

# **Foundation Investigation and Design Report, (GWP 6327-14-00) Replacement of Peterson Creek Culvert, Highway 619 Near Rainy River, Northwest Region Site No. 45-155C**

Assignment 3014-E-0025  
Geocres No.: 52D-27

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PETERSON CREEK CULVERT, HIGHWAY 619 NEAR RAINY RIVER, NORTHWEST REGION SITE  
NO. 45-155C

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# PART A

FOUNDATION INVESTIGATION REPORT  
REPLACEMENT OF Peterson CREEK CULVERT  
HIGHWAY 619 NEAR RAINY RIVER  
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## 1.0 Introduction

The Ministry of Transportation Ontario (MTO) retained Stantec Consulting Ltd. (Stantec) to complete the Detail Design and Class Environmental Assessment (Class EA) for the rehabilitation or reconstruction of 17 structures on Highway 11, 17, 61, 599, 619 and 621 in Northwestern Ontario, under a number of separate group work projects (GWPs) and contracts. The Stantec team is supplemented by Amec Foster Wheeler Americas Limited, operating as Amec Foster Wheeler Environment & Infrastructure (Amec Foster Wheeler) in this assignment.

This report addresses the results of the subsurface investigation carried out by Amec Foster Wheeler on behalf of Stantec for the proposed replacement of the existing Peterson Creek Culvert, Site Number 45-155C on Highway 619.

The terms of reference and scope of work for the foundation engineering services are outlined in MTO's Request for Proposal (RFP) and associated Addendum and clarification responses for Assignment No. 3014-E-0025 and in Section 17.8 of the *Technical and Financial Proposal* for this assignment.

## 2.0 Site Description

The existing culvert is located on Highway 619 approximately 1.7 km south of the Highway 600 within the township of Tovell in the District of Rainy River, Ontario.

The existing crossing consist of two Steel Plate Corrugated Steel Pipe Arch (SP CSPA) culverts each of them about 20 m long with a diameter of about 2.4 m.

In general, the terrain in this area is relatively flat low-lying, with swampy terrain consisting of open water, long shrubs and grassy areas outside of the highway right-of-way.

Highway 619 in the vicinity of the project site runs in a north-south direction and the existing culvert is oriented in the west-east direction at a skew angle of about 85°. The highway grade in the area is at about Elevation 332.9 m, the culvert invert at the upstream (east) end is at about Elevation 329.8 m and the culvert invert at the downstream (west) end is at about Elevation 329.5 m. Therefore, the embankment heights at the east and west sides of the culvert are about 3.1 m and 3.4 m, respectively. The creek water elevation was at about Elevation 331.7 m as reported by others.



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## 3.0 Investigation Procedure

### 3.1 PREVIOUS INVESTIGATIONS

A borehole investigation was completed at this structure site in January, February and March 2015 by Golder Associates Ltd. (Golder), as presented in a report titled "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" and dated September 8, 2015. Upon receipt of the Preliminary Foundation Investigation and Design Report (FIDR) Amec Foster Wheeler reviewed the subsurface information presented in the Preliminary FIDR, and the proposed geotechnical field program for the detail design. Following discussions with MTO Foundations, it was mutually agreed that the geotechnical field program completed for the preliminary design met the Terms of Reference for the detail design and no supplementary field investigation was required to complete the Final FIDR for detail design.

Four boreholes (referenced as Boreholes PT-1 to PT-4, herein) were drilled at the site as part of the 2015 investigation as shown on Drawing 1. Boreholes PT-1 and PT-4 were advanced at the toe of the slope near the culvert outlet and inlet and Boreholes PT-2 and PT-3 were advanced from the existing highway platform.

All boreholes were advanced using a CME drilling rig and 108 mm inside diameter hollow stem augers. 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).

Index and classification testing consisting of water 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 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:

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Borehole Designation	Location (MTM NAD83 Zone 15)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m)	Easting (m)		
PT-1	5,421,754.4	209,930.5	332.2	6.4
PT-2	5,421,768.1	209,936.9	332.9	11.6
PT-3	5,421,754.9	209,940.6	332.9	11.0
PT-4	5,421,757.0	209,953.7	332.2	6.7

## 4.0 Geological and Subsurface Conditions

### 4.1 SITE GEOLOGY

The Northern Ontario Engineering Geology Terrain Study (NOEGTS) Map 52DNE indicates that the surficial soil in the vicinity of the culvert consists of glaciolacustrine deposits of silt and clay. The geological mapping by the Ministry of Northern Development and Mines (MNDM) Map 2542 indicates that the surficial soil is underlain by bedrock of Archean Era, comprised of foliated tonalite suite consisting of tonalite to granodiorite.

### 4.2 SUBSURFACE CONDITIONS

All four (4) boreholes were advanced in the vicinity of the existing culverts as part of the 2015 investigation.

The approximate borehole locations, ground surface elevations and interpreted stratigraphic conditions based on the investigation at the site are presented on Drawing 1 and are included in Appendix A. The results of geotechnical laboratory testing from the investigation are presented in Appendix B.

In general the subsurface conditions at site consist of granular fill, only encountered at the location of Boreholes PT-2 and PT-3 which were advanced through the highway embankment, and silty peat, underlain by a firm to very stiff silty clay to clay which extended to the borehole termination depths.

#### 4.2.1 Fill

Sand and gravel fill was encountered at the ground surface in Boreholes PT-2 and PT-3 and extended to a depth of 0.7 m (Elevation 332.2 m) in both boreholes.

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## 4.2.2 Silty Peat

Sandy or silty fibrous peat was encountered at the ground surface in Boreholes PT-1 and PT-4 and below the fill in Boreholes PT-2 and PT-3 and extended to a depth of 0.2 m to 1.4 m (Elevations 333.2 m and 332.8 m, respectively).

The SPT 'N' values within the silty peat were between 8 blows and 72 blows per 0.3 m of penetration. It should be noted that the peat was frozen at the time of the investigation and the SPT N values are not representative of its compactness state.

## 4.2.3 Clay

A deposit of brown to grey clay containing laminations and bedded layers of sand was encountered below the peat in all boreholes and extended to the borehole termination depths of 6.4 m and 6.7 m (Elevations 325.8 m and 325.5 m) in Boreholes PT-1 and PT-4 and to depths of 8.5 m and 8.0 m (Elevations 324.4 m and 324.9 m) in Boreholes PT-2 and PT-3, respectively.

The SPT 'N' values within the deposit range from 0 blows (i.e., 0.3 m of penetration under static weight of hammer) to 11 blows per 0.3 m of penetration. In situ vane testing was conducted in this deposit and the measured undrained shear strengths were from 34 kPa to greater than 100 kPa indicating that the clay has a firm to very stiff consistency. The in-situ sensitivity values based on the ratio of undisturbed and remolded shear vane strengths range between 1 and 3, predominantly 2.

The results of the grain size distribution tests conducted on selected samples of the silty clay to clay are presented on the borehole records in Appendix A, and in Appendix B, and are summarized as follows:

Gravel	0 %
Sand	7 % and 8 %
Silt	18 % and 25 %
Clay size fines	75 % and 67 %

Atterberg limits testing carried out on selected samples of the clay measured plastic limits of 20 % to 32 % and liquid limits of 51 % to 92 % suggesting a clay of high plasticity (CH). The test results are plotted on a plasticity chart in Appendix B.

## 4.2.4 Silty Clay

A deposit of grey sandy silty clay to silty clay containing trace to some gravel was encountered below the clay in Boreholes PT-2 and PT-3 and extended to the borehole termination depths of 11.6 m and 11.0 m (Elevations 321.3 m and 321.9 m), respectively.





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The SPT 'N' values within the deposit were 7 blows and 8 blows per 0.3 m of penetration. In situ vane testing was conducted in this deposit and the measured undrained shear strengths were from 77 kPa to greater than 100 kPa indicating that the silty clay has a stiff to very stiff consistency. The in-situ sensitivity values based on the ratio of undisturbed and remolded shear vane strengths was 2.

The results of the grain size distribution tests conducted on a selected sample of the silty clay are presented on the borehole records in Appendix A, and in Appendix B, and are summarized as follows:

Gravel	8 %
Sand	29 %
Silt	34 %
Clay size fines	29 %

Atterberg limits testing carried out on two selected samples of the silty clay measured plastic limits of 15 % and 16 % and liquid limits of 37 % and 39 % suggesting a silty clay of intermediate plasticity (CI). The test results are plotted on a plasticity chart in Appendix B.

## 4.3 GROUNDWATER CONDITIONS

Borehole PT-1 was reported dry upon completion of drilling. Groundwater was encountered in the open boreholes upon completion of drilling at Boreholes PT-2 to PT-4 and are summarized below:

Borehole Designation	Depth to Groundwater (m)	Groundwater Elevation (m)
PT-2	1.5	331.4
PT-3	1.5	331.4
PT-4	2.7	329.5

The creek ice level was reported to be at about Elevation 331.2 m on January 27, 2015.

The groundwater, and creek water and creek ice levels should also be expected to fluctuate seasonally and should be expected to rise during wet periods of the year.

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## 5.0 Closure

This Foundation Investigation Report was prepared by Mr. Mehdi Mostakhdemi, M.Sc., P.Eng., a geotechnical engineer at Amec Foster Wheeler. Mr. Ty Garde, M.Eng., P.Eng., a Designated Foundation Contact for Amec Foster Wheeler, conducted an independent review of the report.

Sincerely,

**Amec Foster Wheeler Environment & Infrastructure**  
**a Division of Amec Foster Wheeler Americas Limited**

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# PART B

FOUNDATION DESIGN REPORT  
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## 6.0 Discussion and Engineering Recommendations

### 6.1 GENERAL

This section of the report provides foundation design recommendations for the proposed replacement of the Peterson Creek culvert located on Highway 619 within the township of Tovell in the District of Rainy River, Ontario. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the preliminary subsurface investigation at this site. The discussion and recommendations presented are intended to provide the designers with sufficient information to assess foundation alternatives and to carry out the design of the structure foundations. Where comments are made on construction, they are provided to highlight those aspects that could affect the 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.

### 6.2 FOUNDATIONS FOR CULVERT REPLACEMENT

The existing Peterson Creek twin culvert consists of two Steel Plate Corrugated Steel Pipe Arch (SP CSPA) culverts each of them about 20 m long with a diameter of about 2.4 m. The highway grade in the area is at about Elevation 332.9 m, the culvert invert at the upstream (east) is at about Elevation 329.8 m and the culvert invert at the downstream (west) is at about Elevation 329.5 m. Therefore, the embankment heights at the east and west sides of the culvert are about 3.1 m and 3.4 m, respectively.

Based on the subsurface conditions at this site, pipe culvert, open footing culvert and box culvert options have been considered for the proposed replacement of the existing culverts at the site. A summary of the advantages and disadvantages associated with each option is provided below, and a comparison of the alternative foundation options based on advantages, disadvantages, risks and relative costs is provided in Table 1 following the text of this report.

- **Pipe Culvert:** Pipe culverts are feasible for the replacement culvert but would provide less flow through capacity compared to other alternatives. SP CSPA culverts similar to the existing culverts at the site also provide shorter design life compare to concrete pipes.
- **Open Footing Culvert:** Open footing culverts are feasible for the replacement culvert but would provide less flow through capacity compared to box culverts. Therefore, deeper excavation would be required for this option would compared to box culverts, which would result in increased excavation support requirements as well as increased volume of soil disposal.



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- **Box Culvert:** Precast Concrete Box culverts would be the most feasible option due to their relatively high flow-through capacity, reduced depth of excavation and reduced spoil disposal volume, as well as reduced volume of dewatering (groundwater control) to be conducted during construction. Precast box culverts segments are more tolerant of differential settlement if the highway embankment is widened in the future.

Based on the above considerations, the preferred option from a geotechnical/foundations perspective is to replace the existing culverts with precast concrete box culverts.

Based on the General Arrangement drawing for the replacement culverts, it is understood that the new twin culverts will be constructed at the same location of the existing culverts. The new creek bed will be at about Elevation 328.5 m across the length of the culvert. The proposed culverts will be approximately 4.2 m (outside wall to outside wall) wide each and 24.4 m long. It is also understood that the highway grades in the vicinity of the culverts will remain un-changed.

In considering the height and weight of the existing fill on site, the available information indicates that the stress level within the clay deposit is at or near its pre-consolidation pressure (i.e., the deposit is normally consolidated or slightly over consolidated). Therefore, any increase in the stress above the existing value can be expected to result in significant settlements.

The General Arrangement drawing indicates that the preferred option is to replace the existing culverts with twin precast concrete box culverts. Either open footing concrete culverts or box culvert structures are considered feasible for the replacement of the existing culvert. Recommendations for both options are provided in the following sections of this report.

## 6.2.1 Open Footing Culvert

Strip footings for an open footing culvert replacement, and for any associated concrete wing walls/retaining walls, 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 Ontario Provincial Standard Drawing (OPSD) 3090.100 (Foundation Frost Depths for Northern Ontario). In addition, the footings should extend below any existing fill and surficial organic materials, where present, as these materials are not considered to be competent to support the foundations. Considering the creek bed will have a minimum elevation of 329.7 m, strip footings would be required to be founded at or below Elevation of 327.4 m. The 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 clay deposit to the frost depth is carried out, the footings may still be subject to frost heaving because 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 north and south sides). Further, if the fill material is placed subaqueously (i.e., below the water level), the footings/culvert may be



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subject to additional settlement if adequate compaction of the engineered fill, where required is not achieved.

Based on the borehole information strip footings at Elevation 327.4 m will be founded in the firm to very stiff clay. For 0.6 m wide to 1.2 m wide strip footings placed on properly prepared subgrade, at the approximate founding elevation of 327.4 m, a factored geotechnical resistance (assuming an ultimate geotechnical resistance factor of 0.5 for a typical degree of understanding) at Ultimate Limit States (ULS) of 150 kPa may be used in the design. A factored geotechnical resistance (assuming a serviceability geotechnical resistance factor of 0.8 for a typical degree of understanding) at Serviceability Limit States (SLS) of 120 kPa may be used in the design.

The ULS resistance and settlement are dependent on the footing size, configuration and applied loads; the geotechnical resistances/reactions should, therefore, be reviewed if the selected footing width or founding elevation differs significantly from those given above. The geotechnical resistances/reactions provided above are given under the assumption that the loads will be applied perpendicular to the surface of the footings. Where the load is not applied perpendicular to the surface of the footing, inclination of the load should be taken into account in accordance with Section 6.10.4 of the Canadian Highway Bridge Design Code (CHBDC) 2014.

The footing subgrade should be cleaned of any loosened / softened material and inspected by qualified geotechnical personnel, to check that all existing fill and surficial organic soils or other unsuitable materials have been removed and to confirm the adequacy of the foundation conditions for the design geotechnical resistance.

## 6.2.2 Box Culvert

Rigid box structures can tolerate small magnitudes of movements (settlement and heave) related to the freeze-thaw actions and therefore, box culverts could be founded above the frost penetration depth. However, box culverts should be founded below any existing fill and surficial organic materials as they typically undergo larger amounts of settlements. In addition, box culverts should be provided with at least 200 mm of OPSS 1010.PROV Granular A or Granular B Type II material for bedding purposes, as discussed in Section 6.2.4.

The factored geotechnical resistance at Ultimate Limit States (ULS) for the culverts will be controlled by both the combined strength of the granular bedding, where present, and the native clay. Based on the borehole data, and assuming a bearing width of 8.4 m, the factored ULS resistance may be taken as 165 kPa (assuming an ultimate geotechnical resistance factor of 0.5 for a typical degree of understanding) for box culverts placed at about Elevation 328.5 m.

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The ULS resistance and settlement are dependent on the footing size, configuration and applied loads; the geotechnical resistances should, therefore, be reviewed if the founding elevation differs significantly from that given above. The geotechnical resistances/reactions provided above are based on loading applied perpendicular to the surface of the footings. Where the load is not applied perpendicular to the surface of the footing, inclination of the load should be taken into account in accordance with Section 6.10.4 of the CHBDC 2014.

It is understood that the existing CSP Arch culvert is to be replaced with a Precast Box Culvert at the same location. It is also understood that the highway grade will remain at the same elevation and that no embankment widening will take place at the culvert site. It is assumed that any existing fills present below the existing CSP culvert will be removed to native subgrade and replaced with engineered fill according to section 6.2.4. A factored geotechnical resistance (assuming a serviceability geotechnical resistance factor of 0.8 for a typical degree of understanding) at Serviceability Limit States (SLS) of 120 kPa may be used in the design.

The subgrade should be cleaned of loose / softened material and inspected by qualified geotechnical personnel, to check that all existing fill or other unsuitable materials have been removed and to confirm the adequacy of the foundation conditions for the design geotechnical resistance.

## 6.2.3 Resistance to Lateral Loads / Sliding Resistance

Resistance to lateral forces / sliding resistance between the base slab or concrete footings for the proposed culvert and the subgrade should be calculated in accordance with Section 6.10.5 of the CHBDC. A coefficient of friction ( $\tan \delta$ ) of 0.45 may be used in the sliding assessment between pre-cast concrete box culverts founded on compacted granular fill (bedding). For cast-in-place concrete footings on the residual soil (clay) a coefficient of friction ( $\tan \phi'$ ) of 0.3 may be used in the sliding assessment. The above coefficient of frictions are un-factored and a resistance factor of 0.8 should be applied in accordance with Table 6.2 of CHBDC 2014 based on the available subsurface conditions.

The factored horizontal geotechnical resistance,  $H_{ri}$  or  $H_{rs}$ , as follows:

$$H_{ri} = \psi \phi_{gu} (0.8A'c' + 0.8V \tan \delta) > H_f \text{ (for box culverts)}$$

$$H_{rs} = \psi \phi_{gu} (0.8A'c' + 0.8V \tan \phi') > H_f \text{ (for open footing culverts)}$$

Where:

$A'$  Effective contact area ( $m^2$ )

$C'$  Nil

$\tan \delta$  Coefficient of friction for interface between box culvert base and bedding/leveling pas



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$\tan \phi'$	Coefficient of internal friction for soil close to the underside of the spread/strip footing
V	Unfactored vertical force (kN)
H <sub>f</sub>	Unfactored horizontal load (kN)
$\psi$	Consequence factor (1.0)
$\phi_{gu}$	Geotechnical resistance factor (0.8)

## 6.2.4 Culvert Bedding and Backfill

For the box culvert option, the bedding levelling pad and backfill requirements should be in accordance with OPSS 422 (Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut) for pre-cast rigid frame culverts. Box culverts should be provided with at least 300 mm of OPSS 1010.PROV Granular A or Granular B Type II material for bedding purposes, or alternatively a 100 mm thick concrete working slab with 75 mm of bedding material.

Due to the fine grained nature of the subsurface soil below the bedding, a nonwoven geotextile should be placed between the native soil and 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  $\mu\text{m}$ . The bedding should be placed in maximum 200 mm thick loose lifts and compacted to at least 98 per cent of the standard Proctor maximum dry density (SPMDD) as specified in OPSS.PROV 501 (Compacting).

Backfill and cover for concrete box culverts should be completed in accordance with the manufacturer's recommendations or in general accordance with OPSD 803.010 (Backfill and Cover for Concrete Culverts), provided the box culverts are design to meet these conditions. Backfill to culvert walls should consist of granular fill meeting the requirements of OPSS.PROV 1010 Granular A or Granular B Type II, but with less than 5 per cent passing the No. 200 sieve. The backfill and bedding should be placed and compacted in accordance with OPSS.PROV 501 (Compacting). The fill depth during placement should be maintained equal on both sides of the culvert walls, with one side not exceeding the other by more than 500 mm. The box culvert should be designed for the full overburden and hydrostatic pressures, and live load, assuming that the embankment fill has a unit weight of 22 kN/m<sup>3</sup> for Granular A, and 21 kN/m<sup>3</sup> for Granular B Type II or select earth fill above and/or surrounding the culvert.

The culvert backfill and cover should be placed in maximum 300 mm thick loose lifts and compacted to at least 98 per cent of the standard Proctor maximum dry density (SPMDD) as specified in OPSS.PROV 501 (Compacting).



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Where the top of culvert extends above the frost penetration depth, a frost taper should be constructed similar to the configuration presented in OPSD 803.010 (Backfill and Cover for Concrete Culverts).

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.

## 6.2.5 Erosion Protection

Provision should be made for scour and erosion protection. 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 and downstream 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 extend from a depth of 1 m below the scour level to a minimum horizontal distance of 2 m on either side of the culvert inlet opening, and a minimum vertical height equivalent to the high water level including along the embankment slope.

If the creek flow velocities are sufficiently high, provision should be made for scour and erosion protection (suitable non-woven geotextiles and/or rip-rap) at the culvert inlet and outlet adjacent to the creek channel and to prevent undermining of the shallow foundations. The requirements for and design of erosion protection measures for the culvert should be provided by the hydraulic design engineer. As a minimum, rip-rap at the inlet, outlet and along the length of the culvert (for open footing culvert) should be provided. Erosion protection at the areas where the existing storm pipe(s) enter the culvert should also be provided.

Above the high water level placement of topsoil and seeding or pegged sod is recommended as soon as practicable after construction of the embankments in order to reduce the potential for erosion of the side slopes, due to surface water runoff. The erosion protection should be in accordance with OPSS 804 (Seed and Cover). Below the high water level rip-rap should be provided to control surface erosion.

## 6.3 SEISMIC CONSIDERATIONS

The CHBDC 2014 contains updated seismic analysis and design methodology. The CHBDC 2014 method uses a site classification system defined by the average soil/bedrock properties (e.g. shear wave velocity, Standard Penetration Test (SPT) resistance, undrained soil shear strength etc.) in the top 30 metres below the foundation level. There are 6 site classes from A to F, decreasing in ground stiffness from A, hard rock, to E, soft soil; with site class F used to denote other soils (e.g., sites underlain by thick peat deposits, high plastic clays, liquefiable soils, etc.).



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The site class is then used to obtain acceleration and velocity-based site coefficients  $F(PGA)$  and  $F(PGV)$ , respectively, for the effects of site-specific soil conditions in design.

Based on the results of the previous investigation, a Site Class of E for "Soft Soil" is recommended for seismic design purposes at this site as determined based on Section 4.4.3.2 of CHBDC 2014.

## 6.3.1 Seismic Analysis Coefficient

The Peak Ground Acceleration Ration (PGA), Peak Ground Velocity (PGV), and the 5% damped spectral response acceleration values shall be determined for the 475-year, 975-year, and 2475-year return periods in accordance with Section 4.4.3.1 of the CHBDC 2014.

The corresponding acceleration coefficients associated with return periods of 475 years, 975 years and 2475 years of ground motion for Site Class C at the project site are estimated and summarized in the following table:

Return Period (Years)	Probability of Exceedance	Coefficient of PGA	Coefficient of PGV	5% Damped Spectral Response Acceleration for a Period of 0.2 s, $S_a(0.2)$
475	10% in 50 years	0.0097	0.0064	0.018
975	5% in 50 years	0.018	0.012	0.033
2475	2% in 50 years	0.037	0.024	0.063

Note: Values obtained from the Site Class C of EarthquakesCanada web-site.

Based on Section 4.4.4 of the CHBDC 2014, the new culvert structure is assigned Seismic performance category 1. Therefore, a seismic analysis is not required for this structure in accordance with Section 4.4.5.1 of the CHBDC 2014. This requirement has been reviewed and confirmed by the structural engineer.

## 6.4 LATERAL EARTH PRESSURES FOR ABUTMENTS AND WING WALLS

The lateral earth pressures acting on the culvert walls, culvert retaining walls (if any), as well as road protection system will depend on the type and method of placement of the backfill materials, on the nature of the soils behind the backfill, on the magnitude of surcharge including construction loadings, on the freedom of lateral movement of the structure, and on the drainage conditions behind the walls.

The following recommendations are made concerning the design of the culvert walls. It should be noted that these design recommendations and parameters assume level backfill and ground

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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 specifications of OPSS 1010 Granular 'A' or Granular 'B' Type II should be used as backfill behind the walls. The Granular 'A' or Granular 'B' Type II fill should be compacted in loose lifts not greater than 200 mm thick in accordance with OPSS.PROV 501. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Other aspects of the granular backfill requirements with respect to sub drains and frost taper should be in accordance with OPSD 3101.150 and 3121.150. A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the wall stem. Compaction equipment should be used in accordance with OPSS.PROV 501.06. Other surcharge loadings should be accounted for in the design, as required. The granular fill may be placed either in a zone with width equal to at least 1.2 m behind the back of the wall stem (Case I) in or within the wedge shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical (1.5H:1V) extending up and back from the rear face of the footing (Case II).

- For Case I, the pressures are based on the existing overburden soil materials and the following parameters (unfactored) may be used:

<b>Soil Unit Weight:</b>	<b>21 kN/m<sup>3</sup></b>
<b>Coefficients of static lateral earth pressure:</b>	
Active, $K_a$	0.38
At rest, $K_o$	0.55

- For Case II, the pressures are based on the granular fill as placed and the following parameters (unfactored) may be assumed:

	<b>Granular 'A'</b>	<b>Granular 'B' Type II</b>
<b>Soil Unit Weight:</b>	<b>22 kN/m<sup>3</sup></b>	<b>21 kN/m<sup>3</sup></b>
<b>Coefficients of static lateral earth pressure:</b>		
Active, $K_a$	0.27	0.27
At rest, $K_o$	0.43	0.43

If the wall support and superstructure allow lateral movements of the stem (unrestrained stem), active earth pressure may be used in the design of the structures. If the wall support does not allow lateral movement (restrained stem) such as in box culvert configuration, at rest earth

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pressures should be assumed for geotechnical design. The movement to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure, may be taken as follows:

- rotation (i.e., ratio of wall movement to wall height) of approximately 0.002 about the base of a vertical wall;
- horizontal translation of 0.001 times the height of the wall; or
- a combination of both

## 6.5 OPEN CUT EXCAVATIONS

It is understood that excavation will be required for the removal of the existing culvert and placement of the replacement culvert structure. Where space and construction activities permit the construction of unsupported open-cut excavations, these excavations should be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act (OHSa) for Construction Activities. Based on the OHSa classification system, the soils to be excavated on site would be classified as follow:

Fill Materials	Type 3
Firm to very stiff clay	Type 3

Temporary unsupported excavations (i.e. those that are open for a relatively short time period) should be made with side slopes no steeper than 1H:1V. Stockpile of excavated materials and heavy construction equipment should be kept at least the same horizontal distance from the edge of excavation as the depth of the excavation to prevent local instabilities.

## 6.6 GROUNDWATER CONTROL

Control of the surface water and groundwater will be necessary for the construction of the culvert replacement and any associated wing walls, to allow excavation and foundation construction to be carried out in dry conditions.

Depending on the creek flow at the time of construction, the surface water flow could be passed through the culvert area by means of a temporary pipe, using the existing CSP culverts or diverted by pumping from behind a temporary cofferdam. Surface water should be directed away from the excavation areas, to prevent ponding of water that could result in disturbance and weakening of the sensitive subgrade soils. Any necessary permits should be obtained prior to construction.

Groundwater seepage into the excavations is anticipated at the site. The estimated hydraulic conductivity of the native clay on site is expected to be in the order of  $10^{-5}$  cm/s to



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10<sup>-3</sup> cm/s and therefore, dewatering of temporary excavations by pumping from filtered sumps should be adequate at the site. It is expected that groundwater pumping volumes from the sumps would be less than 50 m<sup>3</sup> per day and that a Permit to Take Water (PTTW) would not be required for the temporary groundwater control system at this site. The dewatering system on site should conform to OPSS 518 (Construction Specifications for Control of Water from Dewatering Operation). Care should be taken to direct the surface water away from the open excavation.

Notwithstanding, a dewatering NSSP should be included in the contract to cover the possibility that the groundwater level increases during construction to the point where some dewatering effort is required to provide a stable platform for construction purposes. A copy of the NSSP is provided in Appendix C. Removal of the existing culvert and construction of the replacement culvert will require control of the stream flow to prevent the stream from flowing into the construction zone. A NSSP for control of stream flow is included in Appendix C.

## 6.7 TEMPORARY PROTECTION SYSTEM

Excavations for box, and open footing options will extend below the creek water level and may therefore require temporary shoring with unwatering along the culvert walls and perpendicular to Highway 619 to allow for construction/placement of the footings and/or placement of bedding material in dry conditions, where required. Temporary shoring and groundwater control 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 of the foundation subgrade.

Temporary excavations for the culvert replacement are anticipated through the existing fill and into the firm to very stiff native clay. Excavation works must be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act and Regulations for Construction Projects. Stockpiles of excavated material should be set back from the edge of the excavation by a distance at least equal to the excavation depth.

If the site conditions are such that open cut excavations are not feasible then the removal of the existing culvert and construction of the new culvert may be carried out within temporary protection systems. These protection systems should be designed and constructed in accordance with OPSS 539 (Construction Specification for Temporary Protection Systems). The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS 539, provided that any adjacent utilities/structures can tolerate this magnitude of deformation.

The designer of the temporary work supports must consider the temporary works design as part of the assessment of ground movements and their impact on existing structures and underground utilities at the site. The criteria for the design and performance of the temporary



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works must also consider such analysis. Sufficient design and analysis will have to be carried out in order to conduct cost estimates of the temporary works, to determine the feasibility of the design criteria, to assess construction feasibility of temporary works alternatives, and to indicate to the contractor the temporary ground support system(s) which are to form the basis of the bid.

## 6.8 SUBGRADE PROTECTION

Where clayey soils are exposed at the footing subgrade level, they will be susceptible to disturbance from construction traffic and/or ponded water. To limit this degradation, it is recommended that a working mat of lean concrete or mass concrete be placed on the subgrade within four hours after preparation, inspection and approval of the footing subgrade. Where a box culvert replacement is adopted, a 75 mm thick levelling pad of Granular "A" or fine aggregate (meeting the gradation requirements set out in OPSS 1002) should be provided on top of the concrete mat. Alternatively, for a box culvert replacement, the subgrade can be protected with a Granular "A" pad in lieu of the lean mix concrete/mass concrete working mat.

This requirement can be addressed either with a note on the General Arrangement drawing, or with a Non-Standard Special Provision (NSSP). A sample NSSP to address this requirement is included in Appendix C.

### 6.8.1 Corrosion Protection

Analytical laboratory tests to assess corrosion potential of the creek water were completed as part of the previous investigation. The test results may be used in the consideration of potential corrosion of the pipe in contact with the creek water. The analytical laboratory test results are outlined below:

Chloride, CL (mg/L)	Sulphate, SO <sub>4</sub> (mg/L)	Electrical Conductivity, EC (mS/cm)	Resistivity (mW.cm)	pH
4.81	1.37	499	<0.33	7.51

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## 7.0 Closure

This Foundation Design Report was prepared by Mr. Mehdi Mostakhdemi, M.Sc., P.Eng. Mr. Ty Garde, M.Eng, P.Eng., a Designated MTO Foundations Contact for Amec Foster Wheeler, conducted an independent review of this report.

Sincerely,

**Amec Foster Wheeler Environment & Infrastructure**  
**a Division of Amec Foster Wheeler Americas Limited**

Amec Foster Wheeler Americas Ltd.

*Report prepared by:*



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Geotechnical Engineer

Amec Foster Wheeler Americas Ltd.

*Report reviewed by:*



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Ty Garde, M.Eng., P.Eng.  
Designated MTO Foundations Contact



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## 8.0 References

Canadian Geotechnical Society, 2006. *Canadian Foundation Engineering Manual*, 4th Edition. The Canadian Geotechnical Society, BiTech Publisher Ltd., British Columbia.

Canadian Standards Association (CSA), 2014. *Canadian Highway Bridge Design Code and Commentary on CAN/CSA S6 14*. CSA Special Publication, S6.1 14.

Kulhawy, F.H. and Mayne, P.W., 1990. *Manual on Estimating Soil Properties for Foundation Design*. EL 6800, Research Project 1493 6. Prepared for Electric Power Research Institute, Palo Alto, California.

### Ontario Provincial Standard Specifications (OPSS)

OPSS.PROV 421	Materials Specification for Aggregate – Base, Subbase, Select Subgrade, and Backfill Material
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cut
OPSS.PROV.501	Construction Specification for Compacting
OPSS 518	Construction Specifications for Control of Water from Dewatering Operations
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS.PROV 1002	Materials Specification for Aggregate
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material
OPSS.PROV 1205	Material Specification for Clay Seal
OPSS 1860	Material Specification for Geotextiles

### Ontario Provincial Standard Drawings (OPSD)

OPSD 208.010	Benching of Earth Slopes
OPSD 802.014	Flexible Pipe Embedment in Embankment
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
OPSD 810.010	General Rip-Rap Layout
OPSD 3101.150	Walls Abutment, Backfill, Minimum Granular Requirement
OPSD 3121.150	Walls Retaining, Backfill, Minimum Granular Requirement



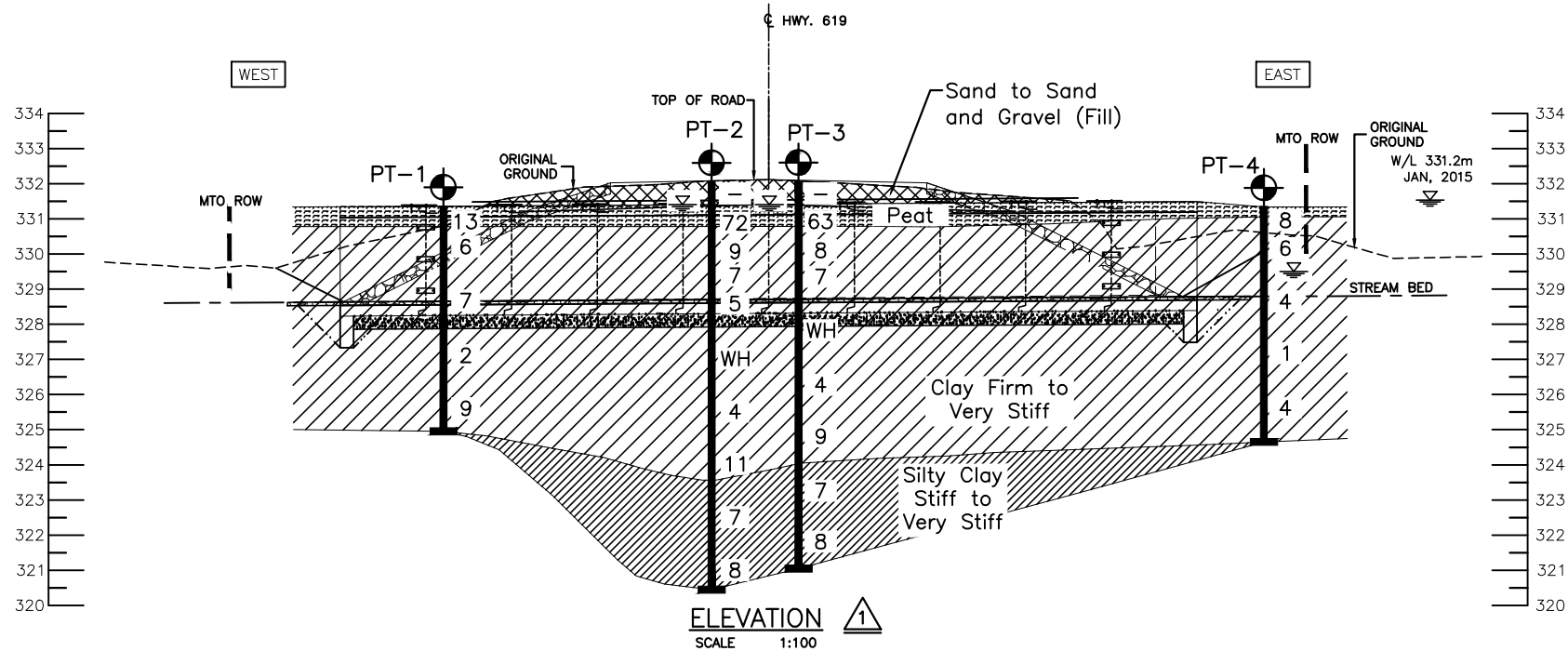
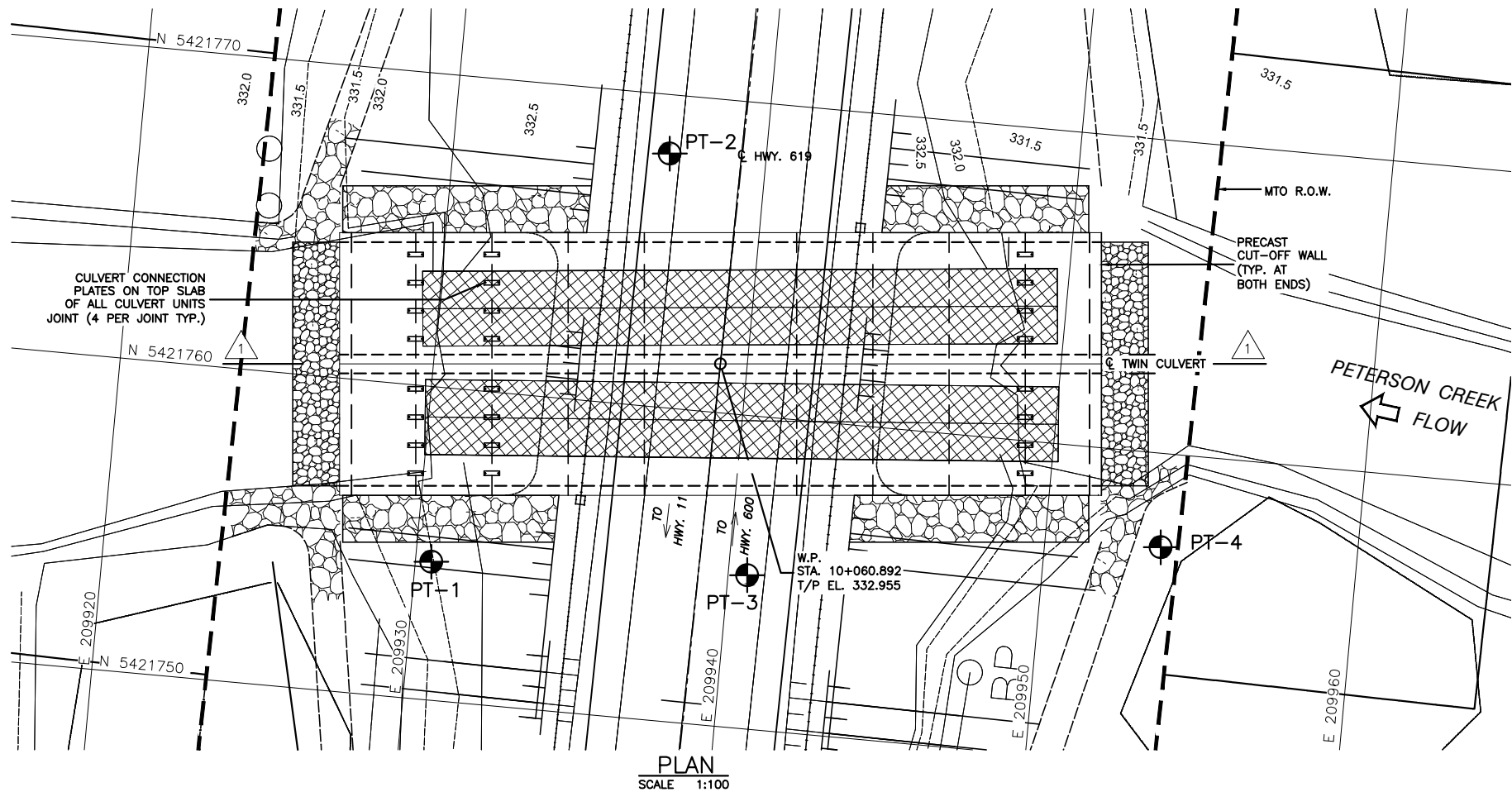
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Table 1: Comparison of Foundation Alternatives

Option	Advantages	Disadvantages	Feasibility
Pipe Culvert	<ul style="list-style-type: none"> <li>Relatively simple installation</li> <li>Lower cost compared to open footing and precast box culverts</li> <li>Limited risk related to settlement performance</li> <li>Bedding under the culvert could be placed under water</li> </ul>	<ul style="list-style-type: none"> <li>Feasibility depends of flow through capacity</li> <li>May require deeper excavation</li> <li>Cut-off wall or clay blanket would be required for scour protection</li> <li>Less durable compare to open footing culvert and precast box culvert</li> </ul>	Feasible
Open Footing Culvert	<ul style="list-style-type: none"> <li>Relatively rapid installation if precast units are used</li> <li>Likely better satisfies fisheries requirements, if applicable</li> </ul>	<ul style="list-style-type: none"> <li>High risk of disturbance of founding soil</li> <li>Longer construction period</li> <li>Would require more groundwater control efforts</li> <li>Less tolerant of differential settlement if the highway is widened or its grade is raised in future</li> <li>Deeper excavation and thicker soil cover would be required for frost protection</li> </ul>	Feasible
Pre-Cast Box Culvert	<ul style="list-style-type: none"> <li>Relatively rapid installation if precast units are used</li> <li>Tolerates larger differential settlements compared to pipe culvert and open footing culvert</li> <li>Excavations would be shallower compared to open footing culverts</li> <li>Bedding under the culvert could be placed under water</li> </ul>	<ul style="list-style-type: none"> <li>High risk of disturbance of founding soil</li> </ul>	Preferred

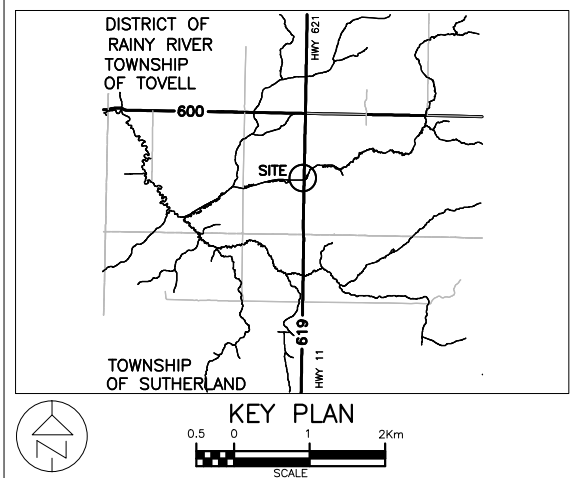
C:\ProgramData\Autodesk\LT15089\TP115089-Peterson-S1\TP115089-Peterson-BH1.dwg Dec 15/16 2:32pm brian.mcmaster



DIST  
CONT No -  
GWP No - 6329-14-00  
PETERSON CREEK CULVERT  
FOUNDATION INVESTIGATION & DESIGN  
BOREHOLE LOCATIONS & SOIL STRATA



SHEET  
1



#### LEGEND

- BOREHOLE LOCATION (PREVIOUS INVESTIGATION BY OTHERS)
- N STANDARD PENETRATION TEST VALUE
- 11 BLOWS/0.3m UNLESS OTHERWISE STATED (STD. PEN. TEST, 475 J/BLOW)
- WATER LEVEL UPON COMPLETION OF DRILLING
- BOREHOLE DRY UPON COMPLETION OF DRILLING

#### NOTES

- THIS DRAWING IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING FOUNDATION INVESTIGATION AND DESIGN REPORT.
- THE INTERPRETED STRATIGRAPHY REPRESENTS SIMPLIFIED SUBSURFACE CONDITIONS. THE BOUNDARIES BETWEEN SOIL STRATA HAVE BEEN DEFINED AT BOREHOLE LOCATIONS ONLY. CONDITIONS BETWEEN BOREHOLE LOCATIONS COULD DIFFER FROM ILLUSTRATED CONDITIONS.
- THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. THE PROPOSED STRUCTURE DETAILS/WORKS ARE SHOWN FOR ILLUSTRATION PURPOSE ONLY AND MAY NOT BE CONSISTENT WITH THE DESIGN CONFIGURATION AS SHOWN ELSEWHERE ON THE DESIGN REPORT.
- ELEVATIONS ARE REFERENCED TO GEODETIC DATUM.

No.	ELEVATION (m)	CO-ORDINATES (MTM, NAD 83 ZONE 15)	
		NORTHING (m)	EASTING (m)
BOREHOLES BY OTHERS			
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



DRAWING NOT TO BE SCALED  
100mm ON ORIGINAL DRAWING

REVISIONS					
DESIGN:	CHK:	MM	CODE CAN/CSA S6-14	LOAD CL-625-ONT	DATE: DEC 2016
DRAWN:	CHK:	MM	SITE GROOSES No.: 52-D-27	SCHEME	DWG:

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**Appendix A:           Record of Boreholes from Previous and Current Investigations**



## 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 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		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						
332.2	GROUND SURFACE							20 40 60 80 100	20 40 60					
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									
325.8							326							
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		RECORD OF BOREHOLE No PT-2				1 OF 1 METRIC								
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 NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
332.9	GROUND SURFACE							20 40 60 80 100	W <sub>p</sub> W W <sub>L</sub>	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			9	SS	7									
8.5	Sandy SILTY CLAY, trace to some gravel Very stiff Grey Wet		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			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
332.9	GROUND SURFACE							20 40 60 80 100						
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*									
331.5														
1.4	CLAY Firm to very stiff Brown to grey Frozen* to wet  Sand laminations throughout.		3	SS	8*									
			4	SS	7									
			5	SS	WH									
			6	SS	4									
			7	SS	9									
324.9														
8.0	SILTY CLAY, trace gravel Stiff to very stiff Grey Wet		8	SS	7									
			9	SS	8									
321.9														
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:

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

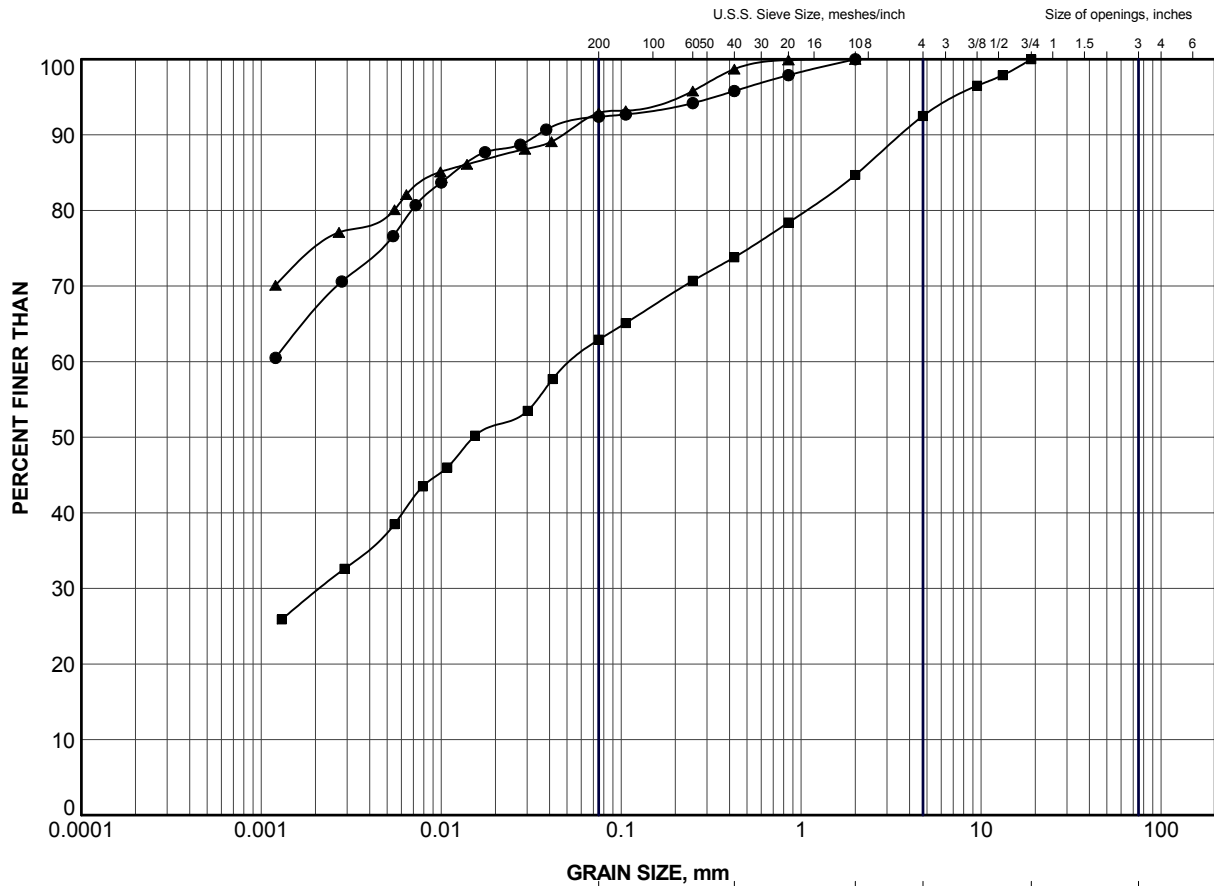


PROJECT 1411523				<b>RECORD OF BOREHOLE No PT-4</b>				1 OF 1 <b>METRIC</b>						
G.W.P. 6328-14-00				LOCATION N 5421757.0; E 209953.7				ORIGINATED BY MR						
DIST _____ HWY 619				BOREHOLE TYPE 108 mm I. D. Continuous Flight Hollow Stem Augers				COMPILED BY AC						
DATUM GEODETIC				DATE March 18, 2015				CHECKED BY DAM						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT 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						
332.2	GROUND SURFACE							20 40 60 80 100						
0.0	Silty Fibrous PEAT		1A	SS	8*		332							
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		330							
			4	SS	1		328							
			5A				327							
			5B	SS	4									
325.5							326							
6.7	END OF BOREHOLE													
	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 ( <i>Italics</i> ).													

**FOUNDATION INVESTIGATION AND DESIGN REPORT, (GWP 6327-14-00) REPLACEMENT OF  
PETERSON CREEK CULVERT, HIGHWAY 619 NEAR RAINY RIVER, NORTHWEST REGION SITE  
NO. 45-155C**

December 2016

**Appendix B: Laboratory Test Results from Current Investigation**

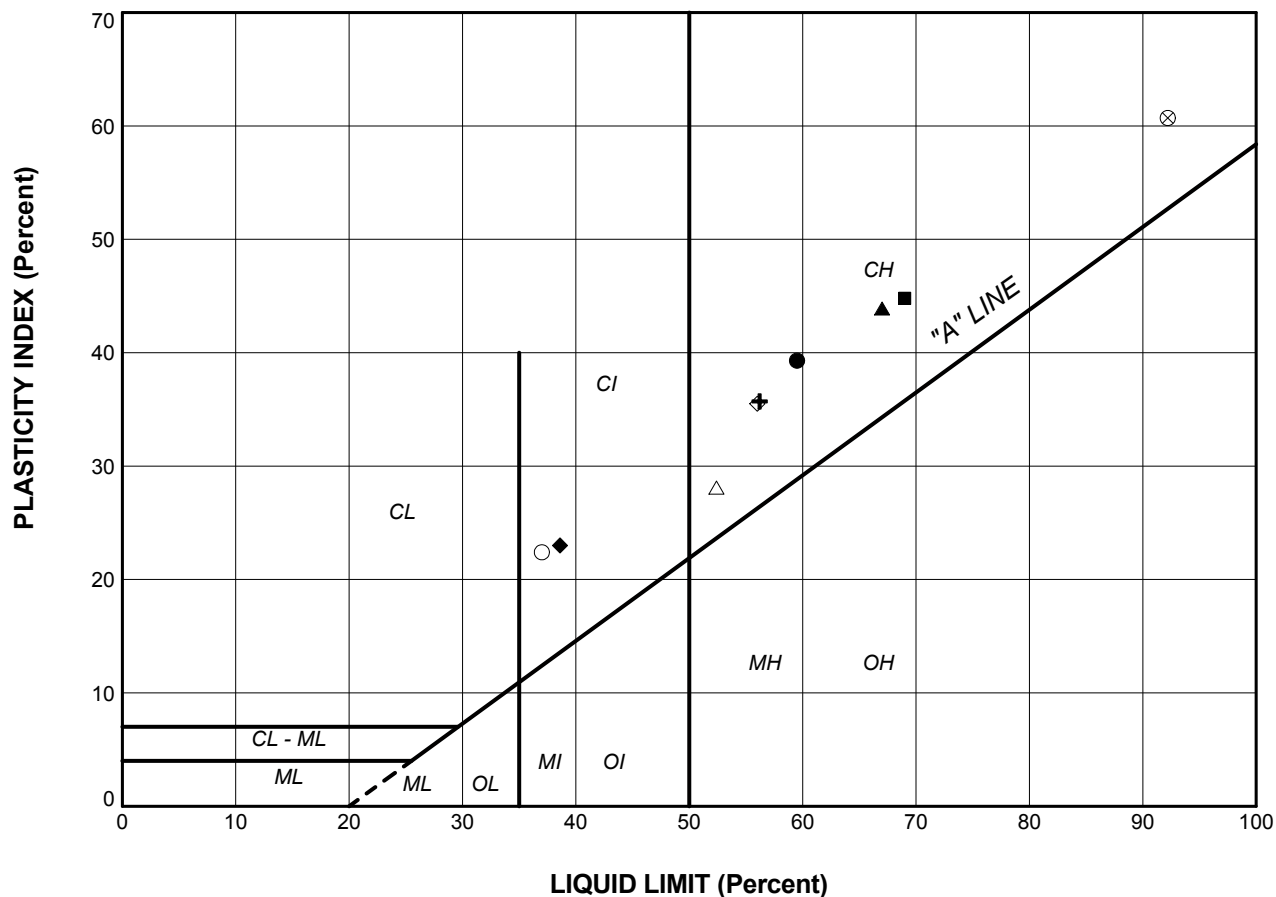


### LEGEND

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		JLL		Apr 2015	
CHECK		DAM		Apr 2015	
APPR		JMAC		Apr 2015	
SCALE		N/A		REV.	
Golder Associates SUDBURY, ONTARIO		FIGURE B2			

**FOUNDATION INVESTIGATION AND DESIGN REPORT, (GWP 6327-14-00) REPLACEMENT OF  
PETERSON CREEK CULVERT, HIGHWAY 619 NEAR RAINY RIVER, NORTHWEST REGION SITE  
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**Appendix C:           Non-Standard Special Provisions (NSSPs)**

FOUNDATION INVESTIGATION AND DESIGN REPORT, (GWP 6327-14-00) REPLACEMENT OF  
PETERSON CREEK CULVERT, HIGHWAY 619 NEAR RAINY RIVER, NORTHWEST REGION SITE  
NO. 45-155C

December 2016

**Dewatering**

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Non-Standard Special Provision (NSSP)

December 2016

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**CONSTRUCTION SPECIFICATION FOR DEWATERING**

**SCOPE**

The work under this item includes the design, installation, operation, maintenance and removal of temporary dewatering systems to facilitate the culvert extensions at the Brusvine Culvert site. Foundations for the culvert extension may require excavation below the groundwater level.

**REFERENCES**

- OPSS 517      Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure  
Excavation
- OPSS 518      Construction Specification for Control of Water from Dewatering Operations

**SUBMISSION AND DESIGN REQUIREMENTS**

Written details for the proposed dewatering system shall be submitted to the Contract Administrator for information purposes a minimum of ten business days prior to commencing dewatering operations. The Contractor shall reference borehole logs included in the Contract Documents as a guide in determining requirements.

**CONSTRUCTION**

**Dewatering System**

The Contractor is responsible for the design, installation, operation and maintenance of an adequate dewatering system to lower the groundwater level to at least 0.3 m below the founding level for the proposed culvert replacement, to allow excavation, subgrade preparation and construction in dry conditions.

**Operation**

A continuous dewatering operation shall be provided to facilitate the installation of the culvert extensions at all times during the work. All components of the dewatering system shall be maintained in an effective, functioning and stable condition at all times during the work. Notwithstanding the above, the work shall be completed in accordance with the environmental and operational constraints specified elsewhere in the contract.

**FOUNDATION INVESTIGATION AND DESIGN REPORT, (GWP 6327-14-00) REPLACEMENT OF  
PETERSON CREEK CULVERT, HIGHWAY 619 NEAR RAINY RIVER, NORTHWEST REGION SITE  
NO. 45-155C**

December 2016

**Restoration**

All equipment and materials placed shall be removed from the right-of-way upon the completion of the work and all areas disturbed as part of this work shall be restored to their preconstruction conditions, unless specified otherwise.

**BASIS OF PAYMENT**

Payment at the contract price for the above tender item shall be full compensation for all labour, equipment and material to do the work.

FOUNDATION INVESTIGATION AND DESIGN REPORT, (GWP 6327-14-00) REPLACEMENT OF  
PETERSON CREEK CULVERT, HIGHWAY 619 NEAR RAINY RIVER, NORTHWEST REGION SITE  
NO. 45-155C

December 2016

**Subgrade Protection**

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Non-Standard Special Provision (NSSP)

December 2016

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**CONSTRUCTION SPECIFICATION FOR SUBGRADE PROTECTION**

The subgrade soils for the culvert foundations or box culverts may be susceptible to disturbance and loosening from construction traffic and ponded water.

**SCOPE**

Where pre-cast box culverts are used, if all the box segments are not placed on the prepared subgrade within four hours of its inspection and approval, a working mat of lean concrete or mass concrete, with minimum thickness of 100 mm, should be placed on the foundation subgrade. A minimum 75 mm thick uncompacted levelling pad consisting of Granular 'A' material or fine aggregates (meeting the grading requirements specified in OPSS.PROV 1002) should be provided on top of the lean concrete mat.

As an alternative to a concrete working mat, the subgrade protection could be provided by placing at least 150 mm of OPSS 1010.PROV Granular A or fine aggregates (meeting the grading requirements specified in OPSS.PROV 1002).

**BASIS OF PAYMENT**

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.