



June 10, 2015

PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT

**SUCKLE CREEK CULVERT - SITE NO. 48E-56/C
HIGHWAY 11, DISTRICT OF THUNDER BAY
TOWNSHIP OF OAKES
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P. 6307-14-00**

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REPORT





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PART A

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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 Suckle Creek culvert (Site No. 48E-56/C). The Suckle Creek culvert is located in the District of Thunder Bay in the Township of Oakes on Highway 11 at STA 11+958, approximately 7.9 km west of Longlac, Ontario. The key plan showing the general location of this section of Highway 11 and the location of the investigated area are shown on Drawing 1.

2.0 SITE DESCRIPTION

The Suckle Creek culvert consists of a two-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 the area of the culvert 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 referenced to project north and therefore may differ from magnetic north shown on the drawing. For the purposes of this report Highway 11 runs in a west-east direction with the culvert perpendicular to the highway in a north-south orientation. At the culvert location, Suckle Creek drains into Suckle Lake located to the north of Highway 11. At the culvert location, the highway grade is at Elevation 332.9 m and the culvert invert is at approximately Elevations 330.0 m and 330.1 m, at the inlet (south) and outlet (north), respectively. The creek water level was measured by others on May 28, 2014, at Elevation 330.6 m and was measured by Golder on December 11, 2014, at Elevation 330.3 m. Surface conditions in the culvert inlet (south) and outlet (north) area are shown on Photographs 1 to 4, attached.

3.0 INVESTIGATION PROCEDURES

The field work for this subsurface investigation was carried out between December 11 and 12, 2014, and between January 25 and 27 and on February 19, 2015, during which time four boreholes (Boreholes SK-1 to SK-4) were advanced at approximately the locations shown on Drawing 1. Boreholes SK-1 and SK-4 were advanced at the toe of slope near the culvert outlet/inlet using 108 mm inside diameter hollow stem augers. Boreholes SK-2 and SK-3 were advanced from the existing highway platform using NW casing, wash boring techniques and where required NQ coring. The drilling equipment was supplied and operated by George Downing Estate Drilling Ltd. of Grenville-Sur-La-Rouge, Quebec and Cartwright Drilling Inc. of Thunder Bay, Ontario.

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). 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 members of Golder's technical staff who: located the boreholes in the field; arranged for the clearance of underground services; supervised the drilling and sampling



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operations; logged the boreholes; and examined and cared for the soil samples. The soil samples were identified in the field, placed in labelled containers and transported to Golder's geotechnical laboratory in Sudbury for further examination and laboratory testing. Index and classification testing consisting of water 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 December 9, 2014) 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 members 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 on drawing E742111.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)
SK-1	5513663.0	330912.8	331.6	5.8
SK-2	5513659.3	330925.0	332.9	9.8
SK-3	5513651.8	330918.8	332.9	8.0
SK-4	5513646.3	330932.3	331.6	4.8

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 Suckle Creek culvert site generally consist of organic terrain deposits comprised of mainly peat/muck bordering with areas of undulating to rolling bedrock knobs and glaciolacustrine plain deposits of sands and silts.

Based on geological mapping by the Ministry of Northern Development and Mines (MNDM)² mapping, the site is underlain by bedrock of the Archean Era, comprised of diorite-monzonite-granodiorite suites comprised of diorite, tonalite, monzonite and granodiorite 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 detailed results

¹ Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 42ENE

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



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of geotechnical laboratory testing are contained in Appendix B. The results of the in situ field tests (i.e., SPT 'N'-values) as presented on the Record of Borehole sheets and in Section 4 are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

Subsoil Conditions

In summary, the subsoil conditions encountered at the site consist of asphalt and/or granular fill underlain by a deposit of gravelly silt and sand to silt and sand (till). 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)	Laboratory Testing
				Relative Density	
Snow/Ice	SK-1	0.1	331.6	n/a	n/a
Asphalt	SK-2, SK-3	0.120 – 0.125	332.9	n/a	n/a
(FILL) ¹ Sand to Sand and Gravel, trace organics ; brown to grey; moist to wet / frozen	SK-1 to SK-4	0.7 – 4.3	332.8 – 331.5	N = 7 – 87 ²	w = 8% – 19% 2 - M (Fig. B1)
				Loose to Very Dense	
Gravelly Silt and Sand to Silt and Sand (TILL) ³ , trace to some clay, brown to grey, moist to wet	SK-1 to SK-4	Boreholes terminated in this deposit	330.8 – 328.5	N = 23 – 156 ⁴	w = 8% - 12% 8 – MH (Fig. B2) 3 – AL = NP
				Compact to Very Dense	

Where:

N = SPT 'N'-value; number of blows for 0.3 m of penetration

w = Natural Moisture Content (%)

MH = Combined Sieve and Hydrometer analysis

M = Sieve analysis

AL = Atterberg Limits Test

NP = Non-Plastic test result

Notes:

¹ Coarse gravel and cobbles were encountered within the fill in Borehole SK-2 between 0.3 m and 3.8 m depth and in Borehole SK-3 between 0.7 m to 1.5 m depth.

² In three instances, split spoon samples did not penetrate the entire SPT depth, inferred to be due to the presence of coarse gravel and cobbles within the fill.

³ Cobbles were encountered within the till in Borehole SK-2 between 7.0 m and 9.2 m depth.

⁴ In five instances, split spoon samples did not penetrate the entire SPT depth, due to the presence of cobbles or the very dense nature of the till material.



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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 330.3 m on December 11, 2014. 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)
SK-1	3.0	328.6
SK-2	2.0	330.9 ¹
SK-3	1.4	331.5 ¹
SK-4	4.2	327.4

Note 1: Boreholes advanced using NW casing and wash boring techniques; water level may not be representative of stabilized groundwater conditions.

5.0 CLOSURE

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



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Report Signature Page

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**PRELIMINARY FOUNDATION REPORT
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PART B

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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 Suckle Creek culvert. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during this subsurface investigation.

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

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

It is assumed that the existing timber culvert is to be replaced with a culvert of similar dimensions, on the same alignment as well as at invert elevations similar to those of the existing culvert. In addition, it is assumed that there will be no embankment grade raise or widening in the area of the culvert as part of the Hwy 11 reinstatement.

6.2 Foundations

6.2.1 Foundation Options

The existing Suckle Creek culvert is located in the District of Thunder Bay in the Township of Oakes on Highway 11 at STA 11+958, approximately 7.9 km west of Longlac, Ontario. The highway embankment is constructed of granular fill material and is approximately 2.9 m high relative to the culvert invert. The existing culvert consists of a two cell timber box, the details of which (i.e., width, height, length, etc.) are summarized in Table 1.

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

- A pre-cast concrete box; and
- A pre-cast open footing culvert comprised of either a pre-cast concrete arch or metal box.

In this report we have considered the following culvert options:

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



We understand that a sheet-pile abutment and concrete cap option is not being considered for culvert replacement on the Highway 11 or 17 corridors. A corrugated steel pipe (CSP) culvert would likely decrease the flow through capacity and generally has a shorter design life than a concrete culvert and, at this culvert location, 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 subsurface conditions at the founding level are suitable for the support of such foundations and the existing culvert 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. A comparison between these two culvert types is presented in Table 2.

6.2.2 Foundation Elevations and Frost Protection

6.2.2.1 Open Footing Culvert

Strip footings for an open footing culvert should be founded at a minimum depth of 2.6 m below the lowest surrounding grade to provide adequate protection against frost penetration, as per OPSD 3090.100 (Foundation, Frost Penetration Depths for Northern Ontario). In addition, the footings should extend below any existing fill and/or organic deposits, where present. Recommended founding elevations and foundation conditions for the replacement open footing culvert alternative are provided in Table 3.

6.2.2.2 Box Culvert

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 compact to very dense gravelly sand and silt to silt and sand till deposit as encountered in the boreholes. In this regard, the central portion of the culvert may have to be constructed on a granular mat/pad replacing the existing fill present along this section of the culvert, as detailed in Section 6.4.2.

6.2.3 Geotechnical Resistances

6.2.3.1 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 an assumed footing width of 0.6 m as noted in Table 3.

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



The geotechnical resistance/reaction provided in Table 3 are based on loading applied perpendicular to the base of the footings; where applicable, inclination of the load should be taken into account in accordance with Section 6.7.4 and Section 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 assumed that no grade raise or embankment widening is planned. It is recommended that the structural engineer exercise caution when utilizing the values of the geotechnical resistance at SLS (as provided in Table 3) in the design of the culvert and that consideration be given to the sequence and staging of construction, particularly if a grade raise or widening is applicable as the settlement under the culvert as a result of soil loading (not culvert loading) may govern.

6.2.3.2 Box Culvert Replacement

A box culvert, placed on the properly prepared subgrade and/or properly placed granular pad/backfill at or below the founding elevation identified in Table 3, should be based on the recommended factored geotechnical axial resistance at Ultimate Limit States (ULS) and geotechnical reaction at Serviceability Limit States (SLS), for 25 mm of settlement, as provided in Table 3. These recommendations are based on the box culvert width of 5 m as noted in Table 3.

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

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

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

6.2.4 Resistance to Lateral Loads / Sliding Resistance

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



6.2.5 Stability and Settlement

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

For the subsurface conditions and the proposed embankments height up to about 2.9 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 compact to very dense nature of the native till soils, it is anticipated that there would not be any settlement or stability issues should a nominal grade raise or widening be required, provided that any organics (if encountered) or loose materials is removed, should these be encountered in the widening footprint area.

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 2.6 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 pressures are based on the proposed embankment fill material and the following parameters (unfactored) may be used:

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



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

6.4 Construction Considerations

6.4.1 Temporary Roadway Protection

The temporary excavation for the culvert replacement will be made through the existing embankment granular fill comprised of loose to dense sand to sand and gravel and into the native soils, which are comprised of compact to very dense gravelly silt and sand to silt and sand till. 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 fill and native soil are considered to be Type 3 soil above the groundwater table and Type 4 soil below the groundwater table. 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 installation of the sheet piles for temporary shoring may likely be impeded by the dense to very dense nature of the native till material and the presence of cobbles within the fill material. The temporary support systems could consist of soldier piles and lagging, where the piles are driven to a suitable depth and horizontal lagging is installed as the excavation proceeds. Support to the temporary roadway protection system could be in the form of struts and walers and rakers or anchors. Where required, temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems). Temporary excavation support systems should be designed to Performance Level 2 for any excavation adjacent to existing roadways.

6.4.2 Excavation and Replacement Below Culvert

Prior to placement of any bedding material, engineered fill or concrete, the existing embankment fill, organics (if encountered) and any 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. While the existing fill material may be suitable for reuse as backfill under the culvert, recognizing that cobbles were encountered with the fill at two borehole locations, it should be sub-excavated then placed in accordance with the recommendations provided below for new fill material to mitigate the potential for differential settlement.

The culvert subgrade should be inspected by a Quality Verification Engineer following sub-excavation to ensure that all existing fill 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 fill is recommended in wet ground conditions or below water and placement should be in accordance with OPSS.PROV 209 (Embankments over Swamps).

6.4.3 Culvert Bedding and Backfill

6.4.3.1 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 (Backfill Cover for Concrete Culverts).

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 in Section 6.4.3.2 for the box culvert replacement option.

A frost taper should be constructed in a similar configuration to that shown in OPSD 803.010. If raised footings are selected as the preferred culvert replacement option, a 20H:1V frost taper should be considered due to the potential for additional frost heaving.

6.4.3.2 Box Culvert

The bedding and levelling pad requirements for a pre-cast box culvert should be in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts). Given the potential for surface water flow and some groundwater seepage through the 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 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 concrete fine aggregate meeting the grading requirements specified in OPSS.PROV 1002 (Aggregates – Concrete) should be provided as shown on OPSD 803.010 (Backfill and Cover for Concrete Culverts).

A frost taper should be constructed in a similar configuration as that shown in OPSD 803.010. Although OPSD 803.010 relates to box culverts with spans less than or equal to 3.0 m, a similar frost taper at 10H:1V is considered acceptable for the assumed 5 m wide box culvert replacement option.

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

Due to the relatively high silt content (up to about 60 per cent), the native soils may 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 suitable, 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, provided it can be constructed given the presence of the water body upstream of the culvert.

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 blanket 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 engineered fill, bedding material and the actual culvert structure, backfill and the roadway pavement structure. Groundwater flow into the excavation can be expected due to the depth of the excavations and the presence of relatively permeable embankment fill. Therefore, control of groundwater will be necessary to allow for construction to be carried out in dry conditions, where required. Surface water should be directed away from the excavation areas to prevent ponding of water that could result in disturbance and weakening of the foundation subgrade.

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

For both the box culvert 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 cut off wall or cofferdam advanced to an appropriate depth to control groundwater inflow from the creek. As discussed in Section 6.4.2, Granular 'B' Type II fill for bedding or 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 Obstructions

The contractor should be alerted to the presence of cobble size material within the granular fill, as encountered in Borehole SK-2 and potentially within the native soils, as encountered in Boreholes SK-2 and SK-3. An NSSP should be developed at the detail design stage for inclusion into the Contract Documents to alert the contractor to the presence of such obstructions.

6.4.8 Analytical Testing for Construction Materials

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



6.5 Recommendations for Further Work During Detail Design

During the detail design phase, additional field investigation and testing may be required, based on the final configuration and/ or alignment of the culvert and the replacement strategy (i.e., staging). 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. It is recommended that a supplemental investigation be carried out at the detail design stage, comprised of two boreholes through the roadway further away from the culvert to provide data for roadway protection design. If a grade raise or widening of the roadway is required at this site, additional settlement and stability analysis may be required. Further, the need for an application for a PTTW should be defined early in the detail design phase of the project as not to delay the start of construction.

7.0 CLOSURE

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



**PRELIMINARY FOUNDATION REPORT
SUCKLE CREEK CULVERT - SITE NO. 48E-56/C**

Report Signature Page

GOLDER ASSOCIATES LTD.

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AC/JMAC/DAM/kp

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n:\active\2014\1190 sudbury\1191\1411523 - hmm 26 culverts thunder bay\reporting\preliminary design\r02 - suckle creek\final\1411523 rpt r02 15june10 suckle creek.docx



PRELIMINARY FOUNDATION REPORT SUCKLE CREEK CULVERT - SITE NO. 48E-56/C

REFERENCES

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

Occupational Health and Safety Act and Regulation for Construction Projects, January 2006.

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

Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 42ENE.

ASTM International:

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

Ontario Provincial Standard Specifications (OPSS)

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

Ontario Provincial Standard Specifications (OPSS) – Provincial Oriented

OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 209	Construction Specification for Embankments over Swamps and Compressible Soils
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 1002	Material Specification for Aggregates - Concrete
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

Ontario Provincial Standard Drawings (OPSD)

OPSD 208.010	Benching of Earth Slopes
OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.100	Foundation, Frost Penetration Depths for Northern Ontario

Ontario Water Resource Act:

Regulation 903	Wells (as amended)
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PRELIMINARY FOUNDATION REPORT SUCKLE CREEK CULVERT - SITE NO. 48E-56/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)	South End of Culvert (m)	North End of Culvert (m)
Hwy 11 STA 11+958	48E-56/C	2.9	Two Cell Timber Box	2.1 m x 1.6 m each cell	20	330.0	330.1

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 E742111.dwg).

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



PRELIMINARY FOUNDATION REPORT SUCKLE CREEK CULVERT - SITE NO. 48E-56/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. ■ 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. ■ Readily suitable for construction using concrete of metal arch sections 	<ul style="list-style-type: none"> ■ Excavation depths are greater than for a concrete box culvert option, resulting in increased excavation support and dewatering/unwatering requirements and additional spoil material to be disposed off-site. ■ 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"> ■ Low risk of disturbance of the native gravelly silt and sand to silt and sand (till) 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. ■ Culvert joints likely 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. ■ 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 seal likely 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 gravelly sand and silt to silt and sand (till) 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.



PRELIMINARY FOUNDATION REPORT
SUCKLE CREEK CULVERT - SITE NO. 48E-56/C

Table 3: Geotechnical Axial Resistance and Reaction for Pre-Cast Box and Open Footing Culvert Replacements

Culvert Location	Approximate Invert Elevation ¹ (North End / South End)	Culvert Type	Approximate Backfill/Bedding/Footing Founding Elevation	Founding Condition	Factored Geotechnical Axial Resistance at ULS ²	Geotechnical Reaction at SLS for 25 mm of Settlement ²
Hwy 11 STA 11+958	330.0 m	Pre-Cast Box	329.4 m	Granular Backfill and/Bedding over Compact to Very Dense Gravelly Silt and Sand t to Silt and Sand (Till)	250 kPa	200 kPa
		Open Footing	327.4 m	Compact to Very Dense Gravelly Silt and Sand to Silt and Sand (Till)	250 kPa	200 kPa

Notes: 1. Culvert invert elevations are based on the profile drawings provided by MTO (Drawing E742111.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 5.0 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.

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



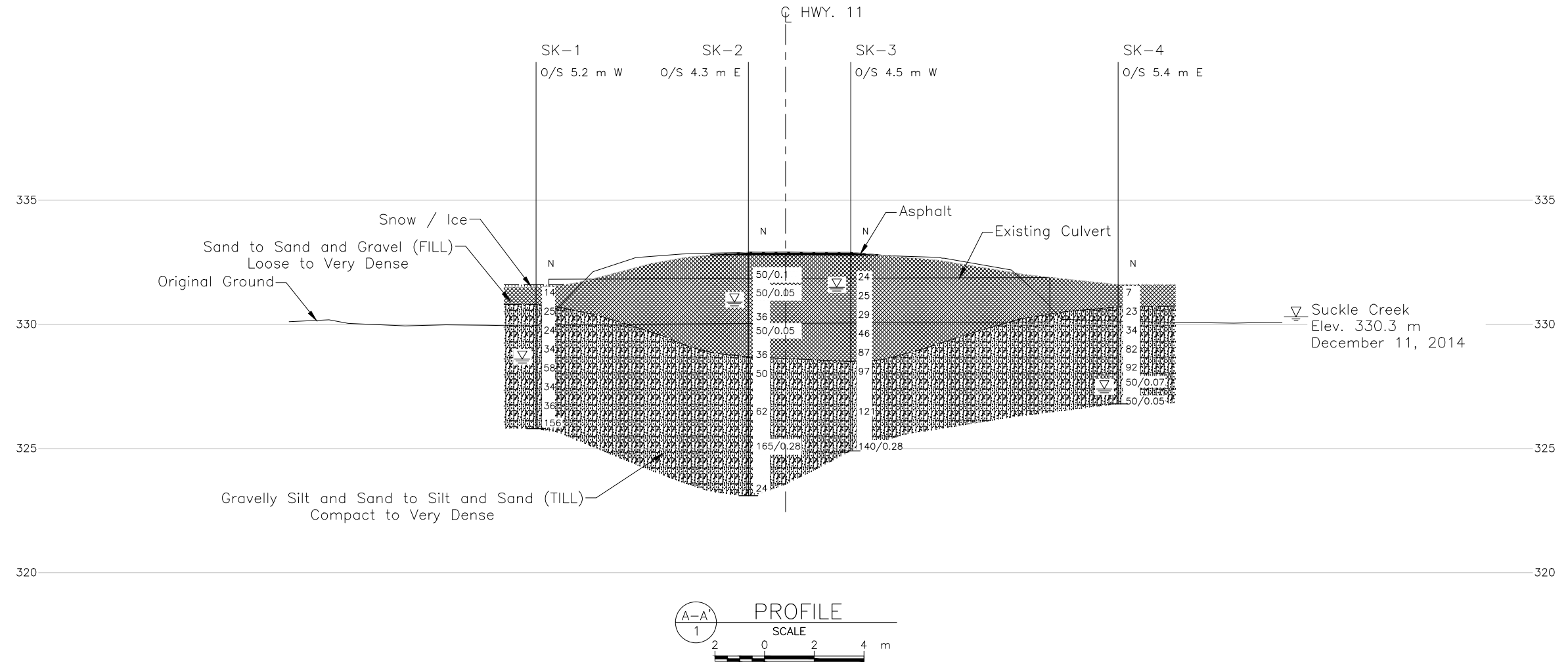
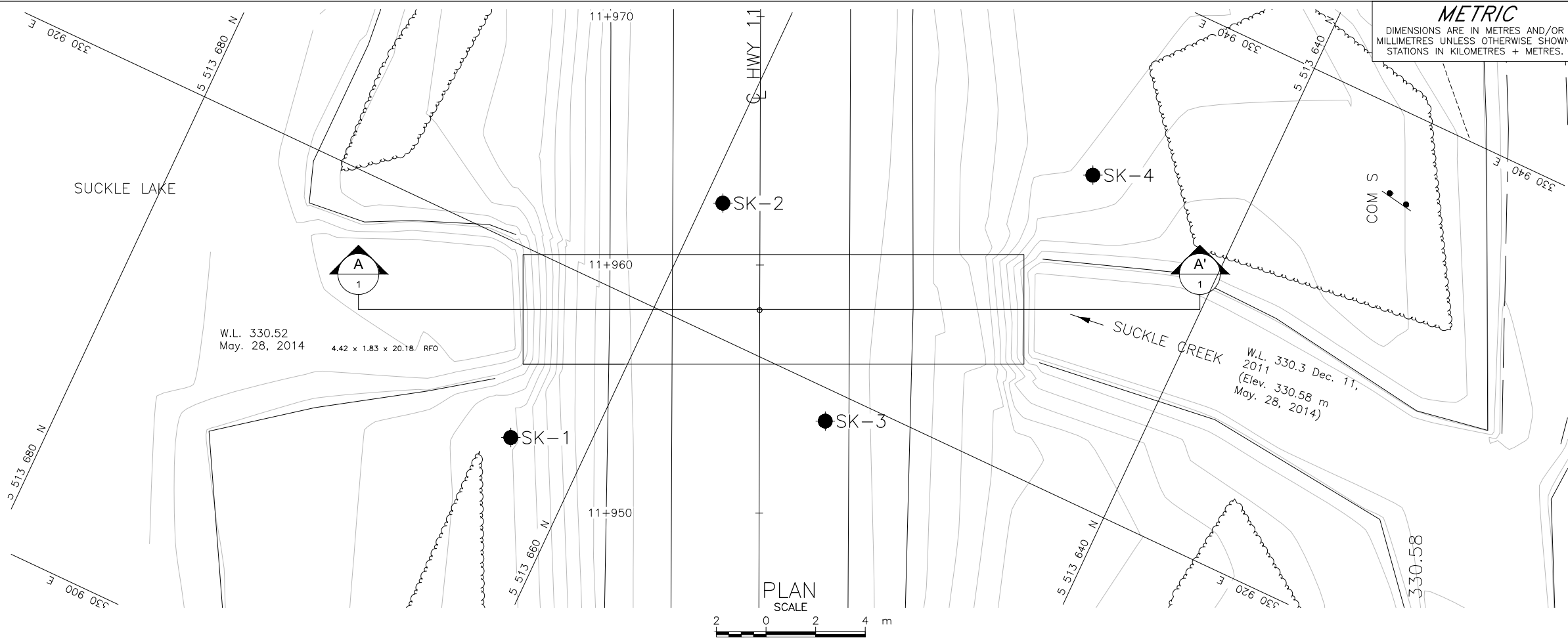
PRELIMINARY FOUNDATION REPORT SUCKLE CREEK CULVERT - SITE NO. 48E-56/C

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

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 11 STA 11+958	Compacted Granular Fill (Levelling Pad)	0.45	Compact to Very Dense Gravelly Silt and Sand to Silt and Sand (Till)	0.45

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: DAM
Reviewed by: JMAC

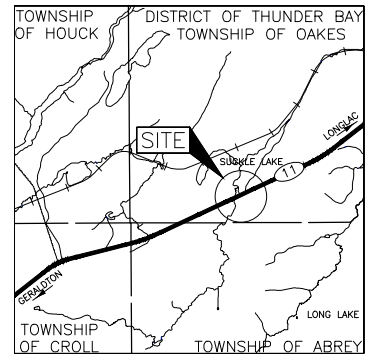


METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No. .
GWP No. 6307-14-00

HIGHWAY 11
SUCKLE CREEK CULVERT STA 11+958
BOREHOLE LOCATIONS AND SOIL
STRATA

SHEET



KEY PLAN
N.T.S.



LEGEND

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

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
SK-1	331.6	5513663.0	330912.8
SK-2	332.9	5513659.3	330925.0
SK-3	332.9	5513651.8	330918.8
SK-4	331.6	5513646.3	330932.3

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. E742111, received JAN 27, 2015.



NO.	DATE	BY	REVISION
1	03/07/2015	JMAC	1
Geocres No. 42E-19			
HWY. 11	PROJECT NO. 1411523		DIST. .
SUBM'D. AC	CHKD. .	DATE: 03/07/2015	SITE: 48E-56/C
DRAWN: TB	CHKD. DAM	APPD. JMAC	DWG. 1



PHOTOGRAPHS

**Photograph 1: Suckle Creek Culvert
North Side - Outlet (Taken from MTO, OSIM_08-22-2012)**



**Photograph 2: Suckle Creek Culvert
South Side - Inlet (Taken from MTO, OSIM_08-22-2012)**





PHOTOGRAPHS

**Photograph 3: Suckle Creek Culvert
Looking East at North Outlet (Golder – February 19, 2015)**



**Photograph 4: Suckle Creek Culvert
Looking North at South Inlet (Golder – December 11, 2014)**





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 SK-1				1 OF 1 METRIC							
G.W.P. 6307-14-00		LOCATION N 5513663.0; E 330912.8				ORIGINATED BY SC							
DIST _____ HWY 11		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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED		WATER CONTENT (%) W _p — W — W _L		γ	GR SA SI CL
331.6	GROUND SURFACE							20 40 60 80 100					
0.0	SNOW / ICE												
330.8	Gravelly sand, trace organics (FILL) Brown Frozen		1	SS	14		331						
0.8	Gravelly Silty SAND to SILT and SAND, trace to some gravel, some clay (TILL) Compact to very dense Grey Moist		2	SS	25		330						25 43 29 3
			3	SS	24		329						
			4	SS	34		328						
			5	SS	58		327						
			6	SS	34								
			7	SS	36								
			8	SS	156		326						9 35 46 10
325.8	END OF BOREHOLE												
5.8	Note: 1. Water level at a depth of 3.0 m below ice surface (Elev. 328.6 m) upon completion of drilling.												

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

PROJECT 1411523		RECORD OF BOREHOLE No SK-3				1 OF 1 METRIC											
G.W.P. 6307-14-00		LOCATION N 5513651.8; E 330918.8				ORIGINATED BY MR											
DIST _____ HWY 11		BOREHOLE TYPE NW Casing, Wash Boring and NQ Coring				COMPILED BY AC											
DATUM GEODETIC		DATE December 12, 2014				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									
332.9	GROUND SURFACE							20	40	60	80	100					
0.0	ASPHALT (120 mm)																
0.1	Sand to silty sand and gravel (FILL) Compact to very dense Grey Wet		1	SS	24												
	Cobbles encountered at 0.7 m and 1.5 m depths.		2	SS	25												
			3	SS	29												
			4	SS	46												
			5	SS	87												
328.5	Gravelly SILT and SAND, trace clay (TILL) Very dense Grey Wet		6	SS	97												
4.4			7	SS	121												
			8	SS	140/0.28												
324.9	END OF BOREHOLE																
8.0	Note: 1. Water level at a depth of 1.4 m below ground surface (Elev. 331.5 m) upon completion of drilling.																

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 20/04/15 DATA INPUT:

PROJECT 1411523		RECORD OF BOREHOLE No SK-4				1 OF 1 METRIC						
G.W.P. 6307-14-00		LOCATION N 5513646.3; E 330932.3				ORIGINATED BY CW						
DIST _____ HWY 11		BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers				COMPILED BY AC						
DATUM GEODETIC		DATE December 11, 2014				CHECKED BY SEMP						
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	W _p W W _L			20 40 60
331.6	GROUND SURFACE											
0.0	Gravelly sand, some silt (FILL) Loose Brown Moist		1	SS	7		331					
330.7	Augers grinding from 0.3 m to 0.8 m depth.		2	SS	23							
0.9	SILT and SAND, trace to some gravel, trace to some clay (TILL) Compact to very dense Brown to grey Moist to wet		3	SS	34		330					
			4	SS	82		329					
			5	SS	92		328					
			6	SS	50/0.07							
			7	SS	50/0.05		327					
326.8	END OF BOREHOLE											
4.8	Note: 1. Water level at a depth of 4.2 m below ground surface (Elev. 327.4 m) upon completion of drilling.											



APPENDIX B

Laboratory Test Results



PRELIMINARY FOUNDATION REPORT SUCKLE CREEK CULVERT - SITE NO. 48E-56/C

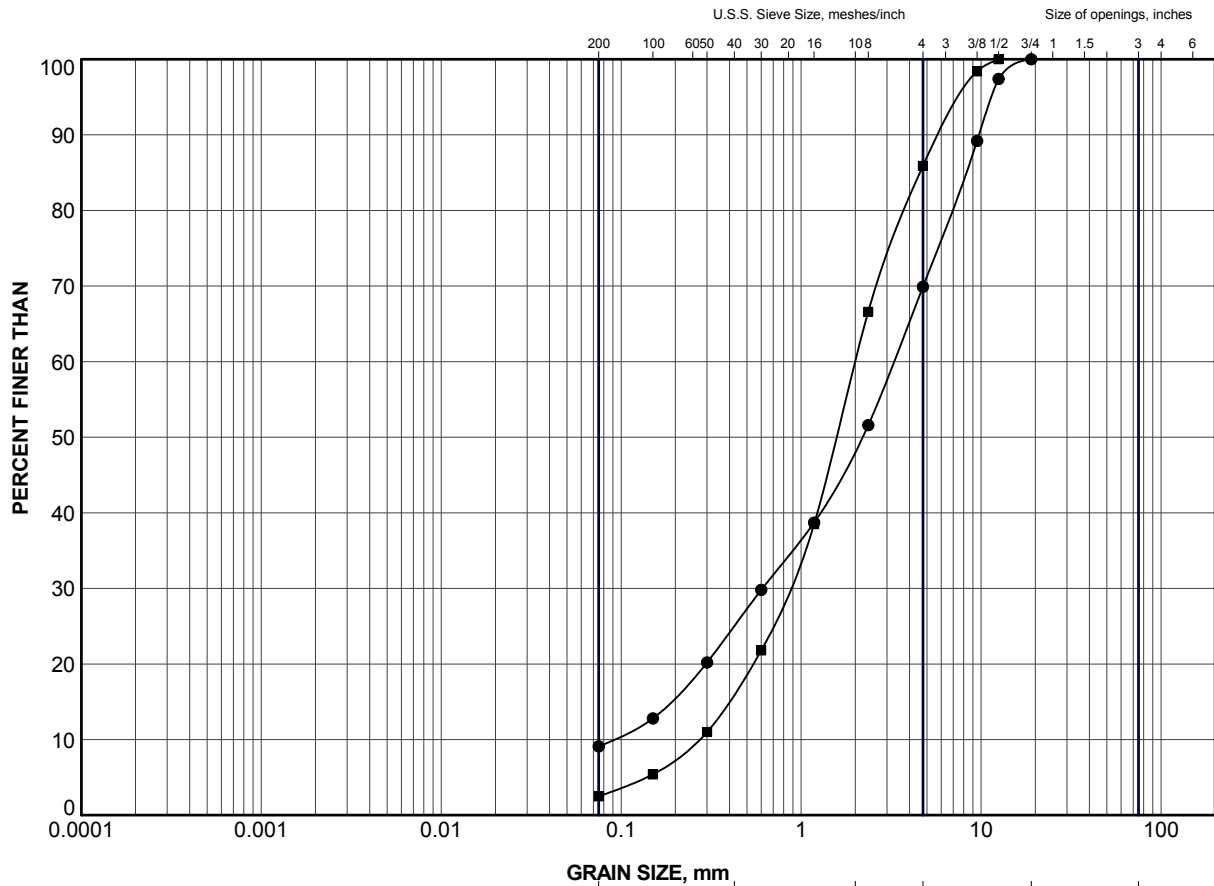
Table B1: Summary of Analytical Testing of Suckle Creek Water Sample

Parameter	Units	Result
Chloride (CL)	mg/L	6.80
Sulphate (SO4)	mg/L	0.56
Conductivity (EC)	µS/cm	120
Resistivity	µohm-cm	<0.33
pH	n/a	6.67

Notes:

1. Sample obtained on December 9, 2014.
2. Analytical testing carried out by ALS Canada Ltd.


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

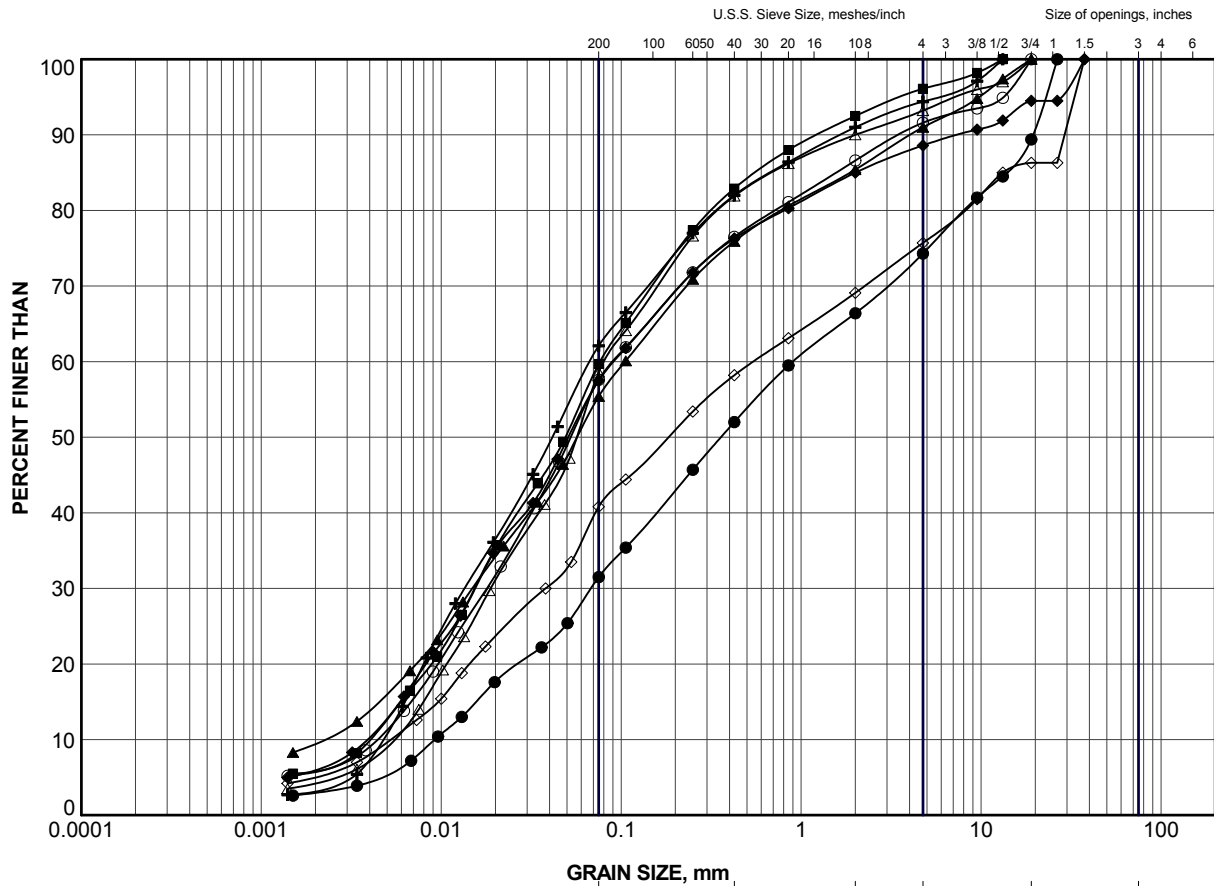



CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	SK-2	1	332.0
■	SK-3	2	331.2

PROJECT					
HIGHWAY 11 SUCKLE CREEK CULVERT STA 11+958					
TITLE					
GRAIN SIZE DISTRIBUTION SAND to SAND and GRAVEL (FILL)					
PROJECT No.		1411523		FILE No. 1411523.GPJ	
DRAWN	JJL	Apr 2015	SCALE	N/A	REV.
CHECK	DAM	Apr 2015			
APPR	JMAC	Apr 2015			
 Golder Associates SUDBURY, ONTARIO			FIGURE B1		



PROJECT				
HIGHWAY 11 SUCKLE CREEK CULVERT STA 11+958				
TITLE				
GRAIN SIZE DISTRIBUTION GRAVELLY SILT and SAND to SILT and SAND (TILL)				
PROJECT No.		1411523		FILE No.
DRAWN		JJL	Apr 2015	SCALE N/A
CHECK		DAM	Apr 2015	REV.
APPR		JMAC	Apr 2015	
 Golder Associates SUDBURY, ONTARIO		FIGURE B2		

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