



**THURBER** ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
REPLACEMENT OF STRUCTURAL CULVERT No. 38S-480  
HIGHWAY 639, 12.5 KM NORTH OF HIGHWAY 108 JUNCTION  
CHRISTIAN CREEK CROSSING STATION 12+330  
DISTRICT OF ALGOMA  
W.P. 5264-10-01  
5013-E-0041**

**GEOCRES NUMBER: 41J-97**

**SUBMITTED TO  
MMM GROUP LIMITED**

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**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 Christian Creek Culvert located on Highway 639, within the District of Algoma, approximately 30 km north of Elliot Lake, Ontario. Thurber carried out the investigation as a subconsultant to MMM Group Limited (MMM) as part of Agreement No. 5013-E-0041.

No previous foundation investigation information for the subject culvert was available. The MTO Design Criteria Report for the Christian Creek Culvert Replacement Project dated June 2015, was provided by MMM 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 38S-480 is located at Station 12+330 on Highway 639, approximately 10.5 km south of Highway 546, near Elliot Lake. It is noted that for project orientation purposes, Highway 639 within the project limits, will be assumed to run south-north. The location of the culvert is shown on the inset Key Plan on Drawing No. 1 in Appendix A.

Within the project limits, Highway 639 is a two-lane, rural arterial, undivided highway with steel beam guide rails located on both sides of the highway. Based on the MTO Design Criteria Report the roadway cross-section consists of two, 3.5 m wide lanes with approximately 1.3 m wide granular shoulders. Culvert 38S-480 carries Christian Creek flow from east to west below the highway. The posted speed limit within the project limits is 80 km/hr. A 2010 AADT of 70 for Highway 639 within the project limits was provided to MMM by MTO. The iCorridor data between the years 2000 and 2008 indicates a fluctuation in AADT value from 190 to 60.

The Design Report also indicates that the existing culvert is a twin cell, timber box culvert that was constructed in 1981. The total length of structure is reported to be 27 m. Each cell is noted as being constructed with a span of 1.8 m and an interior height of 2.1 m. The height of the fill over the culvert was reported to be approximately 1.5 m. A structure inspection was conducted by MTO in May 2012, for Culvert 38S-480 with the report issued March 2014. The report recommended the structure to be replaced within 1 to 5 years of the inspection.

The slopes of the embankment were observed to be covered with rockfill and were graded at approximately 3.5H:1V (Horizontal:Vertical). The elevation at the centreline of the roadway was approximately 361.2 m. The elevation of the top of the culvert was approximately 358.7 m and 358.5 m at the inlet and outlet respectively. The stream bed was at elevation 356.3 m and 355.8 m at the inlet and outlet respectively.

The lands surrounding the roadway are typically forested with little to no development in the area. Frequent bedrock outcrops were noted in the area in close proximity to the south west and the east of the culvert site. Storm water drainage in the area is to ditches and culverts. Typical site photographs are presented in Appendix D.

### 3 SITE INVESTIGATION AND FIELD TESTING

As a component of our standard procedures and due diligence, Thurber contacted Ontario One Call to provide utility locate clearances for the intended borehole locations. The results of the utility locates indicated that there were no buried utilities in the area of the proposed test holes at the time of the field investigation. It should be noted that utility locate clearances will be required for any future excavations.

The field investigation for this site included advancing four boreholes drilled on June 23 and 24, 2015. The stationing, offsets and elevation of the boreholes are shown on the Borehole Location and Soil Strata Drawing No. 1 in Appendix A and are summarized in Table 3-1.

**Table 3-1: Borehole Summary**

Borehole	Location	Station	Offset (m)	Latitude	Longitude	Ground Surface Elevation (m)	Depth (m)
15-1	Highway 639 Northbound	12+323	2.3 RT	46.58569	-82.73905	361.1	5.6
15-2	Highway 639 Southbound	12+337	1.9 LT	46.58578	-82.73919	361.1	5.5
15-3	Culvert inlet	12+328	15.0 RT	46.58578	-82.73894	356.8	0.6
15-4	Culvert outlet	12+339	17.7 LT	46.58573	-82.73934	356.0	0 (Exposed bedrock)

The boreholes advanced through the roadway embankment were advanced with a CME truck mounted drill rig equipped with NW size casing. The inlet and outlet boreholes were advanced with portable drilling equipment. 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. Bedrock was cored in both embankment boreholes using NQ size coring equipment following ASTM Standard D6032-08. Bedrock core samples were stored in core boxes for transport.

A 25 mm inside diameter PVC monitoring well was installed in Boreholes 15-1. Well construction details are illustrated on the Record of Boreholes sheet provided in Appendix B.

The boreholes were backfilled with a low-permeability mixture of auger cuttings and bentonite pellets in general accordance with the intent of Ontario MOE Regulation 903.

The as-drilled locations of the boreholes and ground surface elevations at the borehole locations were surveyed by Thurber on June 24, 2015. The vertical datum used was a temporary benchmark (TBM) provided by MMM, located at Station 12+349.720 with a geodetic elevation of 360.981 m. The location of the TBM is indicated on Drawing No. 1 in Appendix A.

## **4 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.

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

## **5 DESCRIPTION OF SUBSURFACE CONDITIONS**

### **5.1 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 for the culvert area is 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.

For reference, the stratigraphy in the area of the boreholes through the embankment is generally characterized by asphalt surface treatment overlying gravel and sand with silt fill overlying gravel and sand material mixed with rockfill and frequent cobbles and boulders underlain by granite bedrock.

More detailed descriptions of the individual strata are presented below.

### **5.2 Pavement Structure**

#### **Surface Treatment:**

An asphalt surface treatment layer with a thickness of 50 mm was encountered in both embankment boreholes.

#### **Base Materials:**

A granular fill layer consisting predominantly of gravel and sand with varying amounts of silt was encountered below the surface treatment in the embankment boreholes. This layer has a top elevation of 361.0 m and has a thickness ranging from 0.5 m to 0.8 m in Boreholes 15-1 and 15-2. The SPT 'N' values were 40 and 48 blows per 0.3 m of penetration; indicating a dense condition.

The moisture content of the samples tested was 2% and 3%. The results of grain size analysis conducted on two samples of the granular fill material are summarized in Table 5-1 and are illustrated on Figure 1 in Appendix C.

**Table 5-1: Gradation Results for Granular Fill**

Soil Particles	%
Gravel	50 and 51
Sand	47 and 44
Silt and Clay	3 and 5

### **5.3 Embankment Fill (Rockfill)**

A fill layer consisting predominantly of gravel with varying amounts of sand mixed with rockfill with frequent cobbles and boulders was encountered beneath the pavement structure fill in both embankment boreholes. This layer has a top elevation of 360.2 m to 360.5 m and a thickness ranging from 4.0 m to 4.1 m in Boreholes 15-1 and 15-2. Rockfill was also observed in Borehole 15-3 extending from ground surface at elevation 356.8 m to a depth of 0.6 m. The SPT 'N' values ranged from 2 to 69 blows per 0.3 m of penetration; indicating a very loose to very dense condition; but typically compact to dense. Coring techniques were required to advance through this layer in Borehole 15-3.

The moisture content for the sample tested was 7%. The results of a grain size analysis test completed on a single sample of this material indicated a gravel content of 62%, sand content of 31%, and a fines content (combined silt and clay size particles) of 7%.

### **5.4 Bedrock**

Granitic bedrock was encountered beneath the rockfill in both the embankment boreholes; as identified by visual inspection of NQ coring. Borehole 15-3 was terminated at refusal on inferred bedrock. Bedrock was exposed in Borehole 15-4. The bedrock surface ranged in elevation from 356.0 m to 356.4 m. Bedrock total core recovery was 100% in both cored boreholes, solid core recovery ranged from 85% to 87% and the RQD values ranged from 40% to 82%. Based on the RQD values the rock mass quality ranges from poor to good. The bedrock fractures had a flat orientation. The fracture index was 1 fracture per 0.3 m. A photograph of the bedrock cores is provided in Appendix B.

### **5.5 Groundwater Conditions**

Groundwater levels were measured on completion of drilling in the open boreholes prior to backfilling; however these values are not considered representative of existing conditions as water was used to advance the casing and for bedrock coring operations.

A 25 mm inside diameter PVC monitoring well was installed in Boreholes 15-1. Groundwater level in the monitoring well was recorded on June 24, 2015 at a depth of 4.8 m; corresponding to an elevations of 356.3 m.

The water level in Christian Creek was measured at the time of Thurber's field investigation at a depth of 2.2 m below the top of the culvert at the inlet; corresponding to an elevation of 356.5 m.

The groundwater level in the area of the culvert is expected to reflect the water level in Christian Creek. These observations are 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.

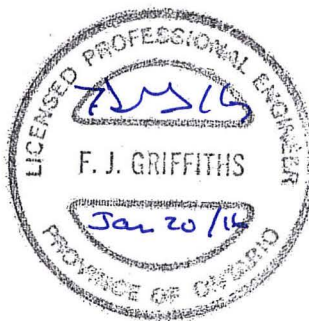
## 6 MISCELLANEOUS

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 stationing, offsets and ground surface elevations based on contract drawings provided by MMM Group Limited. Marathon Drilling Co. Ltd. of Greely, Ontario supplied and operated the CME drill rig and portable 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. Christopher Murray 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 Dr. Fred Griffiths, P.Eng. Interpretation of the field data and preparation of this report was completed by Kenton Power, P.Eng. The report was reviewed by Dr. Fred Griffiths, P.Eng. and Dr. P.K. Chatterji, P.Eng., the Designated Principal Contact for MTO Foundations Projects.



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**PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**7 GENERAL**

This report presents interpretation of the geotechnical data in the factual report and presents foundation recommendations and a geotechnical evaluation of feasible methods for replacement of the Christian Creek culvert beneath Highway 639, approximately 10.5 km south of Highway 546 near Elliot Lake Ontario.

Based on the MTO Design Criteria Report provided, Culvert 38S-480 is a twin cell timber box culvert that was constructed in 1981. The total length of structure is reported to be 27 m. Each cell is noted as being constructed with a span of 1.8 m and a height of 2.1 m. The top of the inlet and outlet of the existing culvert were surveyed at elevations 358.7 m and 358.5 m respectively.

The maximum height of the road embankment from top of pavement to the invert of Culvert 38S-480 is approximately 5.2 m. Existing side slopes are graded at approximately 3.5H:1V (Horizontal:Vertical). The embankment was constructed using rockfill with sand and gravel. Beyond the toe of the slope the area is grassed, brush and tree covered.

Within the project limits, Highway 639 is a two-lane, rural arterial, undivided highway with steel beam guide rails located on both sides of the highway. Based on the MTO Design Criteria Report the roadway cross-section consists of two, 3.5 m wide lanes with approximately 1.3 m wide granular shoulders. Culvert 38S-480 carries Christian Creek flow from east to west below the highway. The posted speed limit within the project limits is 80 km/hr. A 2010 AADT of 70 for Highway 639 within the project limits was provided to MMM by MTO. The iCorridor data between the years 2000 and 2008 indicates a fluctuation in AADT value from 190 to 60.

The water level in Christian Creek was measured at the time of Thurber's field investigation at a depth of 2.2 m below the top of the culvert at the inlet; corresponding to an elevation of 356.5 m. It is anticipated that the groundwater level in the area of the culvert is expected to reflect the water level in Christian Creek. Diversion of creek flow will therefore be necessary during construction.

It is understood based on the December 2015 General Arrangement (GA) drawing that the preferred structural alternative is to replace the existing timber culvert with a precast, concrete, open footing, box culvert along the current alignment. It is noted that the need for replacement of the culvert was identified based on its current condition rather than a need to increase hydraulic capacity. Headwalls are not proposed for the new culvert.

The frost penetration depth at this site is 1.8 m as per OPSD 3090.101.

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

## 8 SEISMIC CONSIDERATIONS

In accordance with Table A3.1.1 of the Canadian Highway Bridge Design Code (CHBDC) the following seismic parameters for Elliot Lake, Ontario, located approximately 30 km south of the project site should be used for design:

- Velocity Related Seismic Zone ( $Z_v$ ) = 1
- Zonal Velocity Ratio, ( $V$ ) = 0.05
- Acceleration Related Seismic Zone ( $Z_a$ ) = 1
- Zonal Acceleration Ratio, ( $A$ ) = 0.05

This site is classified as a Soil Profile Type I in accordance with Section 4.4.6 of the CHBDC.

Based on the combination of the grain size distribution, relative density of the overburden soils, and low zonal acceleration, the overburden soil at this site is classified as “not susceptible” to liquefaction during the design earthquake event.

## 9 DESIGN OPTIONS

### 9.1 Culvert Foundations

The December 2015 GA Drawing indicates that the proposed invert elevation will be set between 356.18 m and 355.62 m.

Foundations for open footing culverts on soil must be provided with frost protection equivalent to 1.8 m of cover. If the foundations are founded on or in the granitic bedrock frost action is not a concern.

For reference, the stratigraphy is generally characterized by asphalt surface treatment overlying, gravel and sand with silt fill, overlying gravel and sand material mixed with rockfill and frequent cobbles and boulders, underlain by granite bedrock encountered at elevations from 356.0 m to 356.4 m. The water level in Christian Creek was measured an elevation of 356.5 m.

Based on the proposed invert elevations the replacement culvert will be founded on or in granite bedrock.

The following sections address replacement of the existing twin timber culvert. It is understood that the new culvert will be constructed along the existing alignment.

### 9.2 Culvert Replacement Alternatives

This section presents discussions on alternate replacement options and foundation alternatives, and provides recommendations on feasible and/or preferred foundation options. Several common culvert and foundation types are listed below and a comparison of these alternatives, based on their respective advantages and disadvantages are outlined below, and are summarized in the table provided in Appendix E.

### 9.2.1 Circular Pipes (Concrete, Steel, HDPE)

From a foundation engineering standpoint, concrete, steel and HDPE pipes are technically feasible and likely the lowest cost alternative. However, the geometry may require bedrock excavation to achieve hydraulic objectives.

### 9.2.2 Concrete, Rigid Frame Open Bottom

A rigid frame, open bottom (RFOB), concrete culvert is considered feasible from a foundation standpoint at this site.

It is understood based on the December 2015 GA drawing that the existing culvert could be replaced with a RFOB concrete culvert with a span of 3.6 m, an interior height of 2.1 m and an invert elevation ranging from 356.18 m and 355.62 m. The foundations would be in bedrock.

A factored vertical geotechnical resistance of 1500 kPa at Ultimate Limit State (ULS) may be used for the design of shallow foundations, founded on or in the bedrock. The factored ULS value includes a resistance factor of 0.5. The SLS condition will not govern for footings in or on the bedrock.

The geotechnical resistances are based on a footing subjected to vertical concentric loading. Where eccentric or inclined loads are applied, the resistance used in the design must be reduced in accordance with the CHBDC Clause 6.7.3 and 6.7.4.

Resistance to lateral forces through sliding resistance between concrete and the bedrock foundation should be evaluated using an unfactored coefficient of 0.70 for cast-in-place concrete.

It is noted that construction will extend below the water level in the creek. Creek diversion and dewatering will be required to construct the footings in the dry.

### 9.2.3 Concrete, Rigid Frame Closed Bottom

From a foundation standpoint, a rigid frame, close bottom (RFCB), concrete culvert is considered feasible at this site.

The June 2015 GA drawing indicates that the existing culvert could be replaced with a RFCB concrete culvert with a span of 3.6 m, an interior height of 2.1 m and an invert elevation ranging from 355.621 m and 356.362 m. Assuming a base slab thickness of 350 mm, the underside of the culvert would be at an approximate elevation between 355.27 m and 356.0 m.

Assuming a bedding layer of 300 mm thick for the culvert, the base of excavation is expected to be at an approximate elevation 354.9; which would require bedrock removal by excavation or blasting techniques to achieve. The founding elevation would be 1.6 m below the creek water level observed on June 24, 2015. Creek diversion and dewatering will be required to place the bedding layer and construct the culvert in the dry. If hydraulic and environmental issues permit it, consideration should be given to raising the culvert invert elevations to minimize bedrock excavation.

A factored vertical geotechnical resistance of 1500 kPa at Ultimate Limit State (ULS) may be used for the design of the box culvert, founded on or in the bedrock. The factored ULS value provided

includes a resistance factor of 0.5. The SLS condition will not govern for footings in or on the bedrock.

The geotechnical resistances are based on a footing subjected to vertical concentric loading. Where eccentric or inclined loads are applied, the resistance used in the design must be reduced in accordance with the CHBDC Clause 6.7.3 and 6.7.4.

Resistance to lateral forces and sliding resistance between concrete and the bedding material should be evaluated using an unfactored coefficients provided in Table 9-1.

**Table 9-1: Unfactored Coefficients of Friction between Concrete and Founding Material**

Concrete Type	Founding Material
	OPSS GranularA
Cast-in-place concrete	0.50
Precast concrete	0.45

Replacement of the existing culvert with a RFCB concrete culvert is considered feasible from a foundation standpoint.

### 9.3 Construction Methodology Alternatives

This section presents discussions on alternative construction methods from a geotechnical point of view for the replacement of the existing culvert. Further comparison of these options are 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 full road closure
3. Open cut with staged construction and roadway protection
4. Open cut with staged construction and platform lowering
5. Open cut and widening the platform with a single lane and traffic lights

#### 9.3.1 Trenchless Techniques

Although trenchless techniques would have the advantage of minimum disruption to traffic and would avoid an excavation through the existing highway embankment, a mixed rockfill / bedrock face present along the alignment is not conducive to tunnelling. Trenchless techniques are not considered suitable for the site conditions.

#### 9.3.2 Open Cut with Full Road Closure

Installation of a new culvert using open cut techniques during a full road closure is the preferred alternative from a foundation perspective. This option would allow for an expedient construction schedule and reduced costs associated with roadway protection, and avoid the need for platform widening, however, it is understood that a road closure is not feasible from a traffic operations perspective.

### 9.3.3 Open Cut with Staged Construction and Roadway Protection

The culvert could be replaced using open cut techniques with staged construction (half and half) and roadway protection in order to keep one lane of traffic open throughout the construction period. The use of traffic lights for traffic control would be required. Increased difficulty with the installation of roadway protection should be anticipated due to the presence of rockfill within the embankment and relatively shallow depth to bedrock at the site.

### 9.3.4 Open Cut with Staged Construction and Platform Lowering

The culvert could be replaced using open cut techniques with staged construction (half and half) and platform lowering. Lowering the platform by approximately 1.0 m to elevation 360 m would provide a platform width of approximately 15 m sufficient to allow traffic for each stage; however culvert cover would be reduced to 0.5 m. This option would be only feasible if the structural integrity of the culvert is confirmed and the culvert is able to support the traffic loading with the reduced cover. Given the poor condition of the existing culvert indicated in MTO's 2012 inspection this is not considered likely. Furthermore, rockfill would be exposed at the lowered elevation and would require subexcavation to prepare a suitable driving surface.

### 9.3.5 Open Cut, Widening the Platform to the East, Single Lane and Traffic Lights

From a foundations perspective, the existing culvert could be replaced using open cut techniques with staged construction (half and half) and platform widening to the east with a single traffic lane and the use of traffic lights for traffic control. Roadway protection may be required. Widening of the platform would require increasing the embankment footprint, a temporary culvert extension and the construction of a detour pavement.

## 9.4 Recommended Approach for the Culvert Replacement

If a full road closure is not possible due to other considerations, then open cut techniques with staged construction using platform widening is considered the preferred alternative.

The existing culvert could then be replaced with a 3.6 m wide open bottom, pre-cast, concrete culvert.

## 10 GENERAL RECOMMENDATIONS

Construction for installation of new culvert should be carried out in accordance with OPSS 904 Construction Specification for Concrete Structures.

### 10.1 Temporary Embankment Widening

Widening the existing embankment to the east of the existing roadway will allow the culvert replacement to be constructed with a staged approach. Roadway protection may be required for this option. Given the shallow depth to bedrock, little settlement is anticipated beneath either the existing or widened portion of the embankment.

Subgrade preparation within the area of the widening should be carried out as described in Section 10.4. The existing culvert will need to be extended prior to fill placement.

The existing side slope should be benched as per OPSD 208.010.

The embankment widening should be carried out in accordance with OPSS 206. The embankment widening material should consist of Granular B Type II material to ensure that lateral drainage is not compromised from the existing embankment. The slope of the widening should be no steeper than 2H:1V.

## 10.2 Excavations

All excavations must be conducted in accordance with the requirements of the Occupational Health & Safety Act & Regulations (OHSA) for Construction Projects. The existing fills at the site should be classified as Type 3 above and Type 4 below the groundwater table in accordance with OHSA.

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

Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor. As rockfill, cobbles and boulders were observed in the boreholes, it is recommended that the contract include an NSSP alerting bidders to their presence. We suggest the following wording: *"Excavations at the site may be impeded by obstructions within the existing fills. The contractor shall be prepared to dislodge and remove, these obstructions and extend the excavations to the design depths."*

## 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. Water from either surface flow and/or groundwater must be diverted away from the excavation at all times. Groundwater perched within the embankment fill, surface runoff and/or the water from the creek will tend to seep into, and accumulate in proposed excavations.

Excavations below the groundwater level are anticipated, a cofferdam may be required to control inflow of water into the excavation. Dewatering and surface water diversion must remain operational and effective until the culvert is replaced. Decisions regarding dewatering, must be carried out by the Contractor.

Once the cofferdam is in place and the creek flow is no longer coming through the culvert then the excavation for the culvert can commence. This excavation will be below the groundwater table. A carefully designed sump and pump dewatering program will be required to proceed with this excavation in the dry.

It is recommended that the Contract Documents identify the highest water level in the creek against which the cofferdam must provide protection and prevent flooding of the work area. At a minimum the expected spring freshet level or the level reached by a storm of an appropriate return period should be used as the design water level.

Further discussion with regards to dewatering at this site is provided in the Non-Standard Special Provision (NSSP) in Appendix F.

## **10.4 Subgrade Preparation**

Subgrade preparation must be carried out in the dry. This work should be carried out in accordance with OPSS 902.

### **10.4.1 Embankment Widening**

In embankment widening areas and after removal of the existing culvert and excavation to the design founding elevation, the exposed surface must be inspected to confirm that the subgrade is suitable and uniformly competent. Any remaining fill, topsoil, organics, creek bed deposits, soft/loose areas, disturbed soils and any deleterious materials within the embankment widening must be removed. The sub-excavated area should be replaced with well compacted granular fill consisting of OPSS 1010 Granular B Type II material as soon as practicable and the subgrade protected from disturbance during construction.

### **10.4.2 Culvert Replacement**

Subgrade preparation for the culvert replacement should include excavation and removal of the existing footings. The existing fill and any soft or organic materials must be removed and replaced with compacted Granular B Type II. The native subgrade within the footprint of the culvert will consist of bedrock. The bedrock surface should be cleaned and level. All loose rock should be removed from the sidewalls and base of the excavations.

## **10.5 Embankment Design and Reinstatement**

The existing embankment is sloped at approximately 3.5H:1V and exhibits no signs of instability. Embankment reconstruction, after culvert replacement, should be carried out in accordance with OPSS 206. The 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.

Provided the subgrade is prepared as outlined in Section 10.4 and embankment fill is placed as recommended herein, an embankment slope inclined at 2H:1V or flatter, will remain stable. An alternative would be to reinstate the embankment using rockfill. As the bedrock surface is at a shallow depth minimal embankment settlement is anticipated.

## **10.6 Backfilling**

Backfill for rigid structures should be in accordance with OPSS 904 and 902. Backfill for the culvert must consist of free draining granular material conforming to OPSS Granular A or B Type II material specifications.

The backfill should be placed and compacted in simultaneous, equal lifts on both sides of the culvert. Heavy compaction equipment should not be used adjacent to the walls and roof of the culvert. Compaction should be carried out in accordance with OPSS 501.



## 10.7 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 a horizontal and for a 2H:1V back-slope are provided in Table 10-1.

**Table 10-1: Static Lateral Earth Pressure Coefficient**

Parameter	Existing Rockfill	OPSS Granular A & OPSS Granular B Type II	Existing Granular Fill	OPSS Granular B Type I
Soil Unit Weight, kN/m <sup>3</sup> , $\gamma$	21	21	20	20
Angle of Internal Friction, $\phi$	40°	35°	33°	30°
<b>Horizontal Back-Slope</b>				
Coefficient of at Rest Earth Pressure, $K_o$ (Restrained Wall)	0.36	0.43	0.46	0.50
Coefficient of Active Earth Pressure, $K_a$ (Unrestrained Wall)	0.22	0.27	0.29	0.33
<b>2H:1V Back-Slope</b>				
Coefficient of Active Earth Pressure, $K_a$	0.30	0.39	0.44	0.54

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.

A lateral pressure due to backfill compaction should be added to the calculated lateral earth pressure in accordance with the Section 6.9.3 of the CHBDC.

The parameters provided in Table 10-1 are based on the assumption that the backfill is fully drained so that there are no unbalanced hydrostatic pressures. The design of the culvert must incorporate measures such as weepholes or subdrains to permit drainage of the culvert backfill. The current GA Drawing indicates that a series of 75 mm diameter wall drains are to be installed to allow for drainage of the backfill material. If adequate drainage cannot be confirmed, the potential for buildup of hydrostatic pressures should be considered in the design.

## **10.8 Erosion Protection**

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the embankment slopes. Normal slope vegetation should be established as soon as possible after completion of the embankment fills in order to control surficial erosion. 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 outlet areas. Design of the erosion protection measures must consider hydrologic and hydraulic factors and should be carried out by specialists experienced in this field.

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 OPSD 810.010. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS 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 1205. A geosynthetic clay liner may be used as a clay seal.

## **10.9 Roadway Protection**

The culvert construction will be carried out in stages in order to keep at least one highway lane operational. Roadway protection if needed, should be provided in accordance with OPSS 539 and designed for Performance Level 2.

Increased difficulty with the installation of roadway protection should be anticipated due to the presence of rockfill within the embankment and relatively shallow depth to bedrock at the site. One option is to use soldier piles and timber lagging with the piles installed in holes predrilled through the embankment and socketed into bedrock. Alternatively, the soldier piles could be supported laterally with bracing.

The design of roadway protection should be the responsibility of the Contractor. All shoring systems should be designed by a Professional Engineer experienced in such designs.

## **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:

- Impact of the excavation on the existing pavement surface. Daily visual inspection of the pavement surface must be carried out in the vicinity of the culvert construction. If cracks form in the pavement or settlement is observed to occur, these matters must immediately be brought to the attention of the C.A. for determining the level of remedial action that is required.

- Construction will likely 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 subgrade in the dry.
- Confirmation that the backfill is adequately placed and compacted to specifications.
- Impacts to property due to widening of the platform.
- Excavation within the highway embankment is expected to encounter rockfill, cobbles and boulders.
- Excavation to the design elevations is expected to encounter bedrock.

The successful performance of the culvert will depend largely upon good workmanship and quality control during construction. Observation of the excavation and backfilling operations by the QVE will be required during construction to confirm that the foundation recommendations are correctly implemented and material specifications are met.

## 12 CLOSURE

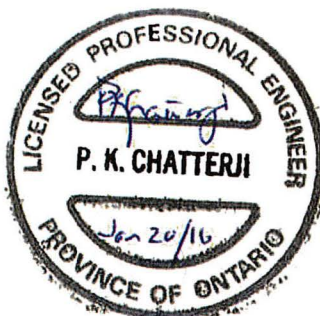
Overall project management and direction of the field program was provided by Dr. Fred Griffiths, P.Eng. Interpretation of the field data and preparation of this report was completed by Kenton Power, P.Eng. The report was reviewed by Dr. Fred Griffiths, P.Eng. and Dr. P.K. Chatterji, P.Eng., the Designated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



Kenton C. Power, P.Eng.  
Geotechnical Engineer



Fred J. Griffiths, P.Eng.  
Senior Associate, Senior Geotechnical Engineer

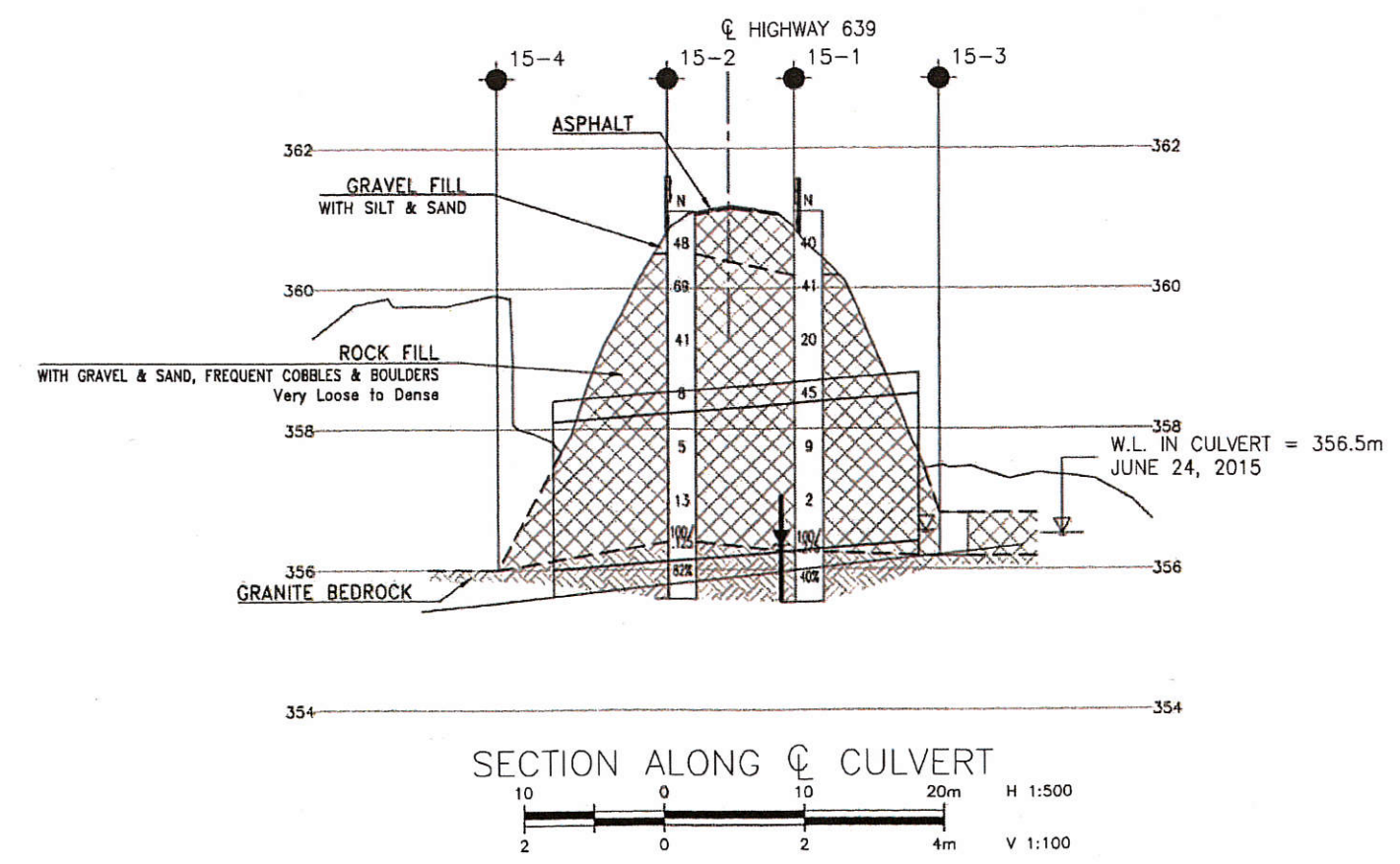
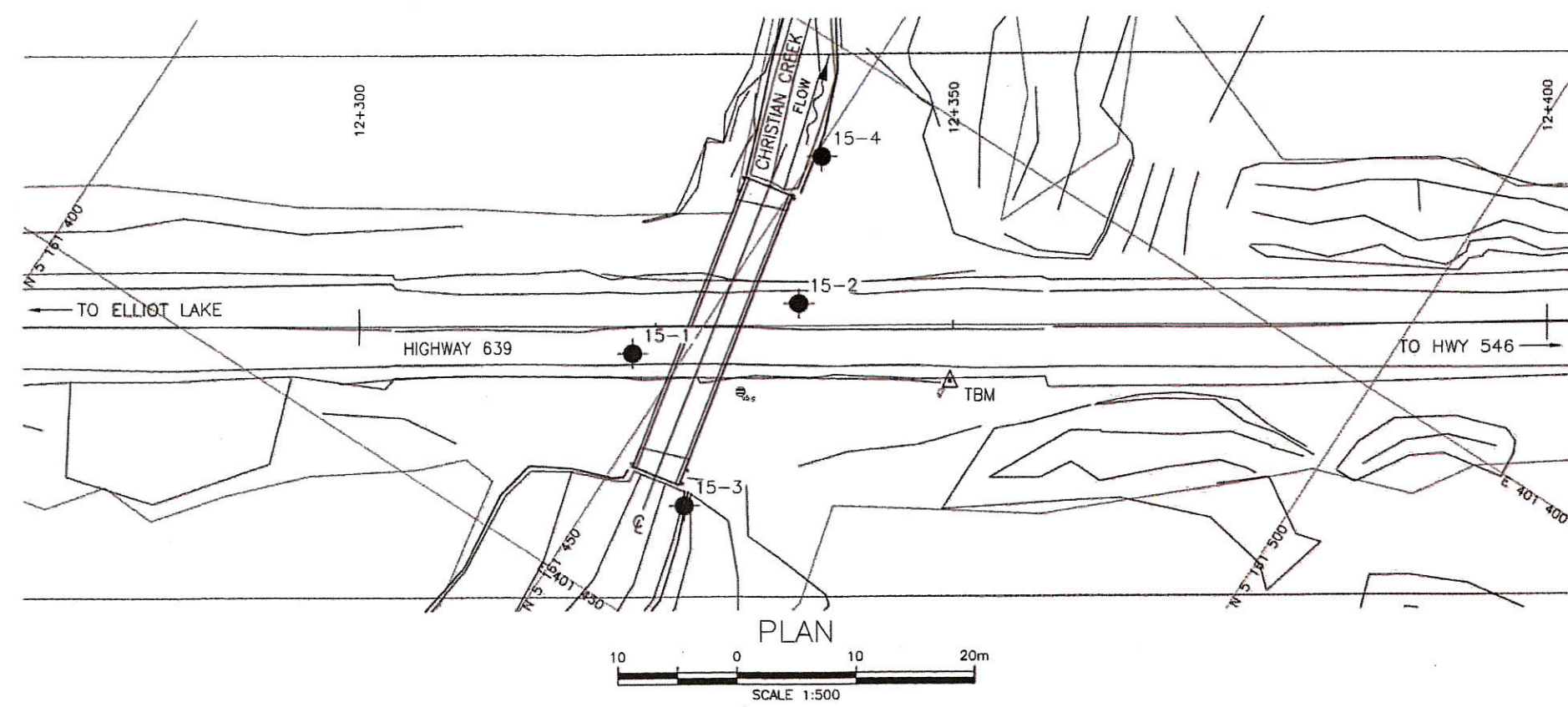


P.K. Chatterji, P.Eng.  
Review Principal, Designated MTO Contact

**APPENDIX A**  
**BOREHOLE LOCATIONS AND SOIL STRATA DRAWINGS**



MINISTRY OF TRANSPORTATION, ONTARIO

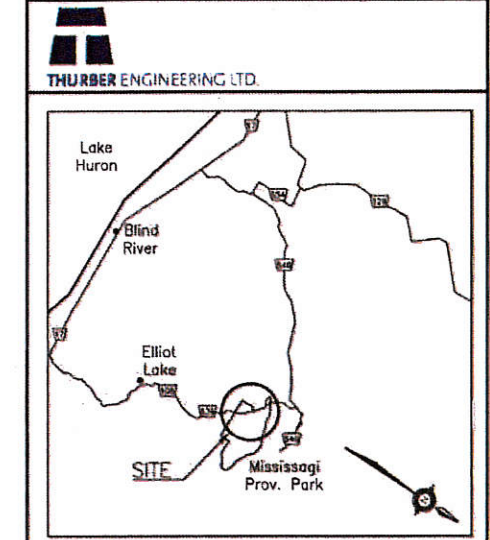


METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

CONT No  
GWP No 5264-10-00

HIGHWAY 639  
CHRISTIAN CREEK  
CULVERT 38S-480/C  
BOREHOLE LOCATIONS AND SOIL STRATA

MMM GROUP



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
15-1	361.1	5 161 446.2	401 431.2
15-2	361.1	5 161 455.7	401 420.0
15-3	356.8	5 161 456.9	401 439.6
15-4	356.0	5 161 450.5	401 408.6

- NOTES**
- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
  - This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
  - Borehole locations are provided in MTM Zone 13 coordinates.

GEOCRES No. 41J-97



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	CM	CHK	PK
DRAWN	MFA	CHK	FG
SITE	38S-480/C	STRUCT	DWG 1
DATE	JAN 2016		

FILENAME: H:\Drawing\1935161\233\1ed1233-PinalProfile(ChristianCreekCulvert).dwg  
PLOTDATE: 1/14/2016 12:59 PM

## **APPENDIX B**

### **RECORD OF BOREHOLE SHEETS PHOTOGRAPHS OF ROCK CORE**





## **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.

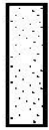


### STRATA PLOT:

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

### SAMPLE TYPES

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

### TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

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

### TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

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

### 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 15-1

1 OF 1

METRIC

GWP# 5264-10-00 LOCATION Culvert 38S-480 12+323 2.3 RT CL ORIGINATED BY CM  
 HWY 639 BOREHOLE TYPE HSA / NQ Coring COMPILED BY CM  
 DATUM Geodetic DATE 2015.06.23 - 2015.06.23 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 (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						
361.1														
0.0														
0.1														

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

20  
15  
10

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 15-2

1 OF 1

METRIC

GWP# 5264-10-00 LOCATION Culvert 38S-480 12+337 1.9 LT CL ORIGINATED BY CM  
 HWY 639 BOREHOLE TYPE NW Casing / NQ Coring COMPILED BY CM  
 DATUM Geodetic DATE 2015.06.23 - 2015.06.23 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 (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL
								20	40	60	80	100	W <sub>P</sub>	W		W <sub>L</sub>			
361.1																			
0.0	50 mm Prime Surface Treatment																		
360.5	GRAVEL (GW-GM) and sand with silt Dry Dense Brown FILL		1	SS	48												51 44 5 (SI+CL)		
0.6	ROCKFILL with gravel and sand Red to Brown Loose to Dense Frequent cobbles and boulders FILL		2	SS	69												62 31 7 (SI+CL)		
			3	SS	41														
			4	SS	8														
			5	SS	5														
			6	SS	13														
356.4			7	SS	100/														
4.7	BEDROCK, Granite Bedrock cored 4.7 m to 5.5 m Fresh weathering Medium bedding Excellent Quality Very Hard		1	RUN	125mm													RUN #1 TCR=100% SCR=85% RQD=82%	
355.6																			
5.5	Borehole terminated at 5.5 m in confirmed bedrock																		

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

20  
15  
10


(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 15-3

1 OF 1

METRIC

GWP# 5264-10-00 LOCATION Culvert Inlet ORIGINATED BY CM  
 HWY 639 BOREHOLE TYPE Portable NW Casing / NQ Coring COMPILED BY CM  
 DATUM Geodetic DATE 2015.06.24 - 2015.06.24 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 (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
							20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>			
356.8																	
0.0	ROCKFILL Frequent cobbles and boulders																
356.1																	
0.6	Unable to progress casing past 0.6 m Unable to core into bedrock with portable drilling gear End of Borehole at 0.6 m on probable bedrock Water level at 0.25 m below surface in open borehole																

ONTMT4S 19-5161-233.GPJ 2012TEMPLATE(MTO).GDT 27/7/15



# RECORD OF BOREHOLE No 15-4

1 OF 1

METRIC

GWP# 5264-10-00 LOCATION Culvert Outlet ORIGINATED BY CM  
 HWY 639 BOREHOLE TYPE Portable NQ Coring COMPILED BY CM  
 DATUM Geodetic DATE 2015.06.24 - 2015.06.24 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 (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
							20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>			
356.0 0.0	Visible Bedrock at surface Unable to core into bedrock with portable gear End of Borehole at 0 m on confirmed bedrock																

**BH 15-1**  
**Cored Length of 4.8 to 5.6 metres**  
**Core Box 1 (of 1)**



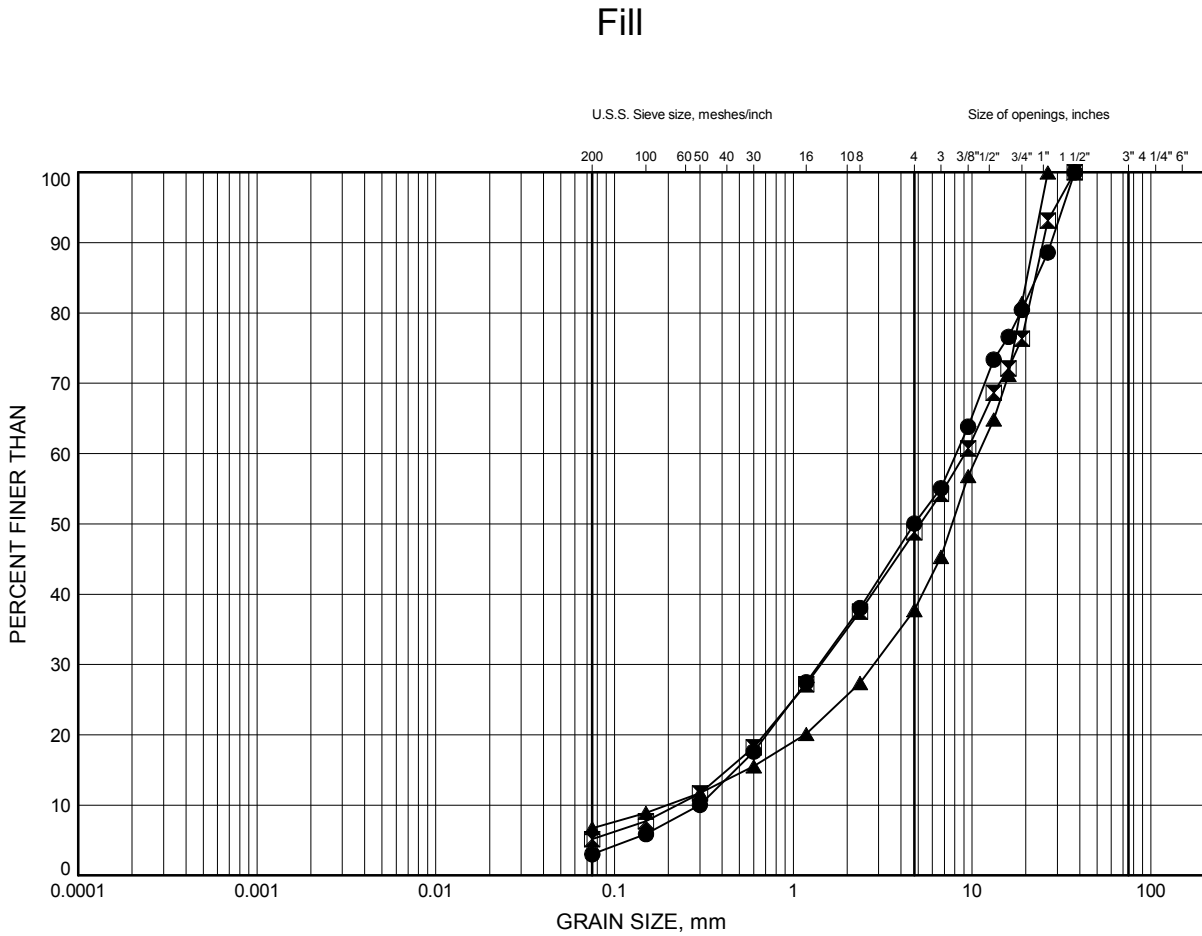
**BH 15-2**  
**Cored Length of 4.7 to 5.5 metres**  
**Core Box 1 (of 1)**



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

# Christian Creek Culvert GRAIN SIZE DISTRIBUTION

FIGURE 1



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	15-1	0.46	360.64
⊠	15-2	0.46	360.68
▲	15-2	1.07	360.07

Date July 2015  
GWP# 5264-10-00



Prep'd KCP  
Chkd. FG

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

19-5161-233





**Figure 1: Roadway Platform at Culvert 38S-480 Looking North**



**Figure 2: Culvert 38S-480 inlet looking west**





**Figure 3: Looking upstream from Culvert 38S-480**



**Figure 4: Culvert 38S-480 outlet looking east**





**Figure 5: End of Culvert 38S-480 Looking West**

**APPENDIX E**

**FOUNDATION ALTERNATIVES COMPARISONS**  
**COMPARISON OF CONSTRUCTION METHODOLOGY OPTIONS**

### Comparison of Culvert Alternatives

<b>Comment</b>	<b>Circular Pipe</b>	<b>Concrete - Open Footing Culvert</b>	<b>Concrete Box (closed) Culvert</b>
<b><i>Advantages</i></b>	Quick installation particularly with a CSP.  Simple construction	Superior geotechnical resistance available with culvert founded on bedrock  Quick installation procedure due to use of pre-cast section	Quick installation procedure due to use of pre-cast sections
<b><i>Disadvantages</i></b>	CSP durability will be lower than a concrete alternative	Additional dewatering and bedrock excavation	NA
<b><i>Risks / Consequences</i></b>	NA	Over excavation of bedrock	Will require substrate on the invert / requiring blasting to lower the culvert to provide sufficient depth to place the substrate
<b><i>Relative Cost</i></b>	lowest	moderate	moderate
	<b>FEASIBLE</b>	<b>RECOMMENDED</b>	<b>FEASIBLE</b>

### Comparison of Construction Methodology Options

Comment	Trenchless: Horizontal Directional Drilling	Staged, with Roadway Protection	Staged, with Embankment Widening
<b>Advantages</b>	<p>Avoids open cut.</p> <p>Does not require staging – minimal traffic impact</p> <p>Relatively well known technology and readily available.</p>	<p>Quick installation particularly with a CSP.</p> <p>Simple construction</p>	<p>Quick installation particularly with a CSP.</p> <p>Simple construction</p>
<b>Disadvantages</b>	<p>High mobilization costs</p> <p>Requires water/groundwater control</p> <p>Mixed face condition with rockfill and bedrock</p>	<p>Traffic impacts</p> <p>Roadway protection requires soldier piles socketed into bedrock</p> <p>Requires water/groundwater control</p>	<p>Traffic impacts</p> <p>Requires temporary extensions to culverts</p> <p>Requires water/groundwater control</p>
<b>Risks/Consequences</b>	Variation in rock elevation/ major cost increase for bedrock excavation	Variation in rock elevation / cost increase for rock sockets	Embankment widening increases subgrade preparation costs.  May require Roadway Protection
<b>Relative Cost</b>	high	moderate	moderate
	<b>NOT FEASIBLE</b>	<b>FEASIBLE</b>	<b>RECOMMENDED</b>

## **APPENDIX F**

### **NON-STANDARD SPECIAL PROVISION LIST OF REFERENCED SPECIFICATIONS**

## **DEWATERING NSSP**

The contractor shall implement groundwater control and ground support systems as are required to carry out the construction in a safe, stable, and dry excavation.

The dewatering system shall be designed by a dewatering specialist engaged by the Contractor. Where a cofferdam is required, the Contractor shall engage an experienced geotechnical engineer licensed to practice in Ontario to carry out the cofferdam design.

## 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 206	Construction Specification for Grading
OPSS 501	Construction Specification for Compacting
OPSS 539	Construction Specification for Temporary Protection Systems
OPSS 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 904	Construction Specification for Concrete Structures
OPSS 1010	Material Specification for Aggregates-Base, Subbase, Select Subgrade, and Backfill Material
OPSS 1205	Material Specification for Clay Seal