



September 8, 2015

## PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT

**MAXIMILLIAN CREEK CULVERT - SITE NO. 45-141/C  
HIGHWAY 71, DISTRICT OF RAINY RIVER  
TOWNSHIP OF POTTS  
MINISTRY OF TRANSPORTATION, ONTARIO  
G.W.P 6339-14-00**

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REPORT





## Table of Contents

### **PART A – PRELIMINARY FOUNDATION INVESTIGATION REPORT**

<b>1.0 INTRODUCTION.....</b>	<b>1</b>
<b>2.0 SITE DESCRIPTION.....</b>	<b>1</b>
<b>3.0 INVESTIGATION PROCEDURES .....</b>	<b>1</b>
<b>4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS .....</b>	<b>2</b>
4.1 Regional Geology .....	2
4.2 Subsurface Conditions.....	2
<b>5.0 CLOSURE.....</b>	<b>4</b>

### **PART B - PRELIMINARY FOUNDATION DESIGN REPORT**

<b>6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS.....</b>	<b>6</b>
6.1 General.....	6
6.2 Foundations .....	6
6.2.1 Foundation Options.....	6
6.2.2 Foundation Elevations and Frost Protection .....	7
6.2.2.1 Box Culvert Replacement .....	7
6.2.2.2 Open Footing Culvert Replacement.....	7
6.2.2.3 Pre-Cast Concrete Slab on Sheet-Pile Abutments .....	7
6.2.3 Geotechnical Resistances.....	8
6.2.3.1 Box Culvert Replacement .....	8
6.2.3.2 Open Footing Culvert Replacement.....	8
6.2.3.3 Pre-Cast Slab and Sheet-Pile Abutments.....	9
6.2.4 Resistance to Lateral Loads / Sliding Resistance .....	9
6.2.5 Stability and Settlement .....	9
6.3 Lateral Earth Pressures .....	9
6.4 Construction Considerations.....	10
6.4.1 Temporary Roadway Protection.....	10
6.4.2 Excavation and Replacement Below Culvert .....	11
6.4.3 Culvert Bedding and Backfill .....	11



## PRELIMINARY FOUNDATION REPORT MAXIMILLIAN CREEK CULVERT - SITE NO. 45-141/C

6.4.3.1	Box Culvert .....	11
6.4.3.2	Open Footing Culvert.....	12
6.4.3.3	Backfill .....	12
6.4.4	Subgrade Protection .....	13
6.4.5	Erosion Protection.....	13
6.4.6	Control of Groundwater and Surface Water .....	13
6.4.7	Obstructions .....	14
6.4.8	Analytical Testing for Construction Materials .....	14
6.5	Recommendations for Further Work During Detail Design .....	15
<b>7.0</b>	<b>CLOSURE.....</b>	<b>15</b>

### REFERENCES

#### TABLES

Table 1	Summary of Culvert Details
Table 2	Comparison of Foundation Alternatives
Table 3	Geotechnical Axial Resistance and Reaction for Pre-Cast Box, Open Footing and Sheet-Pile Abutment - Concrete Cap Culvert Replacements
Table 4	Resistance to Lateral Loads/Sliding Resistance for Pre-Cast Box and Open Footing Culvert Replacements

#### DRAWING

Drawing 1	Borehole Locations and Soil Strata
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#### PHOTOGRAPHS

#### APPENDIX A RECORD OF BOREHOLES

Lists of Abbreviations and Symbols  
Record of Boreholes MX-1 to MX-4

#### APPENDIX B LABORATORY TEST RESULTS

Table B1	Summary of Analytical Testing of Maximillian Creek Water Sample
Figure B1	Grain Size Distribution –Sand (Fill)
Figure B2	Grain Size Distribution – Silty Clay to Clay
Figure B3	Plasticity Chart – Silty Clay to Clay



# **PART A**

**PRELIMINARY FOUNDATION INVESTIGATION REPORT  
MAXIMILLIAN CREEK CULVERT – SITE NO. 45-141/C  
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## **1.0 INTRODUCTION**

Golder Associates Ltd. (Golder) has been retained by Hatch Mott MacDonald (HMM), on behalf of the Ministry of Transportation, Ontario (MTO) to provide preliminary foundation engineering services for the replacement of the Maximillian Creek culvert (Site No. 45-141/C). The Maximillian Creek culvert is located in the District of Rainy River, in the Township of Potts on Highway 71 at STA 10+337, approximately 2.1 km north of the junction of Highway 71 and Highway 600. The key plan showing the general location of this section of Highway 71 and the location of the investigated area are shown on Drawing 1.

## **2.0 SITE DESCRIPTION**

The Maximillian Creek culvert consists of a concrete box, the details of which (i.e., width, height, length, etc.) are summarized in Table 1 following the text of the report.

In general, the topography in this area is relatively flat and the ground surface is relatively low-lying and covered with long grass and shrubs. Highway 71 extends in a north-south direction with the culvert perpendicular in a west-east orientation. At the culvert location, Maximillian Creek flows easterly. The highway grade is at Elevation 367.4 m and the culvert invert is at approximately Elevations 363.6 m and 363.5 m, at the inlet and outlet ends, respectively, and the culvert is covered with about 1.5 m of (roadway) fill. The creek water level was measured at Elevations 364.2 m by others on July 16, 2013, and by Golder on February 19, 2015. Surface conditions at the culvert inlet and outlet areas are shown on Photographs 1 to 4, attached.

## **3.0 INVESTIGATION PROCEDURES**

The field work for this subsurface investigation was carried out between February 16 and 21 and on March 15, 2015, during which time four boreholes (Boreholes MX-1 to MX-4) were advanced at approximately the locations shown on Drawing 1: Boreholes MX-1 and MX-4 were advanced at the toe of slope near the culvert inlet/outlet; and Boreholes MX-2 and MX-3 were advanced from the existing highway platform. All boreholes were advanced using a track mounted drill rig and 108 mm inside diameter hollow stem augers, supplied and operated by George Downing Estate Drilling Ltd. of Grenville-Sur-La-Rouge, Quebec.

Soil samples were obtained in the boreholes at 0.75 m and 1.5 m intervals of depth using 50 mm outer diameter split-spoon samplers driven by an automatic hammer, in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586). Field vane shear tests were conducted in cohesive soils for determination of undrained shear strengths (ASTM D2573) using an MTO Standard 'N' size vane. The groundwater level in the open boreholes was observed during the drilling operations as described on the Record of Borehole sheets in Appendix A. The boreholes were backfilled upon completion in accordance with Ontario Regulation 903 Wells (as amended).

The field work was supervised on a full-time basis by a member of Golder's technical staff who: located the boreholes in the field; arranged for the clearance of underground services; supervised the drilling and sampling operations; logged the boreholes; and examined and cared for the soil samples. The soil samples were identified in the field, placed in labelled containers and transported to Golder's geotechnical laboratory in Sudbury for further examination and laboratory testing. Index and classification testing consisting of water



## PRELIMINARY FOUNDATION REPORT MAXIMILLIAN CREEK CULVERT - SITE NO. 45-141/C

content determinations, grain size distributions, and Atterberg limits were carried out on selected soil samples. The geotechnical laboratory testing was completed according to MTO LS standards.

A sample of the creek water was obtained during the field investigation (on February 24, 2015) using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters, including pH, resistivity, conductivity, sulphates and chlorides.

The as-drilled borehole locations and ground surface elevations were measured and surveyed by member of our technical staff, referenced to the highway centerline and existing culvert and converted into Northing/Easting on the plan drawing. The ground surface elevation of the highway centerline was obtained from the profile provided by MTO on drawing BC830713.dwg. The MTM NAD83 northing and easting coordinates, ground surface elevations referenced to Geodetic datum and borehole depths at each borehole location are presented on the Record of Borehole sheets in Appendix A and summarized below.

Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
MX-1	5410401.5	237503.8	365.2	6.7
MX-2	5410402.4	237515.2	367.3	14.6
MX-3	5410411.3	237519.3	367.3	14.6
MX-4	5410400.7	237529.7	364.8	7.0

## 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

### 4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain (NOEGTS)<sup>1</sup> mapping, the subsoils in the vicinity of the Maximillian Creek culvert site generally consist of glaciolacustrine plain deposits comprised of clay and silt materials.

Based on geological mapping by the Ministry of Northern Development and Mines (MNDM)<sup>2</sup>, the site is underlain by bedrock of the Archean Era, comprised of felsic to intermediate metavolcanic rocks consisting of rhyolitic, diaotitic and andesitic flows bordering with bedrock from the diorite-monzonite-granodiorite suite.

### 4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are given on the Record of Borehole sheets contained in Appendix A. The results of geotechnical laboratory testing are contained in Appendix B. The results of the in situ tests (i.e., SPT 'N' values and undrained shear strengths from field vanes) as presented on the Record of Borehole sheets and in Section 4 are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted

<sup>1</sup> Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 52CNW.

<sup>2</sup> Ministry of Northern Development of Mines. Bedrock Geology of Ontario – West Central Sheet, Ontario Geological Survey – Map 2542.



## PRELIMINARY FOUNDATION REPORT MAXIMILLIAN CREEK CULVERT - SITE NO. 45-141/C

stratigraphic profile on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

### Subsoil Conditions

In summary, the subsoil conditions encountered at the site consist of asphalt and granular fill (for boreholes advanced through the embankment), underlain by a cohesive deposit of silty clay to clay. A more detailed description of the soil deposits and groundwater conditions encountered in the boreholes is provided below.

Deposit/Layer Description	Boreholes	Deposit Thickness (m)	Deposit Surface Elevation (m)	N Values (blows) / Shear Strength	Laboratory Testing
				Consistency or Relative Density	
<b>Asphalt</b>	MX-2, MX-3	0.050	367.3	n/a	n/a
<b>(FILL)</b> Sand to Gravelly Sand, trace to some silt; brown; frozen to moist	MX-2, MX-3	3.1 – 3.6	367.2	N = 7 <sup>1</sup>	w = 6% – 11% 1 - M (Fig. B1)
				<b>Loose</b>	
<b>Silty Clay to Clay</b> , trace to some sand, trace to some gravel, trace organics, brown to grey, frozen to wet	MX-1 to MX-4	Boreholes terminated in this deposit (at 6.7 m to 11.4 m below ground surface)	365.2 – 363.6	N = 5 – 14 <sup>2</sup> s <sub>u</sub> = 96 – >100 S = 1 – 2	w = 19% - 39% w <sub>l</sub> = 37% - 74% w <sub>p</sub> = 17% - 31% I <sub>p</sub> = 19% - 47% 9 – MH (Fig. B2) 10 – AL (Fig. B3)
				<b>Stiff to Very Stiff</b>	

#### Where:

N = SPT 'N'-value; number of blows for 0.3 m of penetration  
w = Natural Moisture Content (%)  
MH = Combined Sieve and Hydrometer analysis  
M = Sieve analysis  
AL = Atterberg Limits Test  
s<sub>u</sub> = Undrained Shear Strength (kPa)  
S = Sensitivity  
w<sub>p</sub> = Plastic Limit (%)  
w<sub>l</sub> = Liquid Limit (%)  
I<sub>p</sub> = Plasticity Index (%)

#### Notes:

<sup>1</sup> In the granular fill, five split spoon samples did not penetrate the entire SPT depth inferred to be due to the frozen nature of the material. An SPT 'N'-value of 61 blows per 0.3 m of penetration was also inferred to be due to the frozen nature of the material and not representative.

<sup>2</sup> In the silty clay to clay deposit, an SPT 'N'-value of 19 blows per 0.3 m was measured, however, this value inferred to be due to the frozen nature of the material and not representative.



## **Groundwater Conditions**

All boreholes were noted to be dry upon completion of drilling. The creek ice level was measured at Elevation 364.2 m on February 19, 2015. Groundwater and creek water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

## **5.0 CLOSURE**

The field drilling program was carried out under the supervision of Mr. Mathew Riopelle and Mr. Daryl Miller, under the overall direction of Mr. David Muldowney, P.Eng. This Preliminary Foundation Investigation Report was prepared by Mr. Adam Core, P.Eng., and Mr. David Muldowney, P.Eng. provided a technical review of the report. Mr. Jorge M.A. Costa, P.Eng., the Designated MTO Foundations Contact and Principal of Golder, conducted an independent quality control review of this report.





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**PRELIMINARY FOUNDATION REPORT  
MAXIMILLIAN CREEK CULVERT - SITE NO. 45-141/C**

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## Report Signature Page

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# **PART B**

**PRELIMINARY FOUNDATION DESIGN REPORT  
MAXIMILLIAN CREEK CULVERT – SITE NO. 45-141/C  
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## **6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS**

### **6.1 General**

This section of the report provides preliminary foundation design recommendations for the proposed replacement of the Maximillian Creek culvert. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during this subsurface investigation.

The discussion and recommendations presented are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and to carry out the preliminary design of the culvert replacement. Further investigation and analysis may be required during detail design, once the configuration of the proposed culvert and replacement strategy is finalized, to confirm and expand on the preliminary foundation recommendations provided in this report.

Where comments are made on construction, they are provided to highlight those aspects that could affect the future detail design of the project, and for which special provisions may be required in the Contract Documents. Those requiring information on the aspects of construction should make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

It is assumed that the culvert will be replaced with a culvert of similar dimensions, along the same alignment as well at a similar invert elevation to that of the existing culvert. In addition, it is assumed that there will be no embankment grade raises or widening in the area of the culvert as part of the Hwy 71 reinstatement.

### **6.2 Foundations**

#### **6.2.1 Foundation Options**

The Maximillian Creek culvert is located in the District of Rainy River, in the Township of Potts on Highway 71 at STA 10+337, approximately 2.1 km north of the junction of Highway 71 and Highway 600. The highway embankment is constructed of granular fill material and is approximately 3.9 m high relative to the culvert invert and with approximately 1.5 m of cover of the existing culvert. The existing culvert is a concrete box, the details of which (i.e., width, height, length, etc.) are summarized in Table 1.

Based on discussions with HMM and the preliminary General Arrangement (GA) drawings, we understand that the following culvert types are being considered at this location:

- a pre-cast concrete box;
- a pre-cast open footing with either a pre-cast concrete arch or metal box; and
- a pre-cast concrete cap on sheet-pile abutments.

In this report we have considered the following options:

- a pre-cast concrete box;
- an open footing and metal box or arch culvert supported on either cast-in-place or pre-cast footings; and



- a pre-cast concrete cap on sheet-pile abutments.

A corrugated steel pipe (CSP) culvert would likely decrease the flow-through capacity and generally has a shorter design life than a concrete culvert and at this culvert location, further, the use of multiple CSP culverts would likely be required to meet the flow capacity. Open footing arch culverts could be considered but the limited soil cover may not allow for proper backfilling for an arch culvert. From a foundation perspective, a pre-cast concrete box culvert sufficiently wide to handle the flow is preferred at this site as the subsurface conditions at the foundation level are suitable for the support of such a structure, due to the accelerated construction schedule by using pre-cast sections and reduced excavation, dewatering and shoring requirements. Other culvert types may be preferred due to construction staging or other considerations such as fisheries requirements related to natural channel substrate. A comparison of culvert types based on advantages/disadvantages and risks/consequences is presented in Table 2.

## **6.2.2 Foundation Elevations and Frost Protection**

### **6.2.2.1 Box Culvert Replacement**

It is not necessary to found a box culvert at the standard depth for frost protection purposes, as a box structure is tolerant of small magnitudes of movement related to freeze-thaw cycles, should these occur. Recommended foundation elevation and foundation conditions for a replacement box culvert are provided in Table 3. We recommend that the replacement box culvert be founded on the stiff to very stiff silty clay to clay deposit as encountered in the boreholes.

### **6.2.2.2 Open Footing Culvert Replacement**

Strip footings for an open footing culvert should be founded at a minimum depth of 2.3 m below the lowest surrounding grade to provide adequate protection against frost penetration, as per OPSD 3090.100 (Foundation Frost Penetration Depths for Northern Ontario). In addition, the footings should extend below any existing fill and/or organic deposits, where present. Recommended founding elevations and foundation conditions for the replacement open footing culvert are provided in Table 3.

### **6.2.2.3 Pre-Cast Concrete Slab on Sheet-Pile Abutments**

Sheet-pile abutments supporting a concrete slab if utilized at this site as the culvert construction option, will penetrate well below the frost depth to bear within the very stiff silty clay to clay deposit. Therefore, such a foundation should not be subject to frost induced heave per se but adhesion of the subsoils to the sheet-pile walls along the depth of the frost penetration zone would have to be considered in the overall assessment of the sheet-pile depths in order to resist uplift (heave). An estimate of the additional depth required to resist uplift can be provided at the detail design stage if this is culvert replacement option is selected.



## **6.2.3 Geotechnical Resistances**

### **6.2.3.1 Box Culvert Replacement**

A box culvert, placed on the properly prepared subgrade and/or properly placed granular pad/backfill at or below the founding elevation identified in Table 3, should be based on the recommended factored geotechnical axial resistance at Ultimate Limit States (ULS) and geotechnical reaction at Serviceability Limit States (SLS), for 25 mm of settlement, as provided in Table 3. These recommendations are based on the box culvert width of 6.0 m as noted in Table 3.

The factored geotechnical axial resistance at ULS and geotechnical reaction at SLS are dependent on the foundation size, configuration and applied loads; the geotechnical resistance/reaction should, therefore, be reviewed if the culvert width or founding elevation differs from those given in Table 3.

The geotechnical resistance/reaction provided in Table 3 are based on loading applied perpendicular to the base of the culvert; where applicable, inclination of the load should be taken into account in accordance with Section 6.7.4 and Section C6.7.4 of the Canadian Highway Bridge Design Code (CHBDC 2006) and its Commentary.

The loading on the foundation soils below the culvert and the associated settlements at the culvert location will be governed by the design height of the overlying and adjacent embankment fill, however it is understood that no grade raise or embankment widening is planned. It is recommended that the structural engineer exercise caution when utilizing the values of the geotechnical resistance at SLS (as provided in Table 3) in the design of the culvert and that consideration be given to the sequence and staging of construction, particularly if a grade raise or widening is applicable as the settlement under the culvert as a result of soil loading (not culvert loading) may govern.

### **6.2.3.2 Open Footing Culvert Replacement**

Strip footings placed on the properly prepared subgrade, at or below the founding elevation recommended in Table 3, should be designed based on the factored geotechnical axial resistance at ULS and geotechnical reaction at SLS, for 25 mm of settlement, as provided in Table 3. These recommendations are based on the assumed footing width of 0.6 m as provided in Table 3. At this site, the bearing resistance is governed by the strength of the silty clay to clay deposit and width of the footing.

The factored geotechnical axial resistance at ULS and geotechnical reaction at SLS are dependent on the foundation size, configuration and applied loads; the geotechnical axial resistance/reaction should, therefore, be reviewed if the culvert footing width or founding elevation differs from those given in Table 3.

The geotechnical resistance/reaction provided in Table 3 are based on loading applied perpendicular to the base of the footings; where applicable, inclination of the load should be taken into account in accordance with Section 6.7.4 and Section C6.7.4 of the CHBDC and its Commentary.

The loading on the foundation soils below the culvert footings and the associated settlements at the culvert location will be governed by the design height of the overlying and adjacent embankment fill, however it is assumed that no grade raise or embankment widening is planned. It is recommended that the structural engineer exercise caution when utilizing the values of the geotechnical resistance at SLS (as provided in Table 3) in the design of the culvert and that consideration be given to the sequence and staging of construction,



particularly if a grade raise or widening is applicable as the settlement under the culvert as a result of soil loading (not culvert loading) may govern.

#### **6.2.3.3     *Pre-Cast Slab and Sheet-Pile Abutments***

The sheet-piles should be driven into the very stiff portion of the silty clay to clay stratum to below the founding elevation given in Table 3, and should be designed based on the factored geotechnical resistances at ULS and unit geotechnical reaction at SLS (for 25 mm of settlement), provided in Table 3. The unit factored geotechnical axial resistance and reaction provided in Table 3 are primarily a function of the toe resistance developed within the very stiff silty clay to clay. These values do not include downdrag forces, which may need to be considered if the grade is raised or the embankments are widened, nor do the estimated depths of sheet-pile embedment account for the uplift stresses due to adhesion to frozen ground.

#### **6.2.4     Resistance to Lateral Loads / Sliding Resistance**

Resistance to lateral forces/sliding resistance between the base of the box culvert and granular bedding material or between the base of the strip footing and subgrade soil should be calculated in accordance with Section 6.7.5 of the CHBDC. Table 4 provides the coefficients of friction between the base of the culvert/footing and potential interface materials.

#### **6.2.5     Stability and Settlement**

Given that an embankment grade raise or widening is not proposed as part of the culvert replacement and highway embankment reconstruction, the existing native soils will not experience additional load, and therefore, settlement of the culvert after embankment reconstruction is estimated to be less than 25 mm.

For the subsurface conditions and the reconstructed embankments height up to about 3.9 m above the existing ground surface adjacent to the culvert (i.e., to the level of the existing embankment), granular fill embankments at this site will be stable at side slopes inclined at 2 Horizontal to 1 Vertical (2H:1V) or flatter.

Given the presence of the stiff to very stiff silty clay to clay subgrade material at this site, additional long term settlement and stability analysis will be required if a grade raise and/or widening is proposed. Further, depending on the magnitude of the grade raise and/or widening, additional field work and/or specialized laboratory testing may be required.

### **6.3     Lateral Earth Pressures**

The lateral earth pressures acting on the side walls (or head/wing walls if required) of the culvert will depend on the type and method of placement of backfill materials, the nature of soils/embankment fill behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the walls.



## PRELIMINARY FOUNDATION REPORT MAXIMILLIAN CREEK CULVERT - SITE NO. 45-141/C

The following recommendations are made concerning the design of the culverts and any wing or head walls. It should be noted that these design recommendations and parameters are applicable to level backfill and ground surface behind the walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope.

- Select, free draining granular fill meeting the requirements of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type I, II or III, but with less than 5 per cent passing the 200 sieve (0.075 mm) should be used as backfill behind the culvert walls, and on top of the culvert for a thickness of up to 300 mm. Backfill should be placed in a maximum of 200 mm loose lift thickness. Weep holes should be installed to allow for positive drainage of the granular backfill. Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS.PROV 501 (Compacting).
- The granular fill may be placed either in a zone with the width equal to at least 2.3 m behind the back of the walls for a restrained wall (see Figure C6.20(a) of the Commentary to the CHBDC), or within the wedge shaped zone defined by a line drawn at 1.5 H:1V extending up and back from the rear face of the base of the walls for an unrestrained wall (see Figure C6.20(b) of the Commentary to the CHBDC).
- The following parameters (unfactored) may be used to calculate the lateral earth pressures acting on the culvert or sheet-piles:

Fill Type	Internal Angle of Friction ( $\phi$ )	Unit Weight	Coefficients of Static Lateral Earth Pressure	
			At-Rest, $K_o$	Active, $K_a$
Granular 'A'	35°	22 kN/m <sup>3</sup>	0.43	0.27
Granular 'B' Type II	35°	21 kN/m <sup>3</sup>	0.43	0.27
Granular 'B' Type I or III	32°	21 kN/m <sup>3</sup>	0.47	0.30
Silty Clay to Clay	27°	17 kN/m <sup>3</sup>	0.55	0.38

If the structure allows for lateral yielding, active earth pressures may be used in the design of the structure(s). If the structure does not allow for lateral yielding, at-rest earth pressures should be assumed for design. The movement to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure, may be taken as presented in Table C6.6 of the Commentary to the CHBDC.

## 6.4 Construction Considerations

### 6.4.1 Temporary Roadway Protection

The temporary excavation for the culvert replacement will be made through the existing embankment granular fill comprised of loose sand to gravelly sand and into native soils which are comprised of stiff to very stiff silty clay to clay. All excavations must be carried out in accordance with Ontario Regulation 213, Ontario Occupational Health and Safety Act for Construction Projects (as amended). The granular fills the and native stiff to very stiff





silty clay to clay soils are considered to be Type 3 and Type 2 soil, respectively, above the groundwater table and should be considered Type 4 soil below the groundwater table. Temporary open-cut excavations in Type 2 and Type 3 soils should remain stable if side slopes are formed no steeper than 1H:1V. In Type 4 soils, the side slopes should be formed no steeper than 3H:1V.

Temporary protection support systems may be required along the highway to facilitate construction staging and maintain traffic during culvert replacement work. The temporary support systems could consist of either driven sheet-piling extended to suitable depth, or soldier piles and lagging where H-piles are driven to a suitable depth and horizontal lagging is installed as the excavation proceeds. Support to the temporary protection system could be in the form of struts and walers and rakers or anchors. Where required, temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems). Temporary excavation support systems should be designed to Performance Level 2 for any excavation adjacent to existing roadways.

## **6.4.2 Excavation and Replacement Below Culvert**

Prior to placement of any bedding levelling course material, engineered fill or concrete, all existing fill, organics (if encountered) and any softened/loosened or disturbed soils, should be sub-excavated from below the plan limits of the proposed works to the founding levels provided in Table 3.

The culvert subgrade should be inspected by a Quality Verification Engineer following sub-excavation to ensure that all organics and other unsuitable materials have been removed as noted above, in accordance with OPSS 422 (Pre-cast Reinforced Concrete Box Culverts) for a pre-cast box culvert and OPSS 902 (Excavating and Backfilling Structures) for an open footing culvert. Following inspection, the sub-excavated area should be backfilled with granular material meeting the requirements of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II or III that is placed and compacted in accordance with OPSS.PROV 501 (Compacting). The use of Granular 'B' Type II is recommended in wet ground conditions or below water and placement should be in accordance with OPSS.PROV 209 (Embankments over Swamps and compressible material).

A sample NSSP can be provided at the detail design stage for fill restrictions, if required depending on final culvert design and construction staging.

## **6.4.3 Culvert Bedding and Backfill**

### **6.4.3.1 Box Culvert**

The levelling layer pad and the bedding, if required, for a pre-cast box culvert should be in accordance with OPSS 422 (Pre-cast Reinforced Concrete Box Culverts). Given the potential for surface water flow and some groundwater seepage through the native soils during excavation to the invert and level of the levelling layer and hence for softening of the subgrade, if the excavation has to be deepened as a result of removal of unsuitable material, the bedding backfill should consist of OPSS.PROV 1010 (Aggregates) Granular 'B' Type II. As the native soil below the bedding would be fine grained, it is recommended that a non-woven geotextile be placed between the native soil and the bottom of the bedding. The geotextile should meet the specifications for OPSS 1860 (Geotextiles) Class II, and have a fabric opening size (FOS) not greater than 212 µm. The bedding should be placed in maximum 200 mm thick loose lifts and compacted to at least 98 per cent of the SPMDD of the





materials as specified in OPSS.PROV 501 (Compacting). In addition, a 75 mm thick uncompacted levelling pad consisting of OPSS.PROV 1010 (Aggregates) Granular 'A' or fine concrete aggregate meeting the grading requirements specified in OPSS.PROV 1002 (Aggregates – Concrete) should be provided with a geometry similar to that provided on OPSD 803.010 (Backfill and Cover for Concrete Culverts), whether placed on the native subgrade soil or on the building layer, and should be placed in dry conditions.

A frost taper should be constructed in accordance with OPSD 803.010 (Backfill and Cover for Concrete Culverts). Although OPSD 803.010 relates to box culverts with spans less than or equal to 3.0 m, a similar frost taper at 10H:1V is considered acceptable for the assumed 6 m wide box culvert replacement option.

#### **6.4.3.2     *Open Footing Culvert***

The excavation and backfilling requirements for the open footing culvert replacement should be in accordance with OPSS 902 (Excavating and Backfilling – Structures) and also in similar configuration to that shown on OPSD 803.010 as noted in Section 6.4.3.

Should a pre-cast open footing culvert be the selected replacement option, a bedding layer and levelling pad will be required above the native soil. The bedding layer and levelling pad for the pre-cast open footings should follow the recommendations as discussed in Section 6.4.3.1 for the box culvert replacement option.

A frost taper should be constructed in accordance with OPSD 803.010 (Backfill and Cover for Concrete Culverts). Although OPSD 803.010 relates to open footing culverts with spans less than or equal to 3.0 m, a similar frost taper at 10H:1V is considered acceptable for the assumed 6 m wide open footing culvert replacement option.

#### **6.4.3.3     *Backfill***

Backfill behind the culvert walls (including the sheet-pile abutments, if selected as the preferred culvert option) should consist of granular fill meeting the specifications for OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type I, II or III, but with less than 5 per cent passing the No. 200 (0.075 mm) sieve. The backfill should be placed in maximum 200 mm thick loose lifts and be compacted to at least 98 per cent of the SPMD in accordance with OPSS.PROV 501 (Compacting). The fill should also be placed concurrently on both sides of the culvert, ensuring that the backfill depth on one side does not exceed the other side by more than 400 mm.

Backfill placement for reconstruction of the roadway embankments adjacent to and over the culvert should be carried out as per OPSD 208.010 (Benching of Earth Slopes) to integrate the existing embankment fill and new fill along the cut faces.

Inspection and field density testing should be carried out by qualified geotechnical personnel during all engineered fill placement operations to ensure that appropriate materials are used, and that adequate levels of compaction have been achieved.



#### **6.4.4 Subgrade Protection**

The cohesive native silty clay to clay subgrade will be susceptible to disturbance from construction traffic and/or ponded water. To limit the effect of this disturbance it may be necessary to sub-excavate deeper and place a 300 mm thick compacted bedding layer on the prepared subgrade, or alternatively construct a concrete working slab on the subgrade if the concrete footings, or the box culvert, is not placed within four hours after preparation, inspection, and approval of the foundation subgrade. The minimum thickness of the concrete working slab should be 100 mm and the concrete should have a minimum 28 day compressive strength of 20 MPa. Consideration should be given to include an NSSP in the contract to address subgrade protection at this site. A sample NSSP can be provided at the detail design stage, if required depending on final culvert design and construction staging.

#### **6.4.5 Erosion Protection**

Provision should be made for scour and erosion protection at the culvert location. In order to prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring) or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a clay seal or concrete cut-off wall should be provided at the upstream end of the culvert. If a clay seal is adopted, the clay material should meet the requirements of OPSS 1205 (Clay Seal), and the seal should be a minimum thickness of 1 m. The clay seal should extend from a depth of 1 m below the scour level to a minimum vertical height equivalent to the high water level. The seal should also extend a minimum horizontal distance of 2 m on either side of the culvert inlet opening. Alternatively, a 0.6 m thick clay blanket may be constructed, extending upstream three times the culvert height and along the adjacent slopes to a height of two times the culvert height or the high water level, whichever is greater.

The requirements for and design of erosion protection measures for the inlet and outlet of the culvert should be assessed by the hydraulics design engineer. As a minimum, rip rap treatment for the outlet of the culvert should be consistent with the standard presented in OPSD 810.010 (Rip Rap Treatment). Erosion protection for the inlet of the culvert should also follow the standard presented in OPSD 810.010 (Rip Rap Treatment) similar to the outlet but with the rip rap placed up to the toe of slope level, in combination with the cut off measures noted above. Similarly, rip rap should be provided over the full extent of the clay blanket, including the creek side slopes and fill slope over the culvert if a clay seal is adopted.

#### **6.4.6 Control of Groundwater and Surface Water**

Excavation along the culvert alignment will be required to remove existing fill, organics (if encountered) and/or softened overburden soils prior to placement of backfill, bedding material if required, levelling layer and the actual culvert structure. Groundwater flow into the excavation can be expected due to the depth of the excavation below the adjacent creek level and the presence of existing relatively permeable embankment fill. Therefore, control of groundwater will be necessary to allow for construction to be carried out in dry conditions, where required. Surface water should be directed away from the excavation areas to prevent ponding of water that could result in disturbance and weakening of the foundation subgrade.



Depending on the creek flow, local surface water flow conditions and groundwater level at the time of construction, water flow could be passed through the area by means of a temporary culvert or diverted by pumping from behind temporary cofferdams.

For both the box and open footing culvert options, excavations will extend below the creek water level, and potentially the groundwater level, although the boreholes suggest dry conditions upon completion of drilling, but will likely require temporary shoring with dewatering to allow for construction/placement of the footings and/or placement of bedding/levelling course fill pad in dry conditions. Temporary shoring and dewatering could be in the form of a sheet-pile cut off wall or cofferdam advanced to an appropriate depth to control groundwater inflow from the creek and to prevent base heaving within the excavation. As discussed in Section 6.4.2, replacement backfill can be placed subaqueously, however, dewatering may still be required for footing/box culvert placement as the culvert invert is at or below the creek water level.

Dewatering of all excavations should be carried out in accordance with OPSS 517 (Dewatering). Consideration should be given to include an NSSP in the contract to address unwatering at this site. A sample NSSP can be provided at the detail design stage, if required depending on final culvert design and construction staging.

At this preliminary stage, an accurate prediction of the groundwater pumping volumes cannot be made, as the groundwater and surface water flow rate would be dependent on construction methods adopted by the contractor. However, it is considered that groundwater pumping volumes could not exceed 50 m<sup>3</sup>/day either during initial unwatering stages and/or during periods of heavy precipitation, provided that surface water flows are properly managed and directed away from the open excavation. At this times it is considered that a Permit to Take Water (PTTW) would be required, but such a requirement should be confirmed at the detail design stage of the project.

#### **6.4.7 Obstructions**

Based on anecdotal evidence, we understand that corduroy roads were commonly used during culvert construction in the Northwest Region. Although wood was not encountered within the sampled boreholes as part of the current geotechnical investigation, the Contractor should be alerted to the potential for buried wood within the fill material. An NSSP should be developed at the detail design stage for inclusion into the Contract Documents to alert the contractor to the potential presence of such obstructions.

#### **6.4.8 Analytical Testing for Construction Materials**

The results of an analytical test on a sample of creek water taken at the culvert site are presented in Table B1 in Appendix B. The suite of parameters tested is intended to allow the design engineer to assess the requirements for the appropriate type of cement to be used in construction and the need for corrosion protection of steel reinforcing elements.



## **6.5 Recommendations for Further Work During Detail Design**

During the detail design phase, additional field investigation and testing may be required, based on the final configuration and/ or alignment of the culvert and the replacement strategy (i.e., staging). In particular, consideration should be given to drilling additional boreholes advanced to a suitable penetration depth within the silty clay to clay deposit if the pre-cast slab supported on sheet-pile abutments option is selected or for design of temporary works if the culvert is to be constructed in stages while maintaining one open lane of traffic. The scope and results of this investigation must be reviewed at the time of the detail design to determine if they meet the then-current MTO requirements for the culvert type or staging strategy under consideration, and if additional investigation and analysis is necessary. If a grade raise or widening of the roadway is required at this site, additional settlement and stability analysis will be required. Further, the need for an application for a PTTW should be defined early in the detail design phase of the project as not to delay the start of construction.

## **7.0 CLOSURE**

This Preliminary Foundation Design Report was prepared by Mr. Adam Core, P.Eng. and the technical aspects were reviewed by Mr. David Muldowney, P.Eng. Mr. Jorge M.A. Costa, P.Eng., Designated MTO Foundations Contact and Principal of Golder, conducted an independent quality control review of this report.



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**PRELIMINARY FOUNDATION REPORT  
MAXIMILLIAN CREEK CULVERT - SITE NO. 45-141/C**

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## Report Signature Page

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AC/DAM/JMAC/kp

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## PRELIMINARY FOUNDATION REPORT MAXIMILLIAN CREEK CULVERT - SITE NO. 45-141/C

### REFERENCES

Canadian Standards Association (CSA), 2006. Canadian Highway Bridge Design Code and Commentary on CAN/CSA S6 06. CSA Special Publication, S6.1 06.

Occupational Health and Safety Act and Regulation for Construction Projects (as amended).

Ministry of Northern Development of Mines. Bedrock Geology of Ontario – West Central Sheet, Ontario Geological Survey – Map 2542.

Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 52CNW.

ASTM International:

ASTM D1586                      Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils

ASTM D2573                      Standard Test Method for Field Vane Shear Test in Cohesive Soil

Ontario Provincial Standard Specifications (OPSS)

OPSS 422                          Construction Specification for Pre-cast Reinforced Concrete Box Culverts and Box Sewers in Open Cut

OPSS 517                          Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation

OPSS 902                          Construction Specification for Excavating and Backfilling – Structures

OPSS 1205                        Material Specification for Clay Seal

OPSS 1860                        Material Specification for Geotextiles

Ontario Provincial Standard Specifications (OPSS) – Provincial Oriented

OPSS.PROV 209                  Construction Specification for Embankments over Swamps and Compressible Soils

OPSS.PROV 501                  Construction Specification for Compacting

OPSS.PROV 539                  Construction Specification for Temporary Protection Systems

OPSS.PROV 1002                Material Specification for Aggregates - Concrete

OPSS.PROV 1010                Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

Ontario Provincial Standard Drawings (OPSD)

OPSD 208.010                  Benching of Earth Slopes

OPSD 803.010                  Backfill and Cover for Concrete Culverts With Spans Less Than or Equal to 3.0 m

OPSD 810.010                  General Rip-Rap Layout for Sewer and Culvert Outlets

OPSD 3090.100                Foundation, Frost Penetration Depths for Northern Ontario



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## **PRELIMINARY FOUNDATION REPORT MAXIMILLIAN CREEK CULVERT - SITE NO. 45-141/C**

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Ontario Water Resource Act:

Regulation 903

Wells (as amended)



## PRELIMINARY FOUNDATION REPORT MAXIMILLIAN CREEK CULVERT - SITE NO. 45-141/C

Table 1: Summary of Culvert Details

Culvert Location (Township)	Site #	Approximate Height of Embankment <sup>1</sup> (m)	Existing Culvert			Approximate Invert Elevation <sup>2</sup>	
			Type	Approximate Dimension <sup>2</sup>	Approximate Length (m)	West End of Culvert (m)	East End of Culvert (m)
Hwy 71 STA 10+337 (Township of Potts)	45-141/C	3.9	Concrete Box	6.1 m x 1.8 m	26	363.6	363.5

- Notes:
1. Embankment height is relative to existing ground surface at the centreline of the roadway and the invert elevation of the culvert.
  2. Culvert dimensions and invert elevations are based on the plan and profile drawings provided by MTO (Drawing BC830713.dwg).

Prepared by: AC  
Checked by: DAM  
Reviewed by: JMAC





## PRELIMINARY FOUNDATION REPORT MAXIMILLIAN CREEK CULVERT - SITE NO. 45-141/C

**Table 2: Comparison of Foundation Alternatives**

Option	Advantages	Disadvantages	Risks/Consequences
Pre-Cast Box Culvert	<ul style="list-style-type: none"> <li>Minimizes depth of excavation, protection system (if required) and dewatering requirements compared to open footing option. Minor excavation required for the removal of unsuitable fill to the base of the bedding/levelling course.</li> <li>Allows faster construction resulting in shorter duration for dewatering and surface water pumping.</li> <li>More tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site, or remnants of the peat deposit are not fully removed or heave/settlement resulting from freeze/thaw of the subgrade.</li> <li>Backfill/bedding under the culvert may be placed underwater (i.e. Granular 'B' Type II) minimizing or eliminating water pumping requirements.</li> </ul>	<ul style="list-style-type: none"> <li>May not satisfy fisheries requirements related to natural channel substrate, if applicable.</li> <li>Cut-off wall (or clay blanket) required at inlet to mitigate potential scour under culvert.</li> <li>Transportation to and on-site lifting of large pre-cast sections will be required.</li> <li>May require water diversion of the creek channel to accommodate construction of the new culvert using a full length culvert section, unless the culvert is comprised of multiple parallel box sections.</li> </ul>	<ul style="list-style-type: none"> <li>Some risk of disturbance of the native silty clay to clay deposit during construction; can be mitigated with use of a tremie concrete working slab or Granular B Type II working pad or bedding layer.</li> <li>Low risk related to settlement performance.</li> </ul>
Open Footing Culvert	<ul style="list-style-type: none"> <li>May be feasible to construct the culvert on pre-cast footing sections, to accelerate construction schedule and reduce time for dewatering/unwatering (pumping) of surface water.</li> <li>Would likely satisfy fisheries requirements related to natural channel substrate, if applicable.</li> <li>Suitable footing founding subgrade at/below the depth of frost penetration.</li> <li>Existing culvert can be used for water diversion while new footings are being constructed adjacent to the existing culvert depending on the width of the new culvert.</li> </ul>	<ul style="list-style-type: none"> <li>Excavation depths are greater than for box culvert option, resulting in increased excavation support requirements and additional spoil material to be disposed off-site.</li> <li>Constructing footings in the dry will take longer due to requirements for installation of a groundwater control system, dewatering and surface water pumping and excavation in a constrained space.</li> <li>Less tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site.</li> <li>Concrete or metal arch sections supported on concrete open (strip) footings may not allow for adequate soil cover to be placed including the roadway pavement structure.</li> </ul>	<ul style="list-style-type: none"> <li>High risk of disturbance of the native silty clay to clay deposit during construction; can be somewhat mitigated with use of a concrete working slab or granular working pad but would require greater depth of dewatering for footing construction.</li> <li>Culvert joints may be required to accommodate total and differential settlement (if applicable).</li> </ul>



## PRELIMINARY FOUNDATION REPORT MAXIMILLIAN CREEK CULVERT - SITE NO. 45-141/C

Option	Advantages	Disadvantages	Risks/Consequences
Sheet-Pile Abutment and Pre-Cast Slab	<ul style="list-style-type: none"><li>■ May not require temporary diversion of the creek depending on the required width of the culvert in comparison to the existing culvert as the sheet-piles can be installed around the existing culvert, which acts as the channel diversion and the new culvert can be constructed in sections.</li><li>■ Minimizes excavation depths and does not require dewatering.</li><li>■ Would satisfy fisheries requirements related to natural channel substrate, if applicable.</li></ul>	<ul style="list-style-type: none"><li>■ Likely will require additional deeper boreholes to assess adequacy of subsurface soils for potentially higher bearing capacities.</li><li>■ Potential difficulties in driving/vibrating sheet-piles due to the sensitivity of the subgrade soils.</li><li>■ Less tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site (i.e. potential for downdrag and/or heave due to adhesion, including during frozen ground conditions, on the sheet-piles).</li><li>■ Steel sheet-piles may not have as long of a design life compared to concrete options.</li></ul>	<ul style="list-style-type: none"><li>■ Joints may need to be incorporated into the slab to accommodate total and differential settlement.</li><li>■ Some risk that additional sheet-pile lengths may be required due to disturbance of the subsurface soils during sheet-pile installation.</li></ul>



**PRELIMINARY FOUNDATION REPORT**  
**MAXIMILLIAN CREEK CULVERT - SITE NO. 45-141/C**

**Table 3: Geotechnical Axial Resistance and Reaction for Pre-Cast Box, Open Footing and Sheet-Pile Abutment-Concrete Cap Culvert Replacements**

Culvert Location (Township)	Approximate Invert Elevation <sup>1</sup> (West End / East End)	Culvert Type	Approximate Backfill/Bedding Founding Elevation (West End / East End)	Founding Condition	Factored Geotechnical Axial Resistance at ULS <sup>2</sup>	Geotechnical Reaction at SLS for 25 mm of Settlement <sup>2</sup>
Hwy 71 STA 10+337 (Township of Potts)	363.6 m / 363.5 m	Pre-Cast Box <sup>2</sup>	363.2 m / 363.1 m	Levelling Layer over Stiff to Very Stiff Silty Clay to Clay	250 kPa	100 kPa
		Open Footing <sup>2</sup>	361.3 m / 361.2 m	Stiff to Very Stiff Silty Clay to Clay	250 kPa	150 kPa
	N/A	Pre-Cast Slab on Sheet-Pile Abutments <sup>3</sup>	~ 353.0 m	Firm Very Stiff Silty Clay to Clay	80 kN/m	65 kN/m

Notes: 1. Culvert invert elevations are based on the profile drawings provided by MTO (Drawing BC5019311053.dwg).  
2. The factored geotechnical axial resistance at ULS and geotechnical reaction at SLS for 25 mm of settlement are estimated based on an assumed 6.0 m wide box culvert and a 0.6 m or 1.2 m wide open footing. The recommended geotechnical resistance/reaction should be reviewed if the founding elevation and/or the foundation widths differ from those given above.  
3. The factored geotechnical resistance at ULS and geotechnical reaction at SLS (for 25 mm of settlement) are provided per horizontal metre of EZ88 series sheet-piling. The recommended geotechnical resistance/reaction should be reviewed once more information becomes available in terms of the final sheet-piling configuration.

Prepared by: AC  
Checked by: DAM  
Reviewed by: JMAC



## PRELIMINARY FOUNDATION REPORT MAXIMILLIAN CREEK CULVERT - SITE NO. 45-141/C

**Table 4: Resistance to Lateral Loads/Sliding Resistance for Pre-Cast Box and Open Footing Culvert Replacements**

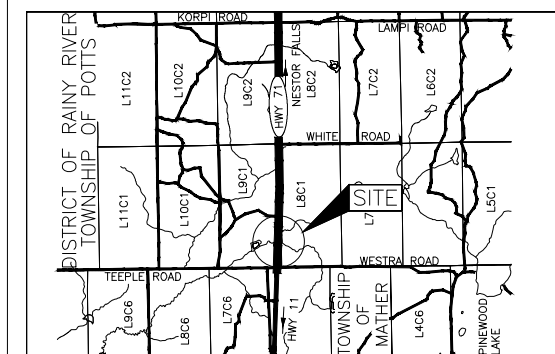
Culvert Location (Township)	Pre-Cast Box Culvert or Open Footing		Cast-in-place Open Footing	
	Interface Material	Coefficient of Friction <sup>1</sup> (tan $\delta$ )	Interface Material	Coefficient of Friction <sup>1</sup> (tan $\delta$ )
Hwy 71 STA 10+337 (Township of Potts)	Compacted Granular Fill (Levelling Pad)	0.35	Very Stiff Silty Clay to Clay	0.30

Notes: 1. These values are unfactored. In accordance with CHBDC, a factor of 0.8 to be applied in calculated the horizontal resistances.

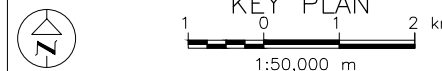
Prepared by: AC  
Checked by: DAM  
Reviewed by: JMAC





SHEET



## KEY PLAN



## LEGEND

- |   |  |
|---|--|
|  | Borehole   |
| N   | Standard Penetration Test Value                                    |
| 16  | Blows/0.3m unless otherwise stated<br>(Std. Pen. Test, 475 j/blow) |
|  | WL upon completion of drilling - Dry                               |

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
MX-1	365.2	5410401.5	237503.8
MX-2	367.3	5410402.4	237515.2
MX-3	367.3	5410411.3	237519.3
MX-4	364.8	5410400.7	237529.7

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NOTES

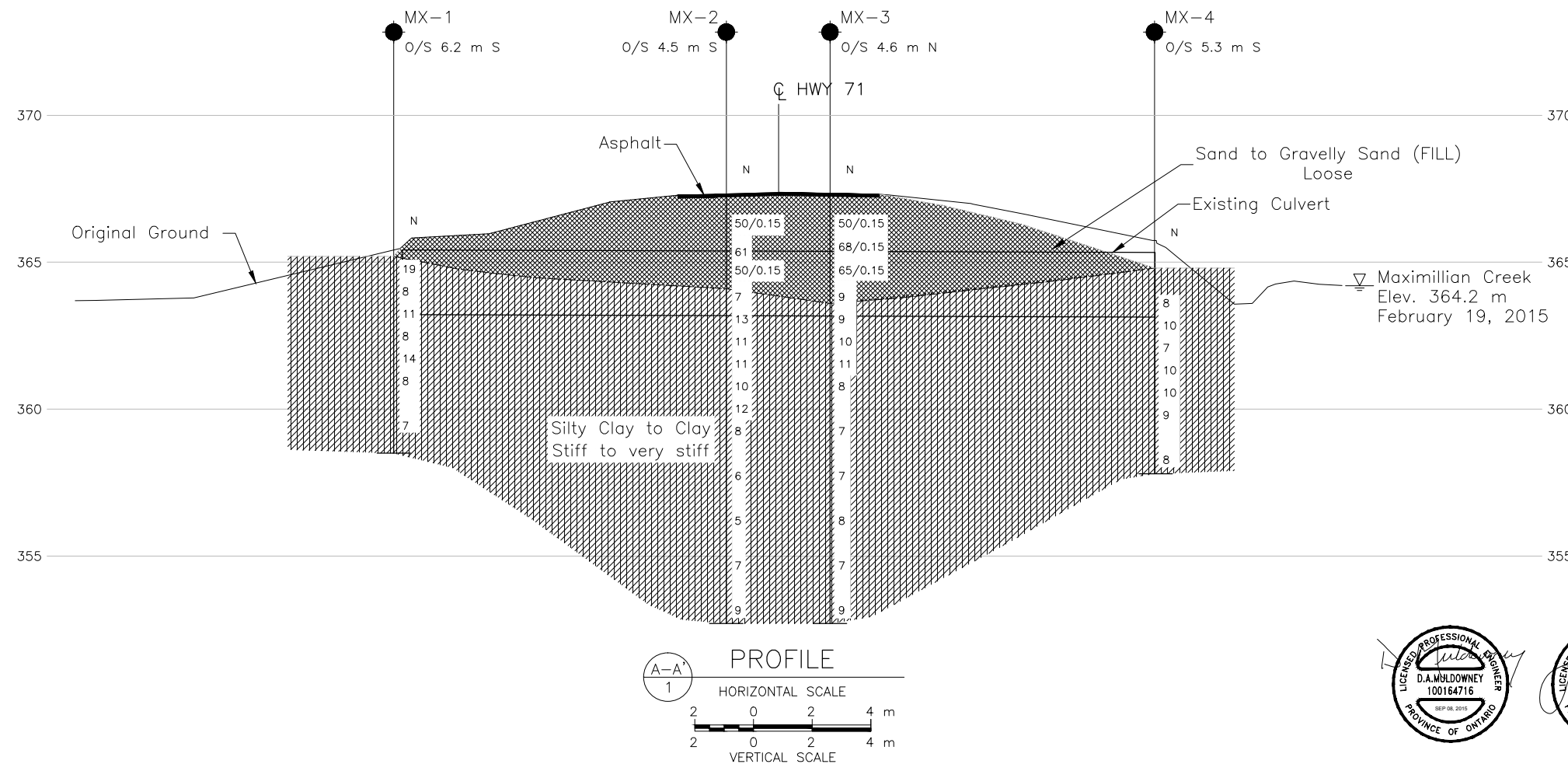
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

## REFERENCE

Base plans provided in digital format by MTO, drawing file no. BC830713, received FEB 20, 2015.




Geocres No. 52C-40

<b>HWY.</b> 71	<b>PROJECT NO.</b> 1411523	<b>DIST.</b> .
<b>SUBM'D. AC</b>	<b>CHKD.</b>	<b>DATE:</b> 8/25/2015
<b>DRAWN:</b> JUL	<b>CHKD.</b> DAM	<b>APPD.</b> JMJC
		<b>DWG.</b> 1





## PHOTOGRAPHS

**Photograph 1: Maximillian Creek Culvert  
West Side - Inlet (Taken from MTO, OSIM\_08-15-2013)**



**Photograph 2: Maximillian Creek Culvert  
East Side - Outlet (Taken from MTO, OSIM\_08-15-2013)**







## PHOTOGRAPHS

**Photograph 3: Maximillian Creek Culvert  
West Side - Inlet (Golder – February 16, 2015)**



**Photograph 4: Maximillian Creek Culvert  
East Side - Outlet (Golder – March 13, 2015)**





# **APPENDIX A**

## **Record of Boreholes**





## LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

### I. GENERAL

$\pi$	3.1416
$\ln x$ ,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

### II. STRESS AND STRAIN

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta \sigma$
$\varepsilon$	linear strain
$\varepsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	Poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

### III. SOIL PROPERTIES

<b>(a)</b>	<b>Index Properties</b>
$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
$\gamma'$	unit weight of submerged soil ( $\gamma' = \gamma - \gamma_w$ )
$D_R$	relative density (specific gravity) of solid particles ( $D_R = \rho_s / \rho_w$ ) (formerly $G_s$ )
e	void ratio
n	porosity
S	degree of saturation

### (a) Index Properties (continued)

w	water content
$w_l$ or LL	liquid limit
$w_p$ or PL	plastic limit
$I_p$ or PI	plasticity index = $(w_l - w_p)$
$w_s$	shrinkage limit
$I_L$	liquidity index = $(w - w_p) / I_p$
$I_C$	consistency index = $(w_l - w) / I_p$
$e_{max}$	void ratio in loosest state
$e_{min}$	void ratio in densest state
$I_D$	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

### (b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

### (c) Consolidation (one-dimensional)

$C_c$	compression index (normally consolidated range)
$C_r$	recompression index (over-consolidated range)
$C_s$	swelling index
$C_\alpha$	secondary compression index
$m_v$	coefficient of volume change
$C_v$	coefficient of consolidation (vertical direction)
$C_h$	coefficient of consolidation (horizontal direction)
$T_v$	time factor (vertical direction)
U	degree of consolidation
$\sigma'_p$	pre-consolidation stress
OCR	over-consolidation ratio = $\sigma'_p / \sigma'_{vo}$

### (d) Shear Strength

$\tau_p, \tau_r$	peak and residual shear strength
$\phi'$	effective angle of internal friction
$\delta$	angle of interface friction
$\mu$	coefficient of friction = $\tan \delta$
$c'$	effective cohesion
$c_u, s_u$	undrained shear strength ( $\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
$p'$	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
$q_u$	compressive strength $(\sigma_1 - \sigma_3)$
$S_t$	sensitivity

\* Density symbol is  $\rho$ . Unit weight symbol is  $\gamma$  where  $\gamma = \rho g$  (i.e. mass density multiplied by acceleration due to gravity)

Notes: 1  
2

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$



## LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

### I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

### II. PENETRATION RESISTANCE

#### Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

#### Dynamic Cone Penetration Resistance; $N_d$ :

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

**WH:** Sampler advanced by static weight of hammer

**WR:** Sampler advanced by weight of sampler and rod

#### Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm<sup>2</sup> pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance ( $Q_t$ ), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

### III. SOIL DESCRIPTION

#### (a) Non-Cohesive (Cohesionless) Soils

Density Index	N
Relative Density	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

#### (b) Cohesive Soils Consistency

	$C_u, S_u$	
	kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

### IV. SOIL TESTS

w	water content
$w_p$	plastic limit
$w_l$	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
$D_R$	relative density (specific gravity, $G_s$ )
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
$SO_4$	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
$\gamma$	unit weight

**Note:** 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

### V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand

PROJECT 1411523		<b>RECORD OF BOREHOLE No MX-1</b>				1 OF 1 <b>METRIC</b>											
G.W.P. 6339-14-00		LOCATION N 5410401.5; E 237503.8				ORIGINATED BY MR											
DIST _____ HWY 71		BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers				COMPILED BY AC											
DATUM GEODETIC		DATE March 15, 2015				CHECKED BY DAM											
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	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)
365.2	GROUND SURFACE																
0.0	SILTY CLAY with sand, trace to some gravel, trace organics Stiff to very stiff Brown to grey Frozen* to wet		1	SS	19*												
			2	SS	8												
			3	SS	11												
			4	SS	8												
			5	SS	14												
			6	SS	8												
			7	SS	7												
358.5	END OF BOREHOLE																
6.7	Note:  1. Borehole dry upon completion of drilling.																

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 08/05/15 DATA INPUT:

PROJECT 1411523				<b>RECORD OF BOREHOLE No MX-2</b>				1 OF 2 <b>METRIC</b>						
G.W.P. 6339-14-00				LOCATION N 5410402.4; E 237515.2				ORIGINATED BY DM						
DIST _____ HWY 71				BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers				COMPILED BY AC						
DATUM GEODETIC				DATE February 17, 2015				CHECKED BY DAM						
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						
367.3	GROUND SURFACE							20 40 60 80 100	20 40 60					
8.9	ASPHALT (50 mm)						367							
	Sand to gravelly sand, trace to some silt (FILL) Brown Frozen		1	SS	50/0.15		366							17 68 (15)
			2	SS	61		365							
			3	SS	50/0.15		364							
364.1			4	SS	7		363							
3.2	SILTY CLAY to CLAY, trace to some sand, trace gravel, trace organics Stiff to very stiff Brown to grey Wet		5	SS	13		362							
			6	SS	11		361							0 11 56 33
			7	SS	11		360							
			8	SS	10		359							
			9	SS	12		358							
			10	SS	8		357							
			11	SS	6		356							
			12	SS	5		355							0 6 27 67
			13	SS	7		354							
			14	SS	9		353							0 6 34 60
352.7														
14.6														

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 08/05/15 DATA INPUT:

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

PROJECT <u>1411523</u>		<b>RECORD OF BOREHOLE No MX-2</b>		2 OF 2 <b>METRIC</b>	
G.W.P. <u>6339-14-00</u>		LOCATION <u>N 5410402.4; E 237515.2</u>		ORIGINATED BY <u>DM</u>	
DIST <u>          </u> HWY <u>71</u>		BOREHOLE TYPE <u>108 mm I. D. Hollow Stem Augers</u>		COMPILED BY <u>AC</u>	
DATUM <u>GEODETIC</u>		DATE <u>February 17, 2015</u>		CHECKED BY <u>DAM</u>	

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL MOISTURE   LIQUID CONTENT   CONTENT   LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					W <sub>p</sub>	W			W <sub>L</sub>
							○ UNCONFINED   +   FIELD VANE ● QUICK TRIAXIAL   ×   REMOULDED					WATER CONTENT (%)					
	<div>--- CONTINUED FROM PREVIOUS PAGE ---</div> <div>END OF BOREHOLE</div> <div>Note:</div> <div>1. Borehole dry upon completion of drilling.</div>																

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 08/05/15 DATA INPUT:

PROJECT 1411523				RECORD OF BOREHOLE No MX-3				1 OF 2 METRIC						
G.W.P. 6339-14-00				LOCATION N 5410411.3; E 237519.3				ORIGINATED BY DM						
DIST _____ HWY 71				BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers				COMPILED BY AC						
DATUM GEODETIC				DATE February 16, 2015				CHECKED BY DAM						
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						
367.3	GROUND SURFACE							20 40 60 80 100	20 40 60					
0.9	ASPHALT (50 mm)						367							
	Sand to gravelly sand, trace to some silt (FILL)						366							
	Loose		1	SS	50/0.15									
	Brown		2	SS	68/0.15									
	Frozen* to moist		3	SS	65/0.15		365			○				
			4	SS	7		364							
363.6							363							
3.7	SILTY CLAY to CLAY, trace to some sand, trace gravel		5	SS	9									
	Very stiff		6	SS	10									
	Brown to grey		7	SS	11		362			○				1 1 47 51
	Wet		8	SS	8		361			○				
			9	SS	7		360							
			10	SS	7		359							1 8 42 49
			11	SS	8		358							
			12	SS	7		357							
			13	SS	9		356							
							355							0 6 27 67
							354							
							353							
352.7														
14.6														

Continued Next Page


+ 3, × 3: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 08/05/15 DATA INPUT:



+ 3, × 3: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

SSUD-MTO 001 1411523.GPJ GAL-MISS.GDT 08/05/15 DATA INPUT:

PROJECT 1411523			RECORD OF BOREHOLE No MX-4			1 OF 1 METRIC																											
G.W.P. 6339-14-00			LOCATION N 5410400.7; E 237529.7			ORIGINATED BY DM																											
DIST _____ HWY 71			BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers			COMPILED BY AC																											
DATUM GEODETIC			DATE February 21, 2015			CHECKED BY DAM																											
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)																		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%) W <sub>p</sub> W W <sub>L</sub>			γ	GR	SA	SI	CL													
364.8 0.0	GROUND SURFACE SILTY CLAY to CLAY, trace to some sand, trace gravel Stiff to very stiff Brown to grey Frozen* to wet							20	40	60	80	100																					
			1	SS	8*			364																									
			2	SS	10			363																									
			3	SS	7			362																						1	6	28	65
			4	SS	10			361																									
			5	SS	10			360																						0	7	31	62
			6	SS	9																												
			7	SS	8			359																									
357.8 7.0	END OF BOREHOLE  Note: 1. Borehole dry upon completion of drilling.						358																										

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 08/05/15 DATA INPUT:





# **APPENDIX B**

## **Laboratory Test Results**



## PRELIMINARY FOUNDATION REPORT MAXIMILLIAN CREEK CULVERT - SITE NO. 45-141/C

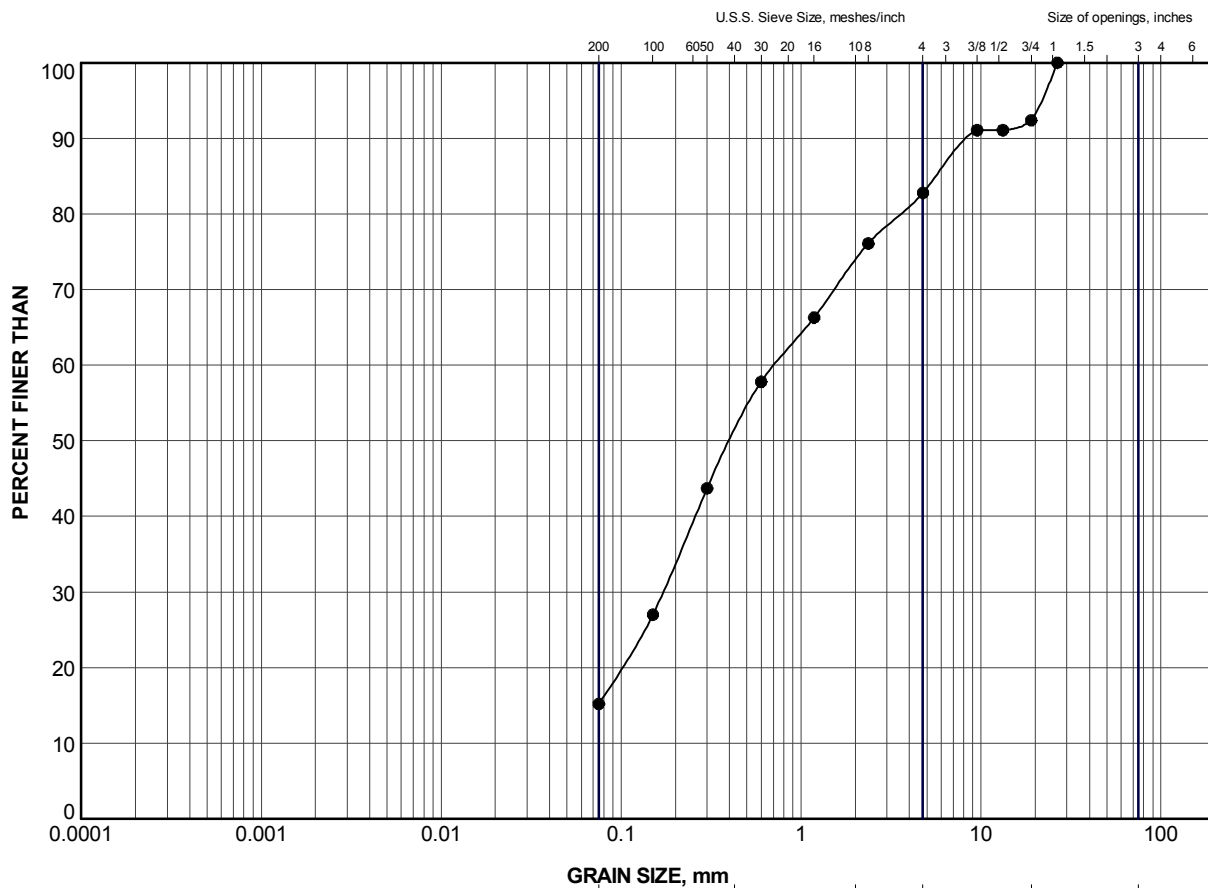
**Table B1: Summary of Analytical Testing of Maximillian Creek Water Sample**

Parameter	Units	Result
Chloride (CL)	mg/L	146
Sulphate (SO4)	mg/L	<0.30
Conductivity (EC)	µS/cm	1080
Resistivity	µohm-cm	<0.33
pH	n/a	6.99

Notes:

1. Sample obtained on February 24, 2015.
2. Analytical testing carried out by ALS Canada Ltd.


Prepared by: AC  
Checked by: DAM  
Reviewed by: JMAC

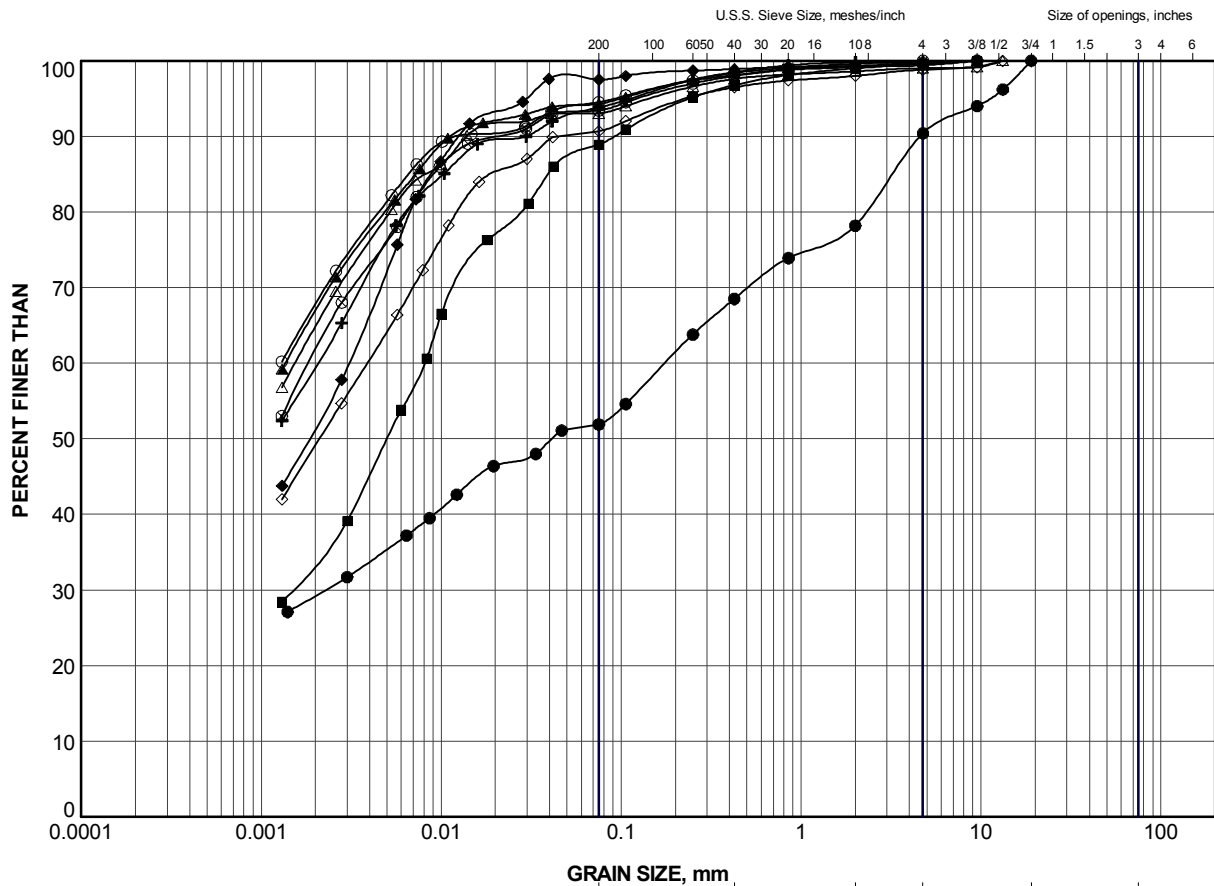


CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	MX-2	2	365.5

PROJECT				
HIGHWAY 71 MAXIMILLIAN CREEK CULVERT STA 10+337				
TITLE				
GRAIN SIZE DISTRIBUTION SAND (FILL)				
		PROJECT No. 1411523		FILE No. 1411523.GPJ
		DRAWN TB	Apr 2015	SCALE N/A
		CHECK DAM	Apr 2015	REV.
		APPR JMAC	Apr 2015	
			<b>FIGURE B1</b>	



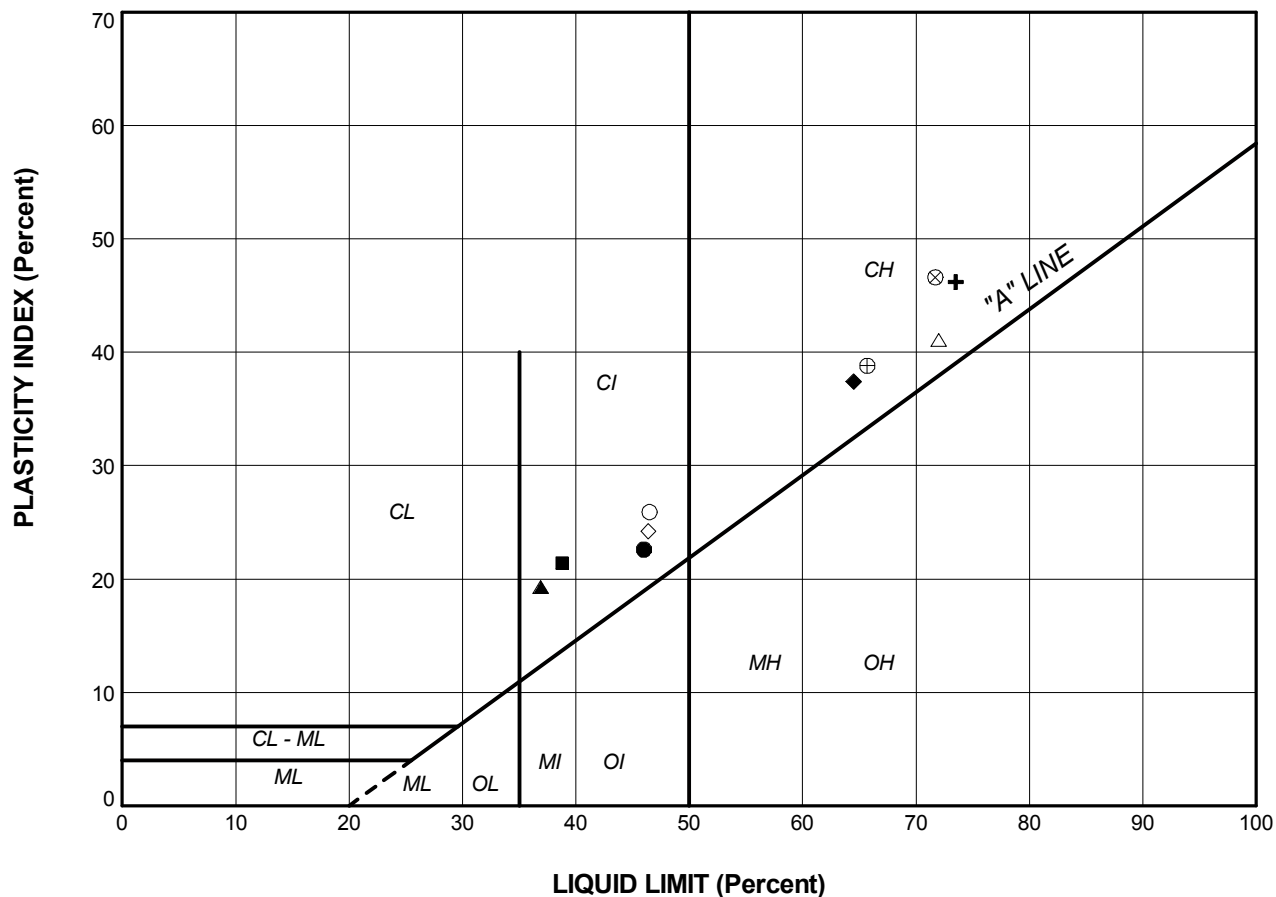
CLAY AND SILT	GRAVEL SIZE, mm						Cobble Size
	fine	medium	coarse	fine	coarse		
	SAND SIZE			GRAVEL SIZE			

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	MX-1	2	364.1
■	MX-2	5	363.2
▲	MX-2	8	360.9
+	MX-2	12	356.3
◆	MX-3	6	362.4
◇	MX-3	9	359.4
○	MX-3	12	354.8
△	MX-4	3	362.2
⊗	MX-4	5	360.7

PROJECT					
HIGHWAY 71 MAXIMILLIAN CREEK CULVERT STA 10+337					
TITLE					
GRAIN SIZE DISTRIBUTION SILTY CLAY to CLAY					
PROJECT No.		1411523		FILE No.	1411523.GPJ
DRAWN	TB	Apr 2015	SCALE	N/A	REV.
CHECK	DAM	Apr 2015			
APPR	JMAC	Apr 2015			
			<b>FIGURE B2</b>		





PROJECT					
HIGHWAY 71 MAXIMILLIAN CREEK CULVERT STA 10+337					
TITLE					
PLASTICITY CHART SILTY CLAY to CLAY					
PROJECT No. 1411523			FILE No. 1411523.GPJ		
DRAWN	TB	Apr 2015	SCALE	N/A	REV.
CHECK	DAM	Apr 2015	FIGURE B3		
APPR	JMAC	Apr 2015			



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