



September 8, 2015

PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT

**FLYNNE CREEK CULVERT - SITE NO. 48E-83/C
HIGHWAY 11, DISTRICT OF THUNDER BAY
UNSURVEYED TERRITORY
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P. 6311-14-00**

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



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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 Flynne Creek culvert (Site No. 48E-83/C). The Flynne Creek culvert is located in the District of Thunder Bay in Unsurveyed Territory on Highway 11 at STA 17+495, approximately 42 km east of the junction of Highway 11 and Highway 625 near 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 Flynne Creek culvert consists of a twin-cell timber structure, the details of which (i.e., width, height, length, etc.) are summarized in Table 1 following the text of the report.

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 on a slight skew from perpendicular to the roadway. 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 on the south side of Highway 11. The north side of Highway 11 is bordered by an open-water pond (or small lake) that drains southerly towards Flynne Lake via Flynne Creek. At the culvert location, the highway grade is at Elevation 272.2 m and the culvert invert is at approximately Elevation 268.6 m at both the inlet and outlet. The creek water level was at Elevation 270.4 m, as measured by others on November 16, 2008. The creek ice level was at Elevation 269.6 m, as measured by Golder on March 22, 2015. Surface conditions in the culvert inlet and outlet areas are shown on Photographs 1 to 4, attached.

3.0 INVESTIGATION PROCEDURES

The field work for this subsurface investigation was carried out on February 15 and between March 19 and 22, 2015, during which time four boreholes (Boreholes FC-1 to FC-4) were advanced at approximately the locations shown on Drawing 1. Boreholes FC-1 and FC-4 were advanced at the toe of slope near the culvert inlet/outlet and Boreholes FC-2 and FC-3 were advanced from the existing highway platform. The boreholes were advanced using a track-mounted CME 850 drill rig supplied and operated by Cartwright Drilling Inc. of Thunder Bay, Ontario.

The boreholes were advanced by using a combination of 108 mm inside diameter hollow stem augers, NW casing and wash boring, and NQ coring techniques. 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 operations; logged the boreholes; and examined and cared for the soil samples. The soil samples were identified in the field, placed in labelled containers and transported to Golder's geotechnical laboratory in Sudbury for further examination and laboratory testing. Index and classification testing consisting of water



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content 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 March 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 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 BC494854114.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)
FC-1	5518890.5	396198.4	271.3	6.0
FC-2	5518881.8	396207.2	272.2	8.4
FC-3	5518877.5	396203.3	272.2	9.3
FC-4	5518863.6	396214.7	270.8	5.9

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 Flynn Creek culvert site generally consist of organic terrain deposits comprised of mainly peat/muck bordering with areas of undulating to rolling bedrock knobs.

Based on geological mapping by the Ministry of Northern Development and Mines (MNDM)², the site is underlain by mafic to intermediate metavolcanic bedrock of the Archean Era, comprised of basaltic and andesite flows, tuffs and breccias, chert and iron formations bordering with massive granodiorite to granite formations.

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 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.

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

² Ministry of Northern Development of Mines. Bedrock Geology of Ontario – East Central Sheet, Ontario Geological Survey – Map 2543.



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Subsoil Conditions

In summary, the subsoil conditions encountered at the site consist of asphalt and sand fill (for boreholes advanced through the embankment) and organics consisting of topsoil or peat (for boreholes advanced from the toe of slope), underlain by deposits of peat, silt, silty sand, clayey silt, and silt and sand to gravelly silty sand, underlain by bedrock. 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	
Asphalt	FC-2, FC-3	0.12	272.2	n/a	n/a
Topsoil	FC-1	0.150	271.3	n/a	n/a
(FILL) Sand , trace to some gravel, trace to some silt; brown; moist to wet / frozen	FC-1 to FC-3	1.0 – 3.5	272.1 – 271.2	N = 3 – 9 ¹	w = 13% – 22% 1 – M (Fig. B1)
				Very loose to loose	
Fibrous Peat ; black; wet / frozen	FC-1, FC-4	0.3 – 0.7	270.2	N = 2	w = 336%
				Very soft	
Silt , trace to some clay, trace sand,; grey; moist to wet	FC-1 to FC-4	1.0 – 2.5	269.9 – 268.6	N = 3 – 10	w = 23% – 24% 3 – MH (Fig. B2) 4 – AL = NP
				Very loose to Compact	
Silty Sand ; grey, wet,	FC-4	0.3	267.4	n/a	n/a
Clayey Silt , trace to some sand; grey; wet	FC-4	1.2	267.1	N = 2	w = 25% w _p = 14% w _l = 24% I _p = 10% 1 – MH (Fig. B3) 1 – AL (Fig. B4)
				Soft	
Silt and Sand, to gravelly Silty Sand , trace clay; grey; wet	FC-1 to FC-4	1.0 – 3.1	267.9 – 265.9	N = 5 – 19 ²	w = 11% - 15% 3 – MH (Fig. B5) 1 – AL = NP
				Loose to Compact	

Where:

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

w = Natural Moisture Content (%)

M = Sieve analysis

MH = Combined Sieve and Hydrometer analysis

AL = Atterberg Limits Test

w_p = Plastic Limit (%)

w_l = Liquid Limit (%)

I_p = Plasticity Index (%)

NP = Non-Plastic test result



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Notes:

¹ In two instances within the granular fill, split spoon samples did not penetrate the entire SPT depth due to the frozen state of the material.

² In Borehole FC-1, the split spoon sample did not penetrate the entire SPT depth due to the presence of coarse gravel and/or inferred cobbles within the silt and sand to gravelly silty sand deposit as evidenced by augers grinding.

Bedrock Conditions

Bedrock was cored in Boreholes FC-2 and FC-3 and the retrieved bedrock core is described as black to white to pink, fine to medium grained and fresh to slightly weathered granodiorite as presented on the Record of Drillhole sheets in Appendix A. Photographs of the retrieved bedrock core samples are shown on Figure B6. The depth to the bedrock surface, elevations and bedrock properties encountered in the boreholes is provided below.

Borehole No.	Depth to Bedrock ¹ (m)	Bedrock Surface Elevation (m)	Core Length (m)	TCR (%)	RQD (%)	Rock Quality ²
FC-2	6.8	265.4	1.6	93%	75%	Fair to Good
FC-3	7.7	264.5	1.6	100%	34%	Poor

Notes:

¹ Below ground surface

² Table 3.10 of CFEM 2006³

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 269.6 m on March 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)
FC-1	1.8	269.5
FC-2	Dry to 4.6	267.6 ¹
FC-3	5.6	266.6
FC-4	Dry to 4.3	266.5 ¹

Note:

¹ Borehole FC-3 and FC-4 caved upon completion of drilling and were noted to be dry to the caved depth. The groundwater elevations are inferred at the caved depth.

³ Canadian Geological Society, 2006. Canadian Foundation Engineering Manual, 4th Edition.



5.0 CLOSURE

The field drilling program was carried out under the supervision of Ms. Selena Contardo and Mr. Nicholas Jamin under the overall direction of Mr. David Muldowney, P.Eng. This Preliminary Foundation Investigation Report was prepared by Mr. Tibor Berecz, 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

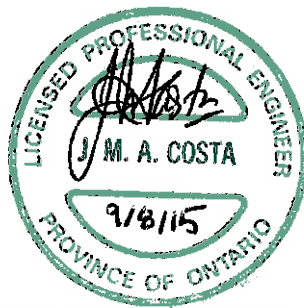
GOLDER ASSOCIATES LTD.

Tibor Berecz

Tibor Berecz, M.Sc. Civil Eng.
Geotechnical Group



David Muldowney, P.Eng.
Geotechnical Engineer



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

TB/AC/DAM/JMAC/kp

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PART B

**PRELIMINARY FOUNDATION DESIGN REPORT
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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 Flynne 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 Highway 11 reinstatement.

6.2 Foundations

6.2.1 Foundation Options

The existing Flynne Creek culvert is located in the District of Thunder Bay, Unsurveyed Territory on Highway 11 at STA 17+495, approximately 42 km east of the junction of Highway 11 and Highway 625 near Longlac, Ontario. The highway embankment is constructed of granular fill material and is approximately 3.6 m high relative to the culvert invert with approximately 1.3 m of cover over the existing culvert. The existing culvert consists of a twin-cell timber structure, the details of which (i.e., width, height, length, etc.) are summarized in Table 1.

Based on discussions with HMM and a review of the 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:

- Twin pre-cast concrete boxes on a slight realignment;
- A pre-cast concrete box on a slight realignment; and
- An open footing culvert with a metal box.

In this report we have considered the following culvert options:

- Single or twin concrete box culvert(s);



- An open footing culvert box or arch culvert supported on either cast-in-place or pre-cast footings; and
- Pipe Culvert(s).

We understand that a concrete cap supported on sheet-pile abutments option is not being considered by MTO or HMM for culvert replacements on the Highway 11 corridor. Pipe culverts, including elliptical and flexible arch sections are considered feasible but would provide less flow-through capacity compared to a box culvert option with a similar span and would likely require multiple, parallel pipes. If a pipe culvert is selected, a concrete pipe would be preferred as structural plate or corrugated steel pipe generally has a shorter design life. Open footing arch culverts could be considered but the flow-through capacity for certain types and sizes, or arches, could be limited or restricted due to the need to provide adequate soil cover (including the roadway pavement structure) and the overall performance of such structures over the longer term is not known. From a foundation perspective, a concrete box culvert sufficiently wide to handle the flow is preferred at this site. A pre-cast concrete box culvert is recommended, rather than an open footing culvert, as the subsurface conditions at the foundation level are suitable for the support of such a box foundation; it can accommodate an accelerated construction schedule; and there are reduced excavation, dewatering and shoring requirements. Further, if twin boxes are considered, one cell of the existing timber culvert could likely be used as the diversion channel during construction. Other culvert types may be preferred due to construction staging or other considerations such as fisheries requirements related to natural channel substrate. A comparison of culvert types based on advantages, disadvantages and risk/consequence is presented in Table 2.

6.2.2 Foundation Elevations and Frost Protection

6.2.2.1 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. Given the proposed culvert invert the replacement box culvert should be founded on a bedding layer of granular material placed over the very loose to compact silt deposit the base of which should be below any existing fill and/or organics. Recommended foundation elevation and foundation conditions for a replacement box culvert are provided in Table 3.

6.2.2.2 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). Given the presence of the clayey silt deposit encountered in Borehole FC-4, we recommend that the replacement open footing culvert be founded on the loose to compact silt and sand to gravelly silty sand deposit at Elev. 265.9 m, below any clayey silt that may be encountered along the alignment of the footings. Recommended founding elevations and foundation conditions for the replacement open footing culvert are provided in Table 3.



6.2.2.3 *Pipe Culvert*

It is not necessary to found a pipe culvert at the standard depth for frost protection purposes, as such a culvert is tolerant to small magnitudes of movement related to freeze-thaw cycles, should these occur. We recommend that the replacement pipe culvert, if adopted, be founded on a bedding layer of granular material placed over the very loose to compact silt stratum. Recommended foundation elevation and foundation conditions for a replacement box culvert are provided in Table 3.

6.2.3 Geotechnical Resistances

6.2.3.1 *Box Culvert*

A box culvert, placed on the properly prepared bedding/layer of granular material at or below the founding elevation identified in Table 3, should be based on the recommended factored geotechnical axial resistance at Ultimate Limit States (ULS) and geotechnical reaction at Serviceability Limit States (SLS), for 25 mm of settlement, as provided in Table 3. These recommendations are based on a 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 proposed as the bearing resistance of the silt stratum is limited and the magnitude of settlement that will occur under the culvert will be governed by the resulting of soil loading, not culvert loading.

6.2.3.2 *Open Footing Culvert*

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 and 1.2 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.



If higher factored geotechnical axial resistance at ULS and geotechnical reaction at SLS are required, consideration could be given to placing the footings directly on the bedrock surface; however additional drilling would be required to determine bedrock surface elevations at the culvert ends.

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, and founding the strip footings on bedrock if a grade raise or widening is proposed as the magnitude of settlement that would occur under the culvert will be governed by the resulting soil loading, not culvert loading.

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

Given the presence of the very soft clayey silt deposit at the south end of the culvert and the loose relative density of the silt deposit under the footprint of and adjacent to the culvert, additional immediate and potentially long-term settlement could occur if a grade raise and/or embankment widening is proposed at this site. Further, the additional settlement would likely occur differentially across the length of the culvert as the clayey silt deposit was only encountered at the south limit.

Additional stability and settlement analysis may be required if a grade raise and/or widening is proposed. Further, depending on the magnitude of the grade raise and/or widening, additional field work may be required to determine the extent of the clayey silt deposit.



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 sand and into the native peat, silt, silty sand, clayey silt, and silt and sand to gravelly silty sand



deposits. 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. At this site, due to the relatively shallow depth to bedrock, sheet-piling may be feasible for the box culvert or pipe culvert(s) options, depending on the required depth of the excavation and the corresponding required depth of the support system; however, a sheet-pile system may not be suitable for the support of the open footing excavation. Further, the installation of the sheet-piles for temporary shoring may be impeded by the presence of inferred cobbles within the native soils, such as encountered within the silt and sand deposit in Borehole FC-1. A sample NSSP should be provided at the detail design stage, if required depending on final culvert design and construction staging.

As an alternative, the temporary support systems could consist of soldier piles and lagging with the piles socketed into bedrock or supported by tiebacks or rakers. The lagging system will need to be adequately tight to mitigate for the potential loss of wet fine grain soils from behind the lagging boards. 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 Fill Below Culvert

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

The bedrock surface is somewhat variable in elevation (about 0.9 m) between Boreholes FC-2 and FC-3 and localized areas of higher bedrock may be present. Minor variations in bedrock surface elevation can be accommodated with cast-in-place open footings or mass concrete can be used to level the bedrock surface. For footings placed directly on bedrock, the surface should be cleaned, scaled, loosened debris removed and inspected before placing concrete.

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). The use of Granular 'B' Type II is recommended in wet ground conditions or below water and placement should be in accordance with OPSS.PROV 209 (Embankments over Swamps).



6.4.3 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 adjacent granular fill and native soils during excavation to the invert and bedding level and the potential for further loosening of the fine grain native soils, 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 soils below the bedding are 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 SPMD 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 OPSS 803.010 (Backfill and Cover for Concrete Culverts).

A frost taper should be constructed in a similar configuration as that shown in OPSS 803.010. Although OPSS 803.010 relates to box culverts with spans less than or equal to 3.0 m, a similar frost taper at 10H:1V is considered acceptable for the assumed 5 m wide box culvert (or twin 2.5 m wide box culverts) replacement option.

6.4.3.2 Open Footing Culvert

The excavation and backfilling requirements for the open footing culvert replacement should be in accordance with OPSS 902 (Excavating and Backfilling – Structures) and also in similar configuration to that shown on OPSS 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 the footings founded a levelling layer of concrete over bedrock. The bedding layer and levelling pad for the pre-cast open footings should follow the recommendations as discussed in Section 6.4.3.1 for the box culvert replacement option.

A frost taper should be constructed in a similar configuration to that shown in OPSS 803.010. Although OPSS 803.010 relates to an open footing culvert with spans less than or equal to 3.0 m, a similar frost taper at 10H:1V is considered acceptable for the assumed 8 m (overall) wide open footing culvert replacement option shown on the preliminary GA drawings.

6.4.3.3 Pipe Culvert

The bedding, levelling and backfill for a concrete pipe, CSP culvert or SP CSP arch should be in accordance with OPSS 802.034 (Rigid Pipe Bedding and Cover in Embankment), OPSS 802.014 (Flexible Pipe, Embedment in Embankment) or OPSS 802.024 (Flexible Pipe Arch, Embedment in Embankment), respectively, and culvert construction should be in accordance with OPSS 421 (Pipe Culvert Installation in Open Cut). It is



important that the backfill at the haunches be well compacted. The pipe culvert should be constructed on a minimum 300 mm thick layer of OPSS.PROV 1010 Granular 'A' or Granular 'B' Type II material for bedding purposes, however this layer thickness should be confirmed at the detail design stage for the actual culvert type and size selected.

A frost taper should be constructed in accordance with OPSD 803.031 (Frost Treatment).

6.4.3.4 Backfill

Backfill behind the culvert walls should consist of granular fill meeting the specifications for OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type I, II or III, but with less than 5 per cent passing the No. 200 (0.075 mm) sieve. The 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 along and over the culvert should be carried out as per OPSD 208.010 (Benching of Earth Slopes) to integrate the existing embankment fill and new fill along the cut faces.

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

6.4.4 Subgrade Protection

The 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, box culvert or pipe 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. An NSSP should 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. Given the presence of the open-water pond (or small lake) at the culvert inlet, a clay blanket is not considered suitable at this site.

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 embankment slope level.

6.4.6 Control of Groundwater and Surface Water

Excavation along the culvert alignment will be required to remove the existing fill, organic soils where present, and some of the native deposits to achieve the required invert/bedding level prior to placement of bedding, the actual culvert, 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 fill and native soils. 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 (or both) of the existing twin-cell culvert or diverted by pumping from behind temporary cofferdams.

For the box culvert and pipe culvert options, the excavations will extend slightly below the creek water level, and potentially below the groundwater level, but will not require dewatering to allow for culvert construction or placement of the bedding or levelling layers. However, shoring and dewatering would temporarily be required to control groundwater inflow from the creek and prevent base heaving if the bedding is to be placed and the culvert constructed in-the-dry. As discussed in Section 6.4.2, dewatering may not be required as Granular 'B' Type II bedding material can be placed sub-aqueously.

For the open footing culvert, excavations will be advanced through the fill and native soils to within close proximity to the bedrock surface; however seepage into the excavation will occur between the bottom of the shoring system through the soils along the soil/bedrock interface. It is likely that standard pumping from sumps will not be adequate to maintain the excavation unwatered and careful consideration will have to be given to the design of the dewatering system for the bedrock founding level to be exposed in the dry. Unwatering 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. An NSSP should 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 will 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 inferred cobbles within the silt and sand deposit as noted in Borehole FC-1. An NSSP should be developed at the detail design stage for inclusion into the Contract Documents to alert the contractor to the potential presence of such obstructions.

6.4.8 Analytical Testing for Construction Materials

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

6.5 Recommendations for Further Work During Detail Design

During the detail design phase, additional field investigation and testing may be required, based on the final configuration and/ or alignment of the culvert and the replacement strategy (i.e., type of culvert and construction 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 one borehole advanced through the roadway further away from the culvert to provide data for roadway protection design and an additional borehole advanced at the south end of the culvert to delineate the depth to bedrock in the event that an open footing culvert is selected as the replacement option. 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, P.Eng. and the technical aspects were reviewed by Mr. David Muldowney, P.Eng. Mr. Jorge M. A. Costa, P.Eng., Designated MTO Foundations Contact and Principal of Golder, conducted an independent quality control review of this report.



**PRELIMINARY FOUNDATION REPORT
FLYNNE CREEK CULVERT - SITE NO. 48E-83/C**

Report Signature Page

GOLDER ASSOCIATES LTD.

Adam Core, P.Eng.
Geotechnical Engineer



David Muldowney, P.Eng.
Geotechnical Engineer



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

TB/AC/DAM/JMAC/kp

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PRELIMINARY FOUNDATION REPORT FLYNNE CREEK CULVERT - SITE NO. 48E-83/C

REFERENCES

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

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

Ministry of Northern Development of Mines. Bedrock Geology of Ontario – West Central Sheet, Ontario Geological Survey – Map 2543.

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

ASTM International:

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

Ontario Provincial Standard Specifications (OPSS)

OPSS 421	Construction Specification for Pipe Sewer Installation in Open Cut
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS 902	Construction Specification for Excavating and Backfilling – Structures
OPSS 1205	Material Specification for Clay Seal
OPSS 1860	Material Specification for Geotextiles

Ontario Provincial Standard Specifications (OPSS) – Provincial Oriented

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

Ontario Provincial Standard Drawings (OPSD)

OPSD 208.010	Benching of Earth Slopes
OPSD 802.014	Flexible Pipe, Embedment in Embankment, Original Ground: Earth or Rock
OPSD 802.024	Flexible Pipe Arch, Embedment in Embankment, Original Ground: Earth or Rock
OPSD 802.034	Rigid Pipe Bedding and Cover in Embankment, Original Ground: Earth or Rock



PRELIMINARY FOUNDATION REPORT FLYNNE CREEK CULVERT - SITE NO. 48E-83/C

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

OPSD 803.031 Frost Treatment – Pipe Culverts, Frost Penetration Line between Top of Pipe and Bedding Grade

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

OPSD 3090.100 Foundation, Frost Penetration Depths for Northern Ontario

Ontario Water Resource Act:

Regulation 903 Wells (as amended)



PRELIMINARY FOUNDATION REPORT FLYNNE CREEK CULVERT - SITE NO. 48E-83/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)	North End of Culvert (m)	South End of Culvert (m)
Hwy 11 STA 17+495	48E-83/C	3.6	Twin-Cell Timber Structure	2.1 m wide x 1.8 m high (each cell)	26	268.6	268.6

- 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 BC494854114.dwg).

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



PRELIMINARY FOUNDATION REPORT FLYNNE CREEK CULVERT - SITE NO. 48E-83/C

Table 2: Comparison of Foundation Alternatives

Option	Advantages	Disadvantages	Risks/Consequences
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. 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 and potentially double the number of pre-cast sections will be required. May require water diversion of a relatively wide creek channel. The clayey silt stratum encountered at the south end of the culvert site may extend under the culvert footprint, potentially subjecting the culvert to differential settlement. 	<ul style="list-style-type: none"> High risk of disturbance of the native silt during construction; can be mitigated with use of a tremie concrete working slab or Granular B Type II working pad. Risk of total and differential settlement if the highway embankment is raised or widened at the culvert site due to the presence of the clayey silt deposit near the south end of the culvert.
Open Footing Culvert	<ul style="list-style-type: none"> May be feasible to construct the culvert on pre-cast footing sections, to accelerate construction schedule and reduce time for dewatering/unwatering (pumping) of surface water. Would be founded below the clayey silt deposit and less susceptible to differential settlement if the highway embankment is raised or widened at the culvert site but less tolerant to differential settlement as a structure. Existing culvert can likely be used for water diversion while new footings are being constructed adjacent to the culvert. Would likely satisfy fisheries requirements related to natural channel substrate, if applicable. Readily suitable for construction using concrete or metal sections. 	<ul style="list-style-type: none"> Excavation depths are greater than for a concrete box or pipe 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. Concrete or metal arch sections supported on concrete open (strip) footings may not allow for adequate soil cover to be placed including the roadway pavement structure. Metal box may not last as long as a concrete structure – long term performance not known. 	<ul style="list-style-type: none"> Some risk of disturbance of the native silt and sand to gravelly silty sand 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. High risk related to being able to install shoring and dewatering system to an adequate depth due to the proximity of the bedrock surface relative to the footing elevation. Risk of encountering bedrock at the recommended footing founding elevation; risk of differential settlement where footings are founded on a combination of soil and bedrock. Culvert joints may be required to accommodate total and differential settlement (if applicable).



PRELIMINARY FOUNDATION REPORT FLYNNE CREEK CULVERT - SITE NO. 48E-83/C

Option	Advantages	Disadvantages	Risks/Consequences
Pipe Culvert(s)	<ul style="list-style-type: none">■ Allows for 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.■ Backfill 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">■ Reduced flow-through capacity - additional flow capacity would have to be provided by multiple pipes.■ Cut-off wall (or clay seal) may be required at inlet to mitigate potential scour under culvert(s).■ Difficult to compact backfill materials to level of culvert springline.■ CSP does not have as long of design life compared to concrete options.	<ul style="list-style-type: none">■ Some risk of disturbance of the native silt deposit during construction; can be mitigated with use of a tremie concrete working slab or Granular B Type II working pad.■ Limited risk related to settlement performance.



PRELIMINARY FOUNDATION REPORT
FLYNNE CREEK CULVERT - SITE NO. 48E-83/C

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

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 17+495	268.6 m	Pre-Cast Box	268.2 m	Granular Bedding over Loose to Compact Silt	125 kPa	75 kPa
		Open Footing (0.6 m width)	265.9 m (below the clayey silt deposit)	Loose to Compact Silt and Sand to gravelly Silty Sand	150 kPa	150 kPa
		Open Footing (1.2 m width)			150 kPa	150 kPa
		Circular Pipe	268.3 m	Granular Bedding over Loose to Compact Silt	N/A	N/A

Notes: 1. Culvert invert elevations are based on the profile drawings provided by MTO (Drawing BC494854114.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 and 1.2 m wide open footing. The recommended geotechnical resistance/reaction should be reviewed if the founding elevation and/or the foundation widths differ from those given above.

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



PRELIMINARY FOUNDATION REPORT FLYNNE CREEK CULVERT - SITE NO. 48E-83/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 11 STA 17+495	Compacted Granular Fill (Levelling Pad over Bedding Layer)	0.45	Loose to Compact Silt and Sand to gravelly Silty Sand	0.35

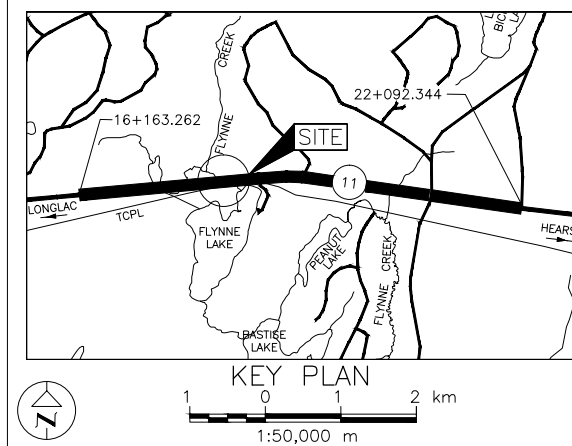
Notes: 1. These values are unfactored. In accordance with CHBDC, a factor of 0.8 is to be applied in calculating the horizontal resistances.

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



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

CONT No.	7
GWP No.	6311-14-00
HIGHWAY 11 FLYNN CREEK CULVERT STA 17+495 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)		
100%	Rock Quality Designation (RQD)		
▽	WL upon completion of drilling		

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
FC-1	271.3	5518890.5	396198.4
FC-2	272.2	5518881.8	396207.2
FC-3	272.2	5518877.5	396203.3
FC-4	270.8	5518863.6	396214.7

NOTES

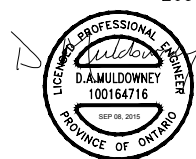
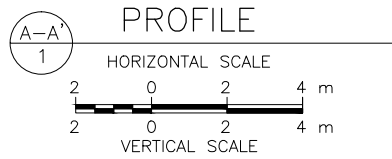
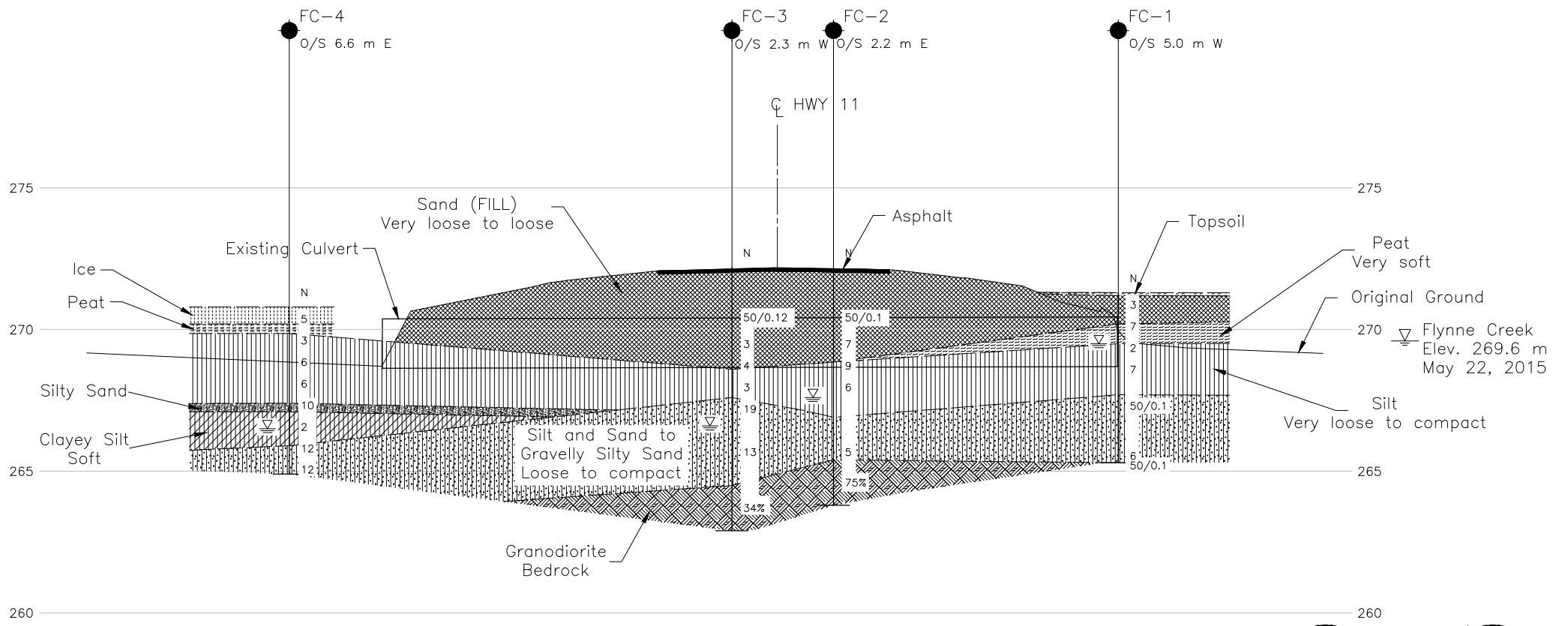
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

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

REFERENCE

Base plans provided in digital format by MTO, drawing file no. BC494854114, received FEB 20, 2015.



NO.	DATE	BY	REVISION
1	8/26/2015	JJL	1
Geocres No. 42F-36			
HWY. 11	PROJECT NO. 1411523	DIST.	
SUBM'D. AC	CHKD.	DATE: 8/26/2015	SITE: 48E-83/C
DRAWN: JJL	CHKD. DAM	APPD. JMAC	DWG. 1



PHOTOGRAPHS

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



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





PHOTOGRAPHS

**Photograph 3: Flynne Creek Culvert
South Side - Outlet (Taken from MTO, OSIM_08-22-2012)**



**Photograph 4: Flynne Creek Culvert
South Side - Outlet (Golder – February 24, 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



LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERINGS STATE

Fresh: no visible sign of weathering

Faintly weathered: weathering limited to the surface of major discontinuities.

Slightly weathered: penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

Moderately weathered: weathering extends throughout the rock mass but the rock material is not friable.

Highly weathered: weathering extends throughout rock mass and the rock material is partly friable.

Completely weathered: rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

BEDDING THICKNESS

Description	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 m to 2 m
Medium bedded	0.2 m to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	Less than 6 mm

JOINT OR FOLIATION SPACING

Description	Spacing
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

GRAIN SIZE

Term	Size*
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: * Grains greater than 60 microns diameter are visible to the naked eye.

CORE CONDITION

Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varied from 0% for completely broken core to 100% for core in solid sticks.

DISCONTINUITY DATA

Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

Dip with Respect to Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90° angle is horizontal.

Description and Notes

An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

Abbreviations

JN Joint	PL Planar
FLT Fault	CU Curved
SH Shear	UN Undulating
VN Vein	IR Irregular
FR Fracture	K Slickensided
SY Stylolite	PO Polished
BD Bedding	SM Smooth
FO Foliation	SR Slightly Rough
CO Contact	RO Rough
AXJ Axial Joint	VR Very Rough
KV Karstic Void	
MB Mechanical Break	

PROJECT 1411523			RECORD OF BOREHOLE No FC-1			1 OF 1 METRIC											
G.W.P. 6311-14-00			LOCATION N 5518890.5; E 396198.4			ORIGINATED BY NJ											
DIST _____ HWY 11			BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers			COMPILED BY AC											
DATUM GEODETIC			DATE March 20, 2015			CHECKED BY DAM											
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									WATER CONTENT (%)
271.3	GROUND SURFACE							20	40	60	80	100					
0.0	TOPSOIL (150 mm)		1	SS	3												
270.2	Sand, some gravel, some silt (FILL) Very loose to loose Brown Moist		A	SS	7												
1.1	Fibrous PEAT Very soft Black Wet		2														
269.5	SILT, trace to some clay, trace sand Loose Grey Wet		A	SS	2												
1.8			3														
			B														
267.9			4	SS	7												
3.4	SILT and SAND, trace gravel, trace clay Loose Grey Wet																
	Augers grinding between 3.8 m and 5.3 m depth on inferred cobbles.		5	SS	50/0.1												
265.3			6	SS	6												
6.0	END OF BOREHOLE		7	SS	50/0.1												
	Note: 1. Water level at a depth of 1.8 m below ground surface (Elev. 269.5 m) upon completion of drilling.																

PROJECT 1411523		RECORD OF BOREHOLE No FC-2				1 OF 1 METRIC								
G.W.P. 6311-14-00		LOCATION N 5518881.8; E 396207.2				ORIGINATED BY NJ								
DIST _____ HWY 11		BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers, NW Casing and NQ Coring				COMPILED BY AC								
DATUM GEODETIC		DATE March 19 and 21, 2015				CHECKED BY DAM								
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	SHEAR STRENGTH kPa		WATER CONTENT (%)				
272.2	GROUND SURFACE							20 40 60 80 100	○ UNCONFINED + FIELD VANE	W _p	W	W _L		
0.0	ASPHALT (120 mm)							20 40 60 80 100	● QUICK TRIAXIAL × REMOULDED					
0.1	Sand, trace to some silt, trace gravel (FILL) Loose Brown Frozen* to wet		1	AS	-									
			2	SS	50/ 0.1*									
			3	SS	7									
268.9	SILT, trace to some clay, trace sand Loose Grey Wet		A 4 B	SS	9									
3.4			5	SS	6									
266.9	SILT and SAND, trace to some gravel, trace clay Loose Grey Wet		6	SS	5									
265.4	GRANODIORITE BEDROCK													
6.8	Bedrock cored from 6.8 m depth to 8.4 m depth. For coring details see Record of Drillhole FC-2.		1	RC	REC 93%									
263.8	END OF BOREHOLE													
8.4	Note: 1. Borehole caved at 4.6 m depth upon completion. Borehole dry to 4.6 m depth upon completion of drilling (inferred depth to water level Elevation 267.6 m)													

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 03/06/15 DATA INPUT:

SHEET 1 OF 1

DATUM: GEODETIC

DRILLING CONTRACTOR: George Downing Estate Drilling Ltd.

CHECKED: DAM

SUD-RCK 1411523.GPJ GAL-MISS.GDT 29/05/15 DATA INPUT:

PROJECT 1411523				RECORD OF BOREHOLE No FC-3				1 OF 1 METRIC									
G.W.P. 6311-14-00				LOCATION N 5518877.5; E 396203.3				ORIGINATED BY NJ									
DIST _____ HWY 11				BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers, NW Casing and NQ Coring				COMPILED BY AC									
DATUM GEODETIC				DATE March 22, 2015				CHECKED BY DAM									
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									
272.2	GROUND SURFACE							20	40	60	80	100					
0.0	ASPHALT (120 mm)																
0.1	Sand, trace to some gravel, trace to some silt (FILL) Very loose Brown Frozen* to wet		1	AS	-		272										
			2	SS	50/0.12		271										
			3	SS	3		270										
268.6			A	SS	4		269										
3.6	SILT, trace to some clay, trace sand Very loose Grey Wet		5	SS	3		268										
267.6			6	SS	19		267										
4.6	Gravelly SILTY SAND, trace clay Compact Grey Wet		7	SS	13		266										
264.5							265										
7.7	GRANODIORITE BEDROCK		1	RC	REC 100%		264										
	Bedrock cored from 7.7 m depth to 9.3 m depth. For coring details see Record of Drillhole FC-3.						263										
262.9																	
9.3	END OF BOREHOLE																
	Note: 1. Water level at a depth of 5.6 m below ground surface (Elev. 266.6 m) upon completion of drilling.																

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 03/06/15 DATA INPUT:

PROJECT: 1411523

RECORD OF DRILLHOLE: FC-3

SHEET 1 OF 1

LOCATION: N 5518877.5 ;E 396203.3

DRILLING DATE: March 22, 2015

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: —

DRILL RIG: CME 850

DRILLING CONTRACTOR: George Downing Estate Drilling Ltd.

DEPTH SCALE METRES	DRILLING RECORD		DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	JN - Joint FLT - Fault SHR - Shear VN - Vein CJ - Conjugate BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular PO - Polished K - Slickensided SM - Smooth RO - Rough MB - Mechanical Break BR - Broken Rock NOTE: For additional abbreviations refer to list of abbreviations & symbols.																NOTES WATER LEVELS INSTRUMENTATION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
								FLUSH	RECOVERY		R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA						HYDRAULIC CONDUCTIVITY k, cm/s				Diametral Point Load Index (MPa)			RMC -Q AVG																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
									TOTAL CORE %	SOLID CORE %			B Angle	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	10	100	1000																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
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DEPTH SCALE

1 : 50



LOGGED: NJ

CHECKED: DAM

SUD-RCK 1411523.GPJ GAL-MISS.GDT 2905/15 DATA INPUT:

PROJECT 1411523		RECORD OF BOREHOLE No FC-4		1 OF 1 METRIC																	
G.W.P. 6311-14-00		LOCATION N 5518863.6; E 396214.7		ORIGINATED BY SC																	
DIST _____ HWY 11		BOREHOLE TYPE 108 mm I. D. Hollow Stem Augers		COMPILED BY AC																	
DATUM GEODETIC		DATE February 15, 2015		CHECKED BY DAM																	
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ			GR SA SI CL		
270.8	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100	20 40 60											
0.0	ICE		1	SS	5																
270.2																					
269.9	Fibrous PEAT Black Frozen		A	SS	3		270														
0.9	SILT, trace to some clay, trace sand Very loose to compact Grey Moist to wet		2 B																		
			3	SS	6		269														
			4	SS	6		268														
267.4			A																		
			5 B	SS	10																
267.1	SILTY SAND Grey Wet						267														
3.7	CLAYEY SILT, trace to some sand Soft Grey Wet		6	SS	2																
			A				266														
265.9	SILT and SAND, trace gravel, trace clay Compact Grey Wet		7 B	SS	10																
			8	SS	10		265														
264.9	END OF BOREHOLE																				
5.9	Note: 1. Borehole caved at 4.3 m depth upon completion of drilling (inferred depth to water level, Elevation 266.5 m).																				

SUD-MTO 001 1411523.GPJ GAL-MISS.GDT 31/08/15 DATA INPUT:



APPENDIX B

Laboratory Test Results



PRELIMINARY FOUNDATION REPORT FLYNNE CREEK CULVERT - SITE NO. 48E-83/C

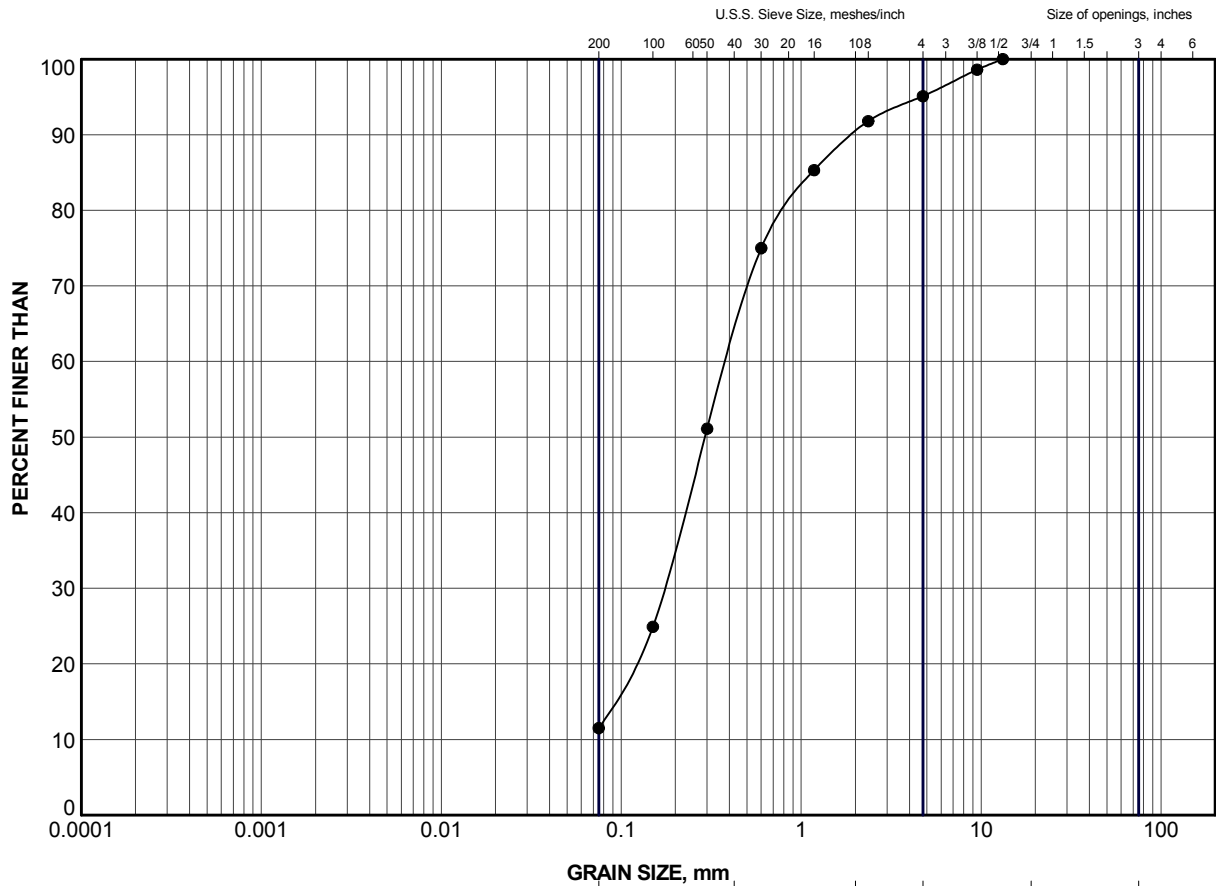
Table B1: Summary of Analytical Testing of Flynn Creek Water Sample

Parameter	Units	Result
Chloride (CL)	mg/L	24.4
Sulphate (SO4)	mg/L	0.42
Conductivity (EC)	µS/cm	298
Resistivity	µohm-cm	<0.33
pH	n/a	6.97

Notes:

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

Prepared by: TB
Checked by: DAM
Reviewed by: JMAC



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

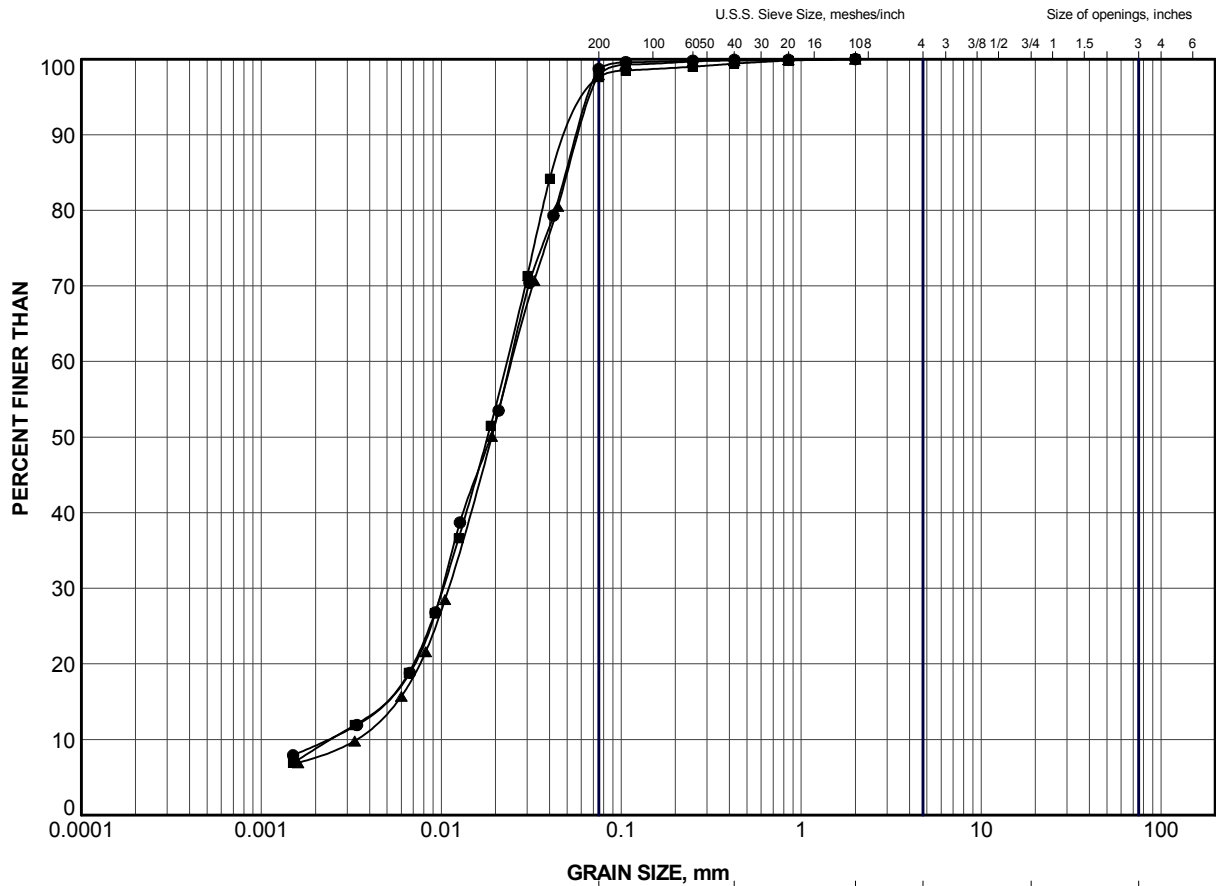
LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	FC-2	3	269.6

PROJECT						HIGHWAY 11 FLYNNE CREEK CULVERT STA 17+495					
TITLE						GRAIN SIZE DISTRIBUTION SAND (FILL)					
PROJECT No.			1411523			FILE No.			1411523.GPJ		
DRAWN	TB	May 2015	SCALE	N/A	REV.	FIGURE B1					
CHECK	DAM	May 2015									
APPR	JMAC	May 2015									



SUD-MTO GSD (NEW) GLDR_LDN.GDT



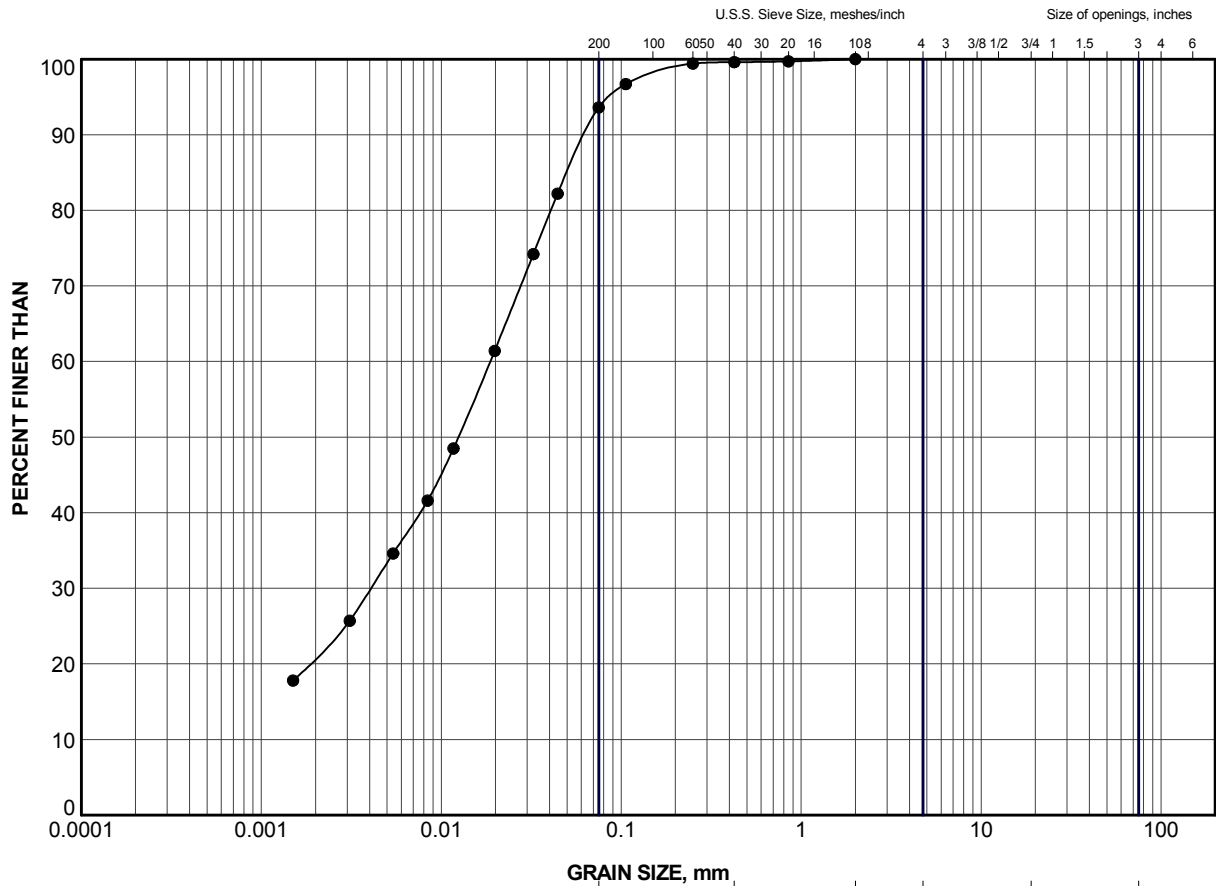
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	FC-1	4	268.7
■	FC-2	5	268.1
▲	FC-4	4	268.2

PROJECT						HIGHWAY 11 FLYNNE CREEK CULVERT STA 17+495					
TITLE						GRAIN SIZE DISTRIBUTION SILT					
PROJECT No.				1411523		FILE No.				1411523.GPJ	
DRAWN	TB	May 2015		SCALE	N/A	REV.					
CHECK	DAM	May 2015									
APPR	JMAC	May 2015									
						FIGURE B2					





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

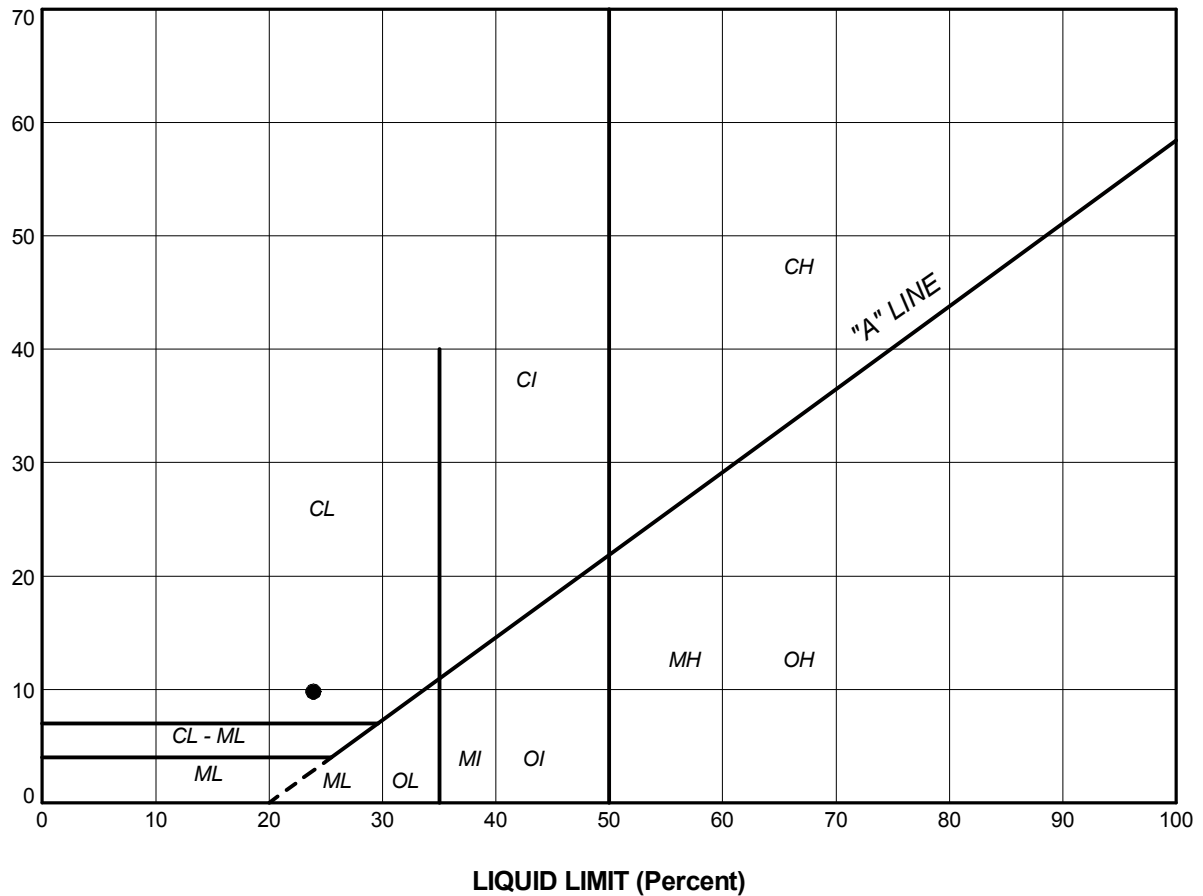
LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	FC-4	6	266.7

PROJECT						HIGHWAY 11 FLYNNE CREEK CULVERT STA 17+495					
TITLE						GRAIN SIZE DISTRIBUTION CLAYEY SILT					
PROJECT No.			1411523			FILE No.			1411523.GPJ		
DRAWN	TB	May 2015	SCALE	N/A	REV.	FIGURE B3					
CHECK	DAM	May 2015									
APPR	JMAC	May 2015									



PLASTICITY INDEX (Percent)



SOIL TYPE
 C = Clay
 M = Silt
 O = Organic

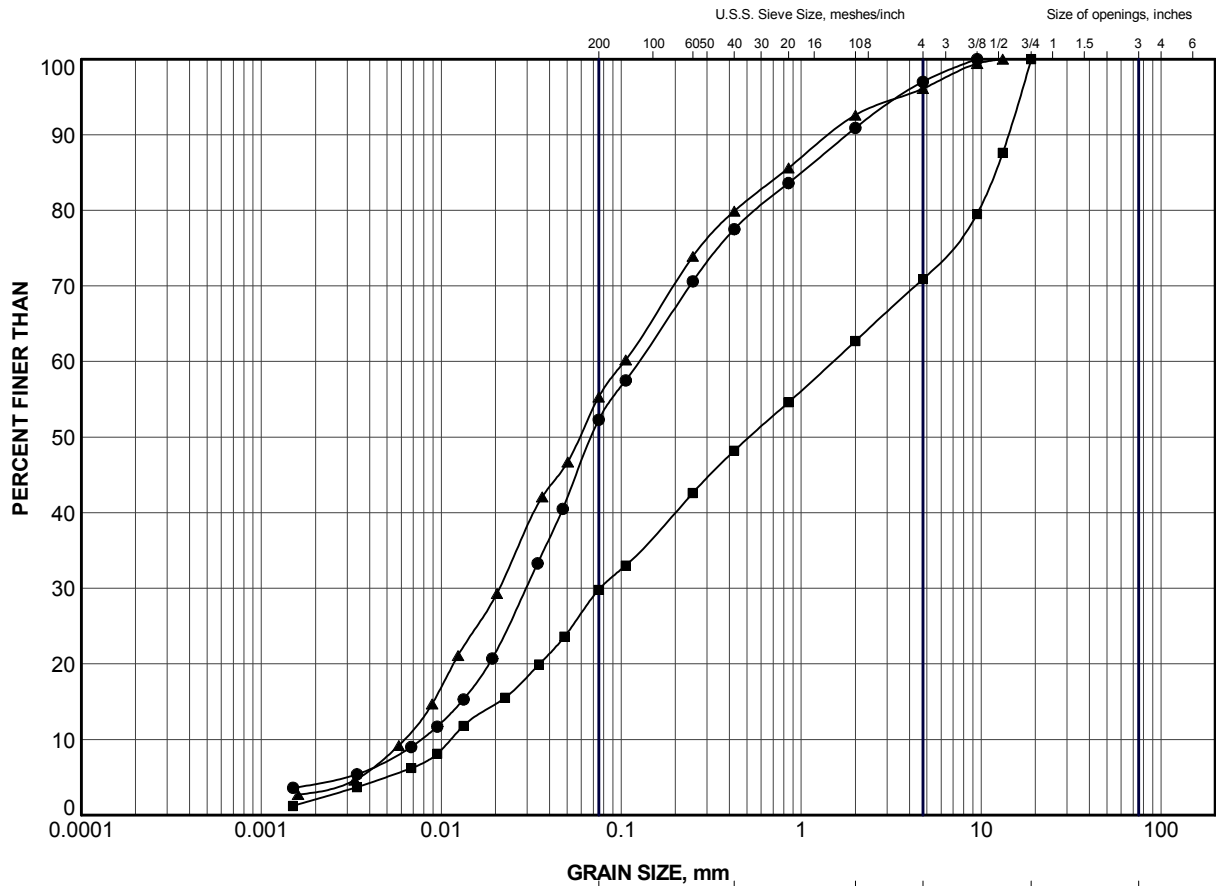
PLASTICITY
 L = Low
 I = Intermediate
 H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	FC-4	6	23.9	14.1	9.8

PROJECT					
HIGHWAY 11 FLYNN CREEK CULVERT STA 17+495					
TITLE					
PLASTICITY CHART CLAYEY SILT					
PROJECT No. 1411523			FILE No. 1411523.GPJ		
DRAWN	TB	May 2015	SCALE	N/A	REV.
CHECK	DAM	May 2015	FIGURE B4		
APPR	JMAC	May 2015			






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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	FC-1	6	265.7
■	FC-3	7	265.8
▲	FC-4	8	265.2

PROJECT						HIGHWAY 11 FLYNNE CREEK CULVERT STA 17+495					
TITLE						GRAIN SIZE DISTRIBUTION SILT and SAND to GRAVELLY SILTY SAND					
PROJECT No.			1411523			FILE No.			1411523.GPJ		
DRAWN	TB	Jun 2015	SCALE	N/A	REV.						
CHECK	DAM	Jun 2015									
APPR	JMAC	Jun 2015									
 Golder Associates SUDBURY, ONTARIO			FIGURE B5								

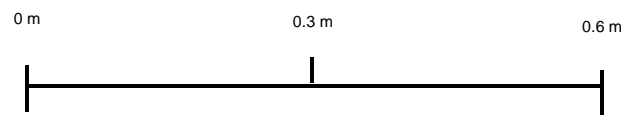
SUD-MTO GSD (NEW) GLDR_LDN.GDT




Borehole FC-2
Elevation 265.4 m to 263.8 m



Borehole FC-3
Elevation 264.5 m to 262.9 m



PROJECT		HIGHWAY 11 FLYNNE CREEK CULVERT STA 17+495	
TITLE		BEDROCK CORE PHOTOGRAPHS	
	PROJECT No.	1411523	FILE No. ----
	DESIGN		SCALE AS SHOWN REV.
	CADD	-- TB May, 2015	
	CHECK	DAM May, 2015	
	REVIEW	JMAC May, 2015	FIGURE B6

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

For more information, visit golder.com

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

solutions@golder.com
www.golder.com

Golder Associates Ltd.
33 Mackenzie Street, Suite 100
Sudbury, Ontario, P3C 4Y1
Canada
T: +1 (705) 524 6861

