



**THURBER** ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
REPLACEMENT OF STRUCTURAL CULVERT No. 29-146/C  
BARBUT CREEK CROSSING OF HIGHWAY 17  
RENFREW COUNTY, ON  
W.P. 4005-13-01  
AGREEMENT NUMBER: 4014-E-0014**

**GEOCRES NUMBER: 31L-203**

**SUBMITTED TO**

**WSP CANADA**

**LOCATION:**

**LATITUDE: 46.26625°**

**LONGITUDE: -78.35435°**

**APRIL 2018**

**19-5161-263**



## Table of Contents

### PART 1: FACTUAL INFORMATION

1	INTRODUCTION .....	1
2	SITE DESCRIPTION .....	1
3	SITE INVESTIGATION .....	2
3.1	Field Investigation .....	2
3.2	LABORATORY TESTING .....	3
4	DESCRIPTION OF SUBSURFACE CONDITIONS .....	3
4.1	Overview / General .....	3
4.2	Asphalt.....	4
4.3	Topsoil.....	4
4.4	Fill.....	4
4.5	Peat .....	5
4.6	Silt (ML) .....	5
4.7	Silty Sand (SM) with Gravel: Till.....	6
4.8	Groundwater .....	6
5	MISCELLANEOUS .....	7

### PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

6	GENERAL.....	8
6.1	Proposed Structure .....	8
6.2	Applicable Codes and Design Considerations.....	9
6.3	Geotechnical Assessment.....	9
7	SEISMIC CONSIDERATIONS .....	10
7.1	Spectral and Peak Acceleration Hazard Values .....	10
7.2	CHBDC Seismic Site Classification.....	10
7.3	Seismic Liquefaction .....	11
8	DESIGN OPTIONS .....	11
8.1	Culvert Type/Foundation Alternatives .....	11
8.1.1	Circular Pipes .....	11
8.1.2	Closed Box (Concrete).....	11

8.1.3	Open Bottom (Steel/Concrete Arch or Concrete Rigid Frame) .....	11
8.1.4	Pre-cast vs Cast-in-Place Concrete Culverts .....	12
8.2	Construction Methodology Alternatives .....	12
8.2.1	Trenchless Techniques .....	12
8.2.2	Open Cut with Staged Construction and Temporary Protection Systems .....	13
8.2.3	Open Cut - Staged Construction with Platform Lowering and/or Widening .....	13
8.2.4	Open Cut with Temporary Modular Bridge .....	13
8.3	Recommended Approach for the Culvert Replacement .....	13
9	FOUNDATION DESIGN RECOMMENDATIONS .....	14
9.1	Culvert Foundation Bearing Resistances .....	14
9.2	Subgrade Preparation and Backfilling .....	15
9.3	Retaining Walls .....	15
9.4	Embankment Design and Reinstatement .....	16
9.5	Lateral Earth Pressures .....	16
9.5.1	Static Lateral Earth Pressure Coefficients .....	17
9.5.2	Combined Static and Seismic Lateral Earth Pressure Parameters .....	18
9.6	Temporary Modular Bridge Foundations .....	19
9.6.1	Bearing Resistances .....	19
9.6.2	Assessment of Global Stability .....	20
9.7	Cement Type and Corrosion Potential .....	20
10	CONSTRUCTION CONSIDERATIONS .....	20
10.1	Excavations .....	20
10.2	Temporary Protection Systems .....	21
10.3	Dewatering .....	21
10.4	Erosion Protection .....	23
11	CONSTRUCTION CONCERNS .....	24
12	CLOSURE .....	25



## **APPENDICES**

Appendix A	Borehole Locations and Soil Strata Drawings
	Preliminary General Arrangement Drawing
Appendix B	Record of Borehole Sheets
Appendix C	Laboratory Test Results
Appendix D	Site Photographs
Appendix E	Comparison of Culvert Type/Foundation Alternatives
	Comparison of Construction Methodology Options
Appendix F	GSC Seismic Hazard Calculation
	Slope Stability Analysis Results
	List of Referenced Specifications
	Non-Standard Special Provision

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
REPLACEMENT OF STRUCTURAL CULVERT No. 29-146/C  
BARBUT CREEK CROSSING OF HIGHWAY 17  
RENFREW COUNTY, ON  
W.P. 4005-13-01  
AGREEMENT NUMBER: 4014-E-0014**

**GEOCRES NUMBER: 31L-203**

**PART 1: FACTUAL INFORMATION**

## **1 INTRODUCTION**

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) for the replacement of the Barbut Creek Culvert located on Highway 17, within Renfrew County. Thurber carried out the investigation as a subconsultant to WSP Canada (WSP) as part of Agreement No. 4014-E-0014.

No previous foundation investigation information for the subject culvert was available. A Preliminary General Arrangement (GA) drawing dated March 29, 2018 and base plan mapping were provided by WSP for the preparation of this report.

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

## **2 SITE DESCRIPTION**

Culvert 29-146/C is located on Highway 17, approximately 28 km east of Mattawa, Ontario. The location of the culvert is shown on the inset Key Plan on Drawing No. 1 in Appendix A.

It is noted that for project orientation purposes, Highway 17 within the project limits has one through lane in each direction and will be assumed to run west-east. Based on the Preliminary GA drawing the roadway cross-section consists of two, 3.75 m wide lanes with gravel shoulders. Steel beam guide rails are present along both sides of the highway in the vicinity of the culvert.

The existing culvert is a cast-in-place, concrete, open bottom, rigid frame, with an internal height of 2.1 m and span of 6 m that carries creek flow from south to north below the highway. One extension has been added to the north end of the original culvert and two separate extensions have been added to the south end. The extensions are conventional open footing rigid frame culverts. Including the extensions, the total length of the structure is reported to be 40.2 m. The March 2018 Preliminary GA drawing, also provided in Appendix A, indicates that elevation of the top of stream bed ranges from Elevation 151.05 m and 150.28 m at the inlet and outlet respectively.

No settlement or stability issues were noted at the culvert at the time of Thurber's field investigation. Due to the high creek water elevation during the field investigation, inspection for scour and erosion at the founding level at the inlet/outlet was not possible.

The culvert is located within a high fill section. The height of the embankment in the area of the culvert is approximately 7 m. The slopes of the embankment were observed to be covered with a

mix of brush and granular material. Some erosion of the granular slopes on both sides of the highway was noted. The embankment slopes were graded with slopes ranging from approximately 2.2H:1V to 2.8H:1V (Horizontal:Vertical). The elevation of the center line of roadway as reported on the Preliminary GA drawing was 157.6 m and the elevation of the top of the culvert at the inlet and outlet ends are indicated as approximately 153.5 m and 152.9 m providing for 4.1 m to 4.7 m of cover.

The site is located within a physiographic region known as the Algonquin Highlands which is characterized as having soils that are generally shallow overburden deposits with rough relief of rounded knobs and ridges, areas of outwash sand and gravel deposits, and frequently exposed bedrock. (Chapman and Putnam 1984).

The lands surrounding the project limits include forest and swampy areas. The Ottawa River is approximately 150 m north of the culvert site and is approximately parallel to Highway 17. Storm water drainage in the area is to ditches along the highway, and to Barbut Creek which outlets into the Ottawa River.

Site photographs showing the general conditions at the site, along the highway embankment and at the inlet and outlet are presented in Appendix D.

### 3 SITE INVESTIGATION

#### 3.1 Field Investigation

A field investigation for the proposed culvert replacement was carried out between October 13, 2015 and December 15, 2015, and included advancing four boreholes (Boreholes 501 through 504). Due to the presence of large boulders within the embankment, an additional borehole (designated Boreholes 502C) was advanced in the eastbound lane using telescoping drilling techniques to advance through the existing rock fill.

Based on the September 2017 Preliminary Staging Drawings provided by WSP, a temporary modular bridge (TMB) will be installed along the south side of the highway in order to maintain traffic during construction for replacement of the culvert. A supplementary foundation investigation was carried to support the design of the TMB. The supplemental investigation was carried out between June 29 and June 30, 2017 and included advancing two additional boreholes (Boreholes 505 and 506).

The approximate locations and elevations of the both the original and supplement boreholes are illustrated on Drawing No. 1 provided in Appendix A and are summarized in Table 3-1.

**Table 3-1: Borehole Summary**

Borehole	Location	Latitude	Longitude	Ground Surface Elevation (m)	Depth (m)
501	Culvert Inlet	46.26611	-78.35431	154.0	4.6
502	Highway 17 EB	46.26629	-78.35430	157.7	5.4
502C	Highway 17 EB	46.26630	-78.35431	157.8	16.0
503	Highway 17 WB	46.26626	-78.35415	157.5	15.3
504	Culvert Outlet	46.26640	-78.35416	154.4	6.0
505	Highway 17 EB	46.26638	-78.35446	157.9	13.8
506	Highway 17 EB	46.26614	-78.35401	157.3	10.9

As a component of our standard procedures and due diligence, Thurber contacted Ontario One Call to provide utility locates/clearances for the intended borehole locations.

The boreholes advanced through the roadway embankment were advanced with either a CME75 truck mounted drill rig equipped with NW size casing or a CME850 truck mounted drill equipped with HW size casing utilizing a telescoping drilling technique. The inlet and outlet boreholes were advanced with portable drilling equipment. Borehole 504 (outlet borehole) was advanced to refusal with Dynamic Cone Penetration Testing (DCPT). The subsurface stratigraphy encountered in the boreholes was recorded in the field by Thurber personnel. Split spoon samples were collected at regular depth intervals in the boreholes via the completion of Standard Penetration Tests (SPT), following the methods described in ASTM Standard D1586-11. All soil samples recovered from the boreholes were placed in moisture-proof containers and the samples were transported to Thurber's Ottawa geotechnical laboratory for further examination and testing.

A 25 mm inside diameter PVC piezometer was installed in Borehole 501 to allow for measurement of the groundwater level at the site. The piezometer construction details are illustrated on the Record of Borehole sheet for Borehole 501, provided in Appendix B. The piezometer was decommissioned on December 15, 2015.

The boreholes without a piezometer were backfilled with a low-permeability mixture of auger cuttings and bentonite pellets in general accordance with the intent of Ontario MOE Regulation 903. Boreholes advanced within paved areas were capped with 150 mm of cold patch asphalt.

The as-drilled locations of the boreholes and ground surface elevations at the borehole locations were surveyed by Thurber. The vertical datum used was a horizontal control point (HCP) identified on base plans provided by WSP as a rock bar with a geodetic elevation of 161.521 m. This HCP is located at Station 13+906, approximately 100 m west of the culvert site and 25 m north of the centerline of Highway 17.

### **3.2 LABORATORY TESTING**

Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all soil samples in accordance with the current MTO standards. Grain size distribution analyses testing was also carried out on selected samples to MTO and ASTM standards. Testing was completed in the Thurber Ottawa laboratory.

The geotechnical laboratory test results are presented on the Record of Borehole sheets in Appendix B and are illustrated on the figures in Appendix C.

Chemical analysis for determination of pH, resistivity, soluble sulphate and chloride concentrations was carried out on one soil sample at Paracel Laboratories Ltd. in Ottawa. A copy of the chemical analysis results is provided in Appendix C.

## **4 DESCRIPTION OF SUBSURFACE CONDITIONS**

### **4.1 Overview / General**

Reference is made to the Record of Borehole sheets in Appendix B for details of the soil stratigraphy encountered in the boreholes. A stratigraphic profile along the culvert alignment and along the highway alignment are presented on Drawing No. 1 in Appendix A for illustrative

purposes. An overall description of the stratigraphy is given in the following paragraphs; however, the factual data presented in the Record of Boreholes governs any interpretation of the site conditions.

In general, the stratigraphy beneath Highway 17 in the area of the culvert is characterized by an asphalt pavement structure overlying embankment fill containing rock fill, overlying a glacial till deposit. A buried layer of peat was encountered between the fill and till in Boreholes 504 and 505 and thin layers of silt and peat were encountered between the fill and till in Borehole 506.

More detailed descriptions of the individual strata are presented below.

## **4.2 Asphalt**

Five boreholes were advanced through the Highway 17 pavement structure. The thickness of the asphalt ranged from 100 mm to 120 mm.

## **4.3 Topsoil**

A topsoil layer with a thickness of 25 mm was encountered at surface in Borehole 504 near the culvert outlet.

## **4.4 Fill**

### **Sand with Gravel Fill**

A fill layer consisting predominantly of sand and gravel with varying amounts of silt was encountered below the asphalt in the embankment boreholes, at the ground surface in Borehole 501 and below the topsoil in Borehole 504. The top of this layer ranges from Elevation 157.2 m to 157.8 m. The thickness of the layer ranged from 700 mm to 1.1 m. The SPT 'N' values ranged from 44 to greater than 100 blows; indicating a dense to very dense condition. Cobbles were noted in this layer.

The moisture content of the samples tested ranged from 2% to 10%. The results of a grain size analysis test completed on samples of this material indicated a gravel content ranging from 28% to 39%, sand content ranging from 56% and 63%, and a fines content (combined silt and clay size particles) ranging from 0% to 9%. Grain size analysis results are illustrated on Figure 1 in Appendix C.

### **Embankment Fill (Rock Fill)**

Rock fill was encountered within the core of the embankment beneath the pavement structure in Boreholes 502/502C, 503, 505 and 506. Where encountered, the top of this layer ranges from Elevation 156.1 m to 156.9 m. The thickness of the layer ranged from 4.1 m to 6.7 m. Trace wood pieces were encountered at the base of this layer in Borehole 503.

The rock fill contained frequent cobble and boulder sized particles. Coring techniques were required to advance the boreholes through this layer due to the presence of the cobble and boulder sized material.



Where samples were recovered with a split spoon sampler, the fill consisted predominantly of gravel and sand with trace amounts of silt. The SPT 'N' values ranged from 5 to greater than 100 blows; indicating a loose to very dense condition; but typically compact to dense.

The moisture content for the recovered samples tested ranged from 2% to 21%. The results of grain size analysis conducted on six samples of this material are summarized in Table 4-1 and are illustrated on Figure 2 in Appendix C. It should be noted that the lab testing was carried out on samples recovered from split spoon samplers which did not include the boulders, cobbles and large gravel material present within the rock fill.

**Table 4-1: Gradation Results for Rock Fill**

<b>Soil Particles</b>	<b>%</b>
Gravel	23 to 62
Sand	35 to 69
Silt and Clay	3 to 9

### **Sand with Silt and Gravel Fill**

A fill layer consisting predominantly of sand and gravel with varying amounts of silt was encountered beneath the topsoil layer in Borehole 504 and at the ground surface of Borehole 501. The top of this layer ranges from Elevation 154.4 m and 154.0 m. The thickness of the layer ranged from 3.0 m and 3.9 m. The SPT 'N' values ranged from 2 to 31; indicating a very loose to dense condition; but typically loose to compact.

The moisture content for the samples tested ranged from 2% to 22%. The results of grain size analysis conducted on samples of this material are summarized in Table 4-2 and are illustrated on Figure 3 in Appendix C.

**Table 4-2: Gradation Results for Fill**

<b>Soil Particles</b>	<b>%</b>
Gravel	19 to 37
Sand	53 to 76
Silt and Clay	5 to 10

### **4.5 Peat**

Peat with trace to some wood pieces was encountered below the fill material in Boreholes 504 and 505 and between silt layers in Borehole 506. The peat in Borehole 505 was mixed with sand and gravel. The top of the peat ranged from Elevation 150.5 m to 151.2. The thickness of the peat layer ranged from 300 mm to 1.0 m.

The moisture content for the samples tested ranged from 107% to 275%. Test results carried on samples of this material indicated an organic content ranging from 20% to 54%.

### **4.6 Silt (ML)**

A silt deposit was encountered between the fill and the till deposits in Borehole 506. The top of this layer was encountered at Elevation 151.9 m. The overall thickness of the layer was 1.7 m, however, a 300 mm thick layer of peat was encountered in the middle of the silt layer. Trace

organic material was observed throughout the silt both above and below the peat. The SPT 'N' values ranged from 3 to 5; indicating a very loose to loose condition.

The moisture content of the samples tested were 47% and 138%. The results of a grain size analysis test completed on a sample of this material indicated a gravel content of 0%, sand content of 11% a silt content of 69%, and a clay content 20%. Grain size analysis results are illustrated on Figure 4 in Appendix C.

#### **4.7 Silty Sand (SM) with Gravel: Till**

A glacial till layer consisting predominantly of silty sand with varying amounts of gravel was encountered in all boreholes. The top of this layer ranges from Elevation 149.6 m to 150.9 m. All boreholes were terminated in this stratum. The SPT 'N' values ranged from 16 to greater than 100 blows; indicating a compact to very dense condition; but typically dense to very dense. Occasional to frequent boulders and cobbles were encountered in this stratum and coring techniques were required to advance through this layer.

The moisture content for the samples tested ranged from was 8% to 20%. The results of grain size analysis conducted on samples of this material are summarized in Table 4-3 and are illustrated on Figures 5 and 6 in Appendix C.

**Table 4-3: Gradation Results for Till**

<b>Soil Particles</b>	<b>%</b>
Gravel	11 to 28
Sand	50 to 69
Silt and Clay	19 to 36

#### **4.8 Groundwater**

The groundwater level was measured in the piezometer installed in Borehole 501 on December 15, 2015, at a depth of 2.1 m; corresponding to an elevation of 151.9 m. The groundwater level was also measured in Borehole 505 during drilling (open borehole) on June 27, 2017, at a depth of 5.65 m; corresponding to an elevation of 152.3 m.

The water level in Barbut Creek was measured at the time of Thurber's field investigations at a depth of 1.3 m below the top of the culvert at the inlet; corresponding Elevation 152.2 m. The groundwater level in the area of the culvert is expected to reflect the creek water level.

These observations are considered short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.

## 5 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. Thurber surveyed the borehole locations, and determined the ground surface elevations based on contract drawings provided by WSP Canada. Ohlmann Geotechnical Services (OGS) Inc. of Almonte, Ontario and Downing George Estate Drilling Ltd. of Hawkesbury, Ontario supplied and operated the drilling equipment to carry out the drilling, sampling, and in-situ testing. The drilling, and sampling operations in the field were supervised on a full-time basis by Mr. Simon Paxton and Justin Gray of Thurber. Laboratory testing was carried out by Thurber in its MTO-approved laboratory in Ottawa.

Overall project management and direction of the field program was provided by Paul Carnaffan, P.Eng. Interpretation of the field data and preparation of this report was completed by Kenton Power, P.Eng. The report was reviewed by Paul Carnaffan, P.Eng. and Dr. P.K. Chatterji, P.Eng., the Designated Principal Contact for MTO Foundations Projects.



Kenton C. Power, P.Eng.  
Geotechnical Engineer



Paul Carnaffan, P.Eng.  
Principal, Senior Geotechnical Engineer



P.K. Chatterji, P.Eng.  
Review Principal, Designated MTO Contact

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
REPLACEMENT OF STRUCTURAL CULVERT No. 29-146/C  
BARBUT CREEK CROSSING OF HIGHWAY 17  
RENFREW COUNTY, ON  
W.P. 4005-13-01  
AGREEMENT NUMBER: 4014-E-0014**

**GEOCRES NUMBER: 31L-203**

**PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**6 GENERAL**

This report presents the interpretation of the factual data obtained from a foundation investigation conducted by Thurber for the replacement of the Barbut Creek Culvert located on Highway 17, in Renfrew, Ontario. Geotechnical assessment and recommendations are provided to assist the design team in designing a suitable foundation for the proposed replacement culvert.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. Contractors must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only 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.

No previous foundation investigation information for the subject culvert was available. A Preliminary General Arrangement (GA) drawing dated March 29, 2018, and base plan mapping were provided by WSP for the preparation of this report. A copy of the Preliminary GA drawing is provided in Appendix A.

The following sections address geotechnical recommendations for the replacement of the existing Barbut Creek Culvert. The discussions and recommendations presented in this report are based on the information provided by WSP and on the factual data obtained during the course of this investigation.

**6.1 Proposed Structure**

Based on the March 2018 Preliminary GA provided by WSP, the existing culvert is to be replaced with a 22 m long, open bottom, metal arch culvert with an approximate span of 10 m; installed on the existing alignment. A concrete headwall would be constructed at both ends of the culvert with concrete retaining walls set at an approximate angle of 45° to the headwall. The exposed height of the walls is anticipated to be a maximum of 5.8 m at the headwall tapering down to 3.5 m.

The design top of stream bed elevation is to range from Elevation 151.0 m to 151.2 m and no permanent changes to the highway profile above the culvert are proposed.

The Preliminary GA also indicates that the span and rise of the new culvert are both about 3 m greater than those of the existing culvert. The new footings will be constructed to the outside of

the existing footings, which have been identified as having an outside to outside dimension of 8.28 m. It is expected that the founding elevation of the new and existing footings will be the same.

A temporary modular bridge (TMB) is proposed to maintain traffic flow during the culvert replacement. The TMB is to be approximately 43 m in length with a design top of bridge deck elevation ranging from 157.6 m to 157.0 m (sloping west to east). The TMB will reduce traffic flow to a single lane, controlled by temporary signals. The TMB is to be supported on temporary concrete pads perched within the existing rock fill founded at approximate Elevations 156.1 m and 155.5 m at the west and east abutments respectively.

It is understood the existing culvert is to be removed in an open excavation under the TMB prior to construction the new culvert. Also, the proposed temporary flow passage for this site is to consist of a pipe or series of pipes installed through the existing culvert to divert creek flow through the construction zone.

## **6.2 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, version CSA S6-14 (CHBDC).

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

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

## **6.3 Geotechnical Assessment**

Based on the results of the field and laboratory investigation and the information provided by WSP with regards to the proposed project requirements, the geotechnical foundation design considerations include:

- The native stiff to very stiff clay and compact to dense glacial till deposit offer moderate bearing resistance for culvert and retaining wall foundations. These deposits are overlain by silt and silty sand deposits that range from very loose to compact, and contain trace to some organic matter at some locations. The very loose to loose silt and sand deposits are not suitable for the support of foundations and should be removed during the subgrade preparation.
- A buried peat layer was identified beneath the edge of the existing embankment on the north side which are not suitable for the support of either culvert or retaining wall foundations and should be removed during the subgrade preparation.
- Rockfill cobbles and boulders were encountered within the embankment fill. Obstructions may be encountered during excavation or during the installation or temporary protection systems. Suggested wording for an NSSP alerting bidders to their presence has been provided in Appendix F.

- Construction will extend below the water level in the creek. An adequate and effective surface water management and dewatering plan must be implemented to construct the replacement culvert and walls in the dry.
- It is understood that portions of the existing culvert may be left in place temporarily (during construction of the new footings) to help facilitate the temporary flow passage system. This is acceptable provided that the new structure is founded at the same elevation as the footings for the existing culvert. If the footings of the existing culvert are shallower than the founding elevation of the new culvert, the existing culvert and footings would be undermined and would therefore need to be removed.
- Depending on the excavation and dewatering procedures employed by the Contractor, unbalanced earth and hydrostatic pressure may develop on the existing culvert walls and/or foundations while excavations for the new footings are carried out. It is expected that backfill above the existing culvert will be removed prior to excavation for the new culvert foundations, greatly reducing the load on the existing culvert foundations and walls. If the proposed and existing culvert are founded at the same elevation, there should be minimal influence between the structure since neither is under significant load prior to backfilling, as the existing culvert would be removed as part of the backfilling operation for the new culvert. However, should the substrate and backfill within the existing culvert footprint remain while excavations for the new footing are carried out (i.e. to support the temporary flow passage pipe(s)), then unbalanced earth pressures will develop and must be taken into consideration in the design of the excavation and dewatering procedures employed by the Contractor.
- The estimated frost penetration depth at this site is 1.9 m as per OPSD 3090.101.

## **7 SEISMIC CONSIDERATIONS**

### **7.1 Spectral and Peak Acceleration Hazard Values**

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

The site coefficients used to determine the design spectral acceleration and displacement values are a function of the Site Class and the site specific peak ground acceleration (PGA).

### **7.2 CHBDC Seismic Site Classification**

In accordance with the CHBDC, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy below the founding elevation. Based on the soil conditions encountered below the anticipated culvert founding elevation, the site is classified as Seismic Site Class C in accordance with Table 4.1 of the CHBDC.



### **7.3 Seismic Liquefaction**

The compact to very dense rock fill and glacial till deposits located below the groundwater level at this site are not considered to be susceptible to liquefaction. The loose to very loose silt material encountered in Borehole 506 is also not considered to be susceptible to liquefaction under the under the design earthquake event.

## **8 DESIGN OPTIONS**

Based on the soil stratigraphy and the existing stream bed elevations which range from 151.0 m at the inlet to 150.3 m at the outlet, it is expected that the replacement culvert will be founded on glacial till. If peat is encountered in the area of the outlet it should be excavated and removed in accordance with OPSS.PROV 902

The narrow highway platform, high embankment fill and presence of rock fill within the embankment will have an impact on construction and staging approaches. Culvert/foundation alternatives and construction approaches are presented and evaluated in the following sections and a preferred replacement alternative from a foundation engineering perspective is recommended.

### **8.1 Culvert Type/Foundation Alternatives**

Common culvert and foundation types are listed below along with a comparison of these alternatives from a foundations perspective. Their respective advantages and disadvantages are outlined below, and are summarized in the table provided in Appendix E.

#### **8.1.1 Circular Pipes**

From a foundation engineering perspective, circular pipes installed with appropriate granular bedding over the native, undisturbed glacial till subgrade are feasible. However, it is understood that numerous circular pipes on new alignments would be required to provide the required hydraulic opening.

#### **8.1.2 Closed Box (Concrete)**

From a geotechnical perspective, the replacement could also be achieved with a closed bottom culvert. Since the base of the closed box does not need to be founded below frost depth the base of the excavation for a closed box would set at a higher elevation than required for the footings of an open bottom culvert. The shallower excavation would have the advantages of a shorter duration for dewatering, construction staging and reduced material handling.

Based on the stream bed elevation of ranging from approximately 151.0 m to 151.2 m indicated on the Preliminary GA drawings, and allowing for 350 mm thick layer of interior substrate, a 400 mm thick concrete base and a 300 mm thick layer of Granular A bedding, the founding elevation is expected to be around Elevation 150 m. The anticipated founding subgrade material would within the native glacial till.

#### **8.1.3 Open Bottom (Steel/Concrete Arch or Concrete Rigid Frame)**

With the design stream bed elevation of ranging from approximately 151.0 m to 151.2 m, an open bottom culvert founded at elevations ranging from 149.1 m to 149.3 m (1.9 m below top of stream

bed elevation) is considered feasible at this site from a foundation standpoint. At this elevation, it is expected that the replacement culvert will be founded on the compact to very dense till. The open bottom culvert could consist of either a concrete rigid frame culvert or an arch structure (steel or precast concrete).

The founding elevation for the open bottom structure will be lower than for the closed box option, thereby requiring a deeper excavation.

#### 8.1.4 Pre-cast vs Cast-in-Place Concrete Culverts

From a foundation engineering perspective, the use of pre-cast or cast-in-place culverts are both considered feasible for this project however a pre-cast culvert is the preferred option from a foundations point of view. Pre-cast units are manufactured in a controlled casting environment eliminating the drawbacks imposed by varying weather and site conditions. Pre-cast units can be installed on site and the excavation backfilled and placed into service without delay, which can shorten installation time for projects where there are strict/short in-water working schedules. Installing pre-cast units is also less labour intensive versus cast-in-place structures also reducing installation time and costs however, larger cranes are likely required for installation of large span pre-cast units which may impact the required construction staging zone. Fabrication and installation of concrete structural culverts under a design build project should be in accordance with Special Provision DBSP3271.

## 8.2 Construction Methodology Alternatives

This section presents discussions from a foundation perspective on alternative construction methods for the replacement of Culvert 29-146/C. Further comparison of these options is summarized in the table provided in Appendix E.

In preparation of these recommendations the following options have been considered.

1. Trenchless techniques
2. Open cut with staged construction and roadway protection
3. Open cut with staged construction, platform lowering and roadway protection
4. Open cut with temporary bridge structure

#### 8.2.1 Trenchless Techniques

Trenchless techniques have the advantage of minimum disruption to traffic and would avoid an excavation through the existing highway embankment, the presence of rock fill within the embankment means that many common trenchless techniques such as jack and bore are not feasible. Some techniques such as hand tunnelling are feasible within the rock fill but are expensive and present a medium to high risk of construction related problems. In addition, a wide body of open water is present at the outlet side of the embankment which is not well suited for entry/exit pits.

Trenchless techniques are not recommended for this site.



### 8.2.2 Open Cut with Staged Construction and Temporary Protection Systems

The culvert could be replaced using open cut techniques with staged construction (half and half). The use of temporary protection systems parallel to the highway would be required in order to keep at least one lane of traffic open throughout the construction period.

The presence of rock fill and boulders within the glacial till will make the installation of temporary protection systems challenging, increasing cost and the risk of construction issues. Sheet piles systems are not considered feasible at this site due to the presence of rock fill. Protection systems would likely consist of H-piles with timber lagging installed by pre-drilling holes for installation of H-piles; soil anchors would likely be required. There is the risk of settlement of the adjacent roadway due to voids during excavation through the oversized particles.

### 8.2.3 Open Cut - Staged Construction with Platform Lowering and/or Widening

The culvert could be replaced using open cut techniques with staged construction and platform lowering and widening. Due to the height of the embankment and narrow highway platform, it is understood that the depth and length of embankment lowering would be significant and would require large volumes of excavation within the rock fill embankment if feasible from a highway geometry perspective.

Temporary embankment widening could be considered, however, it is noted that a buried peat layer was identified beneath the edge of the existing embankment on the north side and open water is present at the existing toe of slope for sections on both the north and south sides.

Additional foundation field investigations would be required to assess widening of the high fill embankments.

### 8.2.4 Open Cut with Temporary Modular Bridge

This approach would consist of installing a temporary modular bridge structure to span the work area, followed by replacement of the culvert beneath the span of the temporary bridge structure.

This approach reduces the number of stages required and avoids the need for temporary protection systems. The temporary modular bridge would be founded either on the existing rock fill embankment or on deep foundations (caissons or H-piles installed within pre-drilled holes), depending on the span required.

## 8.3 Recommended Approach for the Culvert Replacement

From a foundation engineering perspective, replacement of the culvert with a pre-cast, closed box culvert using open cut techniques and a temporary modular bridge to maintain traffic flow is the recommended culvert type and construction methodology.

It is understood that an open footed culvert structure may be preferred from an environmental perspective or to help with water flow management during construction. An open footed culvert installed using open cut techniques and a temporary modular bridge to maintain traffic flow is also considered feasible from a geotechnical perspective.

## 9 FOUNDATION DESIGN RECOMMENDATIONS

### 9.1 Culvert Foundation Bearing Resistances

Based on the Preliminary GA drawing, the design top of substrate is noted as between Elevations 151.2 m and 151.0 m with a minimum thickness of 350 mm. Assuming a culvert base thickness of 400 mm, the culvert will be founded at approximately Elevation 150.0 m.

A closed box culvert structure may be founded on native, undisturbed glacial till. A culvert with a base width between 6 and 7 m founded at Elevation 150.0 m on a concrete mud slab or a granular pad at least 0.3 m thick, can be designed with the following factored geotechnical resistances:

- Factored geotechnical resistance at ULS                      750 kPa
- Factored geotechnical resistance at SLS                      270 kPa

An open footed culvert structure founded on native, undisturbed glacial till at a minimum depth of 1.9 m (frost depth) below top of stream bed elevation (Elevation 149.1 m) may be designed based on the factored geotechnical resistance values provided in Table 9-1. It is understood that the concrete headwall for a metal arch would be supported on the same foundations as the arch.

**Table 9-1: Factored Geotechnical Resistances for Open Footed Culvert**

Footing Width* (m)	ULS (kPa)	SLS (kPa)
1.5	420	400
2.0	450	375
2.5	480	325

\* For intermediate footing sizes, the factored geotechnical resistances values may be interpolated.

The factored geotechnical resistances include the following factors:

- The factored geotechnical resistance values at SLS provided above correspond to the stress increase relative to current site conditions that will result in 25 mm of total settlement.
- Consequence factor ( $\Psi$ ) of 1.0
- Geotechnical resistance factors (CHBDC Table 6.2):
  - Bearing (ULS),  $\phi_{gu} = 0.5$  (static analysis; typical degree of understanding)
  - Settlement (SLS),  $\phi_{gs} = 0.8$  (static analysis; typical degree of understanding)

The structural design of the culvert should consider differential settlement across the culvert. Based on the SLS bearing resistance provided above, a maximum of 25 mm of differential settlement should be anticipated along the culvert alignment.

The geotechnical resistances provided above are for vertical concentric loading and will need to be adjusted for the effects of inclined or eccentric loading, if applicable. The geotechnical resistance should be calculated as illustrated in the CHBDC Clause 6.10.3 and Clause 6.10.4.

Resistance to lateral forces through sliding resistance between concrete and native till or Granular A bedding materials should be evaluated using an unfactored coefficient of friction of 0.55 for cast-in-place concrete and 0.45 for pre-cast concrete.

## **9.2 Subgrade Preparation and Backfilling**

Excavation and backfilling for installation of the new culvert should be carried out in accordance OPSS 902 and MTO Special Provision (SP) No. 109S12, Amendment to OPSS 902, March 2018.

Subgrade preparation for the culvert structure and retaining walls should include excavation and removal of the existing culvert, culvert foundations and backfill materials from beneath the founding elevation. The existing fill and any soft or organic materials must be removed from within the influence zone of the foundations and replaced with compacted Granular B Type II. The native subgrade for the culvert foundations and retaining walls will consist of undisturbed native glacial till. Any boulders encountered at the subgrade elevation should be removed and the excavation backfilled with Granular B Type II.

It is understood that portions of the existing culvert may be temporarily left in place to help facilitate the temporary flow passage system during construction. A pipe or series of pipes is proposed to be installed through the existing culvert to act as a temporary flow passage during construction while the existing culvert is to be removed in an open excavation beneath the temporary modular bridge. Consideration for the unbalanced earth and hydrostatic pressures that may develop during excavations as outlined above in Section 6.1 will need to be considered.

If peat is encountered at the design subgrade elevation it should be excavated and removed in accordance with OPSS.PROV 902.

The glacial till will be easily disturbed when saturated and should be protected with a concrete working slab promptly after excavation and inspection. The exposed subgrade could be covered with a 100 mm thick concrete working slab. After the concrete for the working slab has set, the culvert could then be constructed directly on the working slab without the need for a granular pad or bedding material. Suggested wording for an NSSP to alert the Contractor to the requirement for a working slab has been provided in Appendix F.

Backfill for the culvert should consist of compacted free-draining granular material. Backfill requirements from the arch culvert supplier must also be confirmed.

It is recommended that the backfill detailing of OPSD 803.010 be utilized with a frost penetration line below the top of the culvert. The frost treatment depth,  $k$ , should be set at 1.9 m. The depth of road bed granulars,  $d$ , should be set at 0.790 m.

## **9.3 Retaining Walls**

The March 2018 Preliminary GA drawing includes concrete retaining walls extending out from both side of the concrete headwalls at each end of the culvert. The elevation of the base of the retaining walls is to be at the same elevation as the footings for the arch culvert. The retaining walls are set an approximate angle of  $45^\circ$  to the headwalls. The design of the retaining walls is to include a 2H:1V backslope behind the walls. It is understood that the maximum exposed height of the walls is anticipated to be a maximum of 5.8 m at the headwall tapering down to a height of 3.5 m with an overall length of approximately 5 m and 8 m at the inlet and outlet respectively.

The existing ground conditions beneath the retaining walls may include glacial till, silt, peat, rock fill and granular fill. As noted in Section 9.2, the existing fill, loose silt, and organic materials should be removed from beneath the retaining walls.

The bearing resistance values provided in Section 9.1 and the lateral earth pressure comments provided in Section 9.5 may be used for preliminary design of the proposed retaining walls.

The global stability for the proposed embankment behind the concrete gravity retaining wall constructed using OPSS.PROV 1010 Granular B Type II, with 2H:1V side slopes was evaluated using GeoStudio 2012 Slope/W software for limit equilibrium analysis. Input parameters for the analysis are based on the in-situ SPT 'N' values. The results of the stability analysis are provided in Appendix F.

The following additional parameters were used in the analysis:

- A seismic horizontal loading of 0.131, equal to  $\frac{1}{2}$  of the site adjusted PGA value (0.262g) was used for seismic analysis; and
- Maximum exposed wall height of 5.8 m.

The results of the global stability analysis indicate that a factor of safety of 1.5 and 1.2 were obtained under static and seismic conditions respectively.

#### **9.4 Embankment Design and Reinstatement**

The existing embankments have slopes ranging from approximately 2.2H:1V to 2.8H:1V. Some erosion of the granular cover was noted at the north embankment slope.

Embankment reinstatement, after culvert replacement, should be carried out in accordance with OPSS.PROV 206 and should match the adjacent slope geometry. The new embankment material should consist of imported Granular B Type II material. Excavated granular fill may also be reused as embankment fill provided there is no organic material in the excavated fill and there is sufficient space to stockpile on site and control the moisture content within acceptable limits for compaction. Excavated granular fill must not be used as culvert bedding or backfill.

Granular fill should be placed and compacted in accordance with OPSS.PROV 501. Where new embankment fill is placed against existing embankment slopes the existing earth or fill slope must be benched in accordance with OPSD 208.010.

Provided the subgrade is prepared as outlined and embankment fill is placed as recommended herein, an embankment slope inclined at 2H:1V or flatter, will remain stable.

#### **9.5 Lateral Earth Pressures**

The lateral earth pressure parameters provided in Tables 9-2 and 9-3 in the sections below are based on the assumption that the backfill is fully drained so that there are no unbalanced hydrostatic pressures. If adequate drainage cannot be confirmed, the potential for buildup of hydrostatic pressures should be considered in the design.

### 9.5.1 Static Lateral Earth Pressure Coefficients

Lateral earth pressures acting on structures should be computed in accordance with the CHBDC but generally are given by the expression:

$$P_h = K^*(\gamma h + q)$$

where:

$P_h$  = horizontal pressure on the wall (kPa)

$K$  = earth pressure coefficient

$\gamma$  = unit weight of retained soil (kN/m<sup>3</sup>)

$h$  = depth below top of fill where pressure is computed (m)

$q$  = value of any surcharge (kPa)

The recommended lateral earth pressure parameters for use in the design for horizontal and 2H:1V sloped backfill are provided in Table 9-2.

**Table 9-2: Static Lateral Earth Pressure Coefficient**

Parameter	OPSS Granular A & B Type II	Existing Granular Fill	Rock Fill	Glacial Till
Soil Unit Weight, kN/m <sup>3</sup> , $\gamma$	21.0	20.0	19.0	21.0
Angle of Internal Friction, $\phi$	35°	33°	44°	35°
Coefficient of at Rest Earth Pressure, $K_o$ (Restrained Wall)	0.43	0.46	0.31	0.43
<b>Horizontal Backfill</b>				
Coefficient of Active Earth Pressure, $K_a$ (Unrestrained Wall)	0.27	0.29	0.19	0.27
Coefficient of Passive Earth Pressure, $K_p$ (Unrestrained Wall)	3.69	3.39	5.55	3.69
<b>2H:1V Sloped Backfill</b>				
Coefficient of Active Earth Pressure, $K_a$ (Unrestrained Wall)	0.43	0.46	0.24	0.43
Coefficient of Passive Earth Pressure, $K_p$ (Unrestrained Wall)	10.84	9.29	24.96	10.84

For rigid structures, it is recommended that at-rest horizontal lateral earth pressures be used for design. Active pressures should be used for the design of unrestrained walls.

If the sloped embankment or backfill above the retaining wall or temporary protection systems, is different than that presented in Table 9-2 the lateral earth pressure parameters will need to be adjusted accordingly.

The passive lateral earth pressures parameters have been provided for the design of temporary protection system. A lateral pressure due to backfill compaction should be added to the calculated lateral earth pressure in accordance with Section 6.12.3 of the CHBDC.

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

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 the Mononobe-Okabe Method with:

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

For the 2H:1V backfill, the parameters are beyond the limitations for the Mononobe-Okabe method and the general limit equilibrium method has been used to calculate the seismic lateral earth pressures.

The ratio of wall movement to wall height required to mobilize the active condition would be approximately 0.002 for a yielding structure with respect to the assessment of seismically induced lateral earth pressures.

The recommended lateral earth pressure parameters for use in the design for both a horizontal backslope and a 2H:1V backslope provided in Table 9-3 assume the following:

- Seismic Site Class of C, and a PGA with a 2% probability of exceedance in 50 years of 0.262g; as outlined in Section 7.0

**Table 9-3: Lateral Earth Pressure (Under Seismic Loads)**

Parameter	OPSS Granular A & B Type II	Rock Fill
Soil Unit Weight, $\text{kN/m}^3$ , $\gamma$	21.0	19.0
Angle of Internal Friction, $\phi$	35°	44°
<b>Horizontal Backslope</b>		
Coefficient of Active Earth Pressure, $K_{AE}$ (Restrained Wall)	0.45	0.32
Coefficient of Active Earth Pressure, $K_{AE}$ (Unrestrained Wall)	0.35	0.24
<b>2H:1V Backslope</b>		
Coefficient of Active Earth Pressure, $K_{AE}$ (Restrained Wall)	0.47	0.57
Coefficient of Active Earth Pressure, $K_{AE}$ (Unrestrained Wall)	0.66	0.35

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 soil profile:

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

where:

- $\sigma_h$  = lateral earth pressure at depth,  $d$  (kPa)
- $d$  = depth below the top of the wall (m)
- $K$  = static earth pressure coefficient

( $K_o$  for non-yielding and  $K_a$  for yielding walls)  
 $\gamma$  = unit weight of the backfill soil (kN/m<sup>3</sup>)  
 $K_{AE}$  = combined static and seismic earth pressure coefficient  
 $H$  = total height of the wall (m)

## 9.6 Temporary Modular Bridge Foundations

### 9.6.1 Bearing Resistances

A temporary modular bridge (TMB) may be supported on concrete pad foundations bearing on the existing rock fill. A granular leveling pad consisting of OPSS Granular A placed beneath the proposed concrete pad foundations may also be required. Re-chinking of the rock fill surface should be anticipated. Based on the design drawings provided the top of bearing is at approximately Elevation 156.8 m.

It is anticipated that the excavation side slopes in front of the TMB footings for removal and replacement of the existing culvert will be no steeper than 1.5H:1V. The foundations for the TMB should be set back a minimum of 3 m from the proposed top of the cut slope.

Footings for the TBM with a length of 8 m, a width between 1.0 m and 2.0 m, constructed at the required minimum setback from the proposed top of slope and placed with a minimum embedment of 0.75 m may be designed based on the following factored geotechnical resistances:

- Factored Geotechnical Resistance at ULS (kPa) 400 kPa
- Factored Geotechnical Reaction at SLS (kPa) 225 kPa.

The factored geotechnical resistances include the following factors:

- The factored geotechnical resistance values at SLS provided above correspond to the stress increase relative to current site conditions that will result in 25 mm of total settlement.
- Consequence factor ( $\Psi$ ) of 1.0
- Geotechnical resistance factors (CHBDC Table 6.2):
  - Bearing (ULS),  $\phi_{gu} = 0.5$  (static analysis; typical degree of understanding)
  - Settlement (SLS),  $\phi_{gs} = 0.8$  (static analysis; typical degree of understanding)

The geotechnical resistances are for vertical concentric loading and will need to be adjusted for the effects of inclined or eccentric loading, if applicable. The geotechnical resistance should be calculated as illustrated in the CHBDC Clause 6.10.3 and Clause 6.10.4. In addition, the geotechnical resistances assume that the footings are constructed on horizontal ground and will need to be adjusted to account for the proximity to the excavation slope.

Resistance to lateral forces through sliding resistance between cast-in-place concrete and the granular pad should be evaluated using an unfactored friction coefficient of 0.50.

It is noted that some settlement of the approach embankment and TMB foundations may occur due to grading modifications associated with the construction grading. This settlement would be within the loose silt and organic deposits identified beneath the embankment fill.



## 9.6.2 Assessment of Global Stability

The global stability for the proposed excavation side slope geometry to remove and replace the existing culvert was evaluated using GeoStudio 2012 Slope/W software for limit equilibrium analysis. Input parameters for the analysis are based on the in-situ SPT 'N' values. The following additional parameters were used in the analysis.

- A traffic surcharge load as per Section 6.12.5 of the CHBDC was used for static analysis
- A seismic horizontal loading of 0.131g, equal to ½ of the site adjusted PGA value (0.262g) was used for seismic analysis.
- A maximum excavation side slope geometry of 1.5H:1V.

The results of the global stability analysis indicate a factor of safety (FOS) of 1.5 and 1.2 under static and seismic conditions respectively. The calculated FOS meets the target values of 1.5 and 1.1 under static and seismic conditions respectively. Copies of the output from the global stability analysis for both static and seismic conditions are provided in Appendix F.

## 9.7 Cement Type and Corrosion Potential

A sample of the native soil was submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, and resistivity. The analysis results are summarized in the Table 9-4 and a copy of the test results is provided in Appendix C.

**Table 9-4: Results of Chemical Analysis**

Borehole	Sample	Depth (m)	pH	Resistivity (Ohm-m)	Chloride (µg/g)	Sulphate (µg/g)
501	SS6	3.4	8.0	157	6	7

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. The sulphate results in Table 9-4 were compared with Table 3 of Canadian Standards Association Standards A23.1-14 (CSA A23.1) and generally indicate a low degree of sulphate attack potential on concrete structures at this site. Accordingly, GU could be specified for concrete in below grade applications.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The test results provided in Table 9-4 were compared with Table 3.2 of the MTO Gravity Pipe Design Guideline and generally indicate a low corrosive environment. The test results provided in Table 9-4 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

## 10 CONSTRUCTION CONSIDERATIONS

### 10.1 Excavations

It is anticipated that temporary excavations in the order of 8 m will be required for the removal of the existing culvert and foundations.

All excavations must be conducted in accordance with the requirements of the Occupational Health & Safety Act & Regulations (OHSA) for Construction Projects. The fills at the site should



be classified as Type 3 above and Type 4 below the groundwater table in accordance with OHSA. The glacial till should be classified as Type 2, however, as indicated in the OHSA, if an excavation contains more than one type of soil, the soil type for the excavation shall be classified as the type with the highest number among the soil types present within the excavation. In accordance with OHSA unsupported excavations made in Type 3 soils must have side slopes having a minimum gradient 1H:1V.

Subgrade preparation and placement of culvert bedding or foundations must be carried out in the dry.

Where the existing substrate and backfill inside the existing culvert is to remain the unbalanced earth pressures and hydrostatic pressure must be considered when excavating the for the foundations of the new culvert. Where the Contractor is using parts of the existing structure as part of their temporary protection system or dewatering system, this must be addressed as part of OPSS.PROV 539 and/or OPSS.PROV 517 and SP 517F01

Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor. As rock fill, cobbles and boulders were observed in the boreholes a suggested wording for an NSSP alerting bidders to their presence has been provided in Appendix F.

Excavation and removal of the peat material encountered in the area of the outlet should be carried out in accordance with OPSS.PROV 902.

## **10.2 Temporary Protection Systems**

If required, temporary protection systems should be provided in accordance with OPSS.PROV 539 and designed for Performance Level 2. All protection systems should be designed by a Professional Engineer experienced in such designs. Typical lateral earth pressure coefficients are provided in Table 9-2.

The design of temporary protection systems is the responsibility of the Contractor. All shoring should be designed by a licensed professional engineer experienced in such designs. Lateral earth pressure coefficients for the use in the design are provided in Table 9.2. The designer of the protection systems must ensure the penetration depth is sufficient to provide base fixity and incorporate traffic loading and surcharge loading due to construction equipment and operations and shall consider the slope of temporary embankments above the top of the protection system.

Increased difficulty with the installation of temporary protection systems should be anticipated due to the presence of rock fill within the embankment and boulders present within the glacial till. For preliminary assessment purposes, the use of sheet piles through the rock fill is not considered feasible. One option is to use H-piles and timber lagging with the H-piles installed in pre-drilled holes into the glacial till. Tie back anchors would likely consist of soil anchors installed within the glacial till. Recommended wording for an NSSP alerting the Contractor to this condition and the requirement to use appropriate equipment and installation techniques is provided in Appendix F.

## **10.3 Dewatering**

The Contractor must be prepared to control the groundwater and surface water flow at the site to permit the proposed culvert replacement to be constructed in a dry and stable excavation. The groundwater level for the site at the time of the proposed replacement should be taken as the

water level in the creek. It is recommended that the replacement be conducted during a drier season such as after the spring freshet or prior to the fall season.

Temporary water course diversion will be required to replace the culvert in the dry. It is understood that that a pipe or a series of pipes is proposed to be installed through the existing culvert to act as a temporary flow passage during construction and that the existing culvert is to be removed in an open excavation under the temporary modular bridge prior to constructing the new culvert.

Excavations below the groundwater level are anticipated for constructing the footings for the arch culvert. A cofferdam with pumping from sumps may be required to control inflow of water into the excavation prepare the subgrade and to construct the footings in the dry. Dewatering and surface water diversion must remain operational and effective until the culvert is replaced.

The design of any dewatering system that may be required is the responsibility of the Contractor. The Contract Documents must alert the Contractor to this responsibility and to design the system in accordance with SP No. FOUN0003.

The Dewatering Systems Designer Fill-in information for SP No. FOUN0003 are provided in the following table.

Design Storm Return Period	Preconstruction Survey Distance
*	**
Where required, fill-in information will be provided in the WSP's Draft Hydrogeological Assessment in Support of an Environmental Activity and Sector Registry (EASR) for Culvert Replacement Work at Barbut Creek dated March 2018	N/A

In accordance with Section 902.04 of SP FOUN0003, the dewatering system is to be designed in accordance with OPSS.PROV 517 and SP 517F01; Amendment to OPSS 517, July 2017.

The Table A Fill-ins for SP 517F01 are as provided below.

IDF Curve Location	Latitude: 45.58687°		Longitude: -76.83145°			
Temporary Flow Passage Systems						
Site Name / Station Reference	Minimum Return Period (Years)	Return Period Flow Estimates (m³/s)				Design Engineer Requirements (Note 1)
		2 Year	5 Year	10 Year	25 Year	
**	***	****	****	****	****	*****
Site 29-146/C Barbut Creek Culvert Crossing of Highway 17, Approximate Station 14+060	Where required, fill-in information will be provided in the WSP's Draft Hydrogeological Assessment in Support of an Environmental Activity and Sector Registry (EASR) for Culvert Replacement Work at Barbut Creek dated March 2018.					

<b>Dewatering Systems</b>		
<b>Site Name / Station Reference</b>	<b>Preconstruction Survey Distance (Note 2) (m)</b>	<b>Design Engineer Requirements (Note 1)</b>
<b>**</b>	<b>*****</b>	<b>*****</b>
Site 29-146/C Barbut Creek Culvert Crossing of Highway 17, Approximate Station 14+060	Yes Within a 150 m radius around the Highway 17 Barbut Creek Culvert crossing site	No
<p>Note:</p> <ol style="list-style-type: none"> <li>1. "Yes" means the design Engineer and design-checking Engineer shall have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work. "No" means a minimum experience level is not required for the design Engineer and design-checking Engineer.</li> <li>2. "N/A" indicates a preconstruction survey is not required.</li> </ol>		

The groundwater level will fluctuate and the minimum groundwater elevation for the site at the time of the proposed culvert replacement should be taken as the water level in the creek at the time of construction as defined by SP 517F01. Excavation below the groundwater level to construct the culvert foundation will be required and excavation below the groundwater level without prior dewatering is not recommended since the inflow of groundwater will cause base heave/boiling and sloughing of the foundation soil below the water level, making it difficult to maintain a dry, sound base on which to work.

Cofferdams may be required to prevent the creek from spilling into the adjacent excavation for the new culvert and during creek realignment. Further assessment of dewatering requirements and the need for a PTTW should be carried out by specialists experienced in this field. Reference should be made to WSP's Draft Hydrogeological Assessment in Support of an Environmental Activity and Sector Registry (EASR) for Culvert Replacement Work at Barbut Creek dated March 2018, with regards to volume of water expected to be withdrawn for the excavations for the culvert replacement.

#### 10.4 Erosion Protection

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the embankment slopes. The contractor should provide silt fences and erosion control blankets, as required, throughout the duration of the construction to prevent silt/sediments from running off the site as per OPSS 805.

Erosion protection should be provided at the culvert inlet and outlet areas. Details on the erosion control analyse and protection measures proposed for this project are illustrated on the Preliminary GA drawing. Further reference should be made to WSP's Hydrology and Hydraulic Assessment Report, dated March 2018. If the Contractor proposes design changes to erosion protection measures they must consider hydrologic and hydraulic factors presented in WSP's report and should be carried out by specialists experienced in this field. The results of the final erosion control analyse should be reviewed by the foundation engineer to ensure that the foundation design and related earthworks are in accordance with the recommendations provided.

Typically, rock protection should be provided over all surfaces with which culvert water is likely to be in contact. Treatment at the outlets should be in accordance with OPSP 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 clay seal be used to minimize the potential for erosion near the inlet area. The clay seal should extend a minimum of 0.3 m above the high-water level and laterally for the width of the granular material, and have a minimum thickness of 0.5 m. The material requirements should be in accordance with OPSS.PROV 1205. A geosynthetic clay liner may be used as a clay seal.

## **11 CONSTRUCTION CONCERNS**

The planned construction methodology includes an open cut excavation for the installation of a new culvert.

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

- Peat removal in the area of the culvert outlet may be required prior to installation of the culvert and retaining walls.
- Excavation within the highway embankment is expected to encounter rock fill, cobbles and boulders. Recommended wording for an NISP alerting the Contractor to this condition and the requirement to use appropriate equipment and excavation techniques is provided in Appendix F.
- Construction will extend below the water level in the creek. An adequate and effective surface water management and dewatering plan must be implemented to construct the replacement culvert subgrade and the footings of the culvert in the dry.
- Confirmation that the backfill is adequately placed and compacted to specifications.
- If the footings of the existing culvert are shallower than the founding elevation of the new culvert, the existing culvert and footings would be undermined and would therefore need to be removed.
- Depending on the excavation and dewatering procedures employed by the Contractor, unbalanced earth and hydrostatic pressure may develop on the existing culvert walls and/or foundations while excavations for the new footings are carried out. These forces must be taken into consideration in the design of the excavation and dewatering procedures employed by the Contractor.
- Boulders may be encountered in the glacial till subgrade surface at the founding elevation and may require localized sub-excavation and replacement.

The successful performance of the construction of this structure will depend largely upon good workmanship and quality control during construction. Observation of the excavation and backfilling operations will be required as per MTO SP No. 109S12, amendment to OPSS 902 during construction to confirm that the foundation recommendations are correctly implemented and material specifications are met.

## 12 CLOSURE

Overall project management and direction of the field program was provided by Paul Carnaffan, P.Eng. Interpretation of the field data and preparation of this report was completed by Kenton Power, P.Eng. The report was reviewed by Paul Carnaffan, P.Eng. and Dr. P.K. Chatterji, P.Eng., the Designated Principal Contact for MTO Foundations Projects.



Kenton C. Power, P.Eng.  
Geotechnical Engineer



Paul Carnaffan, P.Eng.  
Principal, Senior Geotechnical Engineer

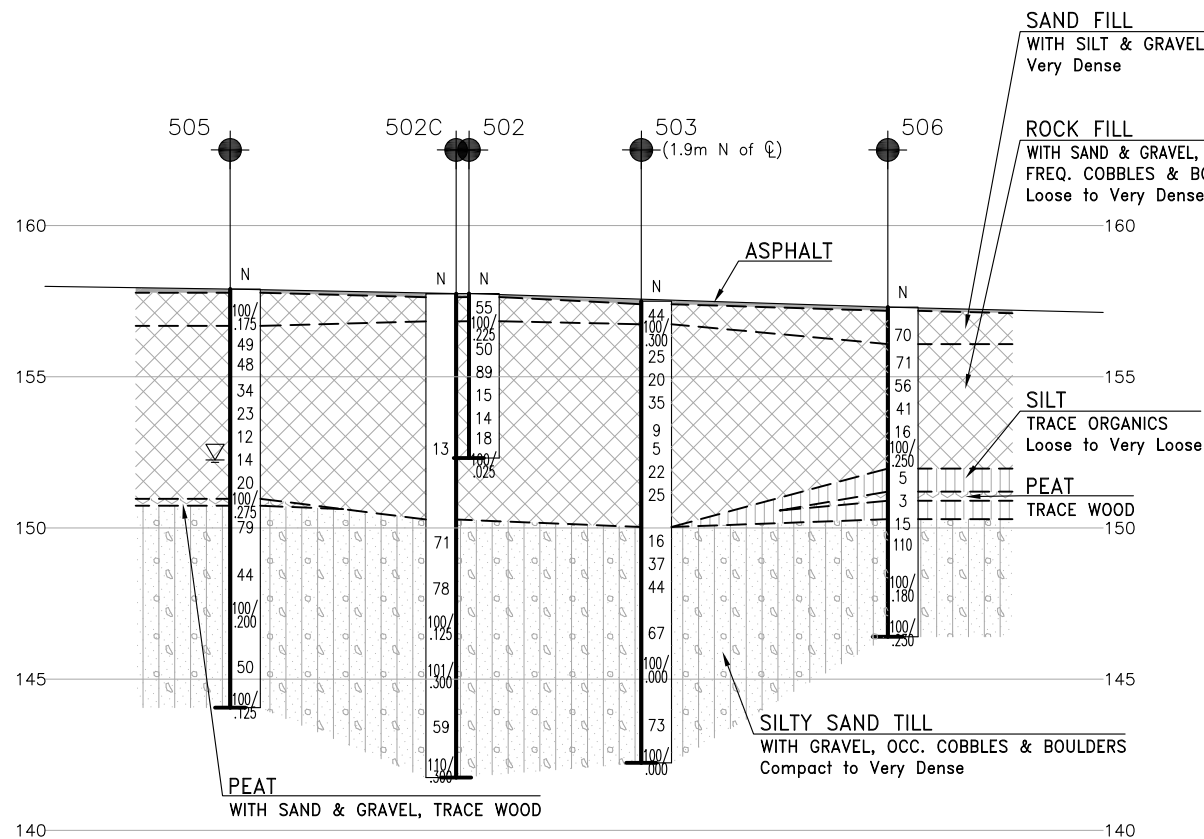
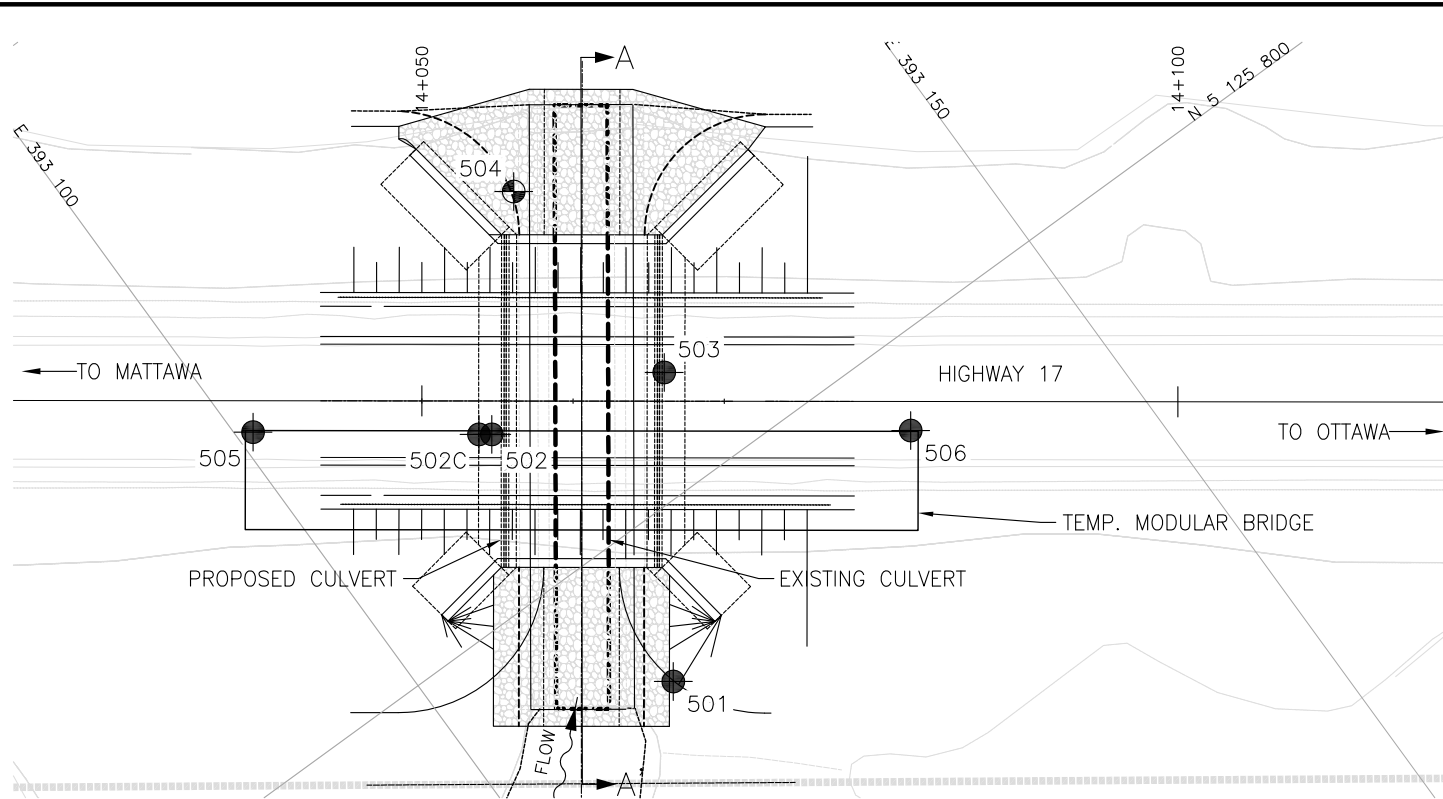


P.K. Chatterji, P.Eng.  
Review Principal, Designated MTO Contact

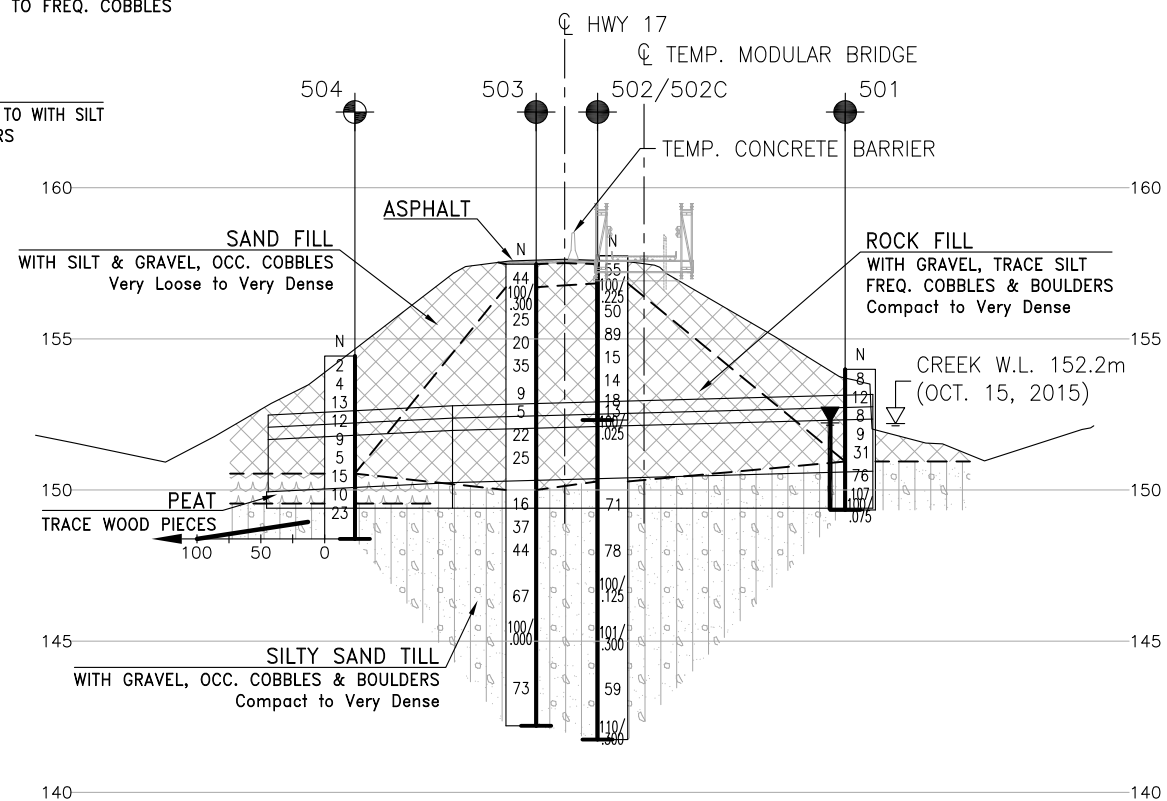
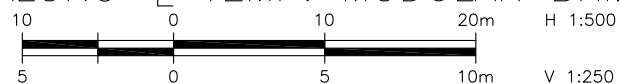
## **APPENDIX A**

### **BOREHOLE LOCATIONS AND SOIL STRATA DRAWINGS PRELIMINARY GENERAL ARRANGEMENT DRAWING**

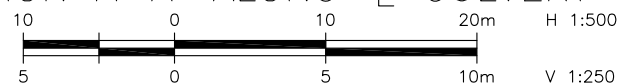




PROFILE ALONG  $\text{CL}$  TEMP. MODULAR BRIDGE



SECTION A-A' ALONG  $\text{CL}$  CULVERT



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

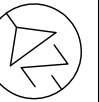


CONT No  
WP No 4005-13-01

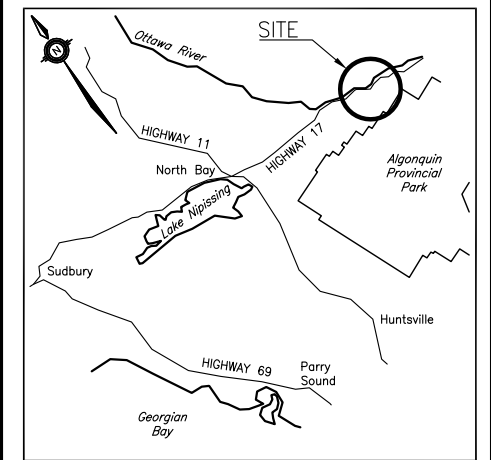
HIGHWAY 17  
BARBUT CREEK  
CULVERT REPLACEMENT  
BOREHOLE LOCATIONS AND SOIL STRATA

WSP

THURBER ENGINEERING LTD.



SHEET



KEYPLAN

LEGEND

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

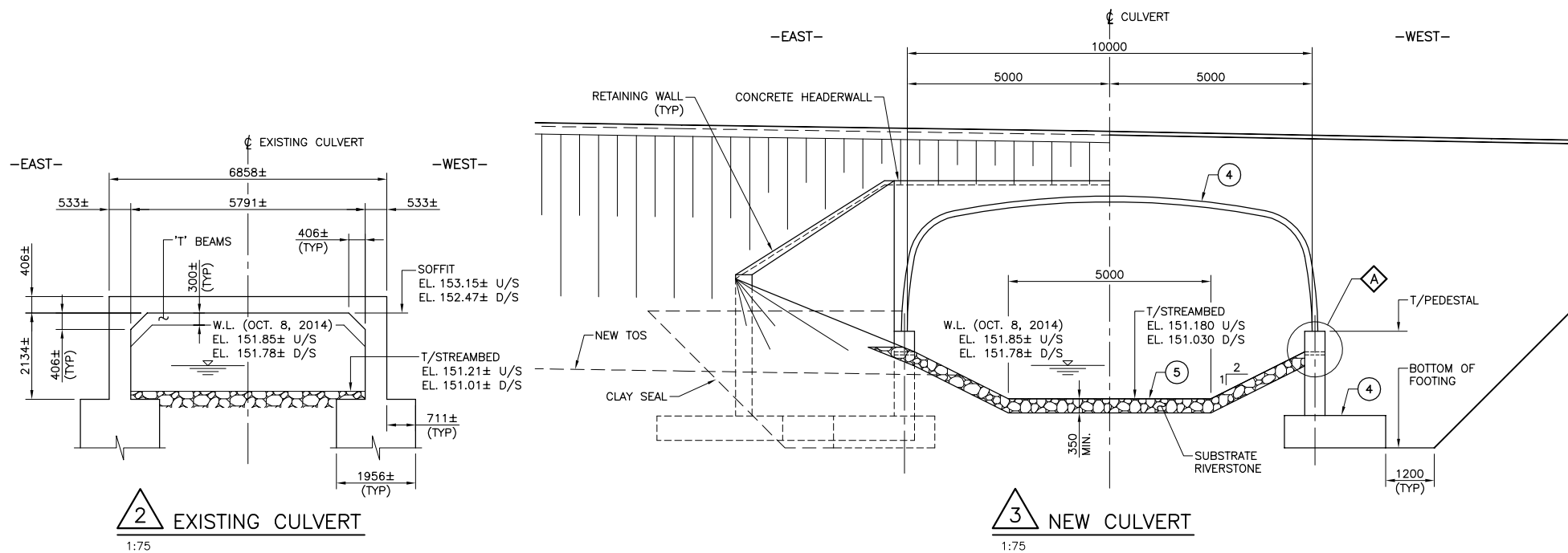
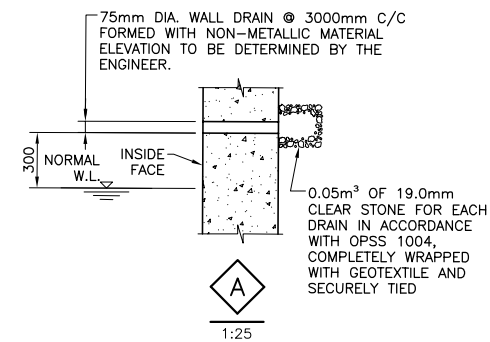
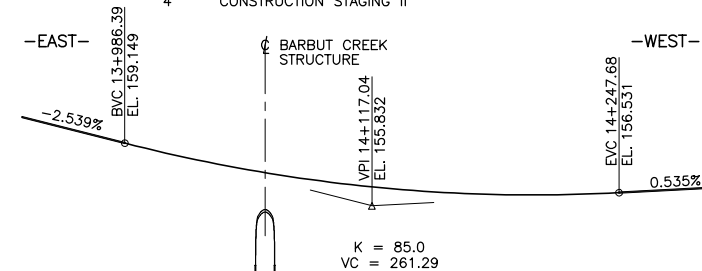
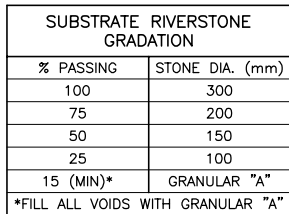
NO	ELEVATION	NORTHING	EASTING
501	154.0	5 125 790.3	393 113.8
502	157.7	5 125 810.6	393 113.7
502C	157.8	5 125 811.1	393 113.0
503	157.5	5 125 807.2	393 125.4
504	154.4	5 125 822.7	393 124.4
505	157.9	5 125 820.0	393 101.0
506	157.3	5 125 794.5	393 136.3

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.
- Borehole locations are shown in MTM Zone 10 coordinates.

GEOCRES No. 31L-203

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	KP	CHK -	CODE
DRAWN	MFA	CHK KP	SITE 29-146/C/STRUCT
DATE	APR 2018	DATE	APR 2018
DWG	1	DWG	1



REVISIONS								
DESCRIPTION								
DESIGN DE/JT	CHK NB	CODE S6-14	LOAD CL-625-ONT	DATE MAR 2018				
DRAWN AHN	CHK DE	SITE 29-146/C	STRUCT	SCHEME	DWG 1			

PRELIMINARY  
2018/03/29  
NOT FOR CONSTRUCTION

DRAWING NOT TO BE SCALED  
100mm ON ORIGINAL DRAWING



**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).

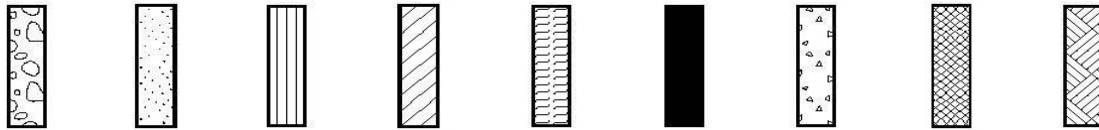
### **DYNAMIC CONE PENETRATION TEST (DCPT):**

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 501

1 OF 1

METRIC

W.P. 4005-13-01 LOCATION 29-146/C Barbut Creek Culvert: MTM Zone 10: N 5 125 790.3 E 393 113.8 ORIGINATED BY SMP  
 HWY 17 BOREHOLE TYPE Portable NW Casing COMPILED BY SMP  
 DATUM Geodetic DATE 2015.10.27 - 2015.10.27 CHECKED BY KP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT  W <sub>P</sub>	NATURAL MOISTURE CONTENT  W	LIQUID LIMIT  W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE									
154.0																				
0.0	Sand with silt and gravel Loose to dense Brown FILL		1	SS	8											37 53 10 (SI+CL)				
			2	SS	12															
			3	SS	8															
			4	SS	9															
			5	SS	31															
150.9																				
3.0	Silty SAND (SM) some gravel, TILL Very dense Grey - frequent cobbles and boulders		6	SS	76															
			7	SS	107															
			8	SS	100/												11 53 36 (SI+CL)			
149.3																				
4.6	End of Borehole Splitspoon refusal on inferred boulder Groundwater level was measured in piezometer at 2.1 m BGS (elev. 152.3 m) on 2015/12/15				75mm															

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

# RECORD OF BOREHOLE No 502

1 OF 1

METRIC

W.P. 4005-13-01 LOCATION 29-146/C Barbut Creek Culvert: MTM Zone 10: N 5 125 810.6 E 393 113.7 ORIGINATED BY CAM  
 HWY 17 BOREHOLE TYPE NW Casing COMPILED BY SMP  
 DATUM Geodetic DATE 2015.10.15 - 2015.10.15 CHECKED BY KP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W L	UNIT WEIGHT $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE									
157.7 0.0 0.1	115 mm ASPHALT							20	40	60	80	100					
	Sand with gravel - frequent cobbles Very dense Brown		1	SS	55									○			37 63 0 (SI+CL)
156.8 0.9	FILL		2	SS	100/ 225mm									○			
	Gravel with sand trace silt - frequent cobbles and boulders Compact to very dense Brown		3	SS	50												
	ROCK FILL		4	SS	89									○			60 36 4 (SI+CL)
			5	SS	15										○		
			6	SS	14												
			7	SS	18												
152.3 5.4	End of Borehole Splitspoon refusal on inferred boulder		8	SS	100/ 25mm												

ONTMT4S 19-5161-263 BARBUT CREEK GPJ 2012TEMPLATE(MTO).GDT 17/1/18

## METRIC

[illegible]

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

ONTMT4S 19-5161-263 BARBUT CREEK.GPJ 2012TEMPLATE(MTO).GDT 17/1/18



## METRIC

[illegible]

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

# RECORD OF BOREHOLE No 503

1 OF 2

METRIC

W.P. 4005-13-01 LOCATION 29-146/C Barbut Creek Culvert: MTM Zone 10: N 5 125 807.2 E 393 125.4 ORIGINATED BY CAM  
 HWY 17 BOREHOLE TYPE HSA/NW Casing COMPILED BY SMP  
 DATUM Geodetic DATE 2015.10.13 - 2015.10.14 CHECKED BY KP

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 (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								20 40 60 80 100					
								20 40 60 80 100					
157.5													
0.0	100 mm ASPHALT												
0.1	Sand with gravel - frequent cobbles Very dense Brown		1	SS	44								
156.7	FILL		2	SS	100/								
0.8	Sand with silt and gravel - frequent cobbles and boulders Loose to very dense Brown ROCK FILL				300mm								
			3	SS	25								
			4	SS	20								
			5	SS	35								
	- Boulders from 3.7 m to 4.0 m		6	SS	9								
			7	SS	5								
			8	SS	22								
			9	SS	25								
	- Boulders from 6.7 m to 7.3 m												
150.0	- trace wood pieces												
7.5	Silty SAND (SM) with gravel, TILL - occasional cobbles and boulders Compact to very dense Grey		10	SS	16								
			11	SS	37								
			12	SS	44								

Continued Next Page

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

ONTMT4S 19-5161-263 BARBUT CREEK GPJ 2012TEMPLATE(MTO).GDT 17/1/18

## METRIC

[illegible]

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

# RECORD OF BOREHOLE No 504

1 OF 1

METRIC

W.P. 4005-13-01 LOCATION 29-146/C Barbut Creek Culvert: MTM Zone 10: N 5 125 822.7 E 393 124.4 ORIGINATED BY SMP  
 HWY 17 BOREHOLE TYPE Portable NW Casing COMPILED BY SMP  
 DATUM Geodetic DATE 2015/10/26. - 2015/10/26. CHECKED BY KP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W P W W L							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%)							
154.4							20 40 60 80 100												
0.0	<b>25 mm TOPSOIL</b>																		
	Sand with silt and gravel Very loose to compact Brown FILL		1	SS	2														
			2	SS	4														
			3	SS	13									○					33 62 5 (SI+CL)
			4	SS	12									○					
			5	SS	9														
	- Grey below 3 m		6	SS	5									○					
150.5														○					19 76 5 (SI+CL)
3.9	<b>PEAT</b> , trace wood pieces Brown to black - saturated		7	SS	15												114		
			8	SS	10												121		
149.6																			
4.9	<b>Silty SAND (SM)</b> with gravel, <b>TILL</b> - occasional cobbles and boulders Compact Grey  - Casing refusal on inferred boulder Advanced DCPT from 5.5 m to 6.0 m		9	SS	23									○					12 69 19 (SI+CL)
148.4	End of Borehole DCPT Resulsal on inferred boulder																		
6.0																			

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

# RECORD OF BOREHOLE No 505

1 OF 2

METRIC

W.P. 4005-13-01 LOCATION 29-146/C Barbut Creek Culvert: MTM Zone 10: N 51 258.0 E 3 931.0 ORIGINATED BY JAG  
 HWY 17 BOREHOLE TYPE HW Casing COMPILED BY JAG  
 DATUM Geodetic DATE 2017.06.26 - 2017.06.27 CHECKED BY KP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				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			SHEAR STRENGTH kPa					
								20 40 60 80 100					
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE					
				WATER CONTENT (%)				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT W <sub>P</sub> W      W <sub>L</sub>					
157.9													
0.0	120 mm ASPHALT												
0.1	Sand with silt and gravel - occasional cobbles Very dense Brown FILL		1	AS									28 63 9 (SI+CL)
156.7			2	SS	100/ 175mm								
1.2	Sand with silt and gravel - frequent cobbles and boulders Compact to very dense Brown ROCK FILL		3	SS	49								23 69 8 (SI+CL)
	- switch to HW casing		4	SS	48								
	- cobbles - 240 mm boulder at 2.9 m		5	SS	34								
	- 120 mm cobble at 3.7 m		6	SS	23								
			7	SS	12								
	- cobbles		8	SS	14								
	- 120 mm cobble at 5.8 m		9	SS	20								
151.0													
6.9 150.7	PEAT with sand and gravel, trace wood		10	SS	100/ 275mm							107	27 30 34 9 20% organic content
7.2	Silty SAND (SM) with gravel, TILL - occasional cobbles and boulders Compact to very dense Grey - 210 mm boulder at 7.3 m		11	SS	79								

Continued Next Page


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

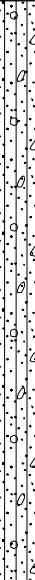
20  
15  
10

(%) STRAIN AT FAILURE

ONTMT4S 19-5161-263 BARBUT CREEK GPJ 2012TEMPLATE(MTO).GDT 17/1/18

## METRIC

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

Continued from Previous Page																			
144.1	<b>Silty SAND (SM)</b> with gravel, <b>TILL</b> - occasional cobbles and boulders dense to very dense Grey		13	SS	100/														
			200mm																
			14	SS	50														
145																			
146																			
147																			
148																			
149																			
150																			
151																			
152																			
153																			
154																			
155																			
156																			
157																			
158																			
159																			
160																			
161																			
162																			
163																			
164																			
165																			
166																			
167																			
168																			
169																			
170																			
171																			
172																			
173																			
174																			
175																			
176																			
177																			
178																			
179																			
180																			
181																			
182																			
183																			
184																			
185																			
186																			
187																			
188																			
189																			
190																			
191																			
192																			
193																			
194																			
195																			
196																			
197																			
198																			
199																			
200																			
201																			
202																			
203																			
204																			
205																			
206																			
207																			
208																			
209																			
210																			
211																			
212																			
213																			
214																			
215																			
216																			
217																			
218																			
219																			
220																			
221																			
222																			
223																			
224																			
225																			
226																			
227																			
228																			
229																			
230																			
231																			
232																			
233																			
234																			
235																			
236																			
237																			
238																			
239																			
240																			
241																			
242																			
243																			
244																			
245																			
246																			
247																			
248																			
249																			
250																			
251																			
252																			
253																			
254																			
255																			
256																			
257																			
258																			
259																			
260																			
261																			
262																			
263																			
264																			
265																			
266																			
267																			
268																			
269																			
270																			
271																			
272																			
273																			
274																			
275																			
276																			
277																			
278																			
279																			
280																			
281																			
282																			

ONTMT4S 19-5161-263 BARBUT CREEK.GPJ 2012TEMPLATE(MTO).GDT 17/1/18

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

# RECORD OF BOREHOLE No 506

1 OF 2

METRIC

W.P. 4005-13-01 LOCATION 29-146/C Barbut Creek Culvert: MTM Zone 10: N 51 258.0 E 3 931.0 ORIGINATED BY JAG  
 HWY 17 BOREHOLE TYPE HW Casing COMPILED BY JAG  
 DATUM Geodetic DATE 2017.06.27 - 2017.06.28 CHECKED BY KP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT			NATURAL MOISTURE CONTENT			LIQUID LIMIT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W P			W			W L				GR	SA	SI	CL																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
157.3																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																

Continued Next Page

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

20  
15  
10

(%) STRAIN AT FAILURE




# RECORD OF BOREHOLE No 506

2 OF 2

METRIC

W.P. 4005-13-01 LOCATION 29-146/C Barbut Creek Culvert: MTM Zone 10: N 51 258.0 E 3 931.0 ORIGINATED BY JAG  
 HWY 17 BOREHOLE TYPE HW Casing COMPILED BY JAG  
 DATUM Geodetic DATE 2017.06.27 - 2017.06.28 CHECKED BY KP

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			SHEAR STRENGTH kPa									
	Continued From Previous Page																
146.4	Silty SAND (SM) with gravel, TILL - occasional cobbles and boulders Compact to very dense Grey		13	SS	100/		147										
10.9	End of Borehole				230mm												

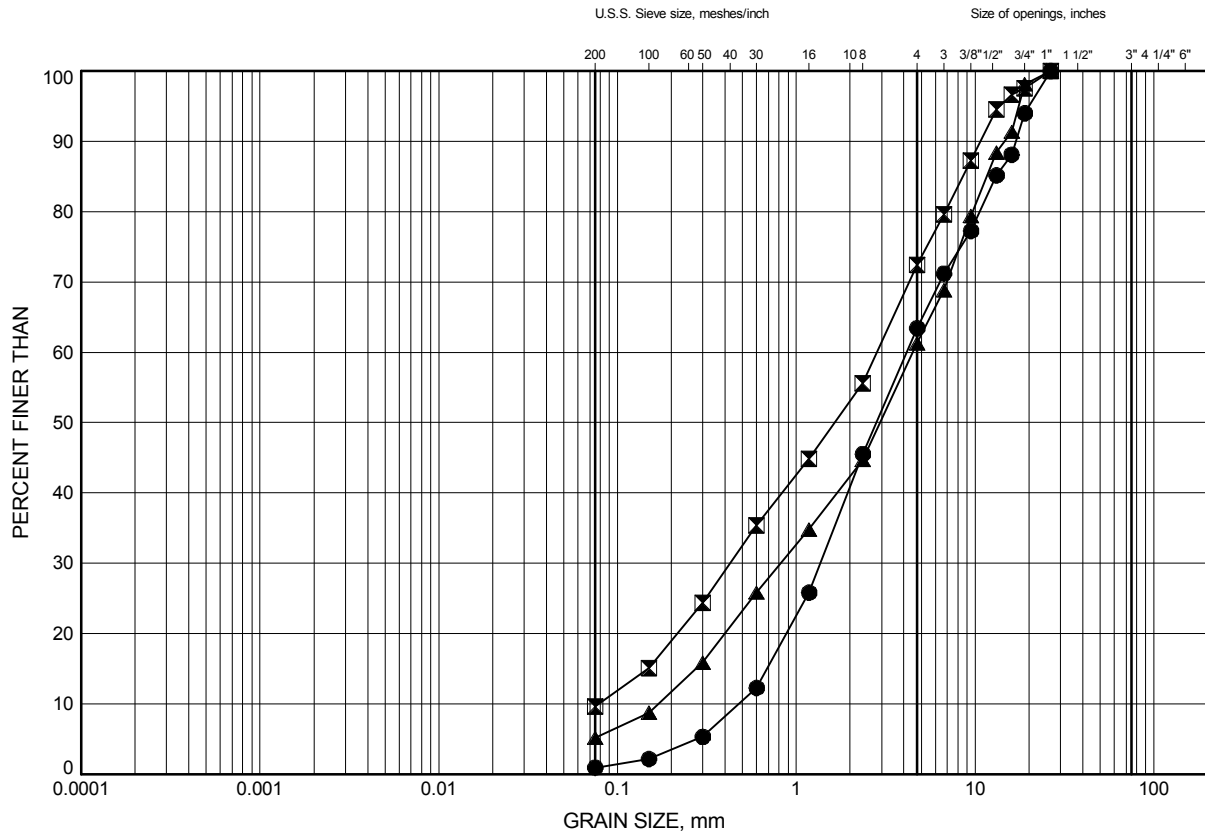
**APPENDIX C**  
**LABORATORY TEST RESULTS**

Site 29-146/C - Barbut Creek

# GRAIN SIZE DISTRIBUTION

FIGURE 1

## Fill - Sand with Gravel



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	502	0.24	157.49
◻	505	0.38	157.52
▲	506	0.46	156.81

Date January 2018  
W.P. 4005-13-01



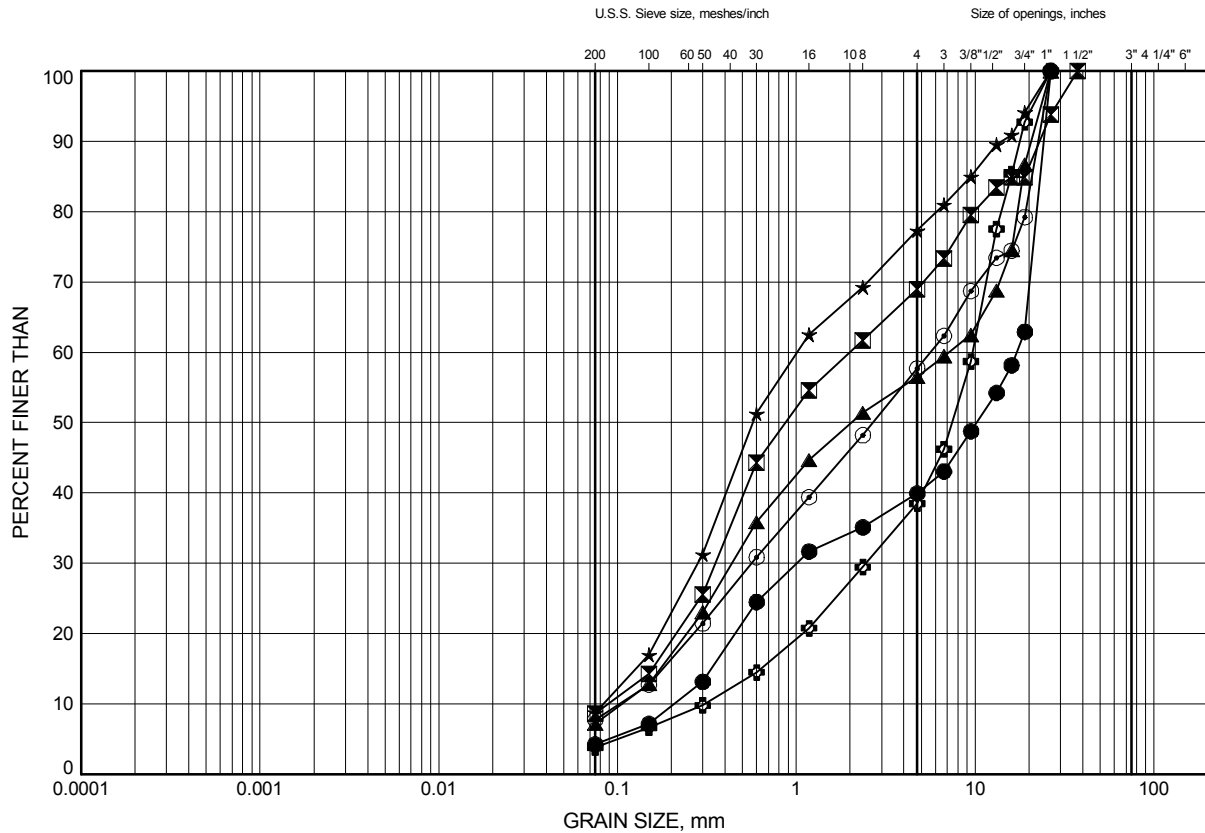
Prep'd KCP  
Chkd. PC

Site 29-146/C - Barbut Creek

# GRAIN SIZE DISTRIBUTION

FIGURE 2

## Embankment Fill (Rock Fill)



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	502	2.59	155.14
⊠	503	2.63	154.84
▲	503	6.40	151.07
★	505	1.83	156.07
⊙	506	2.59	154.68
⊕	502C	5.13	152.67

Date January 2018  
W.P. 4005-13-01



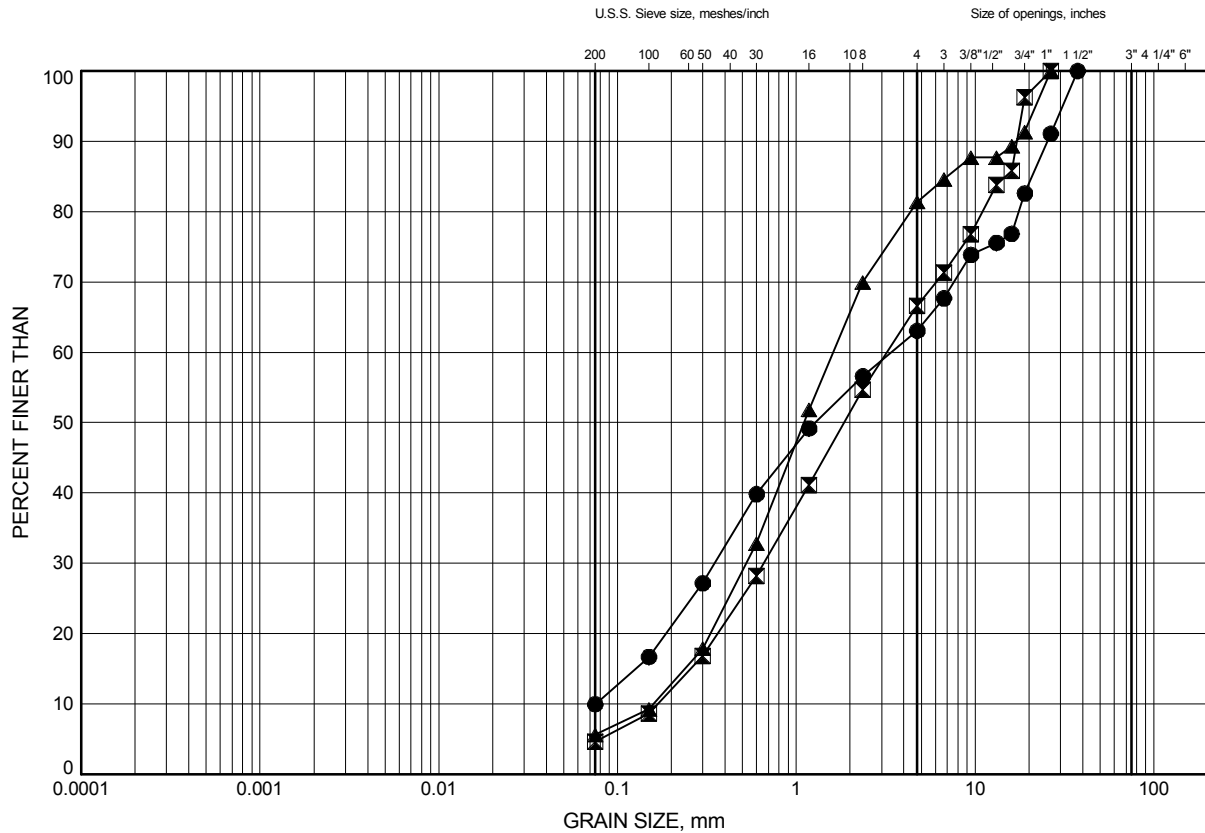
Prep'd KCP  
Chkd. PC

Site 29-146/C - Barbut Creek

# GRAIN SIZE DISTRIBUTION

FIGURE 3

## Fill - Sand with Silt and Gravel



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	501	0.30	153.69
⊠	504	1.52	152.91
▲	504	3.77	150.66

Date January 2018  
W.P. 4005-13-01

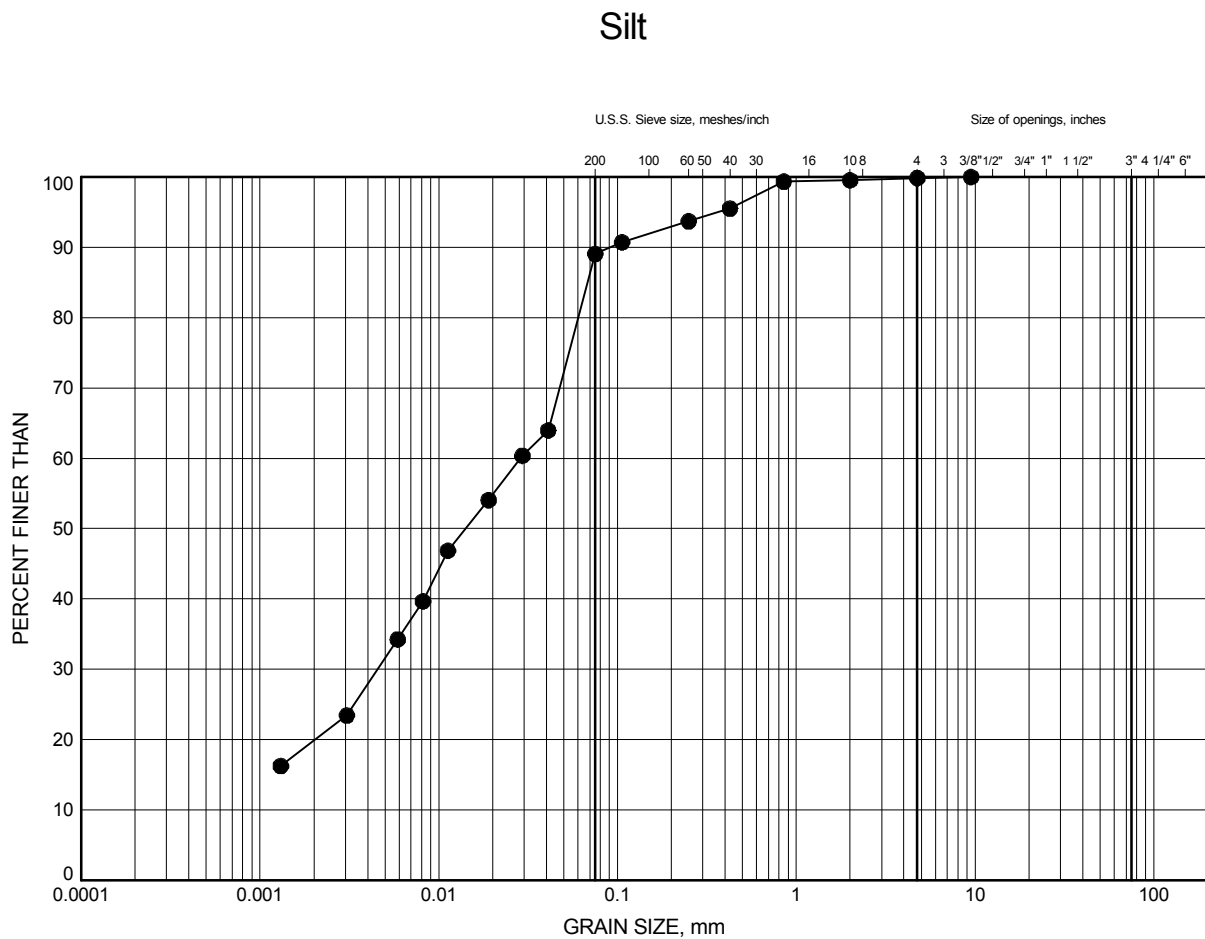


Prep'd KCP  
Chkd. PC

Site 29-146/C - Barbut Creek

# GRAIN SIZE DISTRIBUTION

FIGURE 4



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	506	5.64	151.63

Date ..September 2017.....  
W.P. ....4005-13-01.....



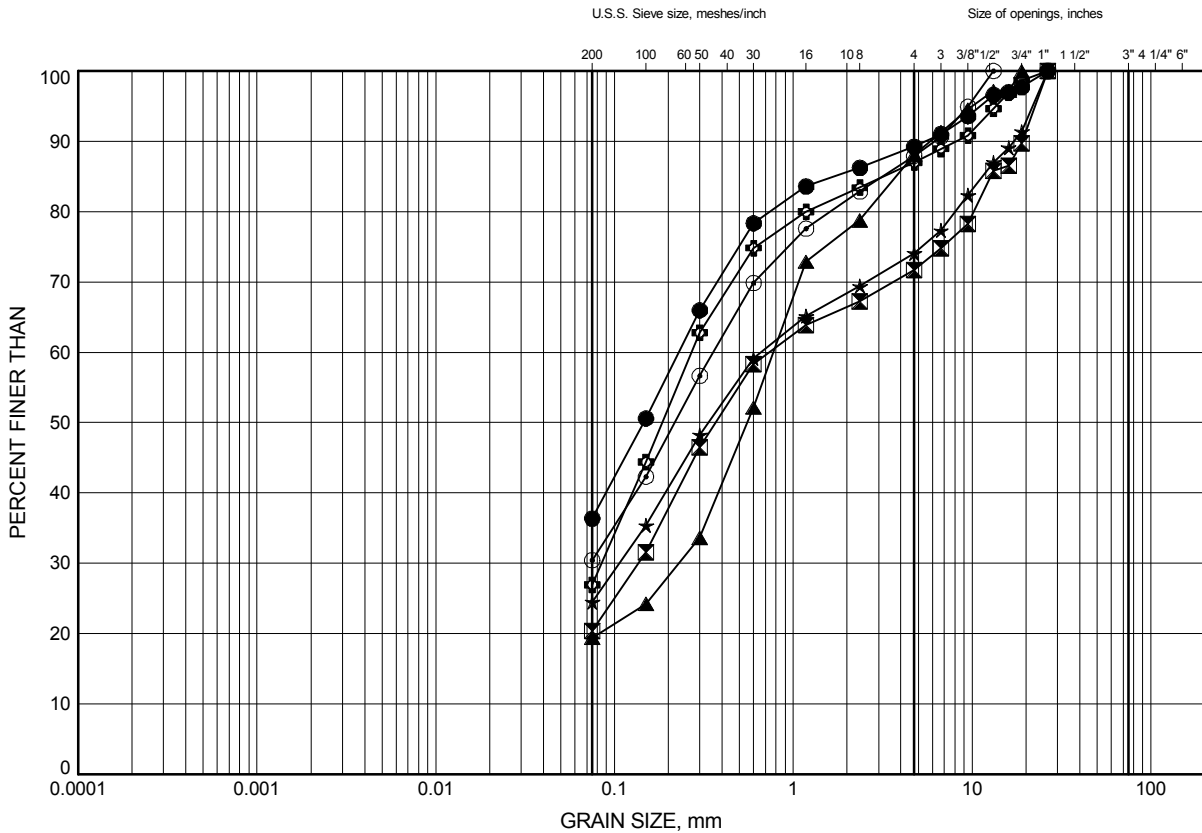
Prep'd .....KCP.....  
Chkd. ....PC.....

Site 29-146/C - Barbut Creek

# GRAIN SIZE DISTRIBUTION

FIGURE 5

## Silty Sand with Gravel: Till



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	501	4.11	149.88
⊠	503	10.97	146.50
▲	504	5.18	149.25
★	505	9.45	148.45
⊙	506	7.77	149.50
⊕	502C	9.75	148.05

Date January 2018  
W.P. 4005-13-01



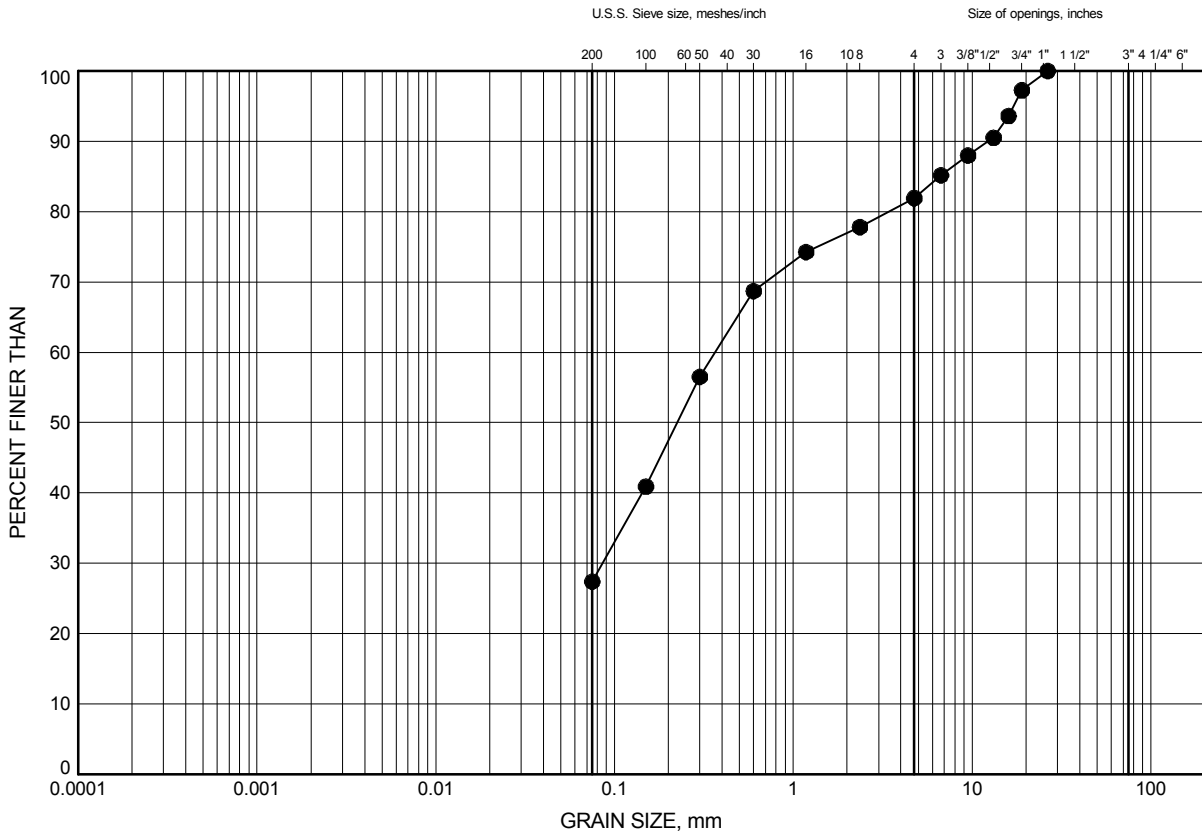
Prep'd KCP  
Chkd. PC

Site 29-146/C - Barbut Creek

# GRAIN SIZE DISTRIBUTION

FIGURE 6

## Silty Sand with Gravel: Till



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	502C	15.77	142.03

Date January 2018  
W.P. 4005-13-01



Prep'd KCP  
Chkd. PC



## Certificate of Analysis

**Thurber Engineering Ltd.**

2460 Lancaster Rd, Unit 107  
Ottawa, ON K1B4S5  
Attn: Kenton Power

Client PO:  
Project: 19-5161-263  
Custody:

Report Date: 13-Nov-2015  
Order Date: 10-Nov-2015

**Order #: 1546148**

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

Paracel ID	Client ID
<del>1546148-01</del>	<del>BH704 SS4 6' to 8'</del>
<del>1546148-02</del>	<del>BH601 SS4 6' to 8'</del>
1546148-03	BH501 SS6 10.5' to 12.5'

Approved By:



Mark Foto, M.Sc.  
Lab Supervisor

## Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

Project Description: **19-5161-263****Analysis Summary Table**

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	12-Nov-15	12-Nov-15
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	11-Nov-15	11-Nov-15
Resistivity	EPA 120.1 - probe, water extraction	12-Nov-15	12-Nov-15
Solids, %	Gravimetric, calculation	12-Nov-15	12-Nov-15

**Certificate of Analysis**

Client: **Thurber Engineering Ltd.**

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

Client PO:

**Project Description: 19-5161-263**

<b>Client ID:</b>		BH704 SS4 6' to 8'	BH601 SS4 6' to 8'	BH501 SS6 10.5' to 12.5'	-
<b>Sample Date:</b>		22-Oct-15	19-Oct-15	27-Oct-15	-
<b>Sample ID:</b>		1546148-01	1546148-02	1546148-03	-
<b>MDL/Units</b>		Soil	Soil	Soil	-
<b>Physical Characteristics</b>					
% Solids	0.1 % by Wt.	81.9	76.3	91.8	-
<b>General Inorganics</b>					
pH	0.05 pH Units	7.56	7.73	7.99	-
Resistivity	0.10 Ohm.m	25.3	31.2	157	-
<b>Anions</b>					
Chloride	5 ug/g dry	129	70	6	-
Sulphate	5 ug/g dry	27	112	7	-

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

Project Description: **19-5161-263**

**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>									
Resistivity	ND	0.10	Ohm.m						

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

Project Description: **19-5161-263**

**Method Quality Control: Duplicate**

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
<b>Anions</b>									
Chloride	7.0	5	ug/g dry	7.1			0.5	20	
Sulphate	24.3	5	ug/g dry	25.1			3.6	20	
<b>General Inorganics</b>									
pH	8.11	0.05	pH Units	7.99			1.5	10	
Resistivity	24.8	0.10	Ohm.m	25.3			1.9	20	
<b>Physical Characteristics</b>									
% Solids	78.2	0.1	% by Wt.	77.6			0.7	25	

## Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

Project Description: **19-5161-263****Method Quality Control: Spike**

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
<b>Anions</b>									
Chloride	100	5	ug/g	7.1	93.3	78-113			
Sulphate	104	5	ug/g	25.1	79.1	78-111			

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

**Project Description: 19-5161-263**

**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.

**APPENDIX D**  
**SELECTED PHOTOGRAPHS**





**Figure 1: Roadway Platform at Culvert 29-146/C looking east**



**Figure 2: Culvert 29-146/C inlet looking north**





**Figure 3: Looking upstream from Culvert 29-146/C**



**Figure 4: Culvert 29-146/C outlet looking south**





**Figure 5: Looking downstream from Culvert 29-146/C**



**Figure 6: South embankment looking west towards Borehole 501**





**Figure 7: Erosion of north embankment granular cover**

## **APPENDIX E**

### **COMPARISON OF CULVERT TYPE/FOUNDATION ALTERNATIVES COMPARISON OF CONSTRUCTION METHODOLOGY OPTIONS**

### Comparison of Culvert Type/Foundation Alternatives

<b>Comment</b>	<b>Circular Pipes</b>	<b>Open Footing Culvert</b>	<b>Closed Box Culvert</b>
<b><i>Advantages</i></b>	Readily available materials and simple installation methods		Wide base spreads out load  Less prone to effects of scour and erosion
<b><i>Disadvantages</i></b>	Numerous parallel pipes required to provide hydraulic opening equivalent to existing culvert.	Founding elevation is deeper than with closed box, requiring deeper excavation	
<b><i>Risks / Consequences</i></b>	Potential for base disturbance if groundwater not controlled / added cost and schedule delays	Potential for base disturbance if groundwater not controlled / added cost and schedule delays	Potential for base disturbance if groundwater not controlled / added cost and schedule delays
<b><i>Relative Cost</i></b>	Moderate	Moderate	Moderate
	<b>NOT RECOMMENDED</b>	<b>FEASIBLE</b>	<b>RECOMMENDED</b>

### Comparison of Construction Methodology Options

Comment	Trenchless	Staged, with Roadway Protection	Open Cut with TMB	Staged Construction with Platform Lowering and/or Widening
<b>Advantages</b>	Avoids open cut.	Limits volume of earthwork compared to platform lowering/widening	Avoids need for installation of protection system through rock fill  Avoids need for multiple traffic staging setups	Avoids need for installation of protection system through rock fill
<b>Disadvantages</b>	Lane reductions may still be required for construction access  Obstructions in rock fill hard to tunnel through  Wide open water at outlet not favourable for entry/exit pit	Rock fill and boulders in till are challenging for installation of protection system		Buried peat beneath toe of slope at North side; likely requires peat/muskeg removal  Open water at or near existing toe of slope makes fill placement/compaction more difficult  Potentially large volumes of earthwork required
<b>Risks/Consequences</b>	Obstructions/delays  Removal of large particles or accidental over excavation leaves voids/settlement of adjacent roadway	Difficulty installing protection system/delays  Removal of oversized particles during installation of protection system leads to settlement of adjacent highway/increased maintenance	Erosion of slopes in front of temporary bridge foundations / reinstatement and protection required to maintain stability	Settlement of widened portion of embankment/ increased maintenance  Loss of temporary pavement structure into underlying rock fill/ increased maintenance
<b>Relative Cost</b>	High	Moderate	Moderate	Moderate
	<b>NOT FEASIBLE</b>	<b>FEASIBLE</b>	<b>RECOMMENDED</b>	<b>FEASIBLE</b>



## **APPENDIX F**

**GSC SEISMIC HAZARD CALCULATION  
SLOPE STABILITY ANALYSIS RESULTS  
LIST OF REFERENCED SPECIFICATIONS  
NON-STANDARD SPECIAL PROVISION**

# 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

January 16, 2018

Site: 46.2663 N, 78.3543 W User File Reference: Barbut Creek Culvert

Requested by: , Thurber Engineering

**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>
0.414	0.487	<b>0.409</b>	0.311	<b>0.219</b>	<b>0.107</b>	<b>0.050</b>	<b>0.013</b>	<b>0.0048</b>	<b>0.262</b>	<b>0.179</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)	0.031	0.129	0.224
Sa(0.1)	0.044	0.164	0.274
Sa(0.2)	0.041	0.141	0.234
Sa(0.3)	0.033	0.108	0.178
Sa(0.5)	0.024	0.076	0.124
Sa(1.0)	0.012	0.038	0.061
Sa(2.0)	0.0049	0.017	0.028
Sa(5.0)	0.0010	0.0039	0.0068
Sa(10.0)	0.0005	0.0016	0.0027
PGA	0.024	0.088	0.149
PGV	0.016	0.057	0.097

## References

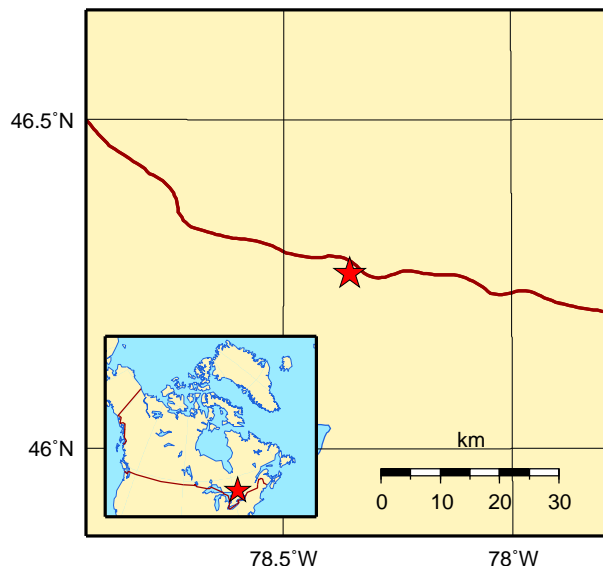
**National Building Code of Canada 2015 NRCC no. 56190;**  
**Appendix C:** Table C-3, Seismic Design Data for Selected Locations in Canada

**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

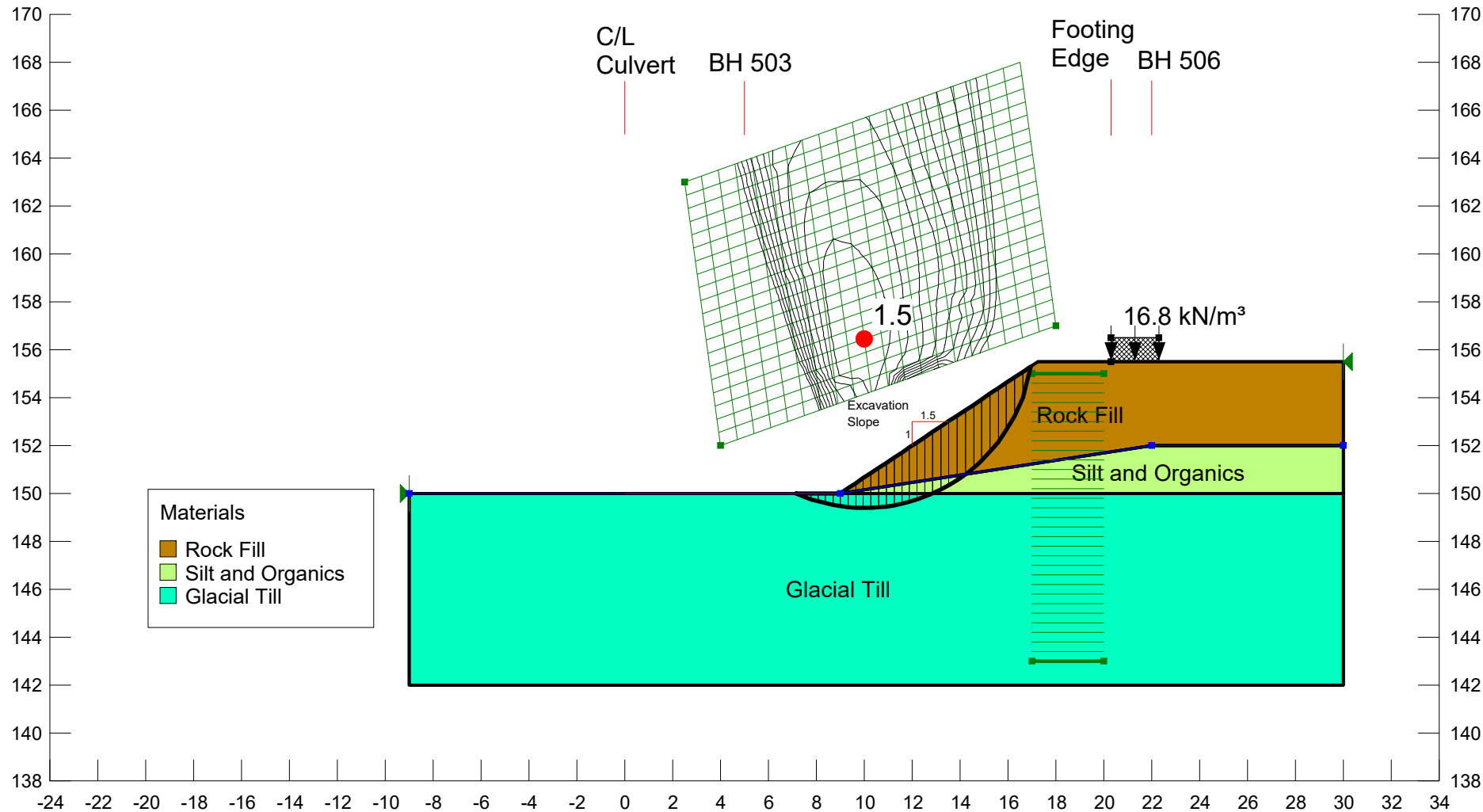
Ressources naturelles  
Canada



Title: Barbut Culvert  
Comments: Global Stability Assessment  
Name: Stage I - Excavation

Method: Morgenstern-Price, Half-Sine  
Minimum Slip Surface Depth: 1.52 m  
PWP Conditions Source: Piezometric Line  
Seismic, H: 0 V: 0  
Slip Surface Center: (10, 156.45) w/ Radius: 7.05 m  
FoS Contours: 1.4 to 2.4, ++0.1

Rock Fill	19 kN/m <sup>3</sup>	0 kPa	45 °
Silt and Organics	18 kN/m <sup>3</sup>	0 kPa	27 °
Glacial Till	21 kN/m <sup>3</sup>	0 kPa	35 °



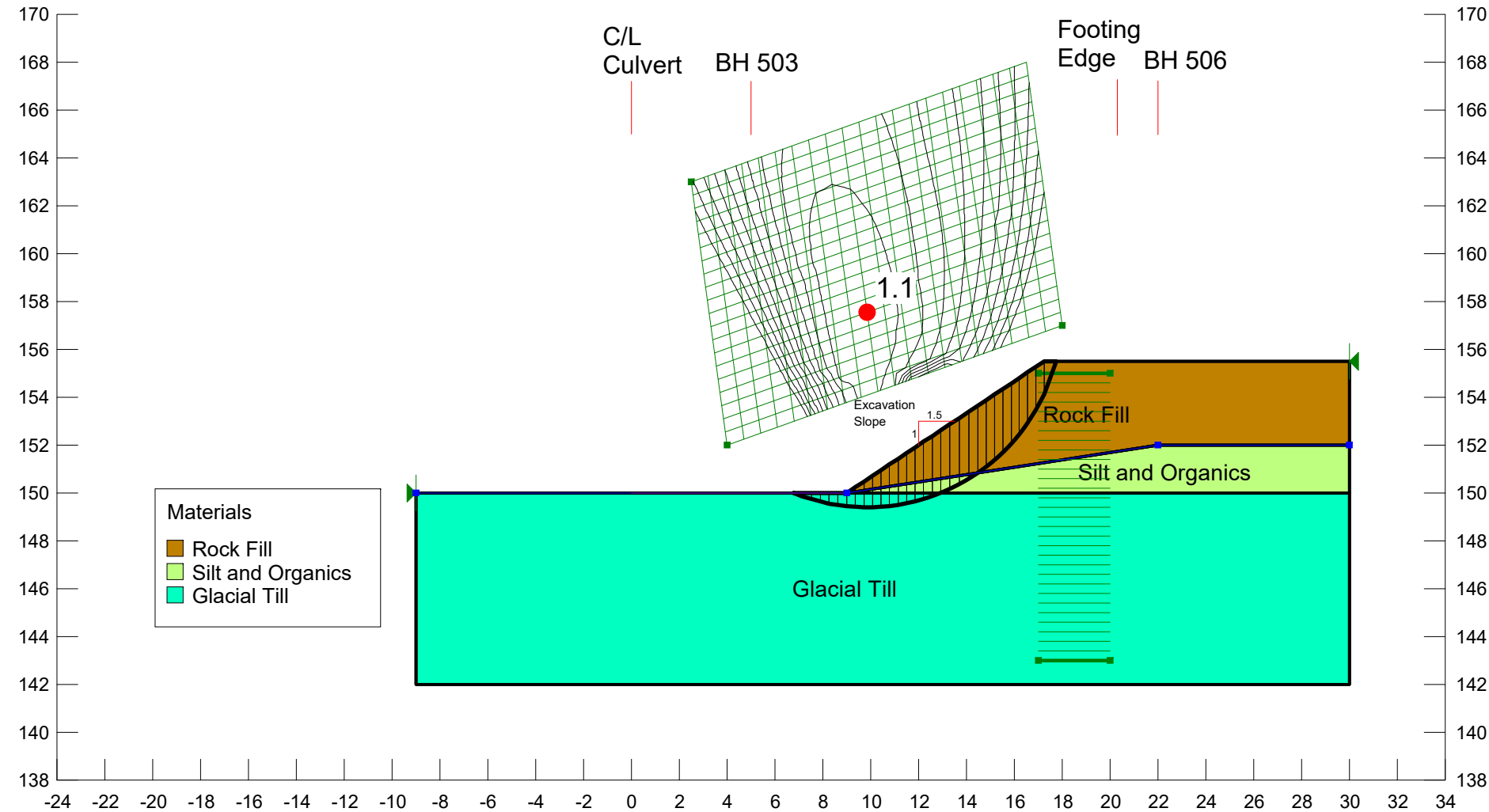
Reviewed By: \_\_\_\_\_  
Tool Version: 8.15.5.11777  
Last Solved Date: 2/27/2018, 4:28:52 PM  
Directory: \\192.168.104.30\Project Data\Projects\19\5161\263 - ER Mega 5\Culverts\Site 29-146C-Barbut Creek\Foundations\Analysis\SlopeW\Barbut excavation 2.gsz

Figure 1

Title: Barbut Culvert  
Comments: Global Stability Assessment  
Name: Stage I - Excavation Seismic

Method: Morgenstern-Price, Half-Sine  
Minimum Slip Surface Depth: 1.52 m  
PWP Conditions Source: Piezometric Line  
Seismic, H: 0.131 V: 0  
Slip Surface Center: (9.85, 157.55) w/ Radius: 8.15 m  
FoS Contours: 1.1 to 2.1, ++0.1

Rock Fill	19 kN/m³	0 kPa	45 °
Silt and Organics	18 kN/m³	0 kPa	27 °
Glacial Till	21 kN/m³	0 kPa	35 °



Reviewed By: \_\_\_\_\_  
Tool Version: 8.15.5.11777  
Last Solved Date: 2/27/2018, 4:29:01 PM  
Directory: \\192.168.104.30\Project Data\Projects\19\5161\263 - ER Mega 5\Culverts\Site 29-146C-Barbut Creek\Foundations\Analysis\SlopeW\Barbut excavation 2.gsz

Figure 2

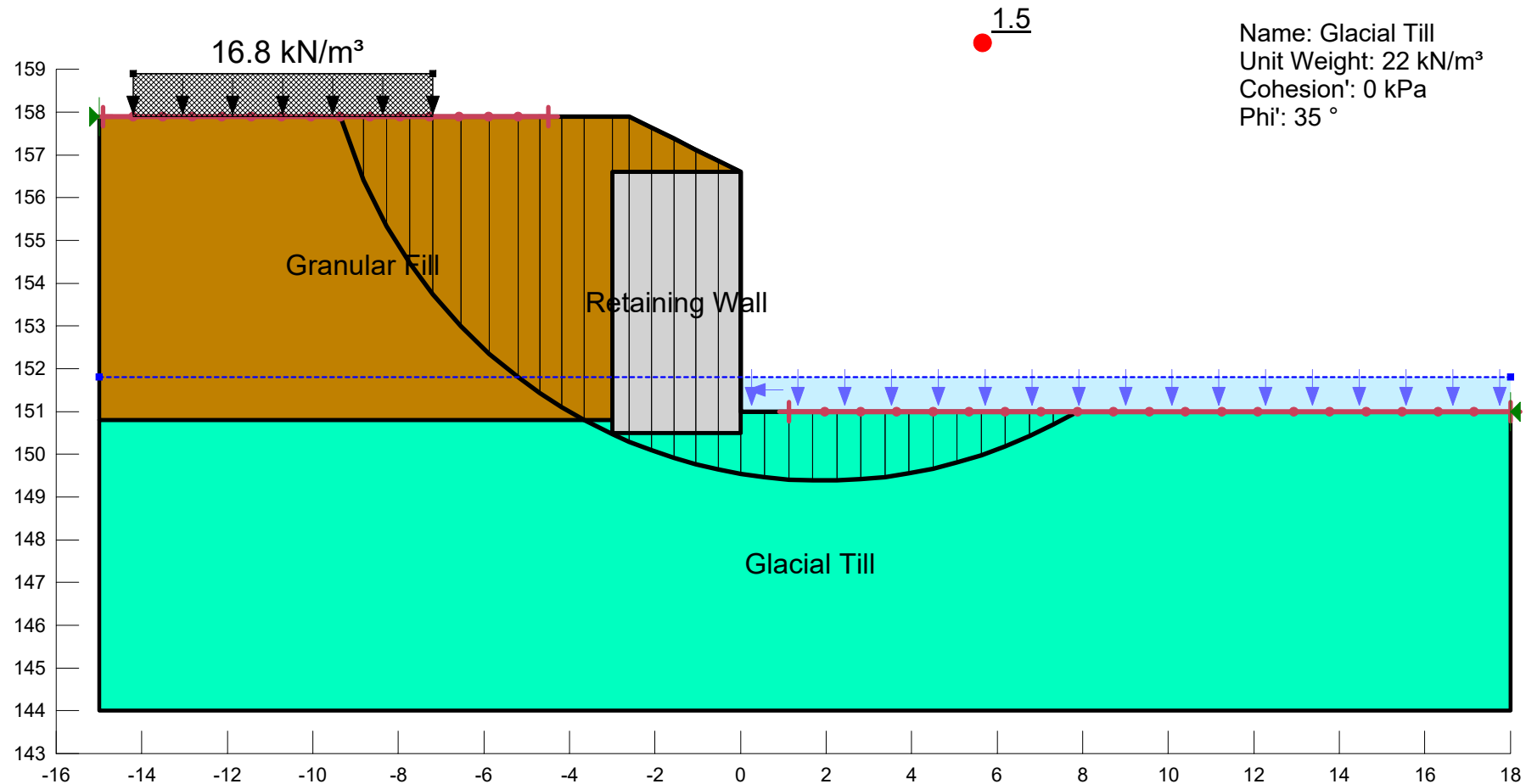
Title: Barbut Culvert Retaining Walls  
Comments: Global Stability Assessment  
Name: Static Analysis

Method: Morgenstern-Price, Half-Sine  
Minimum Slip Surface Depth: 0.1 m  
PWP Conditions Source: Piezometric Line  
Seismic, H: 0 V: 0  
Slip Surface Center: (1.9304758, 161.11572) w/ Radius: 11.733082 m

Name: Granular Fill  
Unit Weight: 20 kN/m<sup>3</sup>  
Cohesion': 0 kPa  
Phi': 32 °

Name: Retaining Wall  
Unit Weight: 20 kN/m<sup>3</sup>

Name: Glacial Till  
Unit Weight: 22 kN/m<sup>3</sup>  
Cohesion': 0 kPa  
Phi': 35 °



Reviewed By: \_\_\_\_\_  
Tool Version: 8.14.1.10087  
Last Solved Date: 10-Apr-18, 3:50:27 PM  
Directory: H:\Projects\19\5161\263 - ER Mega 5\Culverts\Site 29-146C-Barbut Creek\Foundations\Analysis\SlopeW\CM April 10, 2018\Retaining Wall.gsz

Figure 3

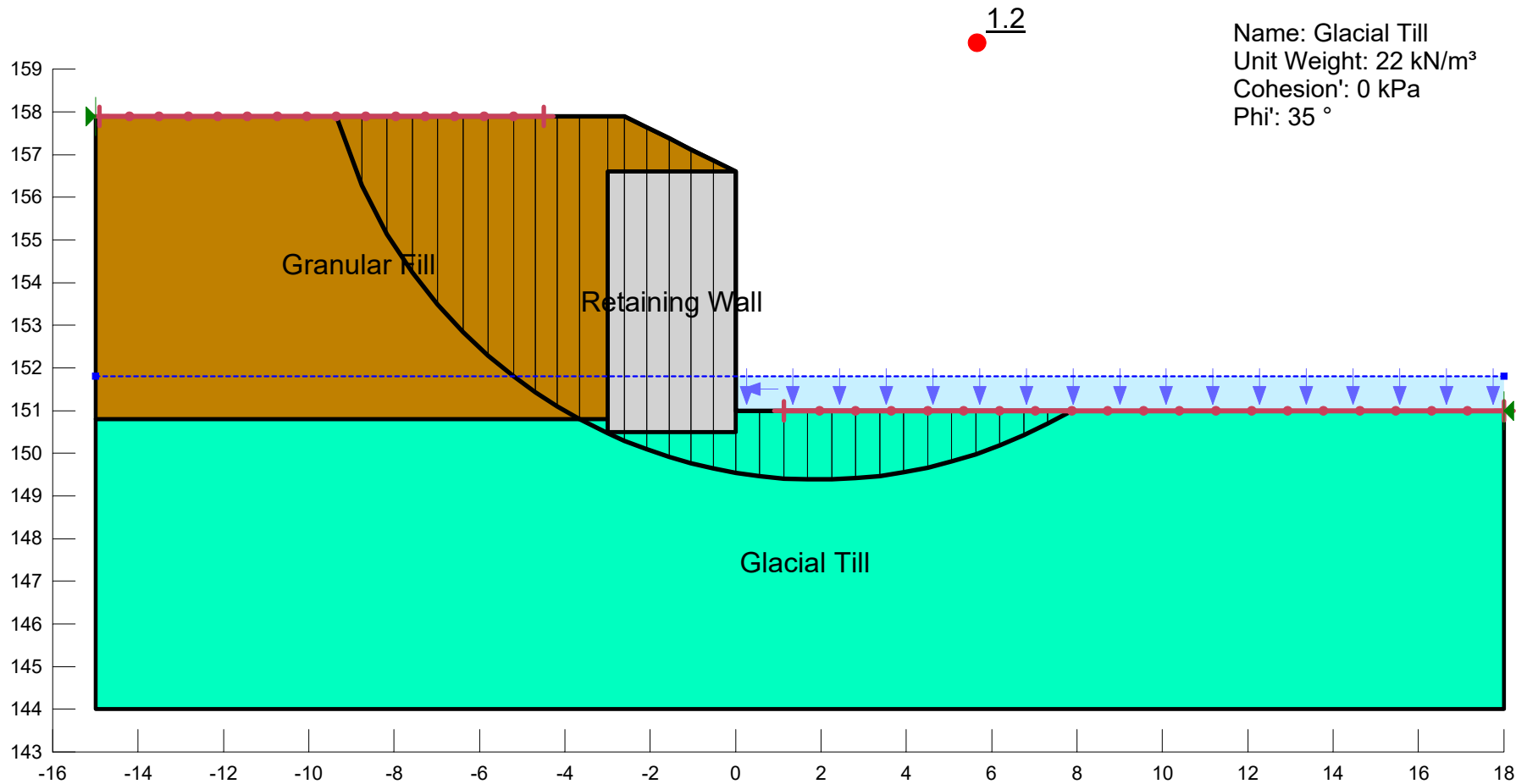
**Title: Barbut Culvert Retaining Walls**  
**Comments: Global Stability Assessment**  
**Name: Seismic Analysis**

Method: Morgenstern-Price, Half-Sine  
Minimum Slip Surface Depth: 0.1 m  
PWP Conditions Source: Piezometric Line  
Seismic, H: 0.131 V: 0  
Slip Surface Center: (1.9304758, 161.11572) w/ Radius: 11.733082 m

Name: Granular Fill  
Unit Weight: 20 kN/m<sup>3</sup>  
Cohesion': 0 kPa  
Phi': 32 °

Name: Retaining Wall  
Unit Weight: 20 kN/m<sup>3</sup>

Name: Glacial Till  
Unit Weight: 22 kN/m<sup>3</sup>  
Cohesion': 0 kPa  
Phi': 35 °



Reviewed By: \_\_\_\_\_

Tool Version: 8.14.1.10087

Last Solved Date: 10-Apr-18, 3:50:29 PM

Directory: H:\Projects\19\5161\263 - ER Mega 5\Culverts\Site 29-146C-Barbut Creek\Foundations\Analysis\SlopeW\CM April 10, 2018\Retaining Wall.gsz

**Figure 4**

## LIST OF REFERENCED SPECIFICATIONS

OPSD 208.010	Benching of Earth Slopes
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.101	Foundation, Frost Penetration Depths for Southern Ontario
OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 209	Construction Specification for Embankments over Swamps and Compressible Soils
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 805	Construction Specification for Temporary Erosion and Sediment Control Measures
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
Special Provision 109S12	Amendment to OPSS 902, November 2010
Special Provision 517F01	Amendment to OPSS 517, November 2016
Design Build Special Provision 3271	Performance-Based Specification for Design and Construction of Structural Culverts

## **NON-STANDARD SPECIAL PROVISIONS**

### **RECOMMENDED WORDING FOR “NSSP – A CONCRETE WORKING SLAB”**

This Non-standard Special Provision covers the requirements for the supply and placement of a concrete working slab to protect the sand and silt subgrade of the entry/exits pits and provide a proper working surface for the tunnelling equipment.

Excavation for the working slab shall be according to OPSS.PROV 902. Within four hours following inspection and approval of the prepared subgrade, a working slab with a minimum thickness of 100 mm shall be placed on the foundation subgrade as specified in the Contract Documents. Concrete for working slabs shall have a minimum 28 day strength of 20 MPa.

### **RECOMMENDED WORDING FOR “NSSP – 902.07.05 EXCAVATION”**

Subsection 902.07.05 of OPSS 902 is amended by the addition of the following:

Excavations at the site may be impeded by obstructions within the existing fill and glacial till. The contractor shall be prepared to dislodge and remove these obstructions and extend the excavations to the design depths.

Reference can be made to the Foundation Investigation Report for the Replacement of Structural Culvert No. 29-146/C, Barbut Creek Crossing of Highway 17 prepared by Thurber Engineering Ltd., 2018, for further details on likely subsurface conditions at the foundation locations.

### **RECOMMENDED WORDING FOR “NSSP – TEMPORARY PROTECTION SYSTEM”**

Temporary protection system will be installed in ground conditions that include rockfill, cobbles and boulders. The Contractor's installation method and temporary protection system must be penetrating obstructions such as rockfill cobbles, boulders or other obstructions within the fill and glacial till.

Reference can be made to the Foundation Investigation Report for the Replacement of Structural Culvert No. 29-146/C Barbut Creek Crossing of Highway 17, prepared by Thurber Engineering Ltd., 2018, for further details on likely subsurface conditions at the foundation locations.