



May 5, 2015

DRAFT PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT

PICKEREL CREEK CULVERT - SITE NO. 41-88/C
HIGHWAY 105, DISTRICT OF KENORA
UNSURVEYED TERRITORY
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P 6365-14-00

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PART A

**PRELIMINARY FOUNDATION INVESTIGATION REPORT
PICKEREL CREEK – SITE NO. 41-88/C
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Hatch Mott MacDonald (HMM), on behalf of the Ministry of Transportation, Ontario (MTO) to provide preliminary foundation engineering services for the replacement of the Pickerel Creek culvert (Site No. 41-88/C). The Pickerel Creek culvert is located in the District of Kenora on Highway 105 at STA 20+698, approximately 51.4 km north of the junction of Highway 17 and Highway 105. The key plan showing the general location of this section of Highway 105 and the location of the investigated area are shown on Drawing 1.

2.0 SITE DESCRIPTION

The Pickerel Creek culvert consists of a three-cell, timber box structure, the details of which (i.e., width, height, length, etc.) are summarized in Table 1 following the text of the report.

In general, the topography in this area is relatively flat with moderate to dense tree cover beyond the highway right-of-way. It should be noted that the orientation (i.e., north, south, east, west) stated in the text of the report is typically reference to project north and therefore may differ from Magnetic North shown on the drawing. For the purposes of this report Highway 105 runs in a north-south direction with the culvert perpendicular in an east-west direction. At the culvert location, Pickerel Creek flows in an easterly direction. At the culvert location, the highway grade is at Elevation 365.4 m and the culvert invert is at approximately Elevation 362.2 m, at both the inlet (west) and outlet (east) ends. The creek water level measured by others on July 5, 2012, to be Elevations 362.6 m at the inlet (west) and outlet (east) ends and was measured by Golder on January 22, 2015, at Elevation 362.5 m. Surface conditions in the culvert inlet (west) and outlet (east) are as are shown on Photographs 1 to 3, attached.

3.0 INVESTIGATION PROCEDURES

The field work for this subsurface investigation was carried out on January 21 and 22, and February 16 and 19, 2015, during which time four (4) boreholes (Boreholes PK-1 to PK-4) were advanced at approximately the locations shown on Drawing 1. Boreholes PK-1 and PK-4 were advanced at the toe of slope near the culvert inlet/outlet using 108 mm inside diameter hollow stem augers. Boreholes PK-2 and PK-3 were advanced from the existing highway platform using NW casing and wash boring techniques. 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). Field vane shear tests were conducted in cohesive soils for determination of undrained shear strengths (ASTM D2573) using an MTO Standard 'N' size vane. The groundwater level in the open boreholes was observed during the drilling operations as described on the Record of Borehole sheets in Appendix A. The boreholes were backfilled upon completion in accordance with Ontario Regulation 903 Wells (as amended).

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



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Sudbury for further examination and laboratory testing. 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 26, 2015) using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters, including pH, resistivity, conductivity, sulphates and chlorides.

The as-drilled borehole locations and ground surface elevations were measured and surveyed by member of our technical staff, referenced to the highway centerline and existing culvert and converted into Northing/Easting on the plan drawing. The ground surface elevation of the highway centerline was obtained from the profile drawing provided by MTO (BC5019311053.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)
PK-1	5566819.7	289210.6	362.8	11.3
PK-2	5566827.4	289205.6	365.3	11.3
PK-3	5566824.5	289192.7	365.4	11.3
PK-4	5566840.7	289197.4	363.1	11.3

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain (NOEGTS)¹ mapping, the subsoils in the vicinity of the Pickerel Creek culvert site generally consist of ground moraine deposits comprised of mainly sandy materials.

Based on geological mapping by the Ministry of Northern Development and Mines (Map 2542)², the site is underlain by bedrock of the Archean era, comprised of massive granodiorite to granite rocks.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are given on the Record of Borehole sheets contained in Appendix A. The results of geotechnical laboratory testing are contained in Appendix B. The results of the in situ tests (i.e., SPT 'N' values and undrained shear strengths from field vanes) as presented on the Record of Borehole sheets and in Section 4 are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions

¹ Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 52KSW.

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



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between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

Subsoil Conditions

In summary, the subsoil conditions encountered at the site consist of asphalt and granular fill (for boreholes advanced through the embankment) underlain by organic deposits consisting of topsoil/peat, topsoil and organic clay. The organic deposits are underlain by a cohesive deposit of clayey silt to silty clay further underlain by deposits of silt to sand. A more detailed description of the soil deposits and groundwater conditions encountered in the boreholes is provided below.

Deposit/Layer Description	Boreholes	Deposit Thickness (m)	Deposit Surface Elevation (m)	N Values (blows) / Shear Strength	Laboratory Testing
				Consistency or Relative Density	
Asphalt	PK-2, PK-3	0.09 – 0.10	365.4 – 365.3	n/a	n/a
(FILL) ¹ Sand, trace to some gravel, trace to some silt; brown; frozen to wet	PK-2, PK-3	3.3 – 3.4	365.3 – 365.2	N = 10 – 24 ²	w = 13% – 25% 1 - M (Fig. B1)
				Compact	
Peat/Topsoil , trace sand, trace wood, dark brown to black, frozen to wet	PK-1 to PK-4	0.1 – 1.5	363.1 – 361.8	n/a ³	w = 71% - 172%
				n/a	
Organic Clay , dark brown, wet	PK-1	0.8	361.3	N = 2	w = 68% w _l = 86% w _p = 40% I _p = 46% OC = 9.4% 1 – AL (Fig. B2)
				Very Soft	
Clayey Silt to Silty Clay , trace sand, trace gravel, trace silt laminated, grey, wet	PK-1 to PK-4	3.0 – 4.4	362.6 – 360.5	N = 0 (weight of hammer) – 7 s _u = 24 – 81 ⁴ S = 2 - 3	w = 32% - 36% w _l = 25% - 38% w _p = 16% - 20% I _p = 8% - 18% 2 – MH (Fig. B3) 4 – AL (Fig. B4)
				Soft to Stiff	
Silt to Sandy Silt , trace clay, grey, wet	PK-1 to PK-4	2.0 – 4.4	358.8 – 357.5	N = 0 (weight of hammer) – 7	w = 26% - 28% 4 – MH (Fig. B5) 2 – AL = NP
				Very Loose to Loose	
Silty Sand to Sand , trace to some silt trace clay, grey, wet	PK-1 to PK-4	Boreholes terminated in this deposit	356.6 – 354.1	N = 5 – 13	w = 16% – 24% 1 – MH and 2 – M (Fig. B6)
				Loose to Compact	



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Where:

N = SPT 'N'-value; number of blows for 0.3 m of penetration
w = Natural Moisture Content (%)
MH = Combined Sieve and Hydrometer analysis
M = Sieve analysis for particle size
AL = Atterberg Limits Test
OC = Organic Content (%)
 s_u = Undrained Shear Strength (kPa)
S = Sensitivity
 w_p = Plastic Limit (%)
 w_l = Liquid Limit (%)
 I_p = Plasticity Index (%)
NP = Non-Plastic test result

Notes:

- ¹ 75 mm diameter cobbles were encountered in Boreholes PK-2 and PK-3 at 0.9 m and 2.1 m depths, respectively.
- ² In the fill, the split spoon samples did not penetrate the entire SPT depth for two samples, inferred to be due to the frozen nature of the material. Additionally, 'N'-values of 44 blows and 81 blows for two samples also inferred to be due to the frozen nature of the material.
- ³ In the peat deposit one SPT 'N'-value of 10 blows was noted, however this is inferred to be due to the frozen nature of the material.
- ⁴ One undrained shear strength was measured at greater than 100 kPa, however this is inferred to be at the transition from the cohesive deposit to the underlying silt deposit and is not representative.

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 362.5 m on January 22, 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)
PK-1	1.6	361.2
PK-2	1.5	363.8
PK-3	2.9	362.5
PK-4	1.5	361.6

Notes:

1. Boreholes PK-2 and PK-3 were advanced using NW casing and wash boring. As such, water levels may not be representative of in-situ groundwater conditions.



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 Ms. Sarah E.M. Poot, P.Eng., Associate, provided a technical review of the report. Mr. Jorge M.A. Costa, P.Eng., the Designated MTO Foundations Contact and Principal, conducted an independent quality control review of this report.



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Report Signature Page


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PART B

**PRELIMINARY FOUNDATION DESIGN REPORT
PICKEREL CREEK – SITE NO. 41-88/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 Pickerel Creek culvert. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during this subsurface investigation.

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

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

It is assumed that the culvert is to be replaced with a culvert of similar dimensions, alignment and invert elevation to that of the existing culvert. In addition, it is assumed that there will be no embankment grade raises or widening in the area of the culvert as part of the Hwy 105 reinstatement.

6.2 Foundations

6.2.1 Foundation Options

The existing Pickerel Creek culvert is located on Highway 105 at STA 20+698, 51.4 km north of the junction of Highway 17 and Highway 105 in the District of Kenora in Unsurveyed Territory. The highway embankment is constructed of granular fill material and is approximately 3.5 m high adjacent to the culvert. The existing culvert consists of a three cell timber box, the details of which (i.e., width, height, length, etc.) are summarized in Table 1.

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

- Sheet-pile abutment and pre-cast concrete cap;
- Pre-cast concrete box; and
- Pre-cast open footing culvert with either pre-cast concrete arch or metal box.

In this report we have considered the following options:

- Sheet-pile abutment and pre-cast concrete cap;
- Pre-cast concrete box; and



- Open footing concrete culvert (cast-in-place or pre-cast footing).

Open footing arch culverts could be considered, however the limited soil cover may not allow for proper backfilling for an arch culvert depending on configuration of the selected arch section (metal or pre-cast concrete). A sheet-pile abutment and pre-cast concrete cap type of culvert is possible but the low cover available should be considered by the designer as it may affect the construction of the of the present structure and the installation of guide rails, etc. A corrugated steel pipe (CSP) culvert would likely decrease the flow through capacity and generally have a shorter design life than a concrete culvert and at this culvert location, the use of multiple CSP culverts would likely be required to meet the flow capacity making this option not practical. From a foundation perspective, an open footing concrete culvert sufficiently wide to handle the flow is preferred at this site as the existing culvert (or portion thereof) likely can be used as the diversion channel during construction of the footings for the new culvert. Other culvert types may be preferred due to construction staging or other considerations such as ease of construction associated with the pre-cast sections.

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 generally firm to stiff clayey silt to silty clay deposit as encountered in the boreholes. In this regard, the eastern half of the culvert may have to be constructed on a granular mat/pad or rock fill backfill replacing the peat and/or organic clay layer present along this section of 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 2.5 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 peat/organic clay deposits, where present. Recommended founding elevations and foundation conditions for the replacement open footing culvert are provided in Table 3.

Consideration may be given to founding the footings on an engineered fill pad in order to raise the footings above the frost penetration depth. However, since the fill will likely be saturated (depending on creek water levels), the footings may be subject to frost heaving, 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 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 *Pre-Cast Concrete Slab on Sheet-Pile Abutments*

It is expected that the sheet-pile abutments will penetrate well below the frost depth to bear within the loose to compact silty sand to sand deposit. Therefore, the foundations should not be subject to frost induced heave. However, adhesion of the subsoils to the sheet-pile walls through the depth of the frost penetration zone would have to be considered in the overall assessment of the sheet-pile depths in order to resist uplift (heave). An estimate of the additional depth required to resist uplift can be provided at the detail design stage if this is culvert replacement option is selected.

6.2.3 Geotechnical Resistances

6.2.3.1 *Box Culvert Replacement*

A box culvert, placed on the properly prepared subgrade and/or properly placed granular pad/backfill at or below the founding elevation identified in Table 3, should be based on the recommended factored geotechnical axial resistance at Ultimate Limit States (ULS) and geotechnical reaction at Serviceability Limit States (SLS), for 25 mm of settlement as provided in Table 3. These recommendations are based on the box culvert width provided in Table 1.

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 Tables 1 and 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 it's Commentary.

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

6.2.3.2 *Open Footing Culvert Replacement*

Strip footings placed on the properly prepared subgrade, at or below the founding elevation recommended in Table 3, should be designed based on the factored geotechnical axial resistance at ULS and geotechnical reaction at SLS, for 25 mm of settlement as provided in Table 3. These recommendations are based on the assumed footing width of 0.6 m.

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 Tables 1 and 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 6.7.4 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 understood that no grade raise or embankment widening is planned. It is recommended that the structural engineer exercise caution when utilizing the values of the geotechnical resistance at SLS (as provided in Table 3) in the design of the culvert and that consideration be given to the sequence and staging of construction, particularly if a grade raise or widening is applicable as the settlement under the culvert as a result of soil loading (not culvert loading) may govern.

6.2.3.3 Pre-Cast Slab and Sheet-Pile Abutments

The sheet-piles should be driven to the generally loose to compact sand to silty sand at or below the founding elevation recommended in Table 3, and should be designed based on the factored geotechnical resistances at ULS and unit geotechnical reaction at SLS (for 25 mm of settlement), provided in Table 3. The unit factored geotechnical axial resistance and reaction provided in Table 3 are primarily a function of the toe resistance developed within the compact sand to silty sand deposit. These values do not include downdrag forces, which may need to be considered if the grade is raised or the embankments are widened.

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 3.5 m above the existing ground surface adjacent to the culvert, granular fill embankments at this site will be stable at side slopes inclined at 2 Horizontal to 1 Vertical (2H:1V) or flatter.

Given the presence of a 3.0 m to 4.4 m thick deposit of soft to stiff, clayey silt to silty clay deposit and should a grade raise or widening be required, additional long term settlements would be anticipated and additional settlement analysis, stability analysis, field work (potentially) and/or specialized laboratory testing may be required.



6.3 Lateral Earth Pressures

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

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 2.5 m behind the back of the walls for a restrained wall (see Figure C6.20(a) of the Commentary to the CHBDC), or within the wedge shaped zone defined by a line drawn at 1.5 H:1V extending up and back from the rear face of the base of the walls for an unrestrained wall (see Figure C6.20(b) of the Commentary to the CHBDC).
- The following parameters (unfactored) may be used to calculate the lateral earth pressures acting on the culvert or sheet-piles:

Fill Type	Internal Angle of Friction (ϕ)	Unit Weight	Coefficients of Static Lateral Earth Pressure	
			At-Rest, K_o	Active, K_a
Granular 'A'	35°	22 kN/m ³	0.43	0.27
Granular 'B' Type II	35°	21 kN/m ³	0.43	0.27
Granular 'B' Type I or III	32°	21 kN/m ³	0.47	0.30
Native Clayey Silt to Silty Clay	27°	17 kN/m ³	0.55	0.37
Native Sandy Silt to Silt	27°	19 kN/m ³	0.55	0.37
Native Sand to Silty Sand	28°	20 kN/m ³	0.53	0.36



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 compact to very dense sand and into native soils which are comprised of very soft peat/organic clay and soft to stiff clayey silt to silty 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 either driven sheet-piling extended to suitable depth, or soldier piles and lagging where H-piles are driven to a suitable depth and horizontal lagging is installed as the excavation proceeds. Support to the 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.

The installation of the sheet-piles for culvert construction and/or temporary shoring may be impeded by the presence of cobbles (up to 75 mm in size) within the fill material. It may be necessary to excavate and replace the existing fill material in the areas of sheet-pile installation in a series of limited length and narrow trenches. In general, the narrowest suitable excavator bucket should be used. The replacement fill could consist of excavated fill material or imported granular material provided that 100 per cent of the material passes the 75 mm size and less than 5 per cent passes the 75 µm size. Sieving, sorting or picking of large particles from the excavated spoil pile may be required if the excavated material is re-used. Alternatively, imported Granular 'A' or Granular 'B' Type I, II or III may be used as backfill for the excavated trench. Excavation and replacement should be carried out on the same day to avoid leaving any trench open overnight. Consideration should be given to include an NSSP in the contract to address obstructions. A sample NSSP can be provided at the detail design stage, if required depending on final culvert design and construction staging.

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 peat, topsoil, organic clay or mixed organic materials) and any softened/loosened or disturbed soils, should be sub-excavated from below the plan limits of the proposed works to the founding levels provided in Table 3.



The culvert subgrade should be inspected by a Quality Verification Engineer following sub-excavation to ensure that all organics and other unsuitable materials have been removed as noted above, in accordance with OPSS 422 (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 II or III that is placed and compacted in accordance with OPSS.PROV 501 (Compacting) or rock fill (depending on the depth of the sub-excavation) that is placed in accordance with OPSS.PROV 206 (Grading). The use of Granular 'B' Type II or rock fill 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 2.5 m of soil cover for frost protection. As indicated in Section 6.2.2, 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 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/organic clay deposits, where present.

If rock fill is used, the rock fill should be well graded and shall consist of fragments of sound rock, free of organic matter or any deleterious material. In addition, 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 for rock fill should be no steeper than 1.25H:1V.

Granular 'B' Type II fill placed above the water table should be compacted to 100% of the Standard Proctor Maximum Dry Density and the compaction should be carried out in accordance with OPSS.PROV 501 (Compacting). If the Granular B Type II fill 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% 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 for granular fill 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 accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts). Given the potential for surface water flow and some groundwater seepage through the native soils during excavation to the invert and 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 Standard Proctor Maximum Dry Density (SPMDD) of the materials as specified in OPSS.PROV 501 (Compacting). In addition, a 75 mm thick uncompacted levelling pad consisting of OPSS.PROV 1010 (Aggregates) Granular 'A' or fine concrete aggregate meeting the grading requirements specified in OPSS.PROV 1002 (Aggregates – Concrete) should be provided with geometry similar to that provided on OPSD 803.010 (Backfill and Cover for Concrete Culverts) for culvert construction in dry conditions.

A frost taper should be constructed with geometry similar to that provided on OPSD 803.010 (Backfill and Cover for Concrete Culverts).

6.4.3.2 Open Footing Culvert

The excavation and backfilling requirements for the open footing culvert replacement should be in accordance with OPSS 902 (Excavating and Backfilling – Structures) and also in similar configuration to that shown on OPSD 803.010 as noted in Section 6.4.3.1.

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 with geometry similar to that provided on OPSD 803.010 (Backfill and Cover for Concrete Culverts).

6.4.3.3 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 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 cohesive native soils 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 concrete footings, or the box culvert, is not placed within four hours after preparation, inspection, and approval of the foundation subgrade. The minimum thickness of the concrete working slab should be 100 mm and the concrete should have a minimum 28 day compressive strength of 20 MPa. Consideration should be given to include an NSSP in the contract to address subgrade protection at this site. A sample NSSP can be provided at the detail design stage, if required depending on final culvert design and construction staging.

6.4.5 Erosion Protection

Provision should be made for scour and erosion protection at the culvert location. In order to prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring) or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a clay seal or concrete cut-off wall should be provided at the upstream end of the culvert. If a clay seal is adopted, the clay material should meet the requirements of OPSS 1205 (Clay Seal), and the seal should be a minimum thickness of 1 m, 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 and overburden soils prior to placement of backfill, bedding material, engineered fill and the actual culvert structure. Groundwater flow into the excavation can be expected due to the depth of the excavations and the presence of relatively permeable 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 a portion of (or all) the existing 3-cell culvert or diverted by pumping from behind temporary sheet-pile cofferdams.

For both the box and open footing culvert options, excavations will extend below the creek water level and potentially the groundwater level and will therefore require temporary shoring with dewatering to allow for construction/placement of the footings and/or placement of 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, engineered fill or organic sub-excavation replacement backfill can be placed sub-aqueously, however, dewatering may still be required for footing/box culvert placement as the culvert invert is at or below the creek water level.

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

At this preliminary stage, an accurate prediction of the groundwater pumping volumes cannot be made, as the flow rate would be dependent on construction methods adopted by the contractor. However, it is considered that groundwater pumping volumes could exceed 50 m³/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 creek water taken at the culvert site are presented in Table B1 in Appendix B. The suite of parameters tested is intended to allow the design engineer to assess the requirements for the appropriate type of cement to be used in construction and the need for corrosion protection of steel reinforcing elements.

6.5 Recommendations for Further Work During Detail Design

During the detail design phase, additional field investigation and testing may be required, based on the final configuration and/ or alignment of the culvert and the replacement strategy (i.e., staging). In particular, we recommend additional boreholes be advanced to a suitable penetration depth within the sand to silty sand deposit if the pre-cast slab and sheet-pile abutment culvert option is selected. 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 Ms. Sarah E.M. Poot, P.Eng., Associate. Mr. Jorge M.A. Costa, P.Eng., Designated MTO Foundations Contact and Principal, conducted an independent quality control review of this report.



Report Signature Page

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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 52KSW.

ASTM International:

ASTM D1586	Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils
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ASTM D2573	Standard Test Method for Field Vane Shear Test in Cohesive Soil
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Ontario Provincial Standard Specifications (OPSS)

OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
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OPSS 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
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OPSS 902	Construction Specification for Excavating and Backfilling – Structures
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OPSS 1205	Material Specification for Clay Seal
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OPSS 1860	Material Specification for Geotextiles
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Ontario Provincial Standard Specifications (OPSS) – Provincial Oriented

OPSS.PROV 206	Construction Specification for Grading
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OPSS.PROV 209	Construction Specification for Embankments over Swamps and Compressible Soils
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OPSS.PROV 501	Construction Specification for Compacting
---------------	---

OPSS.PROV 539	Construction Specification for Temporary Protection Systems
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OPSS.PROV 1002	Material Specification for Aggregates - Concrete
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OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material
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Ontario Provincial Standard Drawings (OPSD)

OPSD 208.010	Benching of Earth Slopes
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DRAFT PRELIMINARY FOUNDATION REPORT PICKEREL CREEK CULVERT - SITE NO. 41-88/C

OPSD 803.010	Backfill and Cover for Concrete Culverts
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 PICKEREL CREEK CULVERT - SITE NO. 41-88/C

Table 1: Summary of Culvert Details

Culvert Location	Site #	Approximate Height of Embankment ¹ (m)	Existing Culvert			Approximate Invert Elevation ²	
			Type	Approximate Dimension ²	Approximate Length (m)	West End of Culvert (m)	East End of Culvert (m)
Hwy 105 STA 20+698	41-88/C	3.3	Three Cell Timber Box	2.1 m x 2.0 m each of 3 cells	21	362.2	362.2

- 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 BC5019311053.dwg).

Prepared by: AC
Checked by: SEMP
Reviewed by: JMAC



DRAFT PRELIMINARY FOUNDATION REPORT PICKEREL CREEK CULVERT - SITE NO. 41-88/C

Table 2: Comparison of Foundation Alternatives

Option	Advantages	Disadvantages	Risks/Consequences
Open Footing Culvert	<ul style="list-style-type: none"> ■ 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. ■ Consideration could be given to founding the footings above the frost penetration depth to limit dewatering requirements if the culvert structure sections can accommodate heave/settlement due to frost action. ■ Would likely satisfy fisheries requirements related to natural channel substrate, if applicable. ■ Suitable footing founding condition likely at similar depth to those of existing timber culvert. ■ Existing culvert can be used for water diversion while new footings are being constructed adjacent to the culvert. 	<ul style="list-style-type: none"> ■ Excavation depths are greater than for box culvert option, resulting in increased excavation support and dewatering/unwatering requirements and additional spoil material to be disposed off-site. ■ Constructing footings in the dry will take longer due to requirements for groundwater control system, dewatering and surface water pumping. ■ Less tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site. ■ Concrete or metal arch sections supported on concrete open (strip) footings may not allow for adequate soil cover to be placed for ordinary construction. 	<ul style="list-style-type: none"> ■ High risk of disturbance of the native clayey silt to silty 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. ■ Risk of frost induced heaving and/or additional settlement for footings founded above the frost penetration depth. ■ Culvert joints may be required to accommodate total and differential settlement (if applicable).
Pre-Cast Box Culvert	<ul style="list-style-type: none"> ■ Minimizes depth of excavation, protection system (if required) and dewatering requirements compared to open footing option. ■ Allows faster construction resulting in shorter duration for dewatering and surface water pumping. ■ More tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site, or remnants of the peat deposit are not fully removed. ■ Backfill/bedding under the culvert may be placed underwater (i.e. Granular 'B' Type II) minimizing or eliminating water pumping requirements. 	<ul style="list-style-type: none"> ■ May not satisfy fisheries requirements related to natural channel substrate, if applicable. ■ Cut-off wall or clay blanket may be required at inlet to mitigate potential scour under culvert. ■ Transportation to and on-site lifting of large pre-cast sections will be required. ■ May require water diversion of a relatively wide creek channel. 	<ul style="list-style-type: none"> ■ Some risk of disturbance of the native clayey silt to silty clay deposit during construction; can be mitigated with use of a tremie concrete working slab or Granular B Type II working pad. ■ Low risk related to settlement performance.



DRAFT PRELIMINARY FOUNDATION REPORT PICKEREL CREEK CULVERT - SITE NO. 41-88/C

Option	Advantages	Disadvantages	Risks/Consequences
Sheet-Pile Abutment and Pre-Cast Slab	<ul style="list-style-type: none">■ Does not require temporary diversion of the river as it can be installed around the existing culvert, which acts as the channel diversion.■ Minimizes excavation depths and does not require dewatering.■ Would satisfy fisheries requirements related to natural channel substrate, if applicable.	<ul style="list-style-type: none">■ Less tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site (i.e. potential for downdrag on the sheet-piles).■ Steel sheet-piles may not have as long of a design life compared to concrete options.■ Consideration of guide rail installation or other design factors given the low cover.	<ul style="list-style-type: none">■ Some risk related to obstructions within the fill; can be mitigated by sub-excavation and replacing material prior to installation of the sheet-piles.■ Joints may need to be incorporated into the slab to accommodate total and differential settlement.



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PICKEREL CREEK CULVERT - SITE NO. 41-88/C**

**Table 3: Geotechnical Axial Resistance and Reaction for Pre-Cast Box, Open Footing and
Pre-Cast Concrete Slab on Sheet-Pile Abutment Replacement Culverts**

Culvert Location	Approximate Invert Elevation ¹ (West End / East End)	Culvert Type	Approximate Backfill/Bedding Founding Elevation	Founding Condition	Factored Geotechnical Axial Resistance at ULS ²	Geotechnical Reaction at SLS for 25 mm of Settlement ²
Hwy 105 STA 20+698	362.2 m	Pre-Cast Box ²	361.9 m (west) - 360.5 (east)	Granular 'B' Type II Replacement Fill/Bedding over Firm to Stiff Clayey Silt to Silty Clay	100 kPa	50 kPa
		Open Footing ²	359.7 m	Firm to Stiff Clayey Silt to Silty Clay	125 kPa	100 kPa
			361.9 m (west) - 360.5 (east)	Engineered fill pad over Firm to Stiff Clayey Silt to Silty Clay	125 kPa	100 kPa
	N/A	Pre-Cast Slab on Sheet-Pile Abutments ³	~352.0 m	Loose to Compact Sand to Silty Sand	350 kN/m	300 kN/m

- Notes:
1. Culvert invert elevations are based on the profile drawings provided by MTO (Drawing BC5019311053.dwg).
 2. The factored geotechnical axial resistance at ULS and geotechnical reaction at SLS for 25 mm of settlement are estimated based on an assumed 7.0 m wide box culvert and a 0.6 m wide open footing. The recommended geotechnical resistance/reaction should be reviewed if the founding elevation and/or the foundation widths differ from those given above.
 3. The factored geotechnical resistance at ULS and geotechnical reaction at SLS (for 25 mm of settlement) are provided per horizontal meter of sheet piling. These values assume the sheeting is driven into the loose to compact sand to silty sand deposit encountered in PK-1 and PK-4 at Elevation ~352.0 m. The recommended geotechnical resistance/reaction should be reviewed once more information becomes available in terms of the final sheet-piling configuration.

Prepared by: AC
Checked by: SEMP
Reviewed by: JMAC



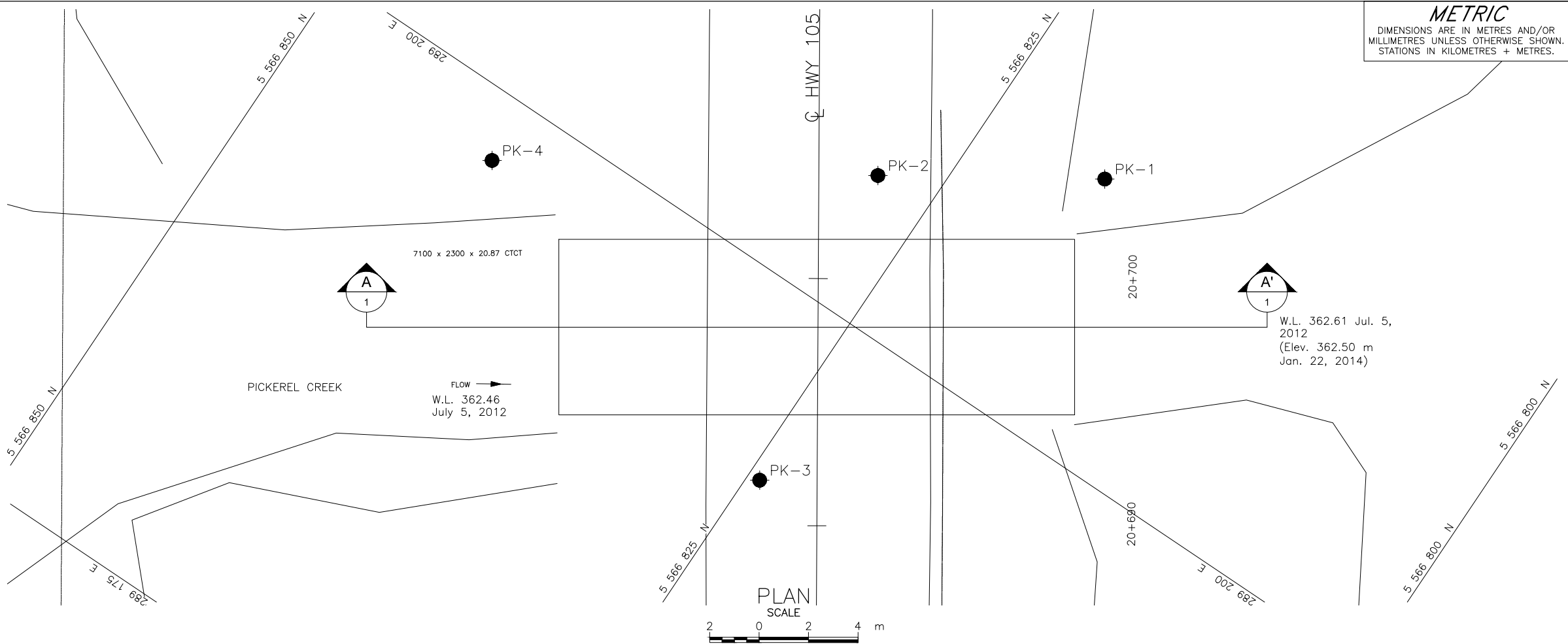
DRAFT PRELIMINARY FOUNDATION REPORT PICKEREL CREEK CULVERT - SITE NO. 41-88/C

Table 4: Resistance to Lateral Loads/Sliding Resistance for Pre-Cast Box and Open Footing Replacement Culverts

Culvert Location	Pre-Cast Box Culvert or Open Footing		Cast-in-place Open Footing	
	Interface Material	Coefficient of Friction ¹ (tan δ)	Interface Material	Coefficient of Friction ¹ (tan δ)
Hwy 105 STA 20+698	Compacted Granular Fill (Backfill/Levelling Pad)	0.45	Firm to Stiff Clayey Silt to Silty Clay	0.35

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

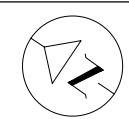
Prepared by: AC
Checked by: SEMP
Reviewed by: JMAC



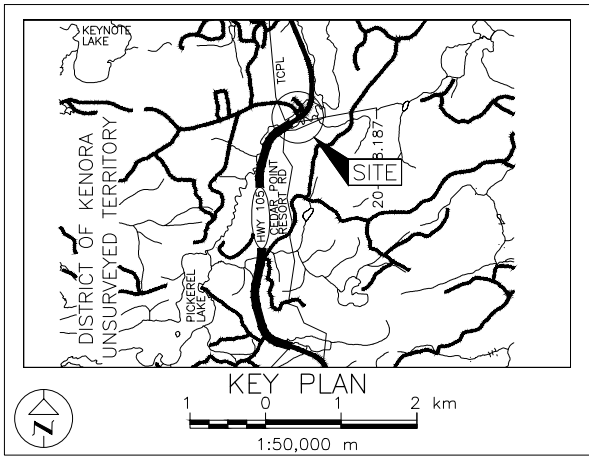
METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No. .
GWP No. 6365-14-00

HIGHWAY 105
PICKEREL CREEK CULVERT STA 20+698
BOREHOLE LOCATIONS AND SOIL
STRATA



SHEET



LEGEND

Borehole - Current Investigation

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
PK-1	362.8	5566819.7	289210.6
PK-2	365.3	5566827.4	289205.6
PK-3	365.4	5566824.5	289192.7
PK-4	363.1	5566840.7	289197.4

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.

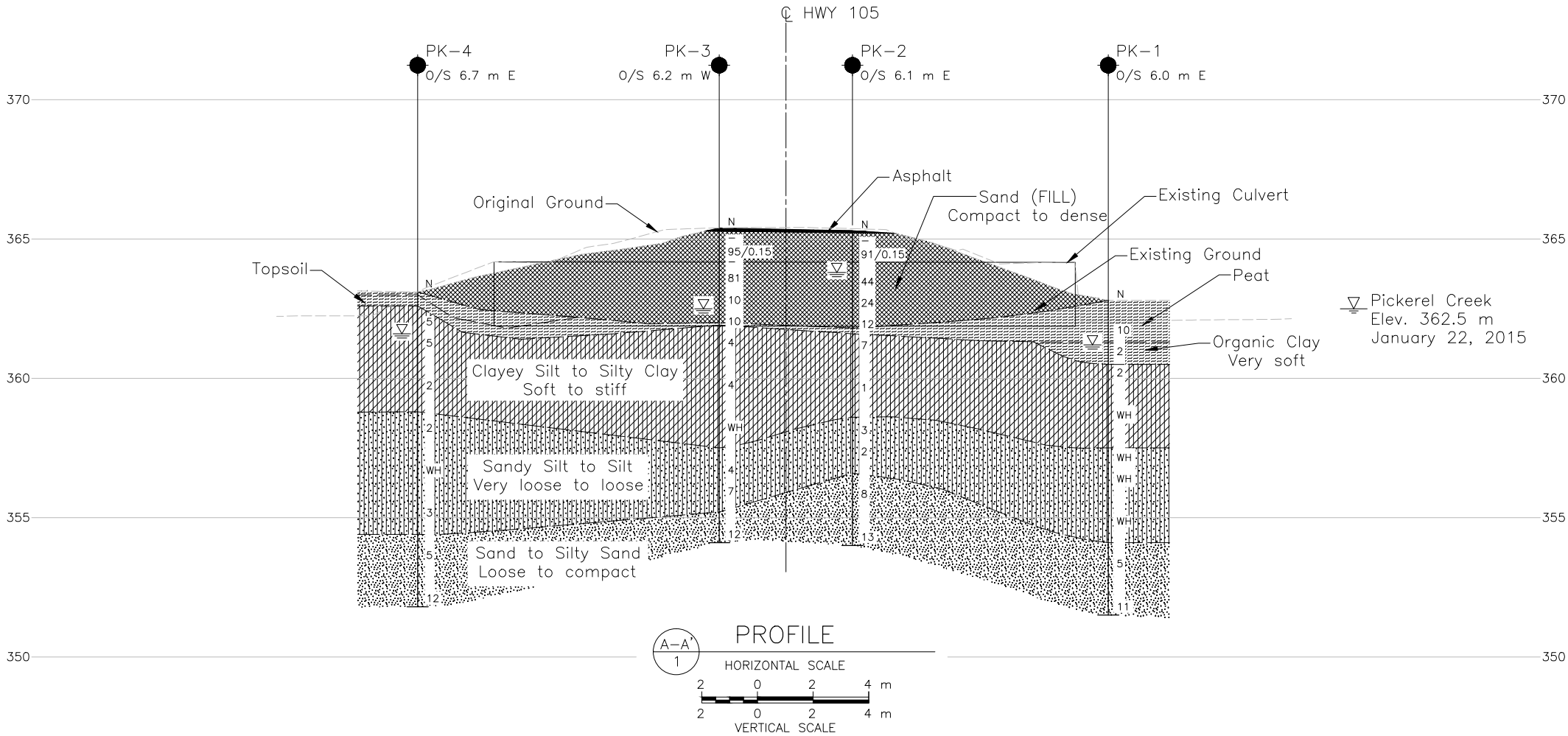
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

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. BC5019311053, received FEB 20, 2015.

DRAFT



NO.	DATE	BY	REVISION
Geocres No. .			
HWY. 105		PROJECT NO. 1411523	
SUBM'D. AC		DATE: 3/25/2015	SITE: 41-88/C
DRAWN: JJL		CHKD. SEMP	APPD. JMAC
		DWG. 1	



PHOTOGRAPHS

**Photograph 1: Pickerel Creek Culvert
West Side - Inlet (Taken from MTO, OSIM 18-Sep-13)**



**Photograph 2: Pickerel Creek Culvert
East Side - Outlet (Taken from MTO, OSIM 18-Sep-13)**





PHOTOGRAPHS

**Photograph 3: Pickerel Creek Culvert
Looking North at Culvert (Golder – January 21, 2015)**





APPENDIX A

Record of Boreholes



LIST OF SYMBOLS

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

I. GENERAL

π	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

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a)	Index Properties
$\rho(\gamma)$	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
γ'	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_α	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
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	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 ρ . Unit weight symbol is γ 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 cm² 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 ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
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)
γ	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			RECORD OF BOREHOLE No PK-1			1 OF 1 METRIC															
G.W.P. 6365-14-00			LOCATION N 5566819.7; E 289210.6			ORIGINATED BY MR															
DIST _____ HWY 105			BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers			COMPILED BY AC															
DATUM GEODETIC			DATE February 19, 2015			CHECKED BY SEMP															
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ			GR SA SI CL		
362.8	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100	20 40 60											
0.0	PEAT (Amorphous) Black to dark brown Frozen*		1	SS	10*		362														
361.3	ORGANIC CLAY Very soft Dark brown Wet		2	SS	2		361														
360.5	CLAYEY SILT, trace clay Soft to firm Grey Wet		3	SS	2		360														
359.5			4	SS	WH		359														
358.5							358														
357.5	SANDY SILT, trace clay Very loose Grey Wet		5	SS	WH		357														
356.5			6	SS	WH		356														
355.5			7	SS	WH		355														
354.1	SAND, some silt, trace clay Loose to compact Grey Wet		8	SS	5		354														
353.1							353														
351.5			9	SS	11		352														
11.3	END OF BOREHOLE																				
Notes:																					
1. Water level at a depth of 1.6 m below ground surface (Elev. 361.2 m) upon completion of drilling.																					
2. Moved 1 m north of borehole and retrieved a Shelby Tube sample at 2.3 m depth below existing grade. Additionally field vanes were obtained between 3.4 m and 3.7 m depth (Italics).																					

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 14/04/15 DATA INPUT:

PROJECT 1411523		RECORD OF BOREHOLE No PK-2				1 OF 1 METRIC								
G.W.P. 6365-14-00		LOCATION N 5566827.4; E 289205.6				ORIGINATED BY MR								
DIST _____ HWY 105		BOREHOLE TYPE NW Casing and Wash Boring				COMPILED BY AC								
DATUM GEODETIC		DATE January 22, 2015				CHECKED BY SEMP								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
365.3	GROUND SURFACE							20 40 60 80 100	20 40 60					
0.0	ASPHALT (90 mm)		1	WS	-		365							
	Sand, trace to some silt, trace to some gravel (FILL) Compact Brown Frozen* to wet		2	SS	91/0 15									
	A 75 mm cobble encountered at 0.9 m depth.						364							
			3	SS	44*									
			4	SS	24		363							
			5A	SS	12		362							
361.8	PEAT, trace wood Dark brown Wet		5B											
3.7	SILTY CLAY, trace gravel, trace silt laminated Firm to stiff Grey Wet		6	SS	7		361							
							360							
			7	SS	1									
							359							
358.6	Sandy SILT, trace clay Very loose Grey Wet		8	SS	3									
6.7							358							
			9	SS	2									
							357							
356.6	SAND, some silt Loose to compact Grey Wet		10	SS	8		356							
8.7							355							
			11	SS	13									
							354							
354.0	END OF BOREHOLE													
11.3	Note: 1. Water level at a depth of 1.5 m below ground surface (Elev. 363.8 m) upon completion of drilling.													

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 14/04/15 DATA INPUT:

PROJECT 1411523			RECORD OF BOREHOLE No PK-3			1 OF 1 METRIC															
G.W.P. 6365-14-00			LOCATION N 5566824.5; E 289192.7			ORIGINATED BY MR															
DIST _____ HWY 105			BOREHOLE TYPE NW Casing and Wash Boring			COMPILED BY AC															
DATUM GEODETIC			DATE January 21, 2015			CHECKED BY SEMP															
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ			GR SA SI CL		
365.4	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100	20 40 60	W _p W W _L										
0.0	ASPHALT (100 mm)		1	WS	-		365														
	Sand, trace to some silt, trace to some gravel (FILL) Compact Brown Frozen* to wet		2	SS	95/0 15																
			3	WS	-		364													0 95 (5)	
			4	SS	81*																
	A 75 mm cobble encountered at 2.1 m depth.		5	SS	10		363														
362.0	PEAT, trace sand Dark brown Wet		6A 6B 6C	SS	10		362														
3.5	CLAYEY SILT, trace sand, trace silt laminated Firm Grey Wet		7	SS	4		361														
			8	SS	4		360														
			9	SS	WH		359														
357.5	SILT, some sand, trace clay Loose Grey Wet		10	SS	4		357													0 16 80 4	
7.9			11	SS	7		356														
355.2	SAND, some silt Compact Grey Wet		12	SS	12		355														
10.2																					
354.1	END OF BOREHOLE																				
11.3	Note: 1. Water level at a depth of 2.9 m below ground surface (Elev. 362.5 m) upon completion of drilling.																				

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 14/04/15 DATA INPUT:

PROJECT 1411523				RECORD OF BOREHOLE No PK-4				1 OF 1 METRIC									
G.W.P. 6365-14-00				LOCATION N 5566840.7; E 289197.4				ORIGINATED BY MR									
DIST _____ HWY 105				BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers				COMPILED BY AC									
DATUM GEODETIC				DATE February 16, 2015				CHECKED BY SEMP									
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED									
363.1	GROUND SURFACE							20	40	60	80	100					
0.0	TOPSOIL						363										
362.6	PEAT Dark brown Frozen						362										
0.5	SILTY CLAY, trace silt, laminated Firm Brown to grey Wet Trace organics in sample 1.		1	SS	5		361										0 0 60 40
			2	SS	5		360										
							359										
358.8	Sandy SILT, trace clay Very loose Grey Wet		3	SS	2		358										0 22 74 4
4.3			4	SS	2		357										
							356										
			5	SS	WH		355										
			6	SS	3		354										
354.4	Silty SAND Loose to compact Grey Wet		7	SS	5		353										
8.7							352										0 74 (26)
351.8	END OF BOREHOLE		8	SS	12												
11.3	Notes: 1. Water level at a depth of 1.5 m below ground surface (Elev. 361.6 m) upon completion of drilling. 2. Moved 1 m east of borehole and retrieved a Shelby Tube sample at 3.0 m depth below existing grade. Additionally, field vanes were obtained between 2.4 m and 4.3 m depth (Italics).																

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 14/04/15 DATA INPUT:



APPENDIX B

Laboratory Test Results



DRAFT PRELIMINARY FOUNDATION REPORT PICKEREL CREEK CULVERT - SITE NO. 41-88/C

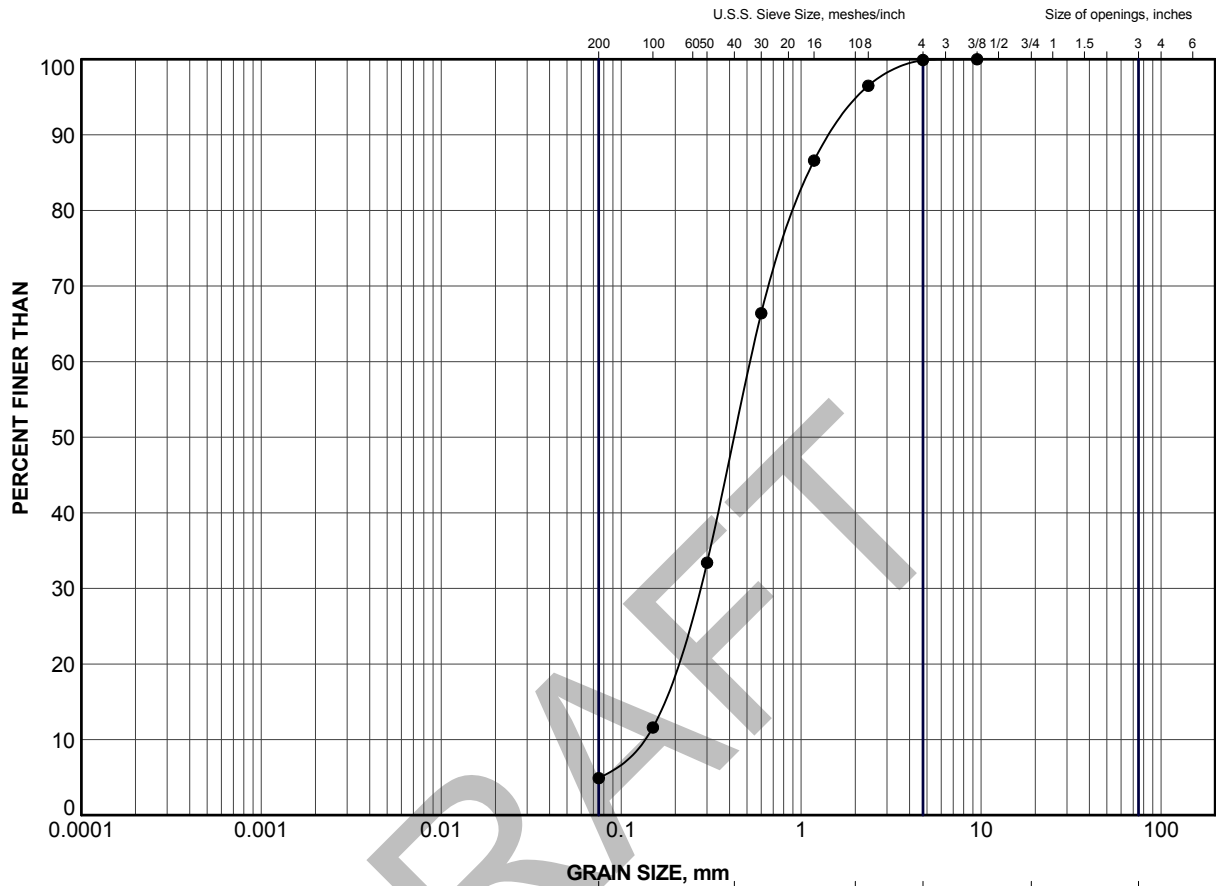
Table B1: Summary of Analytical Testing of Pickerel Creek Water Sample

Parameter	Units	Result
Chloride (CL)	mg/L	4.02
Sulphate (SO4)	mg/L	1.53
Conductivity (EC)	µS/cm	112
Resistivity	µohm-cm	<0.33
pH	n/a	7.14

Notes:

1. Sample obtained on January 26, 2015.
2. Analytical testing carried out by ALS Canada Ltd.

Prepared by: AC
Checked by: SEMP
Reviewed by: JMAC



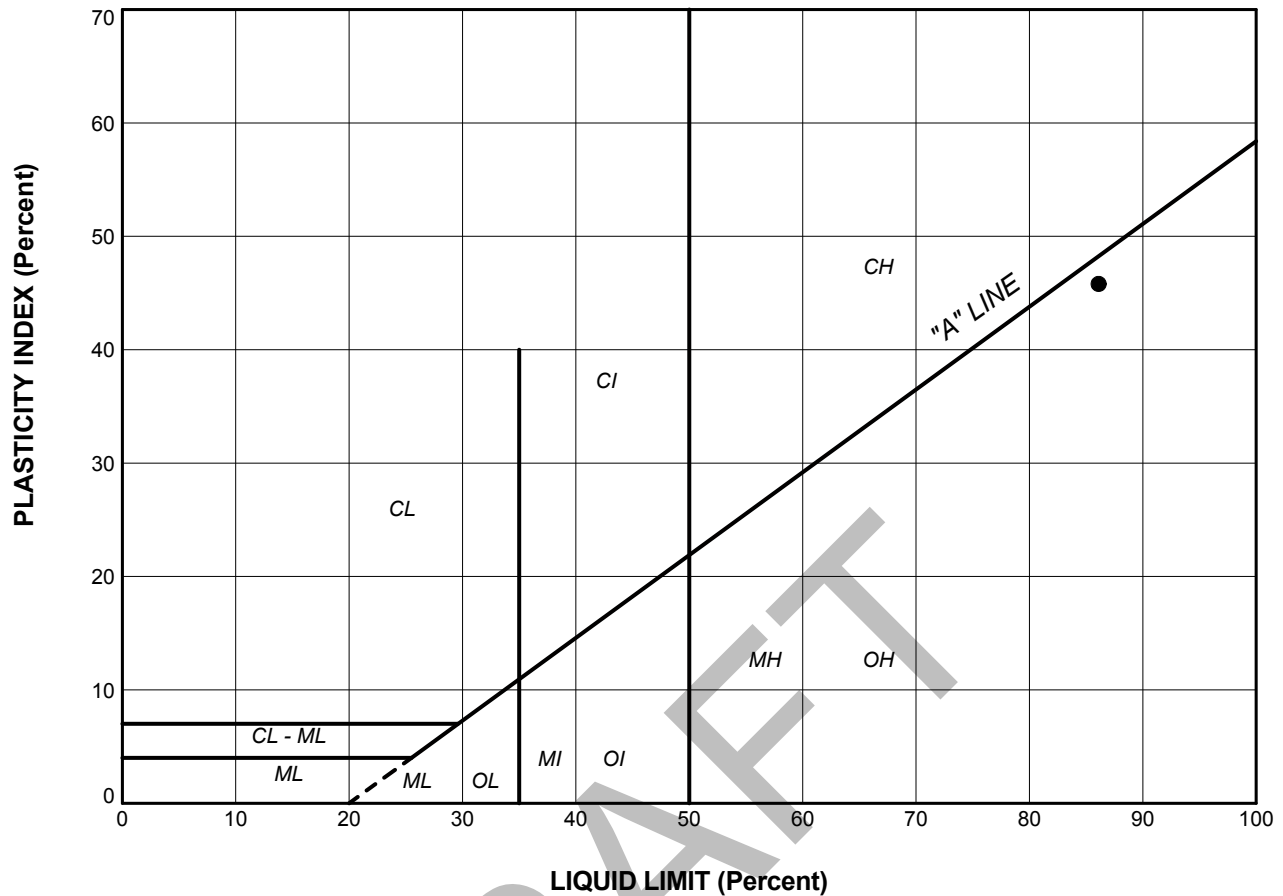
CLAY AND SILT	GRAIN SIZE, mm			Cobble Size	
	fine	medium	coarse	fine	coarse
SAND SIZE				GRAVEL SIZE	

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	PK-3	3	364.2


PROJECT					
HIGHWAY 105 PICKEREL CREEK CULVERT STA 20+698					
TITLE					
GRAIN SIZE DISTRIBUTION SAND (FILL)					
PROJECT No.		1411523		FILE No. 1411523.GPJ	
DRAWN	JJL	Apr 2015	SCALE	N/A	REV.
CHECK	SEMP	Apr 2015	FIGURE B1		
APPR	JMAC	Apr 2015			



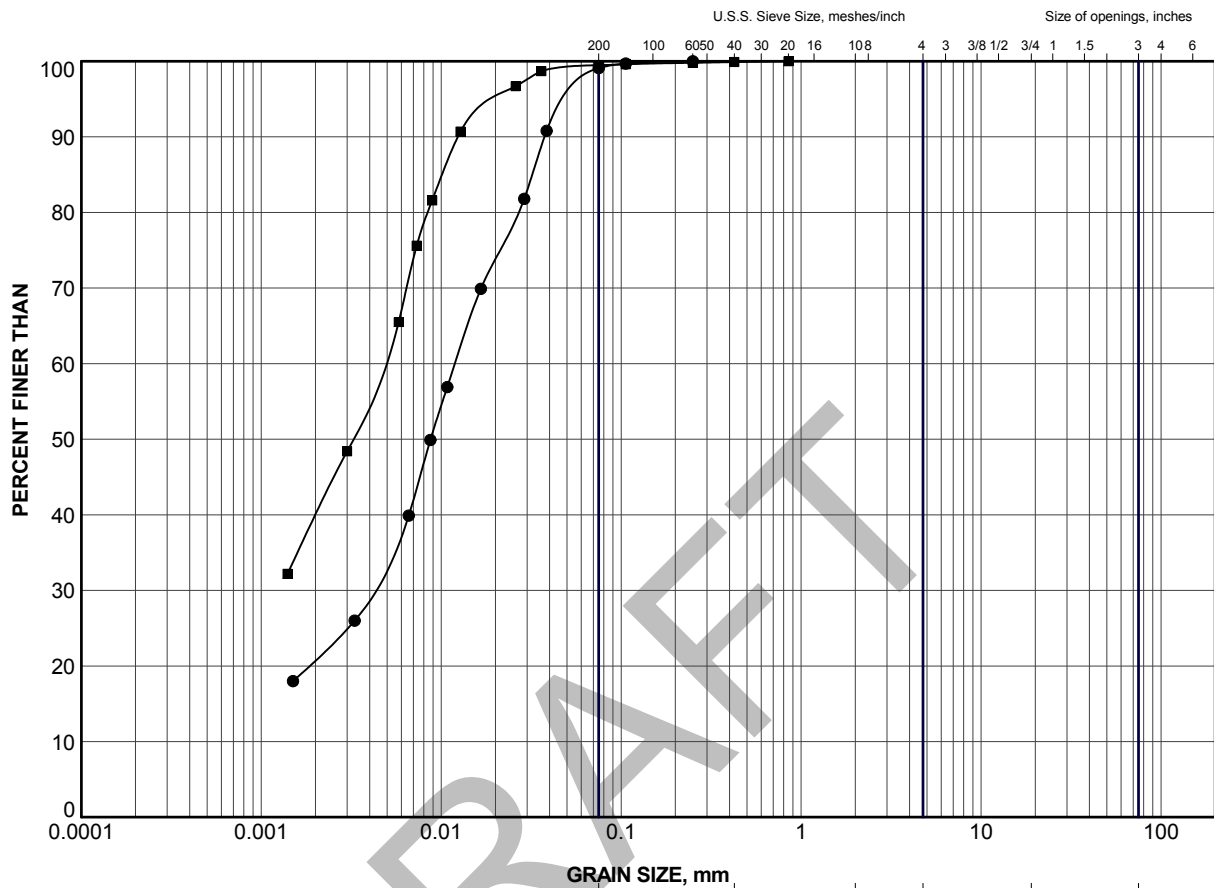


LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	PK-1	2	86.1	40.3	45.8

PROJECT					
HIGHWAY 105 PICKEREL CREEK CULVERT STA 20+698					
TITLE					
PLASTICITY CHART ORGANIC CLAY					
 Golder Associates SUDBURY ONTARIO		PROJECT No.		1411523	
		DRAWN		JJL	Apr 2015
		CHECK		SEMP	Apr 2015
		APPR		JMAC	Apr 2015
		FILE No.		1411523.GPJ	
		SCALE		N/A	REV.
		FIGURE B2			




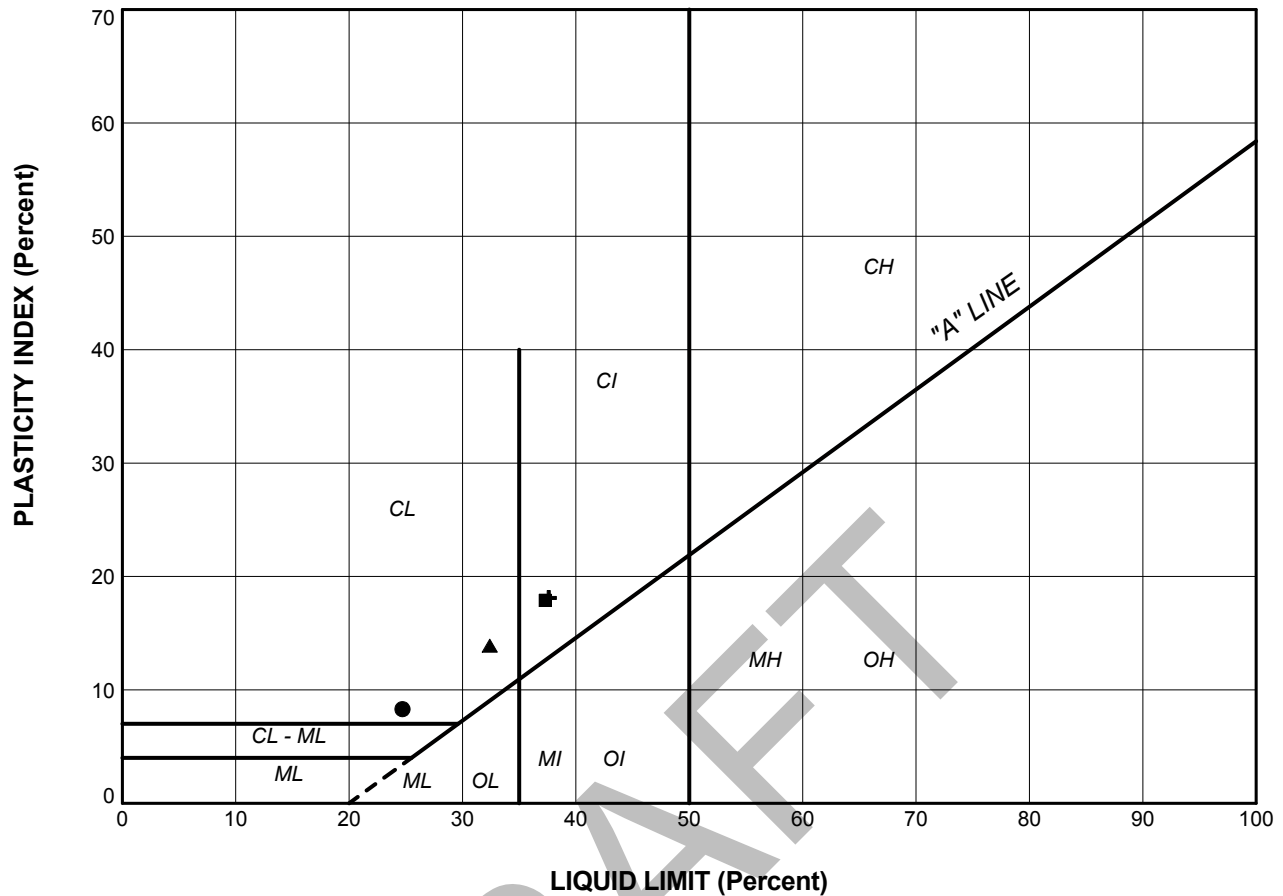


CLAY AND SILT	SAND SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	PK-1	4	358.7
■	PK-4	2	361.3

PROJECT					
HIGHWAY 105 PICKEREL CREEK CULVERT STA 20+698					
TITLE					
GRAIN SIZE DISTRIBUTION CLAYEY SILT to SILTY CLAY					
PROJECT No.		1411523		FILE No. 1411523.GPJ	
DRAWN	JJL	Apr 2015	SCALE	N/A	REV.
CHECK	SEMP	Apr 2015			
APPR	JMAC	Apr 2015			
 Golder Associates SUDBURY, ONTARIO			FIGURE B3		

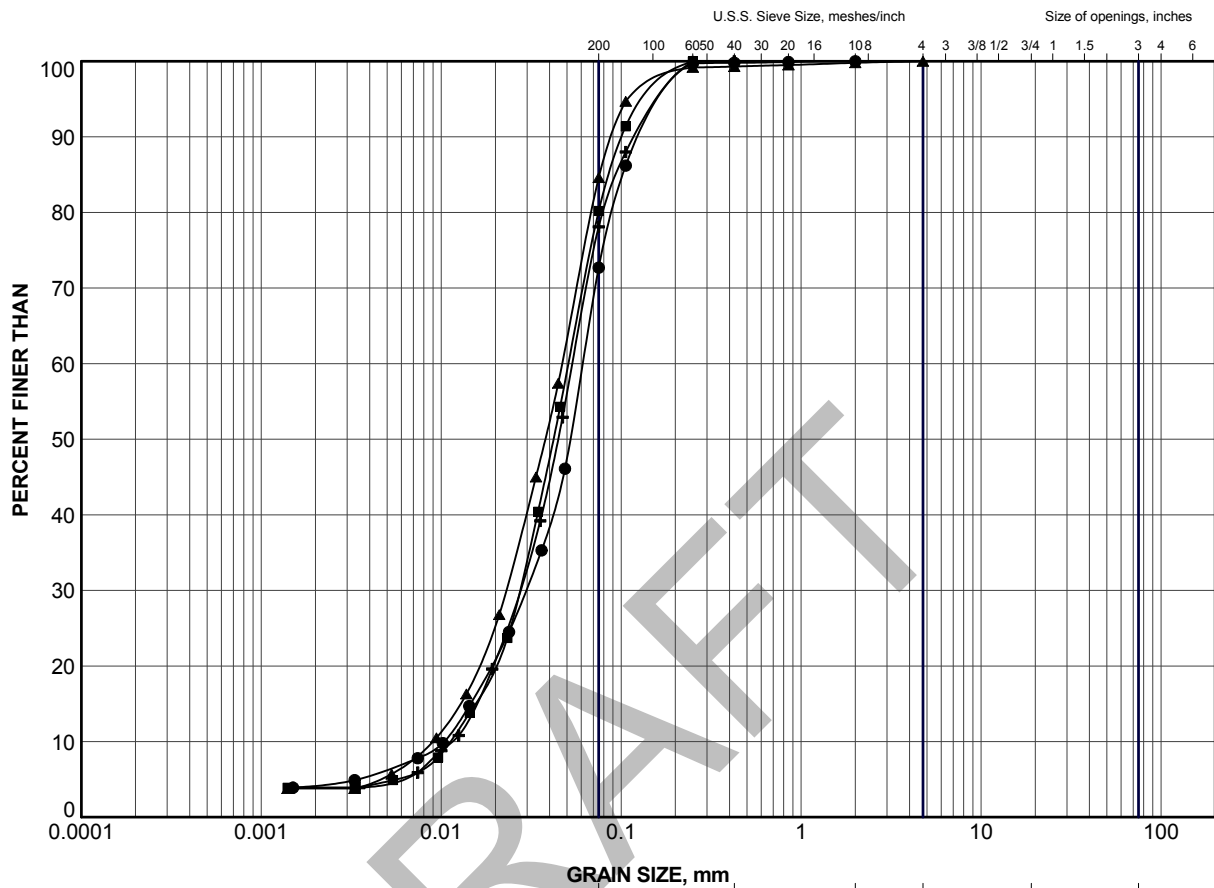


LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	PK-1	4	24.7	16.4	8.3
■	PK-2	6	37.3	19.4	17.9
▲	PK-3	8	32.4	18.5	13.9
+	PK-4	2	37.6	19.5	18.1


PROJECT					
HIGHWAY 105 PICKEREL CREEK CULVERT STA 20+698					
TITLE					
PLASTICITY CHART CLAYEY SILT TO SILTY CLAY					
PROJECT No.		1411523		FILE No.	
DRAWN		JJL	Apr 2015	SCALE N/A	
CHECK		SEMP	Apr 2015	REV.	
APPR		JMAC	Apr 2015	FIGURE B4	

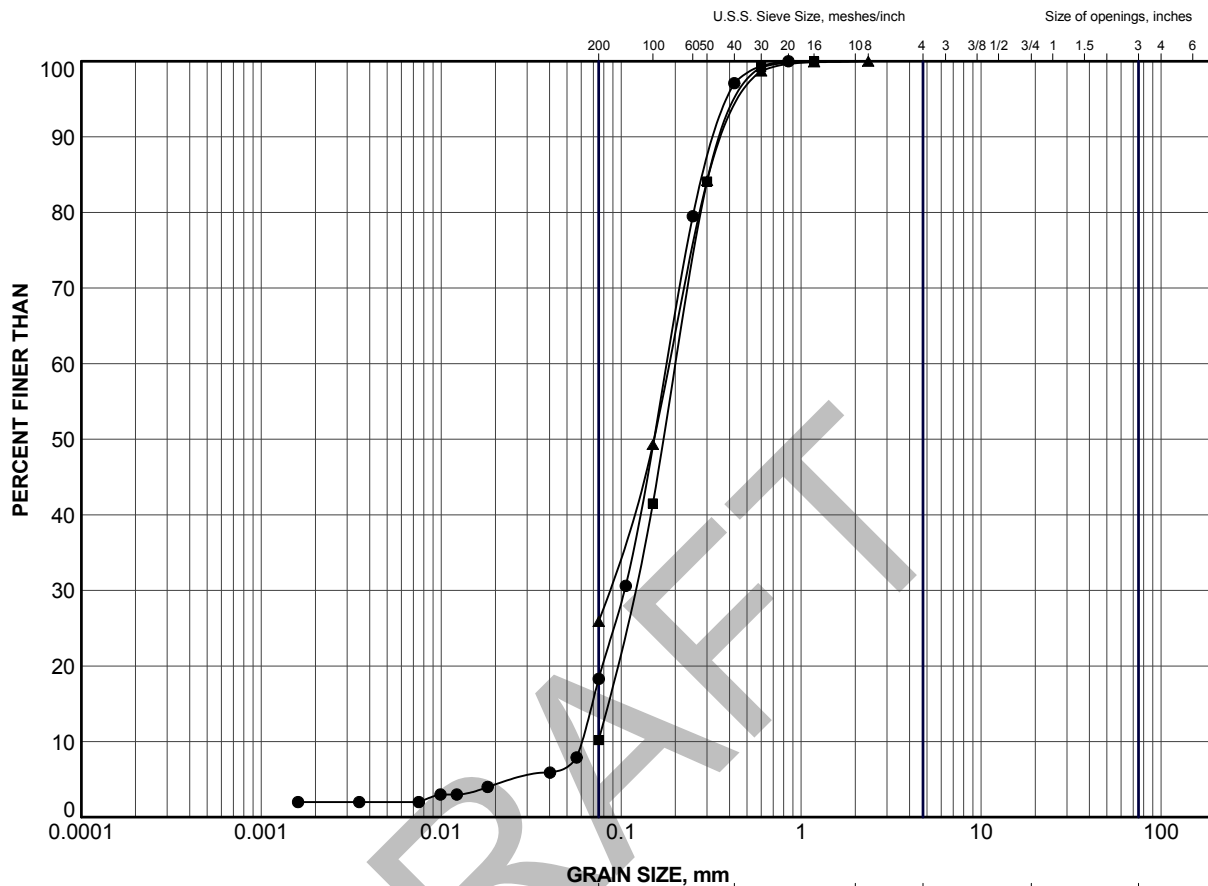




LEGEND


SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	PK-1	5	357.2
■	PK-2	9	357.4
▲	PK-3	10	356.7
+	PK-4	4	358.2

PROJECT				
HIGHWAY 105 PICKEREL CREEK CULVERT STA 20+698				
TITLE				
GRAIN SIZE DISTRIBUTION SANDY SILT to SILT				
PROJECT No.		1411523		FILE No.
DRAWN		JJL	Apr 2015	SCALE N/A
CHECK		SEMP	Apr 2015	REV.
APPR		JMAC	Apr 2015	
 Golder Associates SUDBURY, ONTARIO		FIGURE B5		



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	PK-1	8	353.4
■	PK-2	11	354.3
▲	PK-4	8	352.1

PROJECT					
HIGHWAY 105 PICKEREL CREEK CULVERT STA 20+698					
TITLE					
GRAIN SIZE DISTRIBUTION SAND to SILTY SAND					
PROJECT No. 1411523			FILE No. 1411523.GPJ		
DRAWN	JJL	Apr 2015	SCALE	N/A	REV.
CHECK	SEMP	Apr 2015			
APPR	JMAC	Apr 2015			
 Golder Associates SUDBURY, ONTARIO			FIGURE B6		

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