medium dense sand"		"loose to medium dense sand"		"loose sand"	

Note: (\*) for use with Figure C6.16 of the Commentary to the CHBDC.

The use of a material with a high friction angle and low active earth pressure coefficient (Granular A or Granular B Type II) is preferred as it results in lower earth pressures acting on the culvert.

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 C6.16 of the Commentary to the CHBDC using the soil group designation as outlined in the table above. Active pressures should be used for any head walls or unrestrained walls. For rigid structures such as a concrete box culvert, at-rest/non-yielding horizontal earth pressures should be used for design.

#### 10.4.2 Combined Static and Seismic Lateral Earth Pressure Parameters

In accordance with Clause 4.6.5 of the CHBDC (S6-14), a structure should be designed using combined static and seismic earth pressure coefficient to incorporate the effects of earthquake loading. The following recommendations are per Section C4.6.5 of the Commentary of the CHBDC which states that seismically induced lateral soil pressures may be calculated using 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 10-2 may be used for vertical walls. Table 4.8 of the CHBDC indicates an  $F(PGA)$  of 1.29 with Seismic Site Class D and a  $PGA_{ref}$  of 0.068 (2475-year event); thus the provided earth pressure coefficients have been calculated using an adjusted PGA of 0.088.

**Table 10-2. Combined Static and Dynamic Earth Pressure Coefficients**

Condition	Earth Pressure Coefficient			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Slope Surface Behind Wall (2H:1V)
Active, $K_{AE}$ Yielding Wall	0.29	0.45	0.33	0.55
Active, $K_{AE}$ Non-Yielding Wall	0.32	0.53	0.36	0.71

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

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

where:

- $\sigma_h$  = combined static and dynamic lateral earth pressure on the wall at depth  $d$  (kPa)
- $d$  = depth below the top of the wall where pressure is computed (m)
- $K$  = static earth pressure coefficient (see Table 10-1)  
( $K_A$  for yielding walls,  $K_o$  for non-yielding walls)
- $\gamma$  = unit weight of retained soil, use submerged unit weight below groundwater level
- $K_{AE}$  = combined static and dynamic earth pressure coefficient
- $H$  = total height of the wall (m)

## 10.5 Embankment Design and Reinstatement

### 10.5.1 Embankment Reconstruction

Embankment reconstruction after culvert replacement should be carried out in accordance with OPSS.PROV 206. The embankment should be reinstated with side slopes of 2H:1V

(or flatter) if constructed using Select Subgrade Material (SSM), Granular B Type I, Granular B Type II or Granular A. The fill should be placed and compacted in accordance with OPSS.PROV 501.

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

#### 10.5.2 Embankment Settlement and Stability

The condition of the existing embankment slopes was examined in the field during the field investigation and no evidence of instability (tension cracks etc.) was noted at that time.

It is understood that no grade raise is anticipated along the alignment of Highway 118 and therefore negligible settlement of the soils beneath the embankment is expected to occur.

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

Provided no grade raise or embankment widening is required (temporary or permanent) and proper construction methods are used, no long term or global stability issues are anticipated for embankments re-built at this site.

Material stockpiling above the existing grades is a temporary construction measure and any stability/settlement implications are the responsibility of the Contractor. The selection and placement of construction equipment (such as heavy cranes) are also the Contractor's responsibility.

#### 10.6 Cement Type and Corrosion Potential

Analytical tests were completed to determine the potential for degradation of concrete in the presence of soluble sulphate and the potential for corrosion of exposed steel. The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. Soluble sulphate concentrations less than 1000 µg/g generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater. The class of concrete selected should consider the effects of road de-icing salts.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The tests results provided in Section 5.7 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects. The corrosive effects of road de-icing salts should also be considered.



## 11 CONSTRUCTION CONSIDERATIONS

### 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 existing fills above the water table may be classified as Type 3 soil. Fill, organic silt and native soils below the groundwater level are classified as Type 4 soils.

Excavation for the culvert replacement must be carried out in accordance with OPSS 401 or OPSS 902 and will be carried out through the existing embankment fill and will extend into the underlying native gravel and silty sand deposits. The sides of temporary excavations must be sloped in accordance with the requirement of OHSA. Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor. Protection of adjacent utilities will need to be taken into consideration when evaluating the excavation limits.

At locations where there are space restrictions, the excavations need to be carried out within a protection system. Further discussion is presented in Section 11.2.

### 11.2 Temporary Protection Systems

Temporary Protection Systems may be required during various stages of construction and must be implemented in accordance with OPSS.PROV 539 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.

Lateral earth pressure coefficients, under fully mobilized conditions, that can be used in design of the protection system installed through the existing and new fills are provided in Table 10-1. The lateral earth pressure coefficients for a vertical wall with horizontal backfill for the existing soil layers are given below:

Organic Sandy Silt

$$\begin{aligned}\gamma &= 18 \text{ kN/m}^3 \text{ (use submerged unit weight below groundwater level)} \\ K_A &= 0.38 \\ K_P &= 2.7\end{aligned}$$

Gravel:

$$\begin{aligned}\gamma &= 20 \text{ kN/m}^3 \text{ (use submerged unit weight below groundwater level)} \\ K_A &= 0.31 \\ K_P &= 3.3\end{aligned}$$



Silty Sand (Till):

$\gamma$	=	19 kN/m <sup>3</sup> (use submerged unit weight below groundwater level)
$K_A$	=	0.33
$K_P$	=	3.0

Temporary protection systems are the responsibility of the Contractor and should be designed by a licensed Professional Engineer experienced in such designs and retained by the Contractor. Cobbles and boulders were encountered during the drilling investigation which may interfere with the installation of sheet piles. A suggested NSSP to alert the Contractor is provided in Appendix G. Shallow bedrock was also observed and a varying bedrock surface may be encountered. Therefore, drilled-in soldier piles with lagging 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 the lateral earth pressure loadings including traffic loading and surcharge loading due to construction equipment and operations and minimize lateral deflection of the protection system.

It is recommended that the TPS should be left in place and cut off in accordance with OPSS 539.

### 11.3 Surface and Groundwater Control

Water flow through the culvert was not observed during the time of the borehole investigations, however, some ponded water was noted at the inlet (see Photo 2 of Appendix D). The groundwater level measured in the standpipe piezometer installed in Borehole 18-04 was recorded at an elevation of 300.4 m, which is above the culvert invert. However, this was a short term reading and the water level is expected to fluctuate.

Creek diversion is anticipated to be required. 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 to permit construction in a dry and stable environment.

The design of dewatering systems is the responsibility of the Contractor. The Contract Documents must alert the Contractor to this responsibility.

For pipe culverts, the dewatering system is to be designed in accordance with OPSS.PROV 517 and SP517F01 should be invoked for this site. Given the depth to bedrock may be variable, the ground water level and the presence of granular overburden, the hydrogeology is considered to be complex, thus Designer Fill-In \*\*\*\*\* in SP517F01 should be "Yes". A preconstruction survey is not required, thus Designer Fill-In \*\*\*\*\* in this SP should be "N/A".

For box culverts the dewatering system should be designed in accordance with SP FOUN0003 which amends OPSS 902. A preconstruction survey is not required, thus Designer Fill-In \*\* in NSSP FOUN0003 should be "N/A". The Design Requirements of SP FOUN0003 should be amended by requiring an experienced design engineer as indicated in Appendix G.

The groundwater level will fluctuate and the minimum groundwater elevation for the site at the time of construction should be taken as the water level from the design storm period defined in SP517F01 and SP FOUN0003.

It is suggested that a diversion pipe be used during the replacement of the culvert.

The work zone could be contained within a water tight enclosure, however, cofferdam installation only at the inlet and outlet may also be of consideration. A sand bag cofferdam and sump pumps may be considered. Multiple sump pumps within the enclosure will be required. Sheet pile cofferdams would be difficult to install at this site due to the presence of cobbles and boulders and the presence of shallow bedrock.

Alternatively, it is anticipated that a gravity well point system may need to be installed surrounding the work zone.

While all efforts must be made to construct a cofferdam at the inlet and outlet of the culvert to dewater the work area by pumping/well points, it may not be possible to fully dewater the temporary excavation, particularly since the foundation soils are granular and more than one construction stage may be required to cross the lanes. Accordingly, placement of backfill below the culvert bedding may have to be done in the wet. Granular fill must not be used to backfill excavation below the water level. When backfilling is conducted in the wet, select rock fill should be used. The recommended gradation of the rock fill is as follows:

Sieve Size (mm)	Percent Passing
150	100
106	50 – 100
75	15 – 80
26.5	5 – 15
0.075	2 – 10

A separation layer consisting of a non-woven geotextile should be placed between the native soils and the select rock fill. The geotextile should meet the specification of OPSS 1860 Class II and have a maximum fabric opening size (FOS) of 212  $\mu$ m. The geotextile should be placed as soon as possible after reaching the subgrade level and following receipt of written notice to proceed in accordance with SP 109S12. The select rock fill should be completed wrapped with the geotextile to minimize migration of the fines into the select rock fill. Select rock fill placement below the water level should follow OPSS.PROV 209.

Select rock fill placed above the water level should be placed in a controlled manner (not end dumped) including blading, dozing and chinking of the rock to minimize voids and bridging. Select rock fill above the water level must be compacted as per OPSS.PROV 206. Where granular fill or bedding is placed over the fabric wrapped select rock fill, the rock fill must be blinded with spall material and rock fill chinking shall be in accordance with OPSS.PROV 206. All granular fill must be compacted as per OPSS 501.

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

#### **11.4 Scour Protection and Erosion Control**

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.

Based on the subsurface conditions encountered at the drilled locations through the embankment at this site the embankment fill materials are considered to have moderate susceptibility to erosion as per the Wischmeier Nomograph. The native soils are considered to have low susceptibility to erosion.

Typically, rock protection should be provided over all earth surfaces in contact with flowing water. 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.

It is recommended that a concrete cut-off wall be used to minimize the potential for piping and erosion around the inlet of the culvert.

## **12 CONSTRUCTION CONCERNS**

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

- The bedrock surface was encountered at varying depths during this investigation. It should be noted that there is a risk that the bedrock surface may be shallow and variable, resulting in the possibility of variable founding conditions which could lead to differential settlement if the subgrade (Section 10.2) is not prepared appropriately. Bedrock excavation may be required where encountered near the culvert founding elevation.
- Cobbles and boulders were encountered within the fill and native soils. Buried obstructions may be encountered during excavation in the embankment fill or interfere with driving of protection systems and/or sheet pile cofferdams.





- Groundwater levels will fluctuate. Excavation may require lowering the groundwater level below the excavation base to maintain a reasonably dry excavation and stable side slopes.
- The Contractor's selection of construction equipment and methodology must include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structure fill (i.e., as a pad for crane support).

The successful performance of the culvert installation will depend largely upon good workmanship and quality control during construction. Subgrade examination in accordance with SP109S12 should be carried out by qualified geotechnical personal during construction to confirm that foundation recommendations are correctly implemented, and material specifications are met.



### 13 CLOSURE

Engineering analysis and preparation of this report were carried out by Miss Katya Edney, P.Eng. and Mr. Stephen Peters, P.Eng. The report was reviewed by Dr. Fred Griffiths, P.Eng and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundation Projects.

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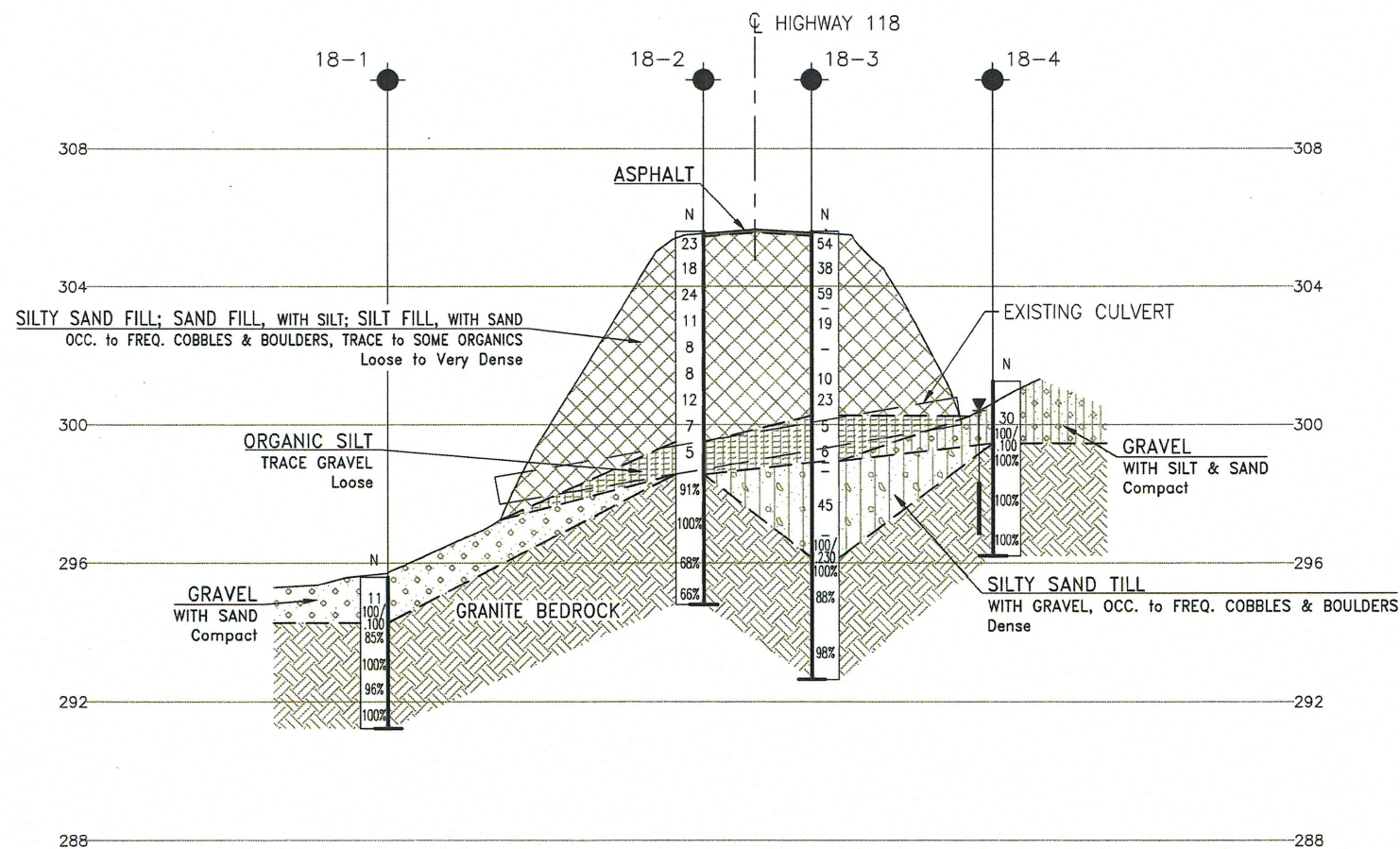
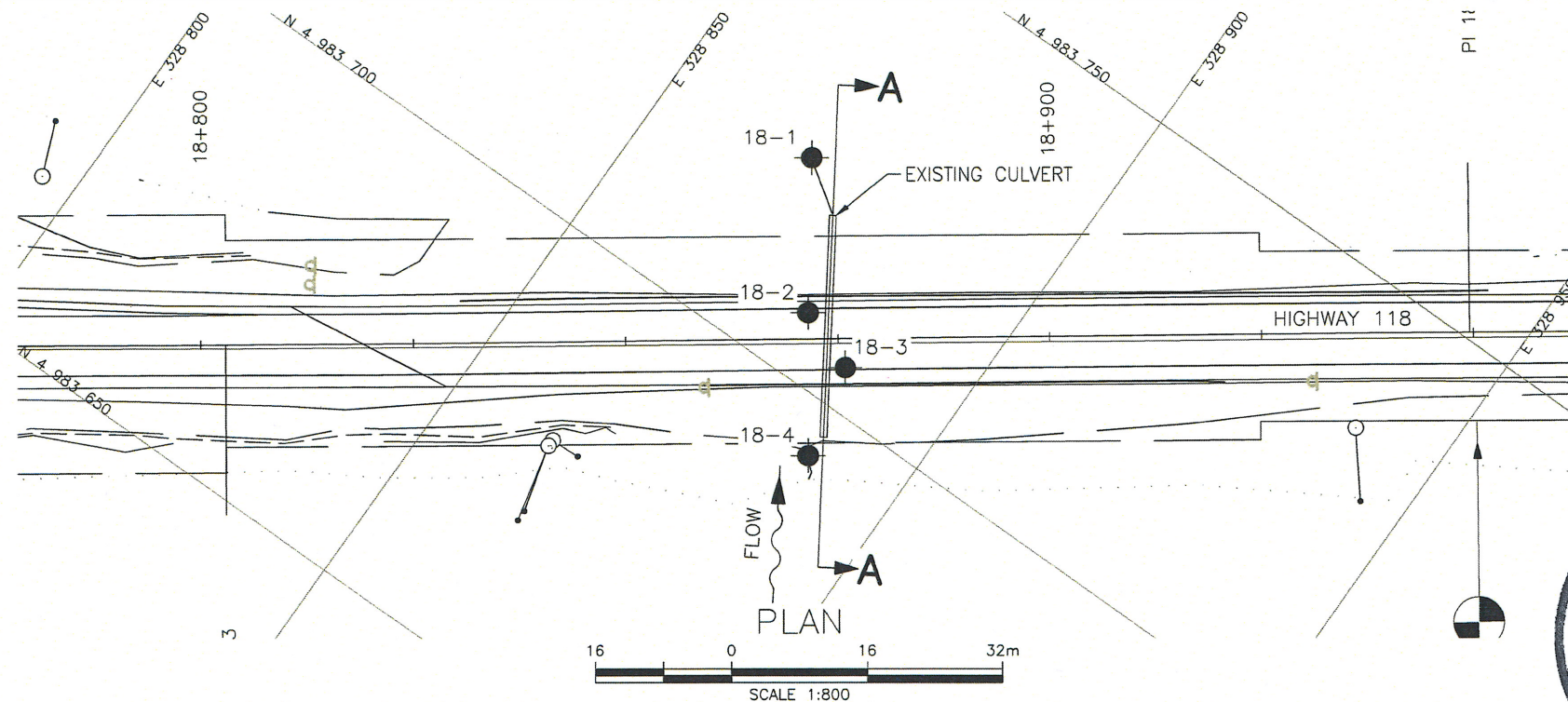
Dr. P.K. Chatterji, P.Eng.  
Review Principal  
Senior Geotechnical Engineer



## **Appendix A.**

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





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



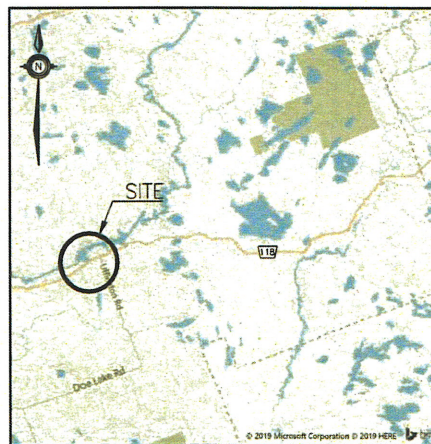
CONT No  
GWP No 5287-14-00

HIGHWAY 118  
STATION 18+874  
CULVERT REPLACEMENT  
BOREHOLE LOCATIONS AND SOIL STRATA

McINTOSH PERRY



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

●	Current Borehole by Thurber
⊕	Previous Borehole by Others (Approx.)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
W	Water Level
⊕	Head Artesian Water
⊕	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
18-1	295.3	4 983 722.8	328 868.7
18-2	305.6	4 983 707.6	328 878.9
18-3	305.6	4 983 704.8	328 886.2
18-4	300.5	4 983 693.8	328 888.6

-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD 83 Zone 10.

GEOCRES No. 31E-401

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	KE	CHK SP	CODE
DRAWN	MFA	CHK KE	SITE
			LOAD
			STRUCT
			DWG
			DATE APR 2019





## **Appendix B.**

### **Record of Borehole Sheets**



## 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 18-1

1 OF 1

METRIC

GWP# 5287-14-00 LOCATION Lat: 44.993085°, Long: -79.194747° St. 18+874 N 4 983 722.8 E 328 868.7 ORIGINATED BY SOB  
 HWY 118 BOREHOLE TYPE Portable NWT Coring COMPILED BY AC  
 DATUM Geodetic DATE 18.09.2018 - 19.09.2018 CHECKED BY KE

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20    40    60    80    100						
295.6														
0.0	STAND													
295.3														
0.3	GRAVEL (GP) with sand compact brown		1	SS	11		295							53   44   3 (SI+CL)
294.3			2	SS	100/									
1.3	BEDROCK GRANITE fresh to slightly weathered coarse grained strong to very strong pink and grey		3	NQ	100 mm									
			1	RUN			294							RUN #1 TCR=100% SCR=100% RQD=85%
			2	RUN			293							RUN #2 TCR=100% SCR=100% RQD=100% UCS=127.8MPa
			3	RUN										RUN #3 TCR=100% SCR=96% RQD=96%
			4	RUN			292							RUN #4 TCR=100% SCR=100% RQD=100%
291.2														
4.4	End of Borehole  A half-weight (32 kg) drop hammer was used to advance the split-spoon sampler. The N values presented have been adjusted to provide an equivalent N value that would have been obtained with a standard 64 kg hammer.													

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

## METRIC

[illegible]

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

DOUBLE LINE ST 18+874.GPJ 2012TEMPLATE(MTO).GDT 23/8/19

## METRIC

[illegible]

# RECORD OF BOREHOLE No 18-3

1 OF 2

METRIC

GWP# 5287-14-00 LOCATION Lat: 44.992922°, Long: -79.194526°  
St. 18+874 N 4 983 704.8 E 328 886.2 ORIGINATED BY AC  
HWY 118 BOREHOLE TYPE NW Washboring COMPILED BY AC  
DATUM Geodetic DATE 18.09.2018 - 18.09.2018 CHECKED BY KE

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
305.6							20	40	60	80	100						
0.0	ASPHALT (100 mm)																
0.1	SILTY SAND with gravel very dense brown		1	SS	54								○				
305.0	FILL																
0.6	SAND with silt occasional to frequent cobbles and boulders compact to very dense brown to grey		2	SS	38								○			1 93 6 (SI+CL)	
	FILL																
	280 mm boulder at 2.1 m		3	SS	59								○				
			4	NQ	-												
			5	SS	19								○				
	frequent cobbles and boulders at 3 m		6	NQ	-												
301.6																	
4.0	SILT with sand some organics loose to compact brown to dark brown		7	SS	10								○				
	FILL		8	SS	23									○			
300.3																	
5.3	ORGANIC SANDY SILT (OL) loose dark brown to dark grey		9	SS	5										○	ORGANIC CONTENT 10.5%	
			10	SS	6									○		1 34 58 7 non-plastic	
298.9																	
6.7	SILTY SAND (SM)TILL some gravel occasional to frequent cobbles and boulders dense brown to red-grey		11	NQ	-												
			12	NQ	-												
			13	SS	45								○			13 55 32 (SI+CL)	
													○				
			14	NQ	-												
			15	SS	100/								○			62 33 5 (SI+CL)	
296.2			16	NQ	230 mm												
9.4	BEDROCK GRANITE fresh		1	RUN	-											RUN #1 TCR=100% SCR=100% ROD=100%	
															FI		
															0		
															0		

Continued Next Page

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

# RECORD OF BOREHOLE No 18-3

2 OF 2

METRIC

GWP# 5287-14-00 LOCATION Lat: 44.992922°, Long: -79.194526° St. 18+874 N 4 983 704.8 E 328 886.2 ORIGINATED BY AC  
 HWY 118 BOREHOLE TYPE NW Washboring COMPILED BY AC  
 DATUM Geodetic DATE 18.09.2018 - 18.09.2018 CHECKED BY KE

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20   40   60   80   100	W <sub>P</sub> W      W <sub>L</sub>								
								SHEAR STRENGTH kPa				WATER CONTENT (%)					
								○ UNCONFINED      + FIELD VANE									
							● QUICK TRIAXIAL      × LAB VANE										
	Continued From Previous Page																
292.6   																	

## METRIC

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity



**Appendix C.**  
**Laboratory Testing**

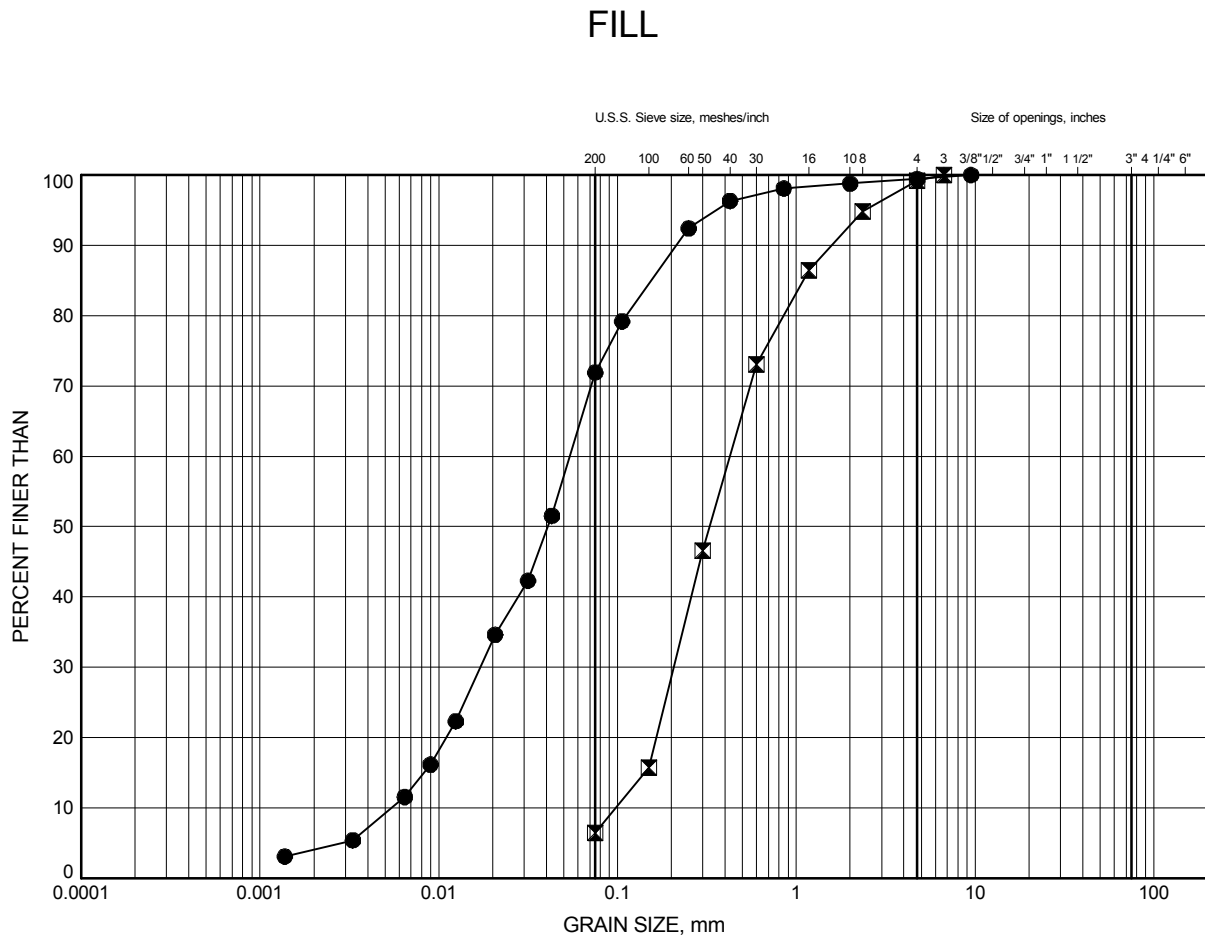




**Appendix C.1**  
**Particle Size Analysis Figures**

# HWY 118 Culverts Station 18+874 GRAIN SIZE DISTRIBUTION

FIGURE C1



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-2	4.1	301.5
⊠	18-3	1.1	304.5

Date ..October 2018.....  
 GWP# ..5287-14-00.....

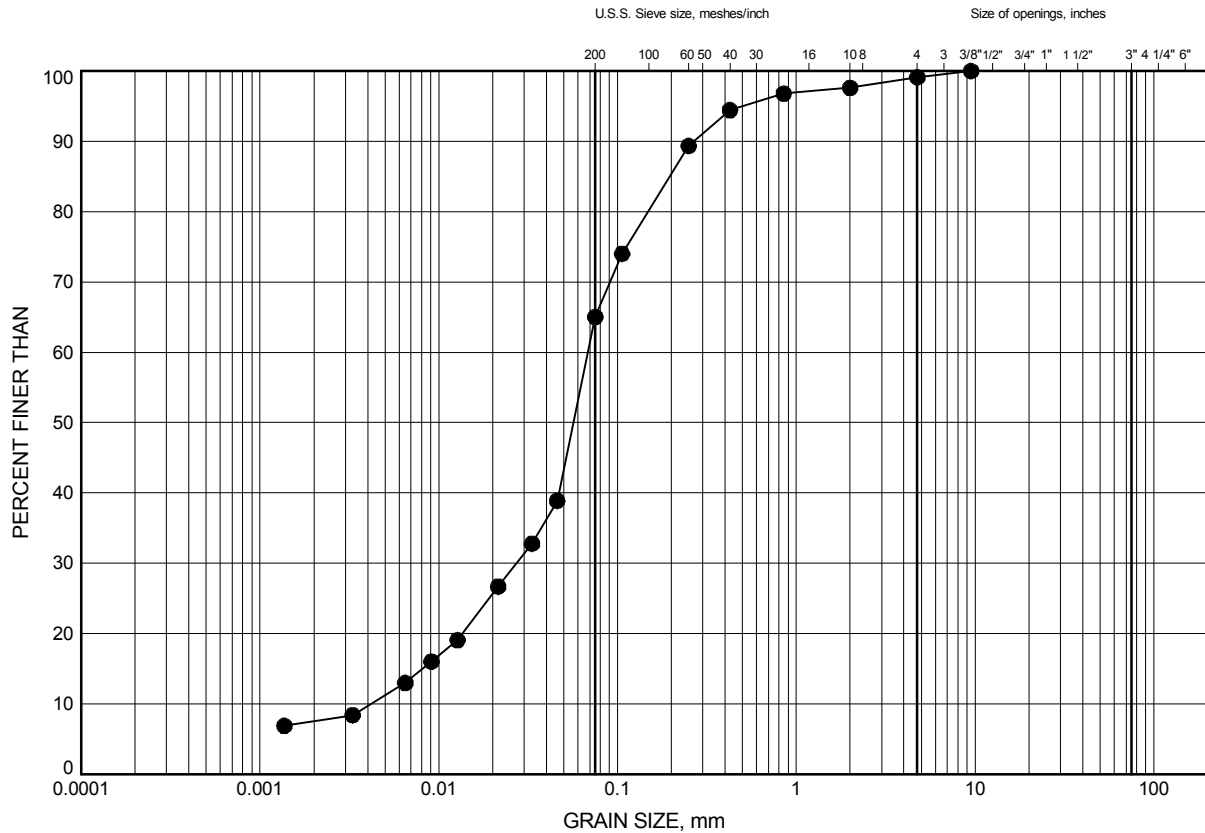


Prep'd .....AC.....  
 Chkd. ....KE.....

# HWY 118 Culverts Station 18+874 GRAIN SIZE DISTRIBUTION

FIGURE C2

## ORGANIC SANDY SILT (OL)



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-3	6.4	299.2

Date November 2018  
GWP# 5287-14-00

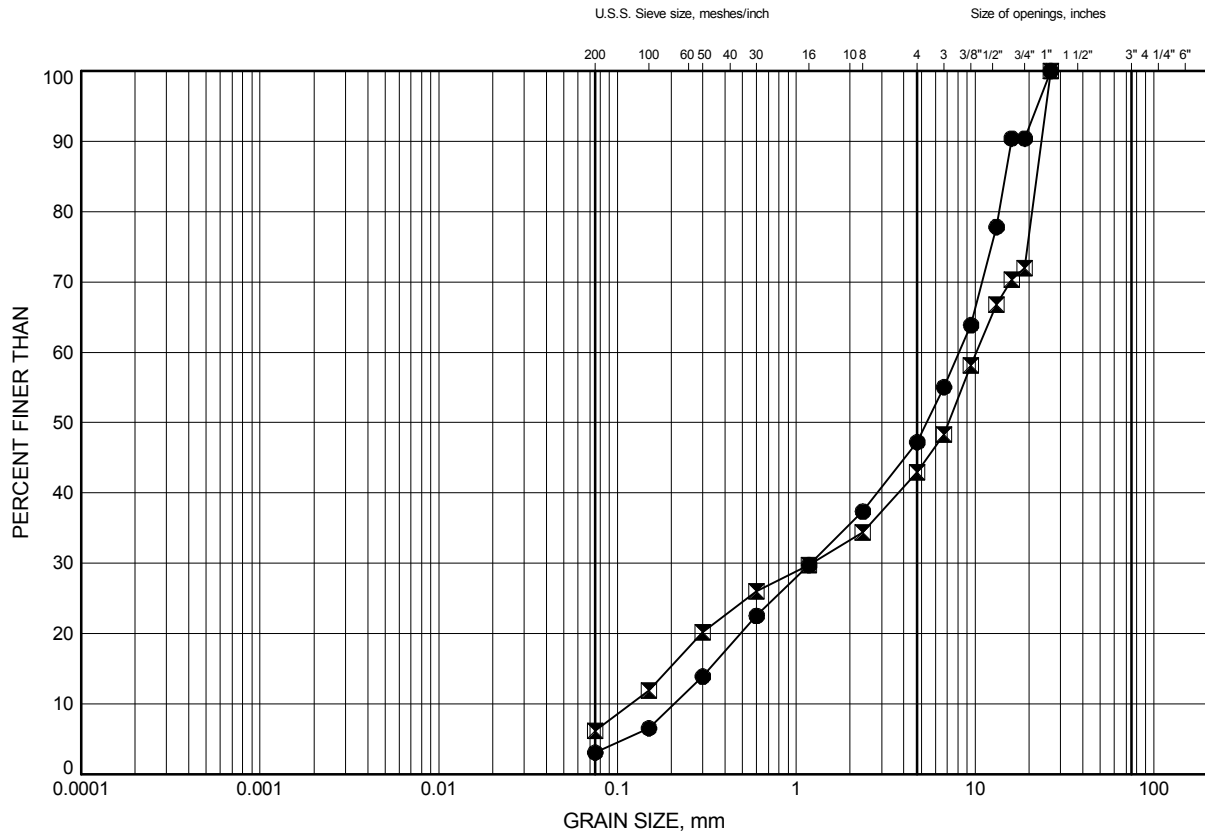


Prep'd AC  
Chkd. KE

# HWY 118 Culverts Station 18+874 GRAIN SIZE DISTRIBUTION

FIGURE C3

GRAVEL (GP) with sand to GRAVEL (GW-GM) with silt and sand



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-1	0.3	295.0
◻	18-4	0.9	299.6

Date ..October 2018.....

GWP# ..5287-14-00.....



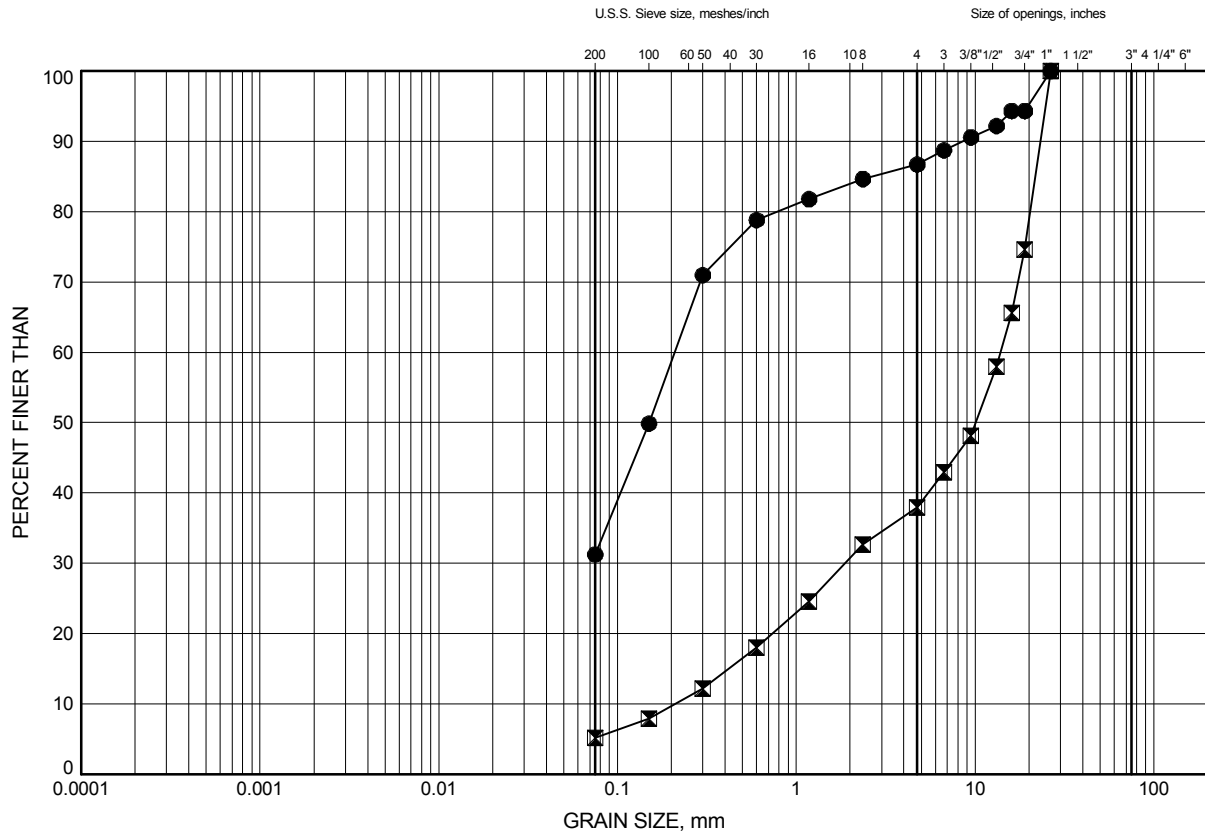
Prep'd .....AC.....

Chkd. ....KE.....

# HWY 118 Culverts Station 18+874 GRAIN SIZE DISTRIBUTION

FIGURE C4

## SILTY SAND (SM) (GLACIAL TILL)



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-3	8.1	297.5
⊠	18-3	9.3	296.3

Date November 2018  
GWP# 5287-14-00



Prep'd KE  
Chkd. FG



**Appendix C.2**  
**Rock Core Photos**  
**Rock Testing Results**

**Borehole 18-1**  
**Run 1 to 4 (of 4)**  
**Elevation 294.3 m to 291.2 m**



**Borehole 18-2**  
**Run 1 to 4 (of 4)**  
**Elevation 298.6 m to 294.8 m**



**THURBER** ENGINEERING LTD.

**Foundation Investigation**  
**Hwy 118 Culverts St. 18+874**  
**Foundations**

**GWP: 5287-14-00**

**Project No.: 20244**



**Borehole 18-3**  
**Run 1 to 3 (of 3)**  
**Elevation 296.2 m to 292.6 m**



**Borehole 18-4**  
**Run 1 to 3 (of 3)**  
**Elevation 299.5 m to 296.2 m**





**Stantec**

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

October 17, 2018  
File: 122410864

**Attention:** Thurber Engineering Ltd., File #20244

**Reference:** ASTM D7012, Method C, Unconfined Compressive Strength of Intact Rock Core

The table below summarizes five (5) rock core unconfined compressive strength results.

Location	Sample Depth	Compressive Strength (MPa)	Description of Break
18+550, 18-2 Run-1	26'1"-27'1"	115.0	Diagonal Fracture with no cracking through ends
18+550, 18-4 Run-1	11'6"-12'1"	141.6	Well-formed cone on one end. Vertical crack, no well-defined cone on the other end
18+875, 18-1 Run-2	7'7"-8'1"	127.8	Well-formed cone on one end. Vertical crack, no well-defined cone on the other end
18+875, 18-4 Run-1	7'2"-7'9"	76.2	Columnar vertical crack through both ends, no well-defined cones
11+490, 18-1 Run-2	23'7"-24'3"	88.4	Columnar vertical crack through both ends, no well-defined cones

Sincerely,

**Stantec Consulting Ltd**

*Brian Prevost*

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



## **Appendix C.3**

### **Analytical Testing Results**

## Certificate of Analysis

**Thurber Engineering Ltd.**

2460 Lancaster Rd, Suite 104  
Ottawa, ON K1B 4S5  
Attn: Katya Edney

Client PO: 20244  
Project: Hwy 11+118  
Custody: 39862

Report Date: 28-Sep-2018  
Order Date: 24-Sep-2018

**Order #: 1839096**

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

Paracel ID	Client ID
1839096-01	18+250 18-1 SS3 6-8'
1839096-02	18+250 18-4 SS3 5'6"-7-6"
1839096-03	18+875 18-2 SS8 17'6"-19'6"
1839096-04	11+490 18-01 SS3B 7-8'

Approved By:



Mark Foto, M.Sc.  
Lab Supervisor

Certificate of Analysis  
Client: Thurber Engineering Ltd.  
Client PO: 20244

Report Date: 28-Sep-2018  
Order Date: 24-Sep-2018  
Project Description: Hwy 11+118

### Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	26-Sep-18	26-Sep-18
Conductivity	MOE E3138 - probe @25 °C, water ext	27-Sep-18	27-Sep-18
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	27-Sep-18	27-Sep-18
Resistivity	EPA 120.1 - probe, water extraction	27-Sep-18	27-Sep-18
Solids, %	Gravimetric, calculation	27-Sep-18	27-Sep-18

Certificate of Analysis  
Client: Thurber Engineering Ltd.  
Client PO: 20244

Report Date: 28-Sep-2018

Order Date: 24-Sep-2018

Project Description: Hwy 11+118

<b>Client ID:</b>		18+250 18-1 SS3 6-8'	18+250 18-4 SS3 5'6"-7-6"	18+875 18-2 SS8 17'6"-19'6"	11+490 18-01 SS3B 7-8'
<b>Sample Date:</b>		09/12/2018 09:00	09/14/2018 09:00	09/19/2018 09:00	09/16/2018 09:00
<b>Sample ID:</b>		1839096-01	1839096-02	1839096-03	1839096-04
<b>MDL/Units</b>		Soil	Soil	Soil	Soil
<b>Physical Characteristics</b>					
% Solids	0.1 % by Wt.	79.4	79.6	80.3	82.1
<b>General Inorganics</b>					
Conductivity	5 uS/cm	227	243	1340	383
pH	0.05 pH Units	5.86	5.11	4.82	5.32
Resistivity	0.10 Ohm.m	44.1	41.1	7.45	26.1
<b>Anions</b>					
Chloride	5 ug/g dry	40	104	1260	236
Sulphate	5 ug/g dry	129	62	70	24

Certificate of Analysis  
Client: Thurber Engineering Ltd.  
Client PO: 20244

Report Date: 28-Sep-2018  
Order Date: 24-Sep-2018  
Project Description: Hwy 11+118

### Method Quality Control: Blank

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
<b>Anions</b>									
Chloride	ND	5	ug/g						
Sulphate	ND	5	ug/g						
<b>General Inorganics</b>									
Conductivity	ND	5	uS/cm						
Resistivity	ND	0.10	Ohm.m						



Certificate of Analysis  
Client: Thurber Engineering Ltd.  
Client PO: 20244

Report Date: 28-Sep-2018  
Order Date: 24-Sep-2018  
Project Description: Hwy 11+118

**Method Quality Control: Duplicate**

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
<b>Anions</b>									
Chloride	22.3	5	ug/g dry	23.2			4.1	20	
Sulphate	15.1	5	ug/g dry	15.6			3.3	20	
<b>General Inorganics</b>									
Conductivity	211	5	uS/cm	204			3.1	6.2	
pH	7.90	0.05	pH Units	7.93			0.4	10	
Resistivity	47.5	0.10	Ohm.m	48.9			3.1	20	
<b>Physical Characteristics</b>									
% Solids	79.2	0.1	% by Wt.	79.5			0.4	25	

Certificate of Analysis  
Client: Thurber Engineering Ltd.  
Client PO: 20244

Report Date: 28-Sep-2018  
Order Date: 24-Sep-2018  
Project Description: Hwy 11+118

### Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
<b>Anions</b>									
Chloride	117	5	ug/g	23.2	93.8	78-113			
Sulphate	120	5	ug/g	15.6	104	78-111			

Certificate of Analysis  
Client: Thurber Engineering Ltd.  
Client PO: 20244

Report Date: 28-Sep-2018  
Order Date: 24-Sep-2018  
Project Description: Hwy 11+118

**Qualifier Notes:**

None

**Sample Data Revisions**

None

**Work Order Revisions / Comments:**

None

**Other Report Notes:**

n/a: not applicable  
ND: Not Detected  
MDL: Method Detection Limit  
Source Result: Data used as source for matrix and duplicate samples  
%REC: Percent recovery.  
RPD: Relative percent difference.

Soil results are reported on a dry weight basis when the units are denoted with 'dry'.  
Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.

## Subcontracted Analysis

**Thurber Engineering Ltd.**2460 Lancaster Rd, Suite 104  
Ottawa, ON K1B 4S5  
Attn: Katya EdneyTel: (613) 247-2121  
Fax: (613) 247-2185Paracel Report No **1839096**Client Project(s): **Hwy 11+118**Client PO: **20244**Reference: **Standing Offer**CoC Number: **39862**Order Date: 24-Sep-18  
Report Date: 27-Sep-18

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
1839096-01	18+250 18-1 SS3 6-8'	Sulphide, solid
1839096-02	18+250 18-4 SS3 5'6"-7-6"	Sulphide, solid
1839096-03	18+875 18-2 SS8 17'6"-19'6"	Sulphide, solid
1839096-04	11+490 18-01 SS3B 7-8'	Sulphide, solid

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.  
Lakefield - Ontario - K0L 2H0  
Phone: 705-652-2000 FAX: 705-652-6365

**Paracel Laboratories**

Attn : Dale Robertson

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

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

27-September-2018

**Date Rec. :** 25 September 2018  
**LR Report:** CA13421-SEP18  
**Reference:** Project#: 1839096

**Copy:** #1

## CERTIFICATE OF ANALYSIS

### Final Report

Sample ID	Sample Date & Time	Sulphide %
1: Analysis Start Date		27-Sep-18
2: Analysis Start Time		12:40
3: Analysis Completed Date		27-Sep-18
4: Analysis Completed Time		13:39
5: QC - Blank		< 0.02
6: QC - STD % Recovery		83%
7: QC - DUP % RPD		ND
8: RL		0.02
9: 18+250 18-1 SS3 6-8'	12-Sep-18	< 0.02
10: 18+250 18-4 SS3 5'6"-7-6"	14-Sep-18	< 0.02
11: 18+875 18-2 SS8 17'6"-19'6"	19-Sep-18	< 0.02
12: 11+490 18-01 SS3B 7-8'	16-Sep-18	< 0.02

RL - SGS Reporting Limit  
ND - Not Detected

Kimberley Didsbury  
Project Specialist  
Environmental Services, Analytical

## Certificate of Analysis

### Thurber Engineering Ltd.

2460 Lancaster Rd, Suite 104  
Ottawa, ON K1B 4S5  
Attn: Katya Edney

Client PO: 20244  
Project: HWY11+118  
Custody: 39863

Report Date: 9-Oct-2018  
Order Date: 2-Oct-2018

**Order #: 1840220**

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

Paracel ID	Client ID
1840220-01	18+550 18-1 SS3 5'6"-6'2"
1840220-02	18+550 18-4 SS2 3-5
1840220-03	18+875 18-4 SS1 2'6"-4'6"
1840220-04	11+490 18-4 SS3 5-7
1840220-05	22+590 18-1 SS2 4-6
1840220-06	22+590 18-4 SS3 6-8'

*Depths provided in these results are measured from the top of the drilling platform not shown on the Record of Borehole Sheet. Platform height measured 0.8 m at Borehole 18-4.*

Approved By:



Mark Foto, M.Sc.  
Lab Supervisor

Certificate of Analysis  
Client: Thurber Engineering Ltd.  
Client PO: 20244

Report Date: 09-Oct-2018

Order Date: 2-Oct-2018

Project Description: HWY11+118

## Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	5-Oct-18	5-Oct-18
Conductivity	MOE E3138 - probe @25 °C, water ext	4-Oct-18	5-Oct-18
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	5-Oct-18	5-Oct-18
Resistivity	EPA 120.1 - probe, water extraction	4-Oct-18	5-Oct-18
Solids, %	Gravimetric, calculation	3-Oct-18	3-Oct-18



Certificate of Analysis  
Client: Thurber Engineering Ltd.  
Client PO: 20244

Report Date: 09-Oct-2018

Order Date: 2-Oct-2018

Project Description: HWY11+118

	<b>Client ID:</b>	18+550 18-1 SS3 5'6"-6'2"	18+550 18-4 SS2 3-5	18+875 18-4 SS1 2'6"-4'6"	11+490 18-4 SS3 5-7
	<b>Sample Date:</b>	09/23/2018 09:00	09/22/2018 09:00	09/20/2018 09:00	09/28/2018 09:00
	<b>Sample ID:</b>	1840220-01	1840220-02	1840220-03	1840220-04
	<b>MDL/Units</b>	Soil	Soil	Soil	Soil
<b>Physical Characteristics</b>					
% Solids	0.1 % by Wt.	85.4	79.7	90.5	82.8
<b>General Inorganics</b>					
Conductivity	5 uS/cm	347	117	124	225
pH	0.05 pH Units	7.47	5.65	6.26	6.22
Resistivity	0.10 Ohm.m	28.8	85.1	80.9	44.5
<b>Anions</b>					
Chloride	5 ug/g dry	211	55	19	124
Sulphate	5 ug/g dry	10	21	6	7
	<b>Client ID:</b>	22+590 18-1 SS2 4-6	22+590 18-4 SS3 6-8'		-
	<b>Sample Date:</b>	09/25/2018 09:00	09/26/2018 09:00	-	-
	<b>Sample ID:</b>	1840220-05	1840220-06	-	-
	<b>MDL/Units</b>	Soil	Soil	-	-
<b>Physical Characteristics</b>					
% Solids	0.1 % by Wt.	86.5	85.5	-	-
<b>General Inorganics</b>					
Conductivity	5 uS/cm	302	15	-	-
pH	0.05 pH Units	6.44	5.59	-	-
Resistivity	0.10 Ohm.m	33.1	653	-	-
<b>Anions</b>					
Chloride	5 ug/g dry	168	<5	-	-
Sulphate	5 ug/g dry	11	<5	-	-

Certificate of Analysis  
Client: Thurber Engineering Ltd.  
Client PO: 20244

Report Date: 09-Oct-2018  
Order Date: 2-Oct-2018  
Project Description: HWY11+118

### Method Quality Control: Blank

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
<b>Anions</b>									
Chloride	ND	5	ug/g						
Sulphate	ND	5	ug/g						
<b>General Inorganics</b>									
Conductivity	ND	5	uS/cm						
Resistivity	ND	0.10	Ohm.m						

Certificate of Analysis  
Client: Thurber Engineering Ltd.  
Client PO: 20244

Report Date: 09-Oct-2018

Order Date: 2-Oct-2018

Project Description: HWY11+118

### Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
<b>Anions</b>									
Chloride	205	5	ug/g dry	211			2.7	20	
Sulphate	9.29	5	ug/g dry	9.98			7.2	20	
<b>General Inorganics</b>									
Conductivity	364	5	uS/cm	347			4.6	6.2	
pH	11.69	0.05	pH Units	11.61			0.7	10	
Resistivity	27.5	0.10	Ohm.m	28.8			4.6	20	
<b>Physical Characteristics</b>									
% Solids	90.9	0.1	% by Wt.	94.3			3.8	25	

Certificate of Analysis  
Client: Thurber Engineering Ltd.  
Client PO: 20244

Report Date: 09-Oct-2018

Order Date: 2-Oct-2018

Project Description: HWY11+118

### Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
<b>Anions</b>									
Chloride	308	5	ug/g	211	97.2	78-113			
Sulphate	110	5	ug/g	9.98	100	78-111			

Certificate of Analysis  
Client: Thurber Engineering Ltd.  
Client PO: 20244

Report Date: 09-Oct-2018  
Order Date: 2-Oct-2018  
Project Description: HWY11+118

**Qualifier Notes:**

None

**Sample Data Revisions**

None

**Work Order Revisions / Comments:**

None

**Other Report Notes:**

n/a: not applicable  
ND: Not Detected  
MDL: Method Detection Limit  
Source Result: Data used as source for matrix and duplicate samples  
%REC: Percent recovery.  
RPD: Relative percent difference.

Soil results are reported on a dry weight basis when the units are denoted with 'dry'.  
Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.

## Subcontracted Analysis

**Thurber Engineering Ltd.**2460 Lancaster Rd, Suite 104  
Ottawa, ON K1B 4S5  
Attn: Katya EdneyTel: (613) 247-2121  
Fax: (613) 247-2185Paracel Report No **1840220**Client Project(s): **HWY11+118**Client PO: **20244**Reference: **Standing Offer**CoC Number: **39863**Order Date: 02-Oct-18  
Report Date: 9-Oct-18

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
1840220-01	18+550 18-1 SS3 5'6"-6'2"	Sulphide, solid
1840220-02	18+550 18-4 SS2 3-5	Sulphide, solid
1840220-03	18+875 18-4 SS1 2'6"-4'6"	Sulphide, solid
1840220-04	11+490 18-4 SS3 5-7	Sulphide, solid
1840220-05	22+590 18-1 SS2 4-6	Sulphide, solid
1840220-06	22+590 18-4 SS3 6-8'	Sulphide, solid

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.  
Lakefield - Ontario - K0L 2H0  
Phone: 705-652-2000 FAX: 705-652-6365

**Paracel Laboratories**

Attn : Dale Robertson

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

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

10-October-2018

**Date Rec. :** 04 October 2018  
**LR Report:** CA12131-OCT18  
**Reference:** Project#:1840220

**Copy:** #1

## CERTIFICATE OF ANALYSIS

### Final Report

Sample ID	Sample Date & Time	Sulphide %
1: Analysis Start Date		05-Oct-18
2: Analysis Start Time		13:35
3: Analysis Completed Date		05-Oct-18
4: Analysis Completed Time		14:36
5: QC - Blank		< 0.02
6: QC - STD % Recovery		99%
7: QC - DUP % RPD		1%
8: RL		0.02
9: 18+550 18-1 SS3 5'6"-6'2"	23-Sep-18	< 0.02
10: 18+550 18-4 SS2 3-5	22-Sep-18	< 0.02
11: 18+875 18-4 SS1 2'6"-4'6"	20-Sep-18	< 0.02
12: 11+490 18-4 SS3 5-7	28-Sep-18	< 0.02
13: 22+590 18-1 SS2 4-6	25-Sep-18	< 0.02
14: 22+590 18-4 SS3 6-8'	26-Sep-18	< 0.02

RL - SGS Reporting Limit

Kimberley Didsbury  
Project Specialist  
Environmental Services, Analytical



## **Appendix D.**

### **Site Photographs**





**Photo 1. Looking Southwest at Culvert 18+874 Outlet (2018/09/11)**





**Photo 2. Looking North at Culvert 18+874 Inlet (2018/09/11)**





**Photo 3. Looking East along HWY 118 at St. 18+874 (2018/09/19)**



**Photo 4. Looking West along HWY 118 at St. 18+874 (2018/09/18)**



## **Appendix E.**

### **Foundation Comparison**

### COMPARISON OF ALTERNATIVE FOUNDATION TYPES

	<b><i>Circular Pipe or Closed Box Culvert</i></b>	<b><i>Circular Pipe Culvert (Trenchless Installation)</i></b>	<b><i>Open Bottom Culvert</i></b>	<b><i>Precast Concrete Slab on Steel Sheet Piles</i></b>
<b><i>Advantages</i></b>	<p>Relatively expedient installation if precast units are used.</p> <p>Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade.</p>	<p>Can tolerate larger magnitude of settlement than concrete (rigid frame) culverts).</p> <p>Avoids open cut</p> <p>Allows two lanes of traffic to be maintained throughout construction</p>	<p>Relatively expedient installation if precast units are used.</p> <p>Possibility to maintain work zone to span the existing waterway.</p>	<p>Potentially minimized volume of excavation and roadway protection</p> <p>Maintains water flow during construction</p> <p>Could allow for winter construction</p>
<b><i>Disadvantages</i></b>	<p>Requires large excavation and roadway protection.</p> <p>Requires water flow realignment or installation of a temporary by-pass culvert to maintain existing water flow alignment</p>	<p>Requires construction of entry and exit pits and access to toes of slope.</p> <p>Requires specialised construction equipment.</p> <p>Feasibility also depends on flow capacity and other hydraulic properties.</p> <p>Not suitable for mixed soil faces.</p>	<p>Requires deeper excavation increasing excavation volume and dewatering concern.</p> <p>Requires roadway protection.</p>	<p>Quantity and cost of sheet piles</p>
<b><i>Risks/ Consequences</i></b>	<p>Disruption to traffic</p>	<p>High risk of encountering obstructions, varying shallow bedrock surface and mixed soils</p> <p>Risk of encountering groundwater in a loose cohesionless soil</p>	<p>Disruption to traffic</p>	<p>High risk of encountering obstructions in fill and till as well as shallow bedrock</p>
<b><i>Relative Cost</i></b>	<b>Low to Medium</b>	<b>Medium to High</b>	<b>Medium</b>	<b><i>Medium to High</i></b>
<b><i>Recommendation</i></b>	<b>Recommended</b>	<b>Not Feasible</b>	<b>Not Recommended</b>	<b>Not Feasible</b>



## **Appendix F.**

### **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

October 29, 2018

Site: 44.993 N, 79.1945 W User File Reference: Sta. 18 874

Requested by: , Thurber Engineering Ltd.

**National Building Code ground motions: 2% probability of exceedance in 50 years (0.000404 per annum)**

Sa(0.05)	Sa(0.1)	<b>Sa(0.2)</b>	Sa(0.3)	<b>Sa(0.5)</b>	<b>Sa(1.0)</b>	<b>Sa(2.0)</b>	<b>Sa(5.0)</b>	<b>Sa(10.0)</b>	<b>PGA (g)</b>	<b>PGV (m/s)</b>
0.084	0.117	<b>0.117</b>	0.102	<b>0.085</b>	<b>0.052</b>	<b>0.027</b>	<b>0.0069</b>	<b>0.0031</b>	<b>0.068</b>	<b>0.071</b>

**Notes.** Spectral ( $S_a(T)$ , where  $T$  is the period in seconds) and peak ground acceleration (PGA) values are given in units of  $g$  ( $9.81 \text{ m/s}^2$ ). Peak ground velocity is given in  $\text{m/s}$ . Values are for "firm ground" (NBCC 2015 Site Class C, average shear wave velocity  $450 \text{ m/s}$ ). NBCC2015 and CSAS6-14 values are specified in **bold** font. 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.*

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.05)	0.013	0.035	0.053
Sa(0.1)	0.020	0.052	0.077
Sa(0.2)	0.021	0.055	0.079
Sa(0.3)	0.019	0.048	0.069
Sa(0.5)	0.015	0.040	0.057
Sa(1.0)	0.0072	0.023	0.034
Sa(2.0)	0.0031	0.011	0.017
Sa(5.0)	0.0007	0.0025	0.0041
Sa(10.0)	0.0004	0.0011	0.0018
PGA	0.011	0.030	0.044
PGV	0.0089	0.029	0.045

## References

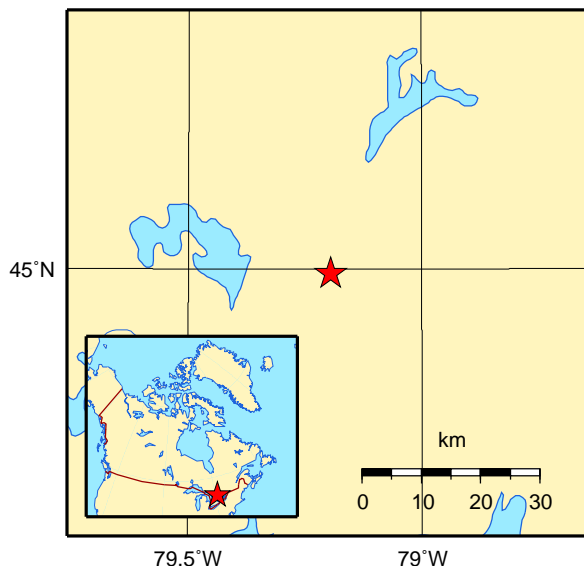
**National Building Code of Canada 2015 NRCC no. 56190;**  
**Appendix C:** Table C-3, Seismic Design Data for Selected Locations in Canada

**User's Guide - NBC 2015, Structural Commentaries NRCC no. xxxxxx** (in preparation)  
**Commentary J:** Design for Seismic Effects

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

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

Aussi disponible en français



Natural Resources  
Canada

Ressources naturelles  
Canada

Canada



## **Appendix G.**

### **List of Special Provisions and OPSS Documents Referenced in this Report**





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

OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 209	Construction Specification for Embankments over Swamps and Compressible Soils
OPSS 421	Construction Specification for Pipe Culvert Installation in Open Cut
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cuts
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 517	Construction Specification for Dewatering
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS 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 1860	Material Specification for Geotextile
OPSD 208.010	Benching of Earth Slopes
OPSD 802.010	Flexible Pipe Embedment and Backfill Earth Excavation
OPSD 803.010	Backfill and Cover for Concrete Culverts with Span Less than or Equal to 3.0 m
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 3090.101	Foundation Frost Penetration Depths for Southern Ontario
SP 517F01	Design Storm Return Period and Preconstruction Survey
SP 109S12	QVE, Backfilling, Compaction, and Certificate of Conformance
NSSP FOUN0003	Dewatering Structure Excavations



2. Suggested text for a NSSP on “Obstructions”  
Obstructions such as cobbles and boulders may be encountered in the embankment and/or native till during excavation, installation of roadway protection systems and/or sheet pile coffer dams. Such obstructions may impede the work from reaching the design depth of installation. The Contractor shall design the temporary works accordingly and/or be prepared to remove, drill through and/or penetrate these obstructions and extend the work to the design depths.
3. Suggested text for an NSSP on “Shallow Bedrock”  
Bedrock was observed to be shallow and of variable depth at this site. The Contractor shall design and construct the temporary roadway protection systems accordingly.
4. Subsection 902.04.01 Design Requirements of SP FOUN0003 is amended by the addition of the following:  
The design Engineer and design-checking Engineer of the dewatering system shall have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work.