



May 5, 2015

## DRAFT PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT

PETERSON CREEK CULVERT - SITE NO. 45-155/C  
HIGHWAY 619, DISTRICT OF RAINY RIVER  
TOWNSHIP OF TOVELL  
MINISTRY OF TRANSPORTATION, ONTARIO  
G.W.P 6328-14-00

**Submitted to:**  
Hatch Mott MacDonald  
200 S. Syndicate Ave., Suite 301  
Thunder Bay, ON  
P7E 1C9



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1 Copy: Ministry of Transportation, Ontario, Downsview (Foundations Section)  
1 Copy: Hatch Mott MacDonald, Thunder Bay, Ontario  
1 Copy: Golder Associates Ltd., Sudbury, Ontario



DRAFT REPORT



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# **PART A**

**PRELIMINARY FOUNDATION INVESTIGATION REPORT  
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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 Peterson Creek culvert (Site No. 45-155/C). The Peterson Creek culvert is located in the District of Rainy River in the Township of Tovell on Highway 619 at STA 10+061, approximately 1.7 km south of the junction of Highway 600 and Highway 619. The key plan showing the general location of this section of Highway 619 and the location of the investigated area are shown on Drawing 1.

## **2.0 SITE DESCRIPTION**

The Peterson Creek culvert consists of twin Steel Plate Corrugated Steel Pipe (SP CSP) culverts, 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 the culvert area is relatively flat with swampy terrain consisting of open water and tall grass/shrubs and sparse to moderate tree cover beyond the highway right-of-way. Highway 619 runs in a north-south direction with the culvert in a west-east orientation on a slight skew. At the culvert location, Peterson Creek flows westerly. The highway grade is at Elevation 332.9 m and the culvert invert is at approximately Elevations 329.8 m and 329.5 m, at the inlet (east) and outlet (west) ends, respectively. The creek water level was at Elevation 331.7 m as measured by others on May 5, 2014. The creek ice level was at Elevation 331.2 m as measured by Golder on January 27, 2015. Surface conditions in the culvert inlet and outlet are shown on Photographs 1 to 4, attached.

## **3.0 INVESTIGATION PROCEDURES**

The field work for this subsurface investigation was carried out on January 27, February 21 and March 18, 2015, during which time four boreholes (Boreholes PT-1 to PT-4) were advanced at approximately the locations shown on Drawing 1. Boreholes PT-1 and PT-4 were advanced at the toe of slope near the culvert inlet/outlet and Boreholes PT-2 and PT-3 were advanced from the existing highway platform. The boreholes were advanced by truck and track mounted CME 55 drill rigs using 108 mm inside diameter hollow stem augers. All drilling equipment was 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). Samples of the cohesive soils were obtained using 76 mm O.D. thin walled Shelby Tubes (ASTM D1587) for relatively undisturbed samples. Field vane shear tests were conducted in cohesive soils for determination of undrained shear strengths (ASTM D2573) using MTO Standard 'N' size vanes. 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



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content and organic 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 January 28, 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 a 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 drawing provided by MTO (E12736191.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)
PT-1	5421754.4	209930.5	332.2	6.4
PT-2	5421768.1	209936.9	332.9	11.6
PT-3	5421754.9	209940.6	332.9	11.0
PT-4	5421757.0	209953.7	332.2	6.7

## 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 Peterson Creek culvert site generally consist of glaciolacustrine plain deposits of silts and clays.

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 a foliated tonalite suite consisting of foliate to massive tonalite to granodiorite.

### 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 field 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 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.

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

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



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### Subsoil Conditions

In summary, the subsoil conditions encountered at the site consist of granular fill (for boreholes advanced through the embankment), and organics comprised of silty to sandy peat overlying deposits of clay and silty 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 (kPa)	Laboratory Testing
				Relative Density or Consistency	
<b>(FILL)</b> Sand, some gravel to Sand and Gravel; brown; frozen	PT-2, PT-3	0.7	332.9	N/A	N/A
Sandy to Silty <b>Fibrous Peat</b> <sup>1</sup> ; dark brown to black; frozen	PT-1 to PT-4	0.2 – 0.7	332.2	N/A <sup>1</sup>	w = 43% - 86% OC = 6.6%
<b>Clay</b> <sup>2</sup> , trace to some sand, trace organics; grey to brown; frozen to wet	PT-1 to PT-4	Boreholes terminated in these deposits (5.7 – 10.2)	332.0 – 331.5	N = 0 (weight of hammer) – 11 s <sub>u</sub> = 34 – > 100 S = 1 – 3	w = 28% – 66% w <sub>l</sub> = 51% – 92% w <sub>p</sub> = 20% - 32% I <sub>p</sub> = 36% – 61% 4 - MH (Fig. B1) 7 – AL (Fig. B2)
				<b>Firm to Very Stiff</b>	
Sandy <b>Silty Clay</b> , trace gravel; grey; wet	PT-2 and PT-3		324.9 and 324.4	N=7 and 8 s <sub>u</sub> = 77 – > 100 S = 2 – 3	w = 20% – 23% w <sub>l</sub> = 37% – 39% w <sub>p</sub> = 15% - 16% I <sub>p</sub> = 22% – 23% 1 – MH (Fig. B1) 2 – AL (Fig. B2)
				<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

AL = Atterberg Limits Test

OC = Organic Content (%)

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 (%)





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### Notes:

<sup>1</sup> In the Peat deposit, SPT 'N'-values ranging from 13 blows to 72 blows per 0.3 m of penetration were measured, however, these are likely indicative of the frozen state of the material and are not representative of the relative density of the deposit.

<sup>2</sup> Sand laminations were noted within the clay deposit as noted on the Record of Boreholes PT-2 and PT-3.

### Groundwater Conditions

Unstabilized groundwater levels measured in the open boreholes upon completion of drilling are summarized below. The creek ice level was measured at Elevation 331.2 m on January 27, 2015. Groundwater and creek water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

Borehole No.	Depth to Groundwater Level (m)	Groundwater Elevation (m)
PT-1	Dry	N/A
PT-2	1.5	331.4
PT-3	1.5	331.4
PT-4	2.7	329.5

## 5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Mathew Riopelle, under the overall direction of Mr. David Muldowney, P.Eng. This Preliminary Foundation Investigation Report was prepared by Mr. Adam Core, E.I.T., 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.



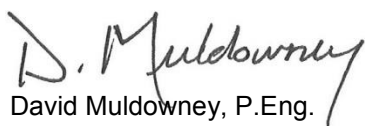


## Report Signature Page

**GOLDER ASSOCIATES LTD.**



Adam Core, E.I.T.  
Geotechnical Engineering Intern



David Muldowney, P.Eng.  
Geotechnical Engineer



Jorge M.A. Costa, P.Eng.  
Designated MTO Contact, Principal

AC/DAM/JMAC/kp

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# **PART B**

**PRELIMINARY FOUNDATION DESIGN REPORT  
PETERSON CREEK – SITE NO. 45-155/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 Peterson 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 existing twin SP CSP culverts are to be replaced with a culvert(s) of similar dimensions, on the same alignment and at similar invert elevations to those of the existing twin culverts. 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 619 reinstatement.

### **6.2 Foundations**

#### **6.2.1 Foundation Options**

The Peterson Creek culvert is located in the District of Rainy River in the Township of Tovell on Highway 619 at STA 10+061, approximately 1.7 km south of the junction of Highway 600 and Highway 619. The highway embankment is constructed of granular material and is approximately 3.3 m high relative to the culvert invert. The existing culvert consists of twin Steel Plate Corrugated Steel Pipes (SP CSP) 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 provided, we understand that a slight realignment of the culvert may be necessary and the following culvert types are being considered at this location:

- A pre-cast concrete box; and
- A pre-cast open footing structure with either pre-cast concrete arch or metal box segments.

In this report we have considered the following options:

- A pre-cast concrete box;
- An open footing box or arch culvert supported on either cast-in-place or pre-cast footings; and



■ Pipe culvert(s).

Given the limited soil cover over the existing twin culvert and over the proposed replacement culvert to maintain the highway grade, we understand that a sheet-pile abutment and concrete cap option is not being considered at this location. Open footing arch culverts could be considered, however the limited soil cover may not allow for proper backfilling over an arch culvert depending on the configuration of the selected arch section (i.e. whether it is metal or pre-cast concrete sections). Pipe culverts (similar to the existing culvert configuration) are considered feasible but would provide less flow-through capacity compared to a box culvert option. If a pipe culvert is selected, a concrete pipe would be preferred as a CSP culvert generally has a shorter design life. From a foundation perspective, a box culvert sufficiently wide to manage the creek flow is preferred. Although an open footing culvert is also suitable for this site, a pre-cast concrete box culvert is recommended as it can accommodate an accelerated construction schedule and there are reduced excavation, dewatering and shoring requirements. Further, if twin boxes are considered, one of the existing CSP culverts can likely be used as the diversion channel during construction. Other culvert types may be preferred due to construction staging or other considerations such as fisheries requirements related to natural channel substrate.

## **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 firm to very stiff clay stratum as encountered in the boreholes. In this regard, the culvert should be constructed on a bedding of granular fill replacing the organics (i.e. peat) present along the culvert, as detailed in Section 6.4.2.

### **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 organics (i.e. peat), where present. Recommended founding elevations and foundation conditions for the replacement open footing culvert are provided in Table 3.

Given that the firm (i.e. lowest strength) portion of the silty clay to clay deposit was encountered at approximately the frost depth, the strength of this material will govern the bearing resistance. Consideration could be given to footings founded at a higher elevation either directly on the clay subgrade where the clay deposit is stiffest or on a raised granular pad constructed on the clay subgrade (refer also to Section 6.4.2.2). The silty clay to clay subgrade material will be susceptible to both frost action (freeze, thaw) and heave/settlement. To protect the founding subgrade from frost penetration, a suitable amount of insulation would be required extending out laterally from the footing. Even if partial or full sub-excavation of the silty clay to clay deposit to the frost depth is carried out, the footings may still be subject to frost heaving due to the fact that the material will likely be saturated (depending on creek water levels), which may occur differentially along the footings or across the



culvert (i.e. between the footings on the west and east sides). Further, if the fill material is placed subaqueously (i.e., below the water level), the footings/culvert may be subject to additional settlement if adequate compaction of the engineered fill is not achieved.

Recommendations regarding engineered fill pad construction are provided in Section 6.4.3.2. The estimated magnitude of frost heave and settlement of subaqueously placed engineered fill can be provided at the detail design stage if this culvert replacement option is selected.

### **6.2.2.3 Pipe Culvert**

It is not necessary to found a pipe culvert at the standard depth for frost protection purposes, as such a culvert is tolerant to small magnitudes of movement related to freeze-thaw cycles, should these occur. Recommended founding elevations and foundation conditions for a circular pipe culvert are provided in Table 3. We recommend that the pipe replacement culvert(s), if adopted, be founded on the native deposit of firm to very stiff clay.

## **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 bedding/engineered fill 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 a (combined) box culvert width of 9 m as provided 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 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.

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

Strip footings placed on the properly prepared subgrade, at or below the founding elevations 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 an assumed footing width of 0.6 m and 1.2 m as provided in Table 3. At this site, the bearing resistance is essentially governed by the strength of the clay deposit and not the 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 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.

#### **6.2.4 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 proposed embankments height up to about 3.3 m above the existing ground surface relative to the culvert invert, 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 the firm to very stiff, silty clay to clay subsurface deposits 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 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.

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:

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

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 sand to sand and gravel and into native soils which are comprised of peat and firm 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 and native soils are considered to be Type 3 soil above the groundwater table and Type 4 soil below. Temporary open-cut excavations in 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 driven sheet-piling extended to a suitable depth, or may also consist of 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 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**

#### **6.4.2.1 Sub-Excavation of Organics**

Prior to placement of any bedding material, engineered fill or concrete, all organics (including topsoil, peat or mixed organic materials) and any softened 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 (Precast 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 I, 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).

#### **6.4.2.2 Sub-excavation for Raised Open Footings**

The open footing culvert should be provided with at least 2.3 m of soil cover for frost protection. As indicated in Section 6.2.2.2, consideration could be given to founding the footings on a fill pad to raise the footings above the frost penetration depth. In this case, the fill pad should be constructed using select rock fill or OPSS.PROV 1010 Granular 'B' Type II. The fill pad should extend at least 1 m beyond the plan limits of the footings, unless shoring is utilized and left in place, and extend below any existing embankment fill and/or peat deposits, where present.



If rock fill is used, the rock fill should be well graded and should consist of fragments of sound rock, free of organic matter or any deleterious material. The rock fill should have a maximum particle size of 300 mm similar to the requirements outlined in MTO Northern Region Directive (2002) titled “Backfill to Structures Adjacent to Rock Embankment Approaches”. Placement of rock fill above the water level should be carried out in accordance with the requirements as outlined in OPSS.PROV 206 (Grading). Rock fill placed below the water level should be in accordance with OPSS.PROV 209 (Embankments over Swamps and Compressible Soils). Side slopes of the rock fill pad should be no steeper than 1.25H:1V.

Granular ‘B’ Type II fill placed above the water table should be compacted to 100 per cent of the Standard Proctor Maximum Dry Density (SPMDD) and the compaction should be carried out in accordance with OPSS.PROV 501 (Compacting). If Granular ‘B’ Type II is placed below the water level, the fill should be placed in accordance with OPSS.PROV 209 (Embankments over Swamps and Compressible Soils). It is recommended that the fines content of the Granular ‘B’ Type II fill placed below the water be restricted to a maximum of 5 per cent passing the No. 200 sieve, to reduce the potential for segregation of fines during placement and to reduce the potential post-construction settlement and associated maintenance needs. Side slopes of the granular fill pad should be no steeper than 2H:1V.

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 bedding and levelling pad requirements for a pre-cast box culvert should be in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts). Given the potential for surface water flow and some groundwater seepage through the adjacent granular fill during excavation to the invert and bedding level, it is recommended that a minimum 300 mm thick layer of OPSS.PROV 1010 (Aggregates) Granular ‘B’ Type II material be used for bedding purposes. As the native soil below the bedding is generally 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 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 geometry similar to that provided on OPSS 803.010 (Backfill and Cover for Concrete Culverts) for culvert construction in dry conditions.

A frost taper should be constructed in a similar configuration as that shown in OPSS 803.010 (Backfill and Cover for Concrete Culverts). Although OPSS 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 9 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). The open footing culvert should be provided with at least 2.3 m soil cover for frost protection.

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 or engineered fill pad. The bedding layer and levelling pad for the pre-cast open footings should follow the recommendations as discussed above in Section 6.4.3.1 for the box culvert replacement option.

A frost taper should be constructed in a similar configuration as the shown in OPSD 803.010 (Backfill and Cover for Concrete Culverts). Although OPSD 803.010 also relates to an open footing culvert with spans less than or equal to 3.0 m, a similar frost taper at 10H:1V is considered acceptable for the assumed 9 m wide open footing culvert replacement option.

### **6.4.3.3 Pipe Culvert**

The bedding, levelling and backfill for a concrete pipe culvert or CSP culvert should be in accordance with OPSD 802.034 (Rigid Pipe Bedding and Cover in Embankment) or OPSD 802.014 (Flexible Pipe Embedment in Embankment), respectively, and culvert construction should be in accordance with OPSS 421 (Pipe Culvert Installation in Open Cut). It is important that the backfill at the haunches be well compacted. The pipe culvert should be constructed on a minimum 300 mm thick layer of OPSS.PROV 1010 Granular 'A' or Granular 'B' Type II material for bedding purposes.

A frost taper should be constructed with geometry similar to that provided on OPSD 803.031 (Frost Treatment) depending on final invert elevation and soil type within which the culvert is being constructed.

### **6.4.3.4 Backfill**

Backfill behind the culvert walls 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 granular backfill should be placed in maximum 200 mm thick loose lifts and be compacted to at least 98 per cent of the SPMDD of the materials 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 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 native clay subgrade will be susceptible to disturbance from construction traffic and/or ponded water. To limit the effect of this disturbance and as an alternative to the 300 mm compacted bedding layer, a concrete working slab should be placed on the subgrade if the box culvert or the concrete footings, are 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, if constructed of natural clay or soil bentonite mix. 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 organic soils, and possibly some of the native clay stratum to achieve the required invert/bedding level, prior to placement of bedding material, the actual culvert structure, backfill and roadway fill. Groundwater flow into the excavation can be expected due to the depth of the excavations and the presence of relatively permeable roadway 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, using one of both of the existing twin-cell CSP culverts or diverted by pumping from behind temporary cofferdams.

Excavations for all three culvert options will extend below the creek water level and groundwater level and will therefore require temporary shoring with dewatering to allow for construction/placement of the footings and/or placement of an engineered 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. As discussed in Section 6.4.2, backfill in areas of sub-excavation of organic materials and to achieve the base level for bedding can be placed subaqueously, however, dewatering may still be required for footing/box culvert placement as the culvert invert is 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 flow rate would be dependent on construction methods adopted by the contractor. However, it is considered that groundwater pumping volumes could exceed 50 m<sup>3</sup>/day during initial drawdown stages and/or during periods of heavy precipitation. For this pumping volume, a Permit to Take Water (PTTW) would be required.

#### **6.4.7 Analytical Testing for Construction Materials**

The results of an analytical test on a sample of river 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). If temporary shoring is required as part of the construction staging or if a grade raise and/or embankment widening is proposed, it is recommended that a supplemental investigation be carried out at the detail design stage to provide data for the roadway protection design and to determine the thickness of the cohesive deposit and strength properties below the borehole termination depths. 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, E.I.T. 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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**DRAFT PRELIMINARY FOUNDATION REPORT  
PETERSON CREEK CULVERT - SITE NO. 45-155/C**

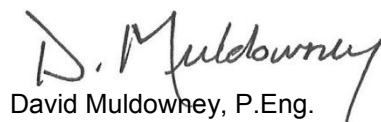
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## Report Signature Page


**GOLDER ASSOCIATES LTD.**



Adam Core, E.I.T.  
Geotechnical Engineering Intern



David Muldowney, P.Eng.  
Geotechnical Engineer



Jorge M.A. Costa, P.Eng.  
Designated MTO Contact, Principal

AC/DAM/JMAC/kp

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## 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, January 2006.

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

Ministry of Transportation, Ontario. Northern Region Directive. “Backfill to Structures Adjacent to Rock Embankment Approaches” dated November 2002.

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

ASTM International:

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

ASTM D1587 Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes

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

Ontario Provincial Standard Specifications (OPSS)

OPSS 421 Construction Specification for Pipe Sewer Installation in Open Cut

OPSS 422 Construction Specification for Precast 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 802.014 Flexible Pipe, Embedment in Embankment, Original Ground: Earth or Rock

OPSD 802.034 Rigid Pipe Bedding and Cover in Embankment, Original Ground: Earth or Rock



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## **DRAFT PRELIMINARY FOUNDATION REPORT PETERSON CREEK CULVERT - SITE NO. 45-155/C**

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OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m
OPSD 803.031	Frost Treatment – Pipe Culverts, Frost Penetration Line between Top of Pipe and Bedding Grade
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.100	Foundation Frost Penetration Depths for Northern Ontario

Ontario Water Resource Act:

Regulation 903	Wells (as amended)
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## DRAFT PRELIMINARY FOUNDATION REPORT PETERSON CREEK CULVERT - SITE NO. 45-155/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 619 STA 10+061 (Township of Tovell)	45-155/C	3.3	Twin SP CSP	2.4 m diameter (each)	20	329.5	329.8

- 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 E12736191.dwg).

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Checked by: DAM  
Reviewed by: JMAC



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PETERSON CREEK CULVERT - SITE NO. 45-155/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 (thin layer of peat along culvert alignment at this site), protection system (if required) and dewatering requirements compared to open footing option.</li> <li>Allows for faster construction resulting in shorter duration for dewatering and surface water pumping.</li> <li>More tolerant of total and differential settlement due to frost penetration into the subgrade soils and if the highway embankment is raised or widened at the culvert site, or remnants of the peat deposit are not fully removed.</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 typically 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 a relatively wide creek channel.</li> </ul>	<ul style="list-style-type: none"> <li>Some risk of disturbance of the native clay deposit during construction; can be mitigated with use of a tremie concrete working slab or Granular B Type II working pad.</li> <li>Lower risk related to settlement performance.</li> </ul>
Open Footing Culvert	<ul style="list-style-type: none"> <li>May be feasible to build 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>Existing twin culverts can be used for water diversion while new footings are being constructed adjacent to the culvert.</li> <li>Readily suitable for construction using concrete or metal sections.</li> <li>May be able to construct precast or metal culvert sections on a raised granular pad, however due to the clay subgrade settlement/heave would likely occur.</li> </ul>	<ul style="list-style-type: none"> <li>Excavation depths are greater than for a concrete box culvert option, resulting in increased excavation support and dewatering/unwatering requirements and additional spoil material to be disposed off-site.</li> <li>Excavation to below depth of frost penetration results in footings being founded in somewhat weaker zone of the clay stratum, resulting in lower bearing resistances.</li> <li>Constructing footings in the dry will take longer due to requirements for groundwater control system, dewatering and surface water pumping.</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 for ordinary construction.</li> <li>Open footing at higher elevation on clay subgrade requires insulation for frost protection.</li> <li>Open footing on a raised granular pad (at ground surface) would likely experience freeze/thaw (heave/settlement) cycles.</li> </ul>	<ul style="list-style-type: none"> <li>High risk of disturbance of the native 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>Risk of additional settlement for footings due to the smaller foundation footprint.</li> <li>Culvert joints may be required to accommodate total and differential settlement (if applicable).</li> </ul>



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Option	Advantages	Disadvantages	Risks/Consequences
Circular Pipe	<ul style="list-style-type: none"><li>■ Allows for 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.</li><li>■ Backfill 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>■ Reduced flow through capacity.</li><li>■ Cut-off wall or clay blanket may be required at inlet to mitigate potential scour under culvert.</li><li>■ CSP does not have as long of design life compared to concrete options.</li></ul>	<ul style="list-style-type: none"><li>■ Some risk of disturbance of the native clay deposit during construction; can be mitigated with use of a tremie concrete working slab or Granular B Type II working pad.</li><li>■ Limited risk related to settlement performance.</li></ul>



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PETERSON CREEK CULVERT - SITE NO. 45-155/C**

**Table 3: Geotechnical Axial Resistance and Reaction for Pre-Cast Box and Open Footing Culverts**

<b>Culvert Location (Township)</b>	<b>Approximate Invert Elevation <sup>1</sup> (West End / East End)</b>	<b>Culvert Type</b>	<b>Approximate Backfill/Bedding Founding Elevation</b>	<b>Founding Condition</b>	<b>Factored Geotechnical Axial Resistance at ULS <sup>2</sup></b>	<b>Geotechnical Reaction at SLS for 25 mm of Settlement <sup>2</sup></b>
Hwy 619 STA 10+061 (Township of Tovell)	329.8 m / 329.5 m	Pre-Cast Box <sup>2</sup>	329.1 m / 329.4 m	Bedding on Firm to Very Stiff Clay Stratum	100 kPa	75 kPa
		Open Footing <sup>2</sup>	327.2 m / 327.5 m	Firm to Very Stiff Clay Stratum	125 kPa	75 kPa
			329.1 m / 329.4 m	Bedding on Very Stiff over Firm Clay Stratum	150 kPa	100 kPa
		Pipe Culvert	329.0 m / 329.3 m <sup>3</sup>	Firm to Very Stiff Clay Stratum	N/A	N/A

Notes: 1. Culvert invert elevations are based on the profile drawings provided by MTO (Drawing E12736191.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 9.0 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 foundation elevation may need to be adjusted based on the size the pipe culvert and required bedding thickness.

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Reviewed by: JMAC



## DRAFT PRELIMINARY FOUNDATION REPORT PETERSON CREEK CULVERT - SITE NO. 45-155/C

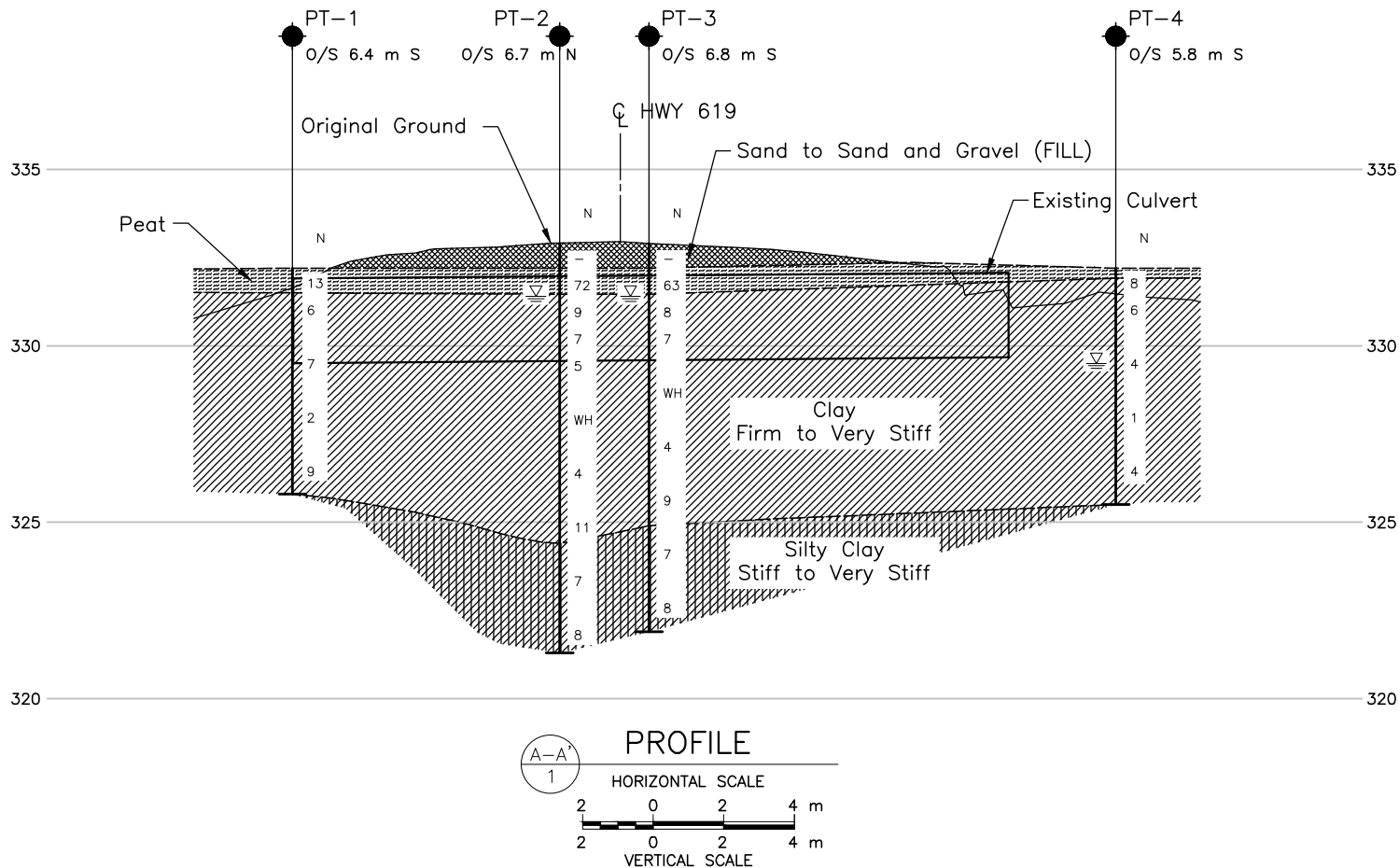
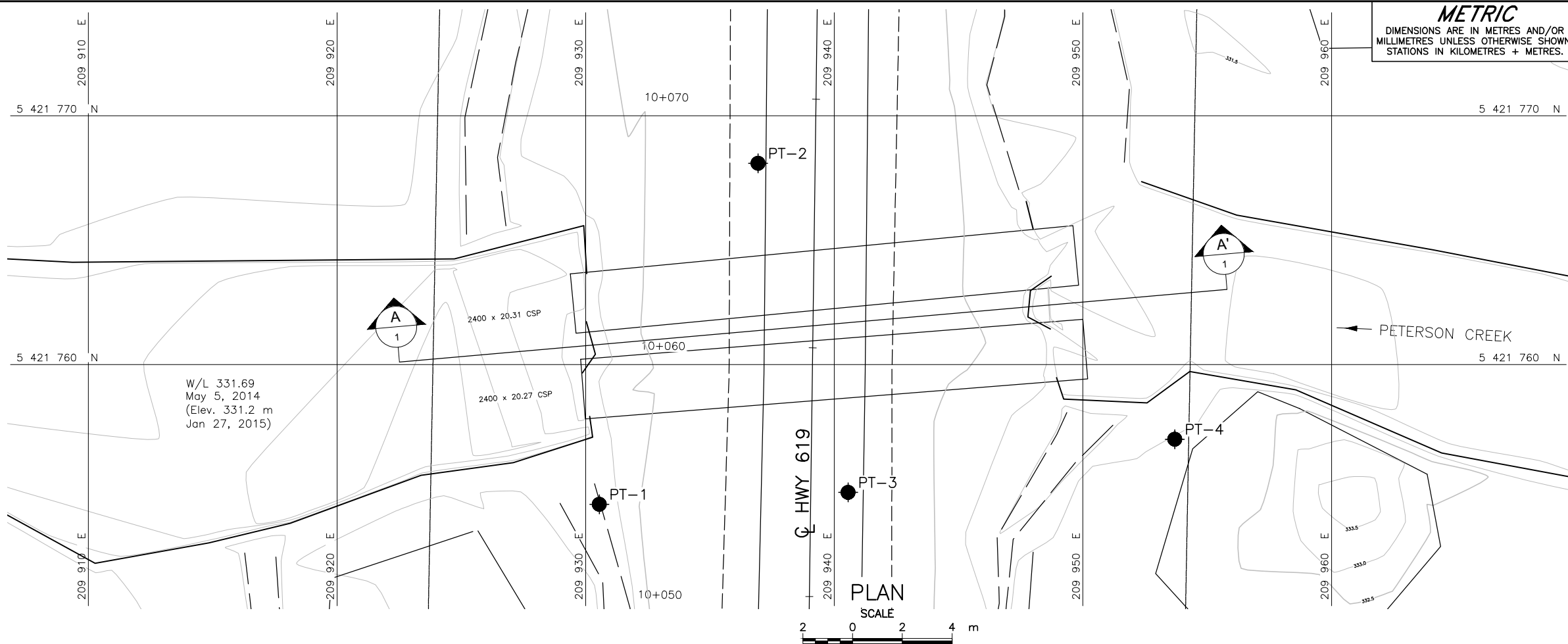
**Table 4: Resistance to Lateral Loads/Sliding Resistance for Pre-Cast Box and Open Footing Culvert Replacements**

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 619 STA 10+061 (Township of Tovell)	Compacted Granular Fill (Backfill/Levelling Pad)	0.45	Firm to Very Stiff Clay Stratum	0.30

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

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Reviewed by: JMAC





CONT No. GWP No. 6328-14-00

HIGHWAY 619  
PETERSON CREEK CULVERTS STA 10+061  
BOREHOLE LOCATIONS AND SOIL STRATA

DISTRICT OF RAINY RIVER  
TOWNSHIP OF TOVELL  
TOWNSHIP OF SUTHERLAND  
KEY PLAN  
1:50,000 m  
0 1 2 km

LEGEND  
● Borehole  
N Standard Penetration Test Value  
16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)  
▽ WL upon completion of drilling

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
PT-1	332.2	5421754.4	209930.5
PT-2	332.9	5421768.1	209936.9
PT-3	332.9	5421754.9	209940.6
PT-4	332.2	5421757.0	209953.7

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. E12736191, received FEB 15, 2015.

DRAFT

NO.	DATE	BY	REVISION

Geocres No.,

HWY. 619  
SUBM'D. AC

PROJECT NO. 1411523  
CHKD. DAM  
DATE: 4/24/2015  
APPD. JMAC

DIST. ,  
SITE: 45-155/C  
DWG. 1



## PHOTOGRAPHS

**Photograph 1: Peterson Creek Culvert  
East End – Inlet (Taken from MTO OSIM\_12\_03\_2013)**



**Photograph 2: Peterson Creek Culvert  
West End – Outlet (Taken from MTO OSIM\_12\_03\_2013)**







## PHOTOGRAPHS

**Photograph 3: Peterson Creek Culvert  
East End - Inlet (Golder – March 18, 2015)**



**Photograph 4: Peterson Creek Culvert  
West End - Outlet (Golder – January 27, 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

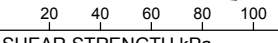


### IV. SOIL TESTS

w	water content
w <sub>p</sub>	plastic limit
w <sub>l</sub>	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 <sub>R</sub>	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 <sub>4</sub>	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 PT-1</b>				1 OF 1 <b>METRIC</b>					
G.W.P. 6328-14-00		LOCATION N 5421754.4; E 209930.5				ORIGINATED BY MR					
DIST _____ HWY 619		BOREHOLE TYPE 108 mm I. D. Continuous Flight Hollow Stem Augers				COMPILED BY AC					
DATUM GEODETIC		DATE February 21, 2015				CHECKED BY DAM					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT  SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED	PLASTIC LIMIT W <sub>p</sub> NATURAL MOISTURE CONTENT W LIQUID LIMIT W <sub>L</sub> WATER CONTENT (%)	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						
332.2	GROUND SURFACE										
0.0	Sandy Fibrous PEAT, some silt Dark brown Frozen		1	SS	13		332				
331.5											
0.7	CLAY, trace to some sand, trace organics Firm to very stiff Brown to grey Frozen* to wet		2	SS	6*		331				
							330				
			3	SS	7						
							329				
			4	SS	2		328				
							327				
	Sand laminations below 5.3 m depth.		5	SS	9						
							326				
325.8											
6.4	END OF BOREHOLE										
	Note:  1. Borehole dry upon completion of drilling.  2. Advanced additional borehole 1.0 m south of Borehole PT-1 and retrieved a Shelby Tube sample at 4.1 m depth and additional field vanes were obtained at 4.9 m and 5.2 m depth ( <i>Italics</i> ).										

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 28/04/15 DATA INPUT:

PROJECT 1411523		<b>RECORD OF BOREHOLE No PT-2</b>				1 OF 1 <b>METRIC</b>								
G.W.P. 6328-14-00		LOCATION N 5421768.1; E 209936.9				ORIGINATED BY MR								
DIST _____ HWY 619		BOREHOLE TYPE 108 mm I. D. Continuous Flight Hollow Stem Augers				COMPILED BY AC								
DATUM GEODETIC		DATE January 27, 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						
332.9	GROUND SURFACE							20 40 60 80 100	20 40 60					
0.0	Sand and gravel (FILL) Brown Frozen		1	AS	-									
332.2														
0.7	Silty Fibrous PEAT Dark brown Frozen*		2	SS	72*									
331.5														
1.4	CLAY, trace sand, trace organics near surface Firm to very stiff Grey Frozen* to wet		3	SS	9*									
			4	SS	7									
			5	SS	5									
			6	SS	WH									
			7	SS	4									
			8	SS	11									
324.4														
8.5	Sandy SILTY CLAY, trace to some gravel Very stiff Grey Wet		9	SS	7									
			10	SS	8									
321.3														
11.6	END OF BOREHOLE													
	Note:  1. Water level at a depth of 1.5 m below ground surface (Elev. 331.4 m) upon completion of drilling.													

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 28/04/15 DATA INPUT:



PROJECT 1411523		<b>RECORD OF BOREHOLE No PT-3</b>				1 OF 1 <b>METRIC</b>						
G.W.P. 6328-14-00		LOCATION N 5421754.9; E 209940.6				ORIGINATED BY MR						
DIST _____ HWY 619		BOREHOLE TYPE 108 mm I. D. Continuous Flight Hollow Stem Augers				COMPILED BY AC						
DATUM GEODETIC		DATE January 27, 2015				CHECKED BY DAM						
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT $\gamma$	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	W <sub>p</sub> W W <sub>L</sub>			20 40 60
332.9	GROUND SURFACE											
0.0	Sand, some gravel (FILL) Brown Frozen		1	AS	-							
332.2												
0.7	Silty Fibrous PEAT, trace sand, trace wood Dark brown Frozen		2	SS	63*		332					
331.5												
1.4	CLAY Firm to very stiff Brown to grey Frozen* to wet  Sand laminations throughout.		3	SS	8*		331					
			4	SS	7		330					
			5	SS	WH		329					
			6	SS	4		328					
			7	SS	9		327					
			8	SS	7		326					
324.9							325					
8.0	SILTY CLAY, trace gravel Stiff to very stiff Grey Wet		8	SS	7							
			9	SS	8		324					
							323					
321.9							322					
11.0	END OF BOREHOLE											
	Note: 1. Water level at a depth of 1.5 m below ground surface (Elev. 331.4 m) upon completion of drilling.											

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 28/04/15 DATA INPUT:

PROJECT 1411523				<b>RECORD OF BOREHOLE No PT-4</b>				1 OF 1 <b>METRIC</b>					
G.W.P. 6328-14-00				LOCATION N 5421757.0; E 209953.7				ORIGINATED BY MR					
DIST _____ HWY 619				BOREHOLE TYPE 108 mm I. D. Continuous Flight Hollow Stem Augers				COMPILED BY AC					
DATUM GEODETIC				DATE March 18, 2015				CHECKED BY DAM					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>p</sub> W W <sub>L</sub>			
332.2	GROUND SURFACE												
0.0	Silty Fibrous PEAT		1A	SS	8*								
0.2	Black Frozen		1B	SS									
	CLAY, trace sand												
	Silt to very stiff		2	SS	6								
	Grey to brown												
	Frozen* to wet												
	Sand laminations between 0.8 m and 2.3 m depth.												
			3	SS	4								
			4	SS	1								
			5A										
			5B	SS	4								
325.5	END OF BOREHOLE												
6.7	Notes:												
	1. Water level at a depth of 2.7 m below ground surface (Elev. 329.5 m) upon completion of drilling.												
	2. Advanced additional borehole 0.7 m north of Borehole PT-4 and retrieved a Shelby Tube sample at 4.2 m depth and additional field vanes were obtained at 4.9 m and 5.2 m depth (Italics).												



# **APPENDIX B**

## **Laboratory Test Results**



## DRAFT PRELIMINARY FOUNDATION REPORT PETERSON CREEK CULVERT - SITE NO. 45-155/C

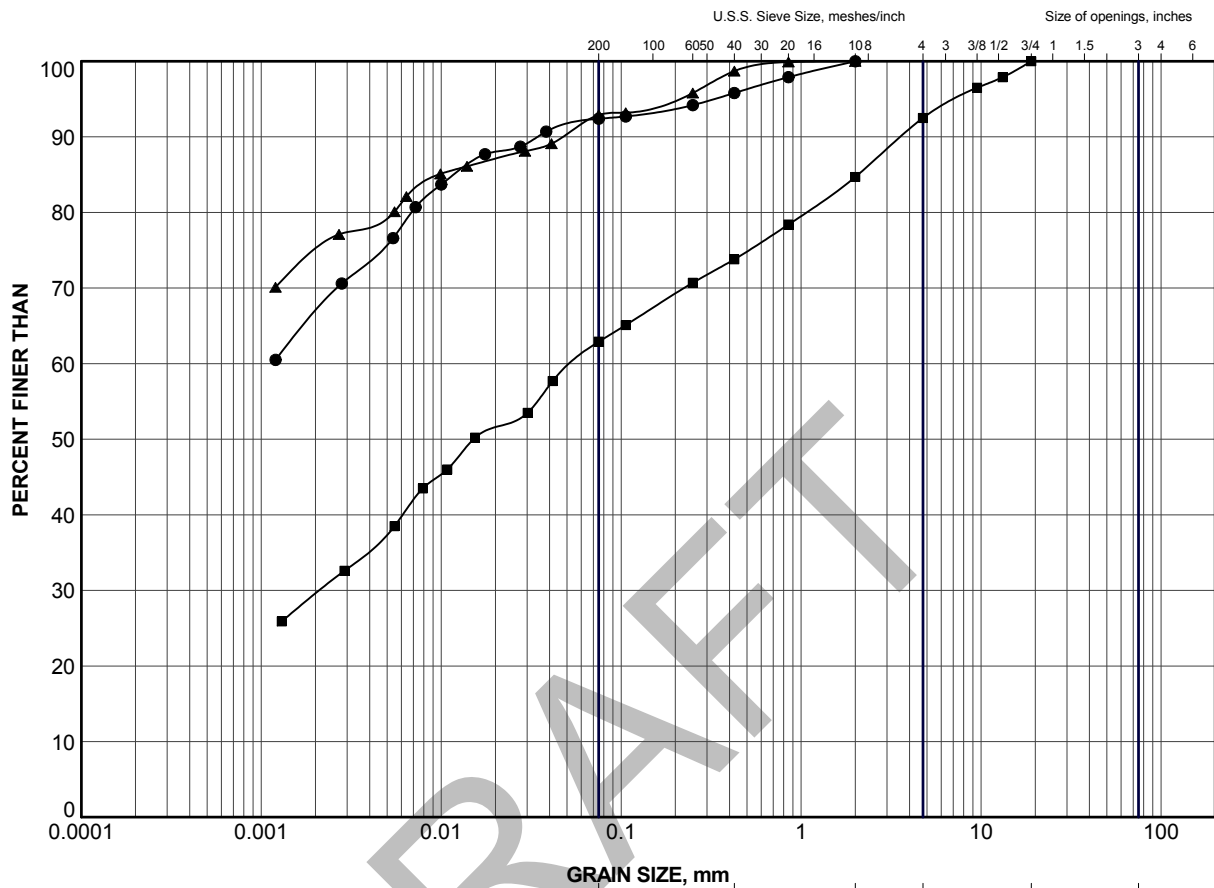
**Table B1: Summary of Analytical Testing of Peterson Creek Water Sample**

Parameter	Units	Result
Chloride (CL)	mg/L	4.81
Sulphate (SO4)	mg/L	1.37
Conductivity (EC)	µS/cm	499
Resistivity	µohm-cm	<0.33
pH	n/a	7.51

Notes:

1. Sample obtained on January 28, 2015.
2. Analytical testing carried out by ALS Canada Ltd.

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



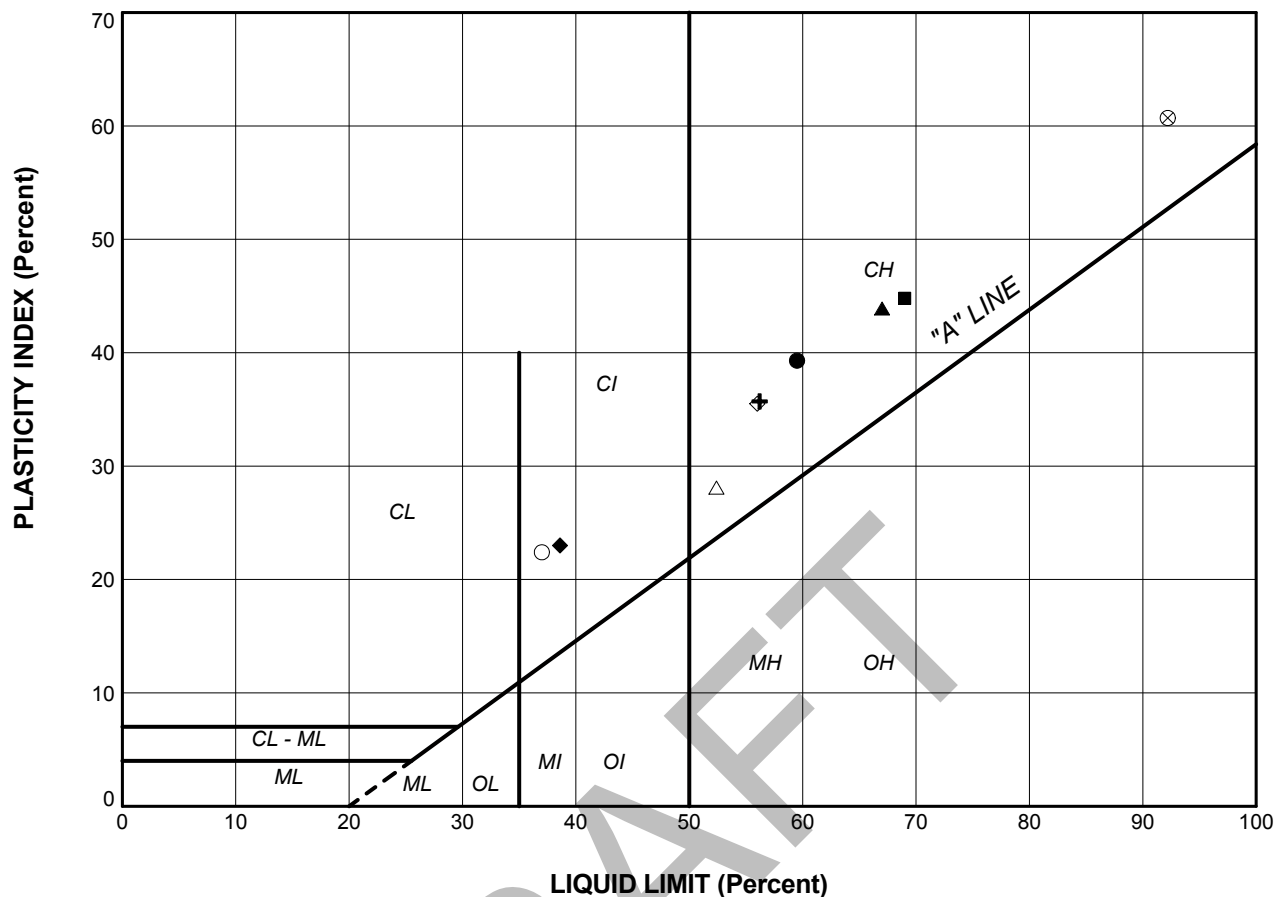
CLAY AND SILT	SAND SIZE, mm			GRAVEL SIZE, mm		Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	PT-1	5	326.6
■	PT-2	9	323.5
▲	PT-4	5B	326.5


PROJECT					
HIGHWAY 619 PETERSON CREEK CULVERT STA 10+061					
TITLE					
GRAIN SIZE DISTRIBUTION SANDY SILTY CLAY to CLAY					
PROJECT No.		1411523		FILE No. 1411523.GPJ	
DRAWN	JJL	Apr 2015	SCALE	N/A	REV.
CHECK	DAM	Apr 2015			
APPR	JMAC	Apr 2015			
			FIGURE B1		





### LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	PT-1	3	59.5	20.2	39.3
■	PT-1	5	69.0	24.2	44.8
▲	PT-2	5	67.0	23.1	43.9
+	PT-2	8	56.2	20.5	35.7
◆	PT-2	9	38.6	15.6	23.0
◇	PT-3	4	56.0	20.5	35.5
○	PT-3	8	37.0	14.6	22.4
△	PT-4	1B	52.4	24.3	28.1
⊗	PT-4	5B	92.2	31.5	60.7

PROJECT					
HIGHWAY 619 PETERSON CREEK CULVERT STA 10+061					
TITLE					
PLASTICITY CHART SILTY CLAY to CLAY					
PROJECT No.		1411523		FILE No.	
DRAWN		JJL		Apr 2015	
CHECK		DAM		Apr 2015	
APPR		JMAC		Apr 2015	
SCALE		N/A		REV.	
 <b>Golder Associates</b> SUDBURY, ONTARIO		<b>FIGURE B2</b>			

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

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Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 44 1628 851851
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

[solutions@golder.com](mailto:solutions@golder.com)  
[www.golder.com](http://www.golder.com)

**Golder Associates Ltd.**  
**1010 Lorne Street**  
**Sudbury, Ontario, P3C 4R9**  
**Canada**  
**T: +1 (705) 524 6861**

