February 10, 2015

PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT

UNNAMED CREEK CULVERT, SITE NO. 42-342/C
RESURFACING OF HIGHWAY 11
FROM MUSKOKA ROAD 117 NORTHERLY TO STEPHENSON ROAD 12, 21.9 KM
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5462-09-00

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REPORT

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PART A

PRELIMINARY FOUNDATION INVESTIGATION REPORT
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM on behalf of Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the rehabilitation of a structural culvert at Unnamed Creek (Site No. 42-342/C) as part of the rehabilitation of Highway 11 in the Townships of Macaulay and Stephenson between Huntsville and Bracebridge, Ontario. The proposed rehabilitation of Highway 11 extends for 21.9 km, from Muskoka Road 117 northerly to Stephenson Road 12. The structural culvert is located approximately 1.2 km north of the junction of Highway 11 with Stephenson Road 1 at STA 11+209. The general location of the culvert is shown on Drawing 1.

The original Terms of Reference and the Scope of Work for the foundation investigation are outlined in MTO's Request for Proposal, dated June 2011. Golder's proposal for foundation engineering services associated with this culvert is contained in Section 6.8 of AECOM's Technical Proposal for this assignment. The work has been carried out in accordance with Golder's Supplementary Specialty Plan for foundation engineering services for this project, dated June 26, 2014. The drawings showing the proposed culvert alignments were provided to Golder by AECOM on October 14, 2014.

This report addresses the investigation carried out for the structural culvert at Unnamed Creek, which has been identified as a culvert for rehabilitation. Separate reports will be submitted detailing the foundation investigations for the remaining culverts within the project limits.

The purpose of this investigation is to obtain subsurface information specific to the structural culvert location by methods of borehole drilling, bedrock coring, in situ testing and laboratory testing on selected soil samples and rock core samples. The boreholes for this culvert were located in the field by Golder and were surveyed relative to stakes and/or nail pins installed by exp. Services Inc. (exp.), a professional surveying company retained by AECOM. The culvert location and ground surface elevations at the investigation location were also surveyed in the field by exp.

2.0 SITE DESCRIPTION

The structural culvert at Unnamed Creek is located at approximately STA 11+209 on Highway 11 in the Township of Stephenson, between Muskoka Road 117 and South Mary Lake Road. The existing culvert at this location is a concrete box structure the details of which (width, height, length etc.) are summarized in Table 1, following the text of this report.

In general, the topography of this section of the overall project limits consists of rolling terrain, including sparsely or densely populated treed areas and numerous bedrock outcrops separated by valleys and swamps containing areas of standing water and various types of vegetation and organic soils. The ground surface at the borehole and DCPT locations advanced for the structural culvert investigation, including through the existing Highway 11 embankments, varies between Elevations 303.9 m and 291.7 m, referenced to Geodetic datum.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation associated with the proposed rehabilitation of the Unnamed Creek culvert was carried out between June 18 and 27 as well as on July 9 and 10, 2014, during which periods a total of six (6) boreholes and five (5) Dynamic Cone Penetration Tests (DCPTs) were advanced at, or in the immediate vicinity of, the culvert alignment,as summarized in Table 1 and as shown on Drawing A1 in Appendix A.

The field investigation was carried out using truck-mounted CME55 and CME 75 drill rigs supplied and operated by Landcore Drilling of Sudbury, Ontario, as well as portable equipment supplied by and operated by George Downing Estate Drilling Ltd of Grenville-Sur-La-Rouge, Quebec.

The boreholes were advanced through the overburden using 108 mm inside diameter hollow-stem augers, or NW casing with wash boring techniques. In general, soil samples were obtained at intervals of depth of about 0.75 m, 1.5 m and 3.0 m, using a 50 mm O.D. split-spoon sampler operated by automatic hammers on the drill rigs, performed in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586). Boreholes advanced by portable equipment generally employed a full-weight hammer lifted manually and dropped from the SPT height. On the drill rigs rock coring was carried out using 'NQ' core barrels beyond auger/casing refusal, where appropriate, and through blast rock fill sections. Coring by portable equipment was carried out using 'BQ' core barrels, through rock fill sections and where bedrock was encountered. All open boreholes were backfilled with bentonite upon completion in accordance with Ontario Regulation 903-Wells (as amended).

The boreholes and DCPTs were advanced to depths generally penetrating about 3 m below the culvert invert, terminating on refusal to further auger, casing and/or split spoon advancement likely on, or in proximity to, the bedrock surface, or upon drilling into probable bedrock. Four boreholes were advanced between approximately 1.2 m to 3.6 m below auger/casing refusal to confirm bedrock.

The groundwater conditions and water levels in the open boreholes were observed during the drilling operations and are described on the Record of Borehole sheets in Appendix A.

A sample of the creek water was obtained during the field investigation at the culvert location, using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters. The results of the analytical testing are summarized in Table A1.

The fieldwork was observed by members of our engineering and technical staff, who located the boreholes, arranged for the clearance of underground services, observed the drilling, sampling and in situ testing operations, logged the boreholes, and examined and cared for the soil samples and rock core. The soil samples and rock core were identified in the field, placed in appropriate containers, labelled and transported to our Sudbury geotechnical laboratory where the samples and core underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO Laboratory Standards and/or ASTM Standards, as appropriate. Classification testing (water content, organic content and grain size distribution) was carried out on selected soil samples. The results of the laboratory testing are provided in Appendix A.

Classification of the rock mass quality of the bedrock with respect to the Rock Quality Designation (RQD) is described based on Table 3.10 of the Canadian Foundation Engineering Manual (CFEM, 2006)[1]. The degree of weathering of the bedrock samples (i.e. fresh to slightly weathered – W1 to W2) and the strength classification of the intact rock mass based on field identification (i.e. strong – R4) are described in accordance with the International Society for Rock Mechanics (ISRM,1985)[2] standard classification system. A laboratory Unconfined

[1]Canadian Geotechnical Society, 2006. Canadian Foundation Engineering Manual, 4th Edition.

[2] International Society for Rock Mechanics Commission on Test Methods, 1985. Int. J. Rock Mech.Min. Sci. & Geomech. Abstr. Vol 22, No. 2, pp. 51-60.

Compression (UC) test was carried out on one core sample of the bedrock and the uniaxial compressive strength (UCS) of the bedrock is described as per Table 3.5 of CFEM (2006) [1].

Survey stakes and/or nail pins were installed by exp. at selected locations in the area of the culvert prior to the commencement of drilling. The as-drilled borehole locations, in stations and offsets, were measured in reference to the applicable stakes and/or nail pins and were subsequently converted into MTM NAD 83 coordinates in AutoCAD. Borehole elevations were surveyed by a member of our technical staff in reference to the ground surface elevations at applicable survey stakes and/or nail pins installed by exp. The borehole locations given on the Record of Borehole sheets and shown on Drawing A1 are positioned relative to MTM NAD 83 northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole locations, ground surface elevations and depths drilled are as follows:

Culvert Location	Borehole/DCPT	Location (m)		Ground Surface Elevation (m)	Depth of Borehole/DCPT (m)
		Northing	Easting		
STA 11+209 (Township of Stephenson)	C10-01	5003077.8	319557.2	294.6	5.7
	C10-02	5003084.6	319576.6	302.4	12.0*
	C10-03	5003066.0	319599.8	296.7	3.2
	C10-03A	5003080.0	319599.5	296.6	4.9*
	C10-04	5003085.4	319624.3	303.8	15.9*
	C10-05	5003079.1	319648.9	291.7	3.7*
	C10-DC01	5003084.8	319556.7	294.5	4.6
	C10-DC02A	5003074.6	319576.8	302.4	5.9
	C10-DC02B	5003073.6	319576.7	302.4	5.7
	C10-DC03	5003080.0	319598.9	296.7	3.7
	C10-DC04	5003075.4	319623.9	303.9	7.7

* Including bedrock coring between 1.2 m and 3.6 m.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

As delineated in *The Physiography of Southern Ontario*[3], this section of Highway 11 lies within the physiographic region known as the "Number 11 Strip", with portions of Highway 11 in contact with the "Georgian Bay Fringe" region. The Number 11 Strip is a narrow belt that extends from Gravenhurst to North Bay and is characterized by deposits of sand, silt and clay, together with more recent swamp deposits between rock knobs and ridges. The bedrock in the area is typically highly deformed gneiss of the Moon River Domain of the Central Gneiss Belt, a subdivision of the Grenville Structural Province (Geology of Ontario, 1991)[4].

[3] Chapman, L.J. and D. F. Putnam, 1984. The Physiography of Southern Ontario, Ontario Geological Survey, Special Volume 2, Third Edition. Accompanied by Map P. 2715, Scale 1:600,000.

[4] Geology of Ontario. 1991. Ontario Geological Society, Special Volume 4, Part 2. Eds. P.C. Thurston, H.R. Williams, R.H. Sutcliffe and G.M. Stott. Ministry of Northern Development and Mines, Ontario.

4.2 General Overview of Local Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced during this investigation, together with the results of the laboratory tests carried out on selected soil and rock core samples, are presented on the Record of Borehole and Drillhole sheets and the laboratory test sheets in Appendix A. The stratigraphic boundaries shown on the Record of Borehole and Drillhole sheets are inferred from non-continuous sampling, observations of drilling progress and in situ testing and are approximate. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations.

The stratigraphy at the location of the culvert consists of surficial layers of peat or embankment fill underlain by native non-cohesive soil deposits and bedrock. A detailed description of the subsurface conditions at the structural culvert crossing is provided in the following section of this report. Where relatively significant thicknesses of overburden were encountered, the various soil types are described in detail for each main deposit or stratum.

4.3 Subsurface Conditions

The plan and profile along the Unknown Creek culvert centreline showing the borehole locations and interpreted stratigraphy at approximately STA 11+209 in Township of Stephenson is shown on Drawing A1. The height of the embankment at this location is between about 9 m and 11 m and the existing concrete culvert is about 89 m long with dimensions of 3100 mm wide by 1500 mm high. A total of six boreholes and five DCPTs were completed to investigate the subsurface conditions at the culvert location: two boreholes (C10-01 and C10-05) and one companion DCPT (C10-DC01) were advanced near the ends of the culvert; and four boreholes (C10-02, C10-03, C10-03A and C10-04) and four DCPTs (C10-DC02A, C10-DC02B, C10-DC03 and C10-DC04) were advanced through the roadway embankments and near the midpoint of the culvert. In general, the topography in the area of the culvert consists of low-lying areas, bedrock outcrops and treed areas.

4.3.1 West Embankment Fill (SBL)

Embankment fill 3.2 m to 8.8 m thick was encountered in the west embankment. The west embankment fill consists of a deposit of silty sand to sand, trace to some gravel, trace clay and trace organics which was encountered at surface Elevations 302.4 m, 296.7 m and 296.6 m in Boreholes C10-02, C10-03 and C10-03A, respectively, and has a thickness ranging from 3.2 m to 6.2 m. Asphalt mixed with sand and gravel was encountered near the ground surface in Borehole C10-02. A 0.8 m thick layer of rock fill was encountered directly below the silty sand to sand fill in Borehole C10-02 at Elevation 296.2 m and is in turn underlain by a 1.8 m thick layer of sand and gravel in Borehole C10-02 at Elevation 295.14 m.

The SPT ‘N’-values measured within the west embankment fill typically range between 9 blows and 34 blows per 0.3 m of penetration in Borehole C10-02 with values of up to 13 blows per 0.13 m, indicating a compact to dense relative density. The SPT ‘N’-values measured in Boreholes C10-03 and C10-03A range from 0 blows (weight of hammer) to 11 blows per 0.3 m of penetration indicating a very loose to compact relative density. SPT ‘N’-values of 100 blows per 0.13 m of penetration and 100 blows per 0.08 m of penetration were measured at contacts with rock fill and upon borehole refusal at the interface with bedrock.

The natural water content measured on eight sample of the silty sand to sand fill in the west embankment ranges from about 11 per cent to about 31 per cent.

The results of the grain size distribution tests completed on five sample of the silty sand to sand fill are shown on Figure A1 in Appendix A.

4.3.2 East Embankment Fill (NBL)

Embankment fill 12.6 m thick was encountered in Borehole C10-04 in the east embankment at a surface Elevation 303.8 m. The fill consists of a 2.2 m thick upper layer of sand and gravel, trace silt fill underlain by a 10.4 m thick layer of blast rock encountered at Elevation 301.6 m.

The SPT 'N'-values measured within the sand and gravel fill range between 16 blows and 19 blows per 0.3 m of penetration indicating a compact relative density. SPT 'N'-values measured within the rock fill range from 13 blows to 100 blows per 0.3 m of penetration to 100 blows per 0.05 m of penetration indicating a compact to very dense relative density. Coring methods were required to advance the borehole between the split spoon samples to penetrate through the rock fill.

The natural water content measured on a sample of sand and gravel fill is about 7 per cent.

The result of the grain size distribution test completed on a sample of the sand and gravel fill is shown on Figure A2 in Appendix A.

4.3.3 Peat

A 0.1 m thick deposit of fibrous peat was encountered in Boreholes C10-01 and C10-05, at ground surface at Elevation 294.6 m and 291.7 m, respectively.

4.3.4 Silty Sand to Sand

A deposit of grey to brown silty sand to sand, trace organics to silt trace to some clay, trace sand was encountered below the peat layer in Borehole C10-01. The top of the deposit was encountered at Elevation 294.5 m and the thickness of the deposit is 2.1 m.

The SPT 'N'-values measured within the silty sand to sand deposit range between 1 blow and 3 blows per 0.3 m of penetration indicating a very loose relative density.

The natural water content measured on a sample of the silty sand to sand deposit is about 51 per cent. The organic content measured on a sample of this deposit is about 5 per cent.

4.3.5 Silt

A 2.7 m thick deposit of silt, trace to some clay, trace sand was encountered underlying the silty sand to sand deposit at Elevation 292.4 m.

The SPT 'N'-values measured within the silt deposit range from 20 blows to 30 blows per 0.3 m of penetration indicating a compact relative density.

The natural water content measured on two samples of the silt deposit measured about 25 per cent and 28 per cent.

The result of the grain size distribution test completed on a sample of the silt is shown on Figures A3 in Appendix A.

4.3.6 Silty Sand and Gravel

A 0.8 m deposit of grey silty sand and gravel was encountered underlying the silt deposit in Borehole C10-01 at Elevation 289.7 m.

The SPT 'N'-values measured within the silty sand and gravel deposit are 29 blows per 0.3 m of penetration and 100 blows per 0.15 m of penetration upon refusal on probable bedrock, indicating a compact to very dense relative density.

The natural water content measured on a sample of the silty sand and gravel deposit is about 10 per cent.

The result of the grain size distribution test completed on a sample of the silty sand and gravel deposit is shown in Figure A4 in Appendix A.

4.3.7 Bedrock / Refusal

Bedrock was encountered in Boreholes C10-02, C10-03A, C10-04 and C10-05 at between Elevations 293.6 m, and 291.2 m and core samples between 1.2 m and 3.6 m long were obtained. Based on a review of the bedrock core samples, the bedrock consists of fine to coarse grained, fresh, pinkish grey to dark grey gneiss.

The Total Core Recovery (TCR) for the core samples ranges from 93 per cent to 100 per cent and the Solid Core Recovery (SCR) ranges from 0 per cent to 100 per cent. The Rock Quality Designation (RQD) measured on the recovered bedrock core samples in the boreholes range between 0 per cent and 100 per cent, and is generally greater than 52 per cent, indicating the rock is of very poor to excellent quality and generally of fair to good quality, according to Table 3.10 in CFEM (2006)[1].

On Unconfined Compression (UC) test (ASTM D7012) was carried out on one core sample of the gneiss bedrock obtained in Borehole C10-02 and measured a Uniaxial Compressive Strength (UCS) value of about 76 MPa, as detailed in Table A2. Based on the laboratory UC test, in accordance with Table 3.5 in CFEM (2006)[1], the gneiss bedrock is classified as strong (R4, 50 MPa < UCS < 100 MPa).

Refusal to split-spoon advancement and DCPT penetration was encountered in and adjacent to Boreholes C10-01, C10-02, C10-03, C10-03A and C10-04 at depths ranging from 3.2 m to 12.6 m below ground surface, ranging from Elevations 296.7 m to 288.9 m..

4.3.8 Groundwater Conditions

The water level was measured in Boreholes C10-01, C10-03, C10-03A and C10-04 upon completion of drilling operations at depths between 1.2 m and 11.6 m below ground surface, ranging from Elevations 295.0 m to 292.2 m. Groundwater levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

5.0 CLOSURE

The field personnel supervising the drilling program were Messr. Indulis Dumpis, Erik Giles and Matthew Thibeault, EIT. This report was prepared by Ms. Madison Kennedy, B.A.Sc. and reviewed by Mr. Christopher Ng, P.Eng. and Associate with Golder. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and Principal with Golder, carried out a quality control review of the report.

Report Signature Page

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PART B

PRELIMINARY FOUNDATION DESIGN REPORT

UNNAMED CREEK CULVERT, Site No. 42-342/C

RESURFACING OF HIGHWAY 11

FROM MUSKOKA ROAD 117 NORTHERLY TO STEPHENSON ROAD 12

MINISTRY OF TRANSPORTATION, ONTARIO

GWP 5462-09-00

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides preliminary foundation design recommendations in support of the design-build ready design of the proposed rehabilitation of the structural culvert at Unnamed Creek (Site No. 42-342/C) as part of the rehabilitation of Highway 11 in the Townships of Macaulay and Stephenson between Huntsville and Bracebridge, Ontario. It is understood that the structural culvert at Unnamed Creek in the Township of Stephenson is to be rehabilitated; however, in the event that the existing culvert requires replacement, the following sections provide design recommendations for pre-cast box culvert and cast-in-place open footing culverts.

The preliminary recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current subsurface investigation at this site. The interpretation and recommendations contained in this report are intended to provide the design engineer with sufficient information to assess the feasible foundation alternatives and to carry out the preliminary design of the culvert foundations. Further investigation and design may be required during the design-build process.

Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project and for which special provisions may be required during construction. Those requiring information on 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.

Preliminary General Arrangement (GA) drawings were not available during preparation of this report, however, it is understood that if the culvert is to be replaced, the dimensions, alignment as well as the invert elevation of the replacement culvert will be the same as that of the existing culvert. In addition, it is understood that there will be no embankment grade raises or widening as part of the overall rehabilitation of Highway 11.

6.2 Foundations for Culvert Replacements

6.2.1 Foundation Options

Both a pre-cast box culvert and a cast-in-place open footing culvert are feasible alternatives for the replacement of the existing culvert.

The advantages and disadvantages associated with replacing the existing culvert with a pre-cast box culvert or a cast-in-place open footing culvert are summarized in Table 2, following the text of this report. From a foundations perspective, the pre-cast box culvert replacement is preferred for this site over a cast-in-place open footing culvert replacement based on the following:

- A pre-cast box culvert minimizes the depth of excavation and groundwater control required as compared with an open-footing culvert;
- Pre-cast box culvert segments can usually be installed more expeditiously than construction of a cast-in-place open footing culvert, resulting in a shorter duration for dewatering and surface water pumping; and,

- Pre-cast box culvert segments are more tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site, or movements due to freeze-thaw of the founding/adjacent soils.

Recommendations for replacement of the existing culverts with a pre-cast box culvert and cast-in-place open footing culvert are provided in the following sections.

6.2.2 Founding Elevations and Frost Protection Requirements

6.2.2.1 Box Culvert Replacement

It is not necessary to found the box culvert replacement at or below the standard depth of frost penetration for frost protection purposes, as box structures are tolerant of small magnitudes of movement related to freeze-thaw cycles, should these occur. Table 3, following the text of this report, provides recommended founding elevations and founding conditions for the replacement culvert. The available information suggests that the existing culvert is founded on bedrock. For a box culvert or culvert founded on bedrock, frost protection measures are not required.

6.2.2.2 Open Footing Culvert Replacement

The strip footings for an open footing culvert is founded on the native sand to silt deposit should be founded at a minimum depth of 1.8 m below the lowest surrounding grade to provide adequate protection against frost penetration, as per OPSD 3090.101 (Foundation, Frost Penetration Depths for Southern Ontario). Where an open footing culvert replacement is founded directly on properly prepared gneiss bedrock or on mass concrete over bedrock, a minimum soil cover for frost protection is not required. Table 3, following the text of this report, provides recommended founding elevations and founding conditions for the replacement culvert.

6.2.3 Geotechnical Axial Resistances and Reactions

6.2.3.1 Box Culvert Replacement

Replacement of the box culvert placed on the properly prepared subgrade, at or below the founding elevations recommended in Table 3, should be designed based on the recommended factored geotechnical axial resistances at Ultimate Limit States (ULS) and the geotechnical reaction at Serviceability Limit States (SLS) for 25 mm of settlement as given in Table 3. These recommendations are based on the box culvert width as given in Table 1.

The factored geotechnical axial resistances at ULS and geotechnical reaction at SLS for 25 mm of settlement are dependent on the culvert width and founding elevation and as such, the geotechnical resistance/reaction should be reviewed if the culvert width or founding elevation differs from that given in Tables 1 and 3.

The geotechnical resistances provided in Table 3 are based on loading applied perpendicular to the surface of the culvert. Where the load is not applied perpendicular to the surface of the culvert, 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) and its *Commentary*.

6.2.3.2 Open Footing Culvert Replacement

Strip footings placed on the properly prepared subgrade, at or below the founding elevations recommended in Table 3, should be designed based on the factored geotechnical axial resistance at ULS and the geotechnical reaction at SLS for 25 mm of settlement as given in Table 3. These recommendations are based on an assumed footing width of 0.5 m.

The factored geotechnical axial resistance at ULS and geotechnical reaction at SLS for 25 mm of settlement are dependent on the footing width and founding elevation and as such, the geotechnical resistance/reaction should be reviewed if the culvert strip footing width or founding elevation differs from that given in Tables 1 and 3.

The geotechnical resistances provided in Table 3 are based on loadings applied perpendicular to the surface of the footings. Where the load is not applied perpendicular to the surface of the footings, inclination of the load should be taken into account in accordance with Section 6.7.4 and Section C6.7.4 of the CHBDC and its *Commentary*.

6.2.4 Resistance to Lateral Loads / Sliding Resistance

Resistance to lateral forces / sliding resistance between the base of the box culvert, or strip footings for the open footing culvert, and the subgrade should be calculated in accordance with Section 6.7.5 of the CHBDC. Table 4, following the text of this report, provides the coefficients of friction (tan δ) between the base of the culvert/footing and potential interface materials.

6.3 Embankment Stability and Settlement

Taking into consideration that grade raise or widening is not required as part of the overall rehabilitation of Highway 11, the current height and geometry of the existing embankment (i.e. about 13 m high with 2H:1V side slopes) and the granular nature of the native overburden as well as the existing and proposed embankment fill, stability issues of the highway embankment are not anticipated after culvert replacement. As the existing native overburden will not experience additional load due to culvert construction, settlement of the culverts will be less than 25 mm.

6.4 Lateral Earth Pressures for Design

The lateral earth pressures acting on the walls of the culvert will depend on the type and method of placement of backfill materials, the nature of the 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 culvert walls. It should be noted that these design recommendations and parameters are for 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 specifications of OPSS.PROV 1010 Granular 'A' or Granular 'B' Type II but with less than 5 per cent passing the No. 200 (0.075 mm) sieve should be used as backfill behind the culvert walls, and on top of the culvert for a thickness of not less than 300 mm. Backfill should be placed in a maximum of 200 mm loose lift thickness and nominally compacted. Weep holes should be installed to provide positive drainage of the granular backfill. Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS 501 (Compacting).

- For restrained walls, granular fill should be placed in a zone with the width equal to at least 1.8 m behind the back of the wall (in accordance with Figure C6.20(a) of the *Commentary* to the *CHBDC*). For unrestrained walls, fill should be placed within the wedge shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical (1.5H:1V) extending up and back from the rear face of the footing (in accordance with Figure C6.20(b) of the *Commentary* to the *CHBDC*). The pressures are based on the proposed embankment replacement backfill material and the following parameters (unfactored) may be used:

Fill Type	Soil Unit Weight	Coefficients of Static Lateral Earth Pressure	
		At-Rest, K_o	Active, K_a
Granular 'A'	22 kN/m^3	0.43	0.27
Granular 'B' Type II	21 kN/m^3	0.43	0.27

If the culvert structure allows for lateral yielding, active earth pressures may be used in the foundation design. If the culvert structure does not allow for lateral yielding, at-rest earth pressures should be assumed for culvert design. The movement to allow active pressures to develop within the backfill, and thereby assume a restrained structure, may be taken as per Table C6.6 of the *Commentary to the CHBDC*.

6.5 Construction Considerations

6.5.1 Temporary Roadway Protection

The temporary excavation for the culvert will be made through the existing embankment fill and into native overburden soils, which typically are comprised of very loose to compact silt to sand. Excavation works must be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act and Regulations for Construction Projects. According to the Occupation Health and Safety Act (OHSA), the existing fill and native overburden soils would be classified as Type 3 soil. Provided that proper groundwater control is in place, temporary open-cut excavation through the embankment fill and native overburden soils should be made with side slopes formed no steeper than 1H:1V.

Temporary protection systems will be required along the existing highway to facilitate construction staging and maintain traffic during culvert replacement work. Given that portions of the highway embankments are constructed of rock fill and that bedrock is present at shallow depths below the adjacent ground surface at the culvert location, it will not be possible to install sheet pile shoring to facilitate replacement of the existing culvert. A soldier pile and lagging system may be used for support of the excavation but will likely required pre-drilling through the existing rock fill to install the soldier piles. Between the piles, the rock fill may have to be line-drilled to break up the rock fill into smaller pieces to facilitate lagging installation and to minimize loosening of the embankment rock fill matrix. Where bedrock is present at shallow depths below the ground surface rakers and tie-backs will be required to provide lateral support or the soldier piles would have to be socketed into bedrock.

Temporary protection systems should be designed and constructed in accordance with OPSS 539 (Temporary Protection Systems) as modified by Special Provision (SP) 539S02, as applicable. The lateral movement of the temporary shoring should meet Performance Level 2 as specified in OPSS 539 provided that any existing adjacent utilities can tolerate this magnitude of deformation.

The selection and design of the protection system is the responsibility of the Contractor.

6.5.2 Excavation and Replacement below Culvert Bedding

Prior to the placement of any bedding material or granular fill, all organic soils should be stripped from the plan limits of the proposed works. Given the design invert elevations of the replacement culvert summarized in Table 4, excavation of the organic material, embankment fill and native overburden soils up to about 13 m below existing ground surface will be required.

The culvert subgrade should be inspected by a Quality Verification Engineer following sub-excavation to ensure that all organic soils or other unsuitable materials have been removed, in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts) for a pre-cast box culvert and OPSS 902 (Excavating and Backfilling Structures) for a cast-in-place open footing culvert. Following inspection, the sub-excavated area should be backfilled with granular material meeting OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II and placed and compacted in accordance with OPSS 501 (Compacting).

All excavations should be carried out in accordance with OPSS 902 (Excavating and Backfilling – Structures) and must be carried out in accordance with Ontario Regulation 213 Ontario Occupational Health and Safety Act for Construction Projects (as amended).

6.5.3 Culvert Bedding and Backfill

6.5.3.1 Box Culvert

The bedding, levelling pad, and granular backfill requirements for the pre-cast box culvert should be in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts). Given the potential for surface water flow and potential groundwater seepage through the native overburden soils during excavation to invert and bedding level, it is recommended that at least 300 mm of OPSS.PROV 1010 (Aggregates) Granular 'B' Type II material be used for culvert bedding. As the overburden deposit below the bedding is generally fine grained it is recommended that a non-woven geotextile be placed between the overburden soils and the bottom of the bedding. The geotextile should be 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 lifts not exceeding 200 mm in loose thickness, and compacted to at least 95 per cent of the Standard Proctor maximum dry density of the material as specified in OPSS 501 (Compacting). In addition, a minimum 75 mm thick uncompacted levelling pad consisting of OPSS.PROV 1010 Granular 'A' or fine concrete aggregate meeting the gradation requirements specified in OPSS.PROV 1002 (Aggregates – Concrete) should be provided as shown on OPSD 803.010 (Backfill and Cover for Concrete Culverts) for culvert construction in dry conditions.

6.5.3.2 Open Footing Culvert

The backfill requirements for the cast-in-place open footing culvert replacement should be in accordance with OPSS 902 (Excavating and Backfilling – Structures). The open footing culvert should be provided with at least 1.8 mm of soil cover for frost protection. Backfill, bedding and cover for the open footing culvert should be in accordance with OPSD 803.010 (Backfill and Cover for Concrete Culverts). The backfill should be placed in lifts not exceeding 200 mm in loose thickness, and compacted to at least 98 per cent of the Standard Proctor maximum dry density of the material as specified in OPSS 501 (Compacting).

6.5.3.3 Backfill

Backfill behind the culvert walls should consist of granular fill meeting the specifications for OPSS.PROV 1010 Granular ‘A’ or Granular ‘B’ Type II, but with less than 5 per cent passing the No. 200 (0.075 mm) sieve. The granular backfill should be placed and compacted in accordance with OPSS 501 (Compacting). The fill should also be placed concurrently on both sides of the culvert walls, ensuring that the backfill depth on one side does not exceed the other side by more than 400 mm for a pre-cast box culvert and 500 mm for an open footing culvert, in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts) and OPSS 902 (Excavating and Backfilling – Structures), respectively.

Inspection and field density testing should be carried out by a Quality Verification Engineer during all engineered fill placement operations to ensure that appropriate materials are used, and that adequate levels of compaction have been achieved.

6.5.4 Subgrade Protection

The non-cohesive overburden 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 requirement, a concrete working slab could be placed on the subgrade if the concrete for the footings, or the box culvert, is not placed within four hours after preparation, inspection and approval of the subgrade. The minimum thickness of the concrete working slab should be 100 mm and the concrete should have a 28-day compressive strength of not less than 20 MPa.

6.5.5 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 pre-cast box 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 1 m thick if constructed of natural clay or soil-bentonite mix and extend from a depth of 1 m below the scour level for pre-cast box culverts and from the ground surface immediately adjacent to an open footing culvert, to a minimum horizontal distance of 2 m on either side of the culvert inlet opening, and to a minimum vertical height equivalent to the high water level, including along the embankment slopes. Alternatively, a 0.6 m thick clay blanket (if constructed of natural clay or a soil-bentonite mix) may be constructed, extending upstream three times the culvert height and along the adjacent slopes to a height of two times the culvert height or the high water level, whichever is greater.

The requirements for and design of erosion protection measures for the inlet and outlet of the culverts should be assessed by the hydraulics design engineer. As a minimum, rip-rap treatment for the outlet of the culverts should be consistent with the standard presented in OPSD 810.010 (Rip-Rap Treatment for Sewer and Culvert Outlets). Erosion protection for the inlet of the culverts should generally follow the standard presented in

OPSD 810.010, 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 culverts if this clay seal option is adopted.

6.5.6 Surface Water and Groundwater Control

Excavation below the level of the adjacent ground surface at the culvert alignment will be required to remove embankment fill and organic and overburden soils prior to placement of backfill, bedding material and the actual culvert structure. As a result, groundwater flow into the excavation can be expected to occur due to the relatively permeable nature of the near ground surface native overburden soils. Therefore, control of groundwater will be necessary to allow for construction to be carried out in dry conditions, where required. Surface water flow should be directed away from the excavation.

Depending on the creek flow condition, 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, or diverted by pumping from behind temporary sheetpile cofferdam(s).

Groundwater control may be required as the foundation excavation to the culvert invert or footing level extend below the groundwater level. Excavations will be advanced through the native silt and sand deposits, however, seepage into the excavation should be adequately controlled by pumping from properly filtered sumps. Dewatering of all excavations should be carried out in accordance with OPSS 517 (Dewatering).

At this preliminary stage, an accurate prediction of the groundwater pumping volumes cannot be made, as the flow rate will be dependent on construction methods adopted by the Contractor. However, it is considered that groundwater pumping volumes could exceed 50 m^3/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.

6.5.7 Analytical Testing for Construction Materials

The results of an analytical test on a sample of creek water taken at the culvert site are presented in Table A1 in Appendix A. 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.

6.6 Recommendations for Future Work during Detail Design

During the design-build phase, additional field investigation and testing may be required. The scope and results of this investigation must be reviewed at that time to determine if they meet the then-current MTO requirements for the culvert type under consideration, and if additional investigation and analysis is necessary. Further, the need for an application for a PTTW should be defined early in the detail design phase of the project so as not to delay the start of construction.

7.0 CLOSURE

This Foundation Design Report was prepared by Ms. Madison Kennedy, B.A.Sc., a member of the geotechnical engineer group. The technical aspects were reviewed by Mr. Christopher Ng, P.Eng., a geotechnical engineer and an Associate with Golder. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and a Principal with Golder, carried out an independent quality control review of the report.

Report Signature Page

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Golder Associates

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Chapman, L.J. and D. F. Putnam, 1984. The Physiography of Southern Ontario, Ontario Geological Survey, Special Volume 2, Third Edition. Accompanied by Map P. 2715, Scale 1:600,000.

Geology of Ontario. 1991. Ontario Geological Society, Special Volume 4, Part 2. Eds. P.C. Thurston, H.R. Williams, R.H. Sutcliffe and G.M. Stott. Ministry of Northern Development and Mines, Ontario.

International Society for Rock Mechanics Commission on Test Methods, 1985. Int. J. Rock Mech.Min. Sci. & Geomech. Abstr. Vol 22, No. 2, pp. 51-60.

ASTM International:

ASTM D1586	Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils
ASTM D7012	Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

Contract Design Estimating and Documentation (CDED):

SP 539S02	Amendment to OPSS 539 - Protection Systems

Ontario Occupational Health and Safety Act:

Ontario Regulation 213/91	Construction Projects as amended by O. Reg. 443/09

Ontario Provincial Standard Drawings:

OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m
OPSD 810.010	Rip-Rap Treatment for Sewer and Culvert Outlets
OPSD 3090.101	Foundation, Frost Depths for Southern Ontario

Ontario Provincial Standard Specification:

OPSS 422	Construction Specifications for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS 501	Construction Specification for Compacting
OPSS 517	Construction Specifications for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS 539	Construction Specification for Temporary Protection Systems
OPSS 902	Construction Specifications for Excavating and Backfilling - Structures
OPSS.PROV 1002	Material Specification for Aggregates – Concrete
OPSS.PROV 1010	Material Specifications for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material

OPSS 1205	Material Specification for Clay Seal
OPSS 1860	Material Specification for Geotextiles

Ontario Water Resources Act:

Ontario Regulation 372/97	Amendment to Ontario Regulation 903

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
υ	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

* Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(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 $= \sigma'_p / \sigma'_{vo}$

(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

Notes:
1. $\tau = c' + \sigma' \tan\phi'$
2. shear strength = (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, 60º cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure
PM: Sampler advanced by manual pressure
WH: Sampler advanced by static weight of hammer
WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 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 Soils

Density Index Relative Density	N 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	c_u, s_u 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

WEATHERING 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^o 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		

TABLES

Table 1: Summary of Culvert Details

Culvert Location (Township)	Culvert ID	Approximate Height of Embankment [1]	Existing Culvert			Approximate Invert Elevation [2]		Boreholes	Dynamic Cone Penetration Tests	Reference Appendix
			Type	Approximate Dimension	Approximate Length	West End of Culvert	East End of Culvert			
STA 11+209 (Stephenson)	C10	Up to 13 m	Concrete Box	1.5 m high by 3.1 m wide	89 m	294.2 m	290.6 m	6 Boreholes (C10-01, C10-02, C10-03, C10-03A, C10-04 and C10-05)	5 DCPTs (C10-DC01, C10-DC02A, C10-DC02B, C10-DC03 and C10-DC04)	A

Notes: 1. Embankment height is relative to existing ground surface level at the toe of embankment adjacent to the culvert.

2. Culvert invert elevations are estimated based on the top of culvert surveys provided by exp. and culvert dimensions provided by AECOM.

Table 2: Comparison of Foundation Alternatives for Culvert Replacements

Replacement Alternatives	Advantages	Disadvantages	Risks/Consequences
Pre-Cast Box Culvert	■ Minimizes the depth of excavation, excavation support and dewatering requirements. ■ 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 at the culvert site. ■ Backfill under culvert may be placed underwater (i.e. Granular 'B' Type II) minimizing or eliminating water pumping requirements.	■ Dewatering would be required where excavation extends below the groundwater level if construction is to be carried out in-the-dry. ■ Cut-off or clay blanket may be required at inlet to mitigate potential for scour under culvert.	■ Some risk of disturbance of the very loose to compact native silt to sand deposit at the west end of the culvert during construction.
Cast-In-Place Open Footing Culvert	■ Potentially easier to construct the median section as the NBL and SBL culverts are connected with a "dog-leg."	■ Construction of footings in-the-dry will take a longer time due to requirements for installation of groundwater control system, dewatering and surface water pumping. ■ A cast-in-place open footing culvert is less tolerant of total and differential settlement. ■ One end of the culvert would be founded on overburden, or require excavation to bedrock, generating spoil which would need to be disposed of off-site.	■ High risk of disturbance of very loose to compact native sand to silt at the west end of the culvert during construction. ■ Culvert joints may be required to accommodate total and differential settlement (if applicable)

Prepared by: MCK
Checked by: CN
Reviewed by: JMAC

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

Culvert Location (Township)	Approximate Invert Elevation [1] (West End / East End)	Culvert Type	Approximate Founding Elevation (West End / East End)	Founding Condition	Factored Geotechnical Axial Resistance at ULS [2]	Geotechnical Reaction at SLS for 25 mm of Settlement [2]
STA 11+209 (Stephenson)	294.2 m / 290.6 m	Pre-Cast Box	293.9 m / 290.3 m	Very Loose to Compact Silty Sand to Sand Stratum	300 kPa	75 kPa
				Gneiss Bedrock	10,000 kPa	N/A [3]
		Cast-In-Place Open Footing	292.4 m / 290.3 m	Compact Silt Stratum	400 kPa	275 kPa
				Gneiss Bedrock	10,000 kPa	N/A [3]

Notes: 1. Culvert invert elevations are estimated based on the top of culvert surveys provided by exp. and culvert dimensions provided by AECOM.

2. For the cast-in-place open footing culvert, the factored geotechnical resistance at ULS and geotechnical reaction at SLS for 25 mm of settlement are estimated based on an assumed footing width of 0.5 m. The recommended geotechnical resistance/reaction should be reviewed if the founding elevation and/or the footing width differ from those given above.

3. Geotechnical reaction at SLS for 25 mm of settlement will be greater than the factored geotechnical axial resistance at ULS and as a result, the SLS condition does not apply.

Prepared by: MCK
Checked by: CN
Reviewed by: JMAC

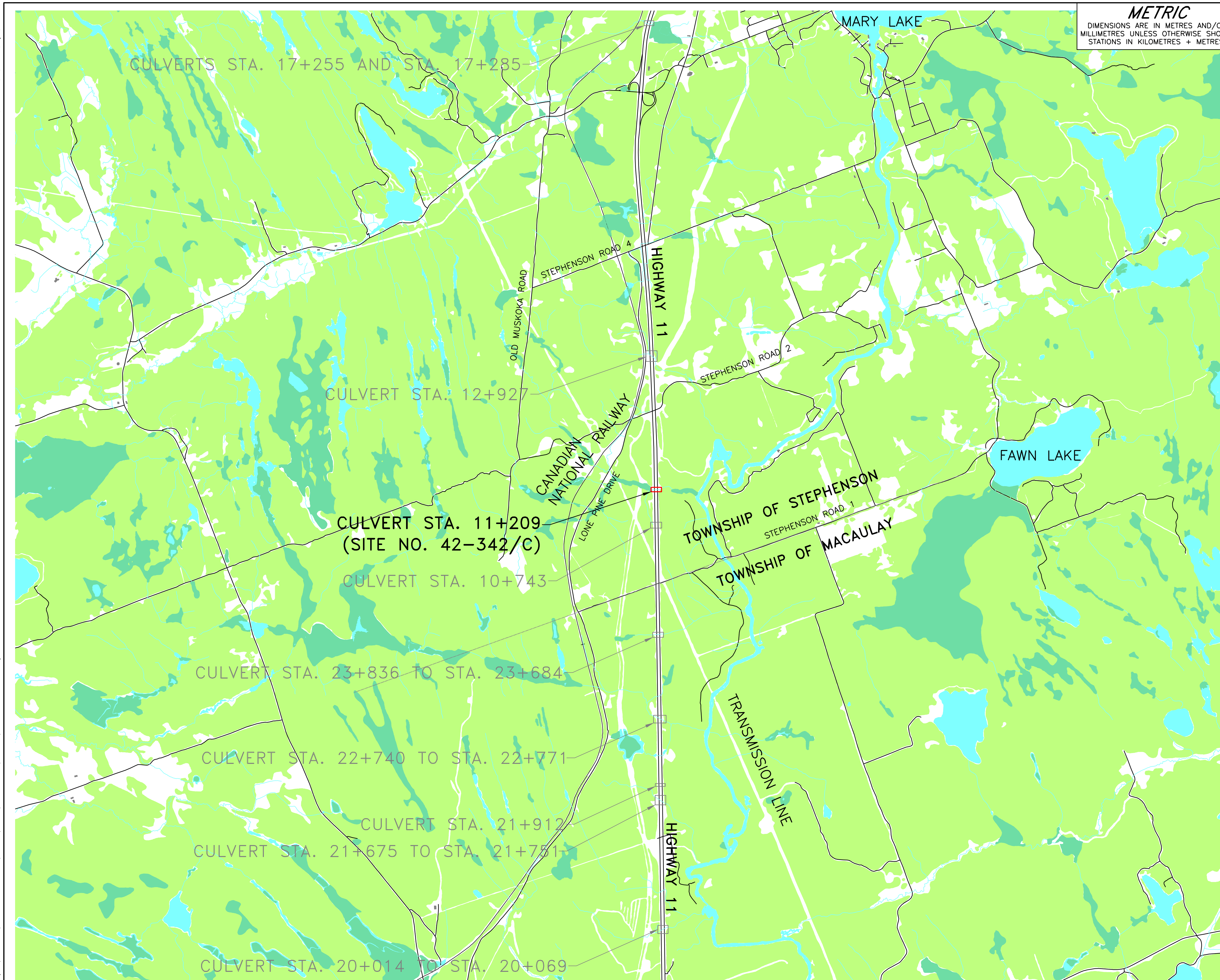
Table 4: Resistance to Lateral Loads/Sliding Resistance for Pre-Cast Box and Cast-In-Place Open Footing Culvert Replacements

Culvert Location (Township)	Pre-Cast Box Culvert		Cast-In-Place Open Footing Culvert	
	Interface Material	Coefficient of Friction ($\tan \delta$)	Interface Material	Coefficient of Friction ($\tan \delta$)
STA 11+209 (Stephenson)	Compacted Granular Fill (Bedding)	0.40	Compact Silt Stratum	0.30
			Gneiss Bedrock	0.70

Prepared by: MCK
Checked by: CN
Reviewed by: JMAC

DRAWINGS

MINISTRY OF TRANSPORTATION, ONTARIO



PLAN

SCALE

500 0 500 1000 m

METRIC

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

CONT No.

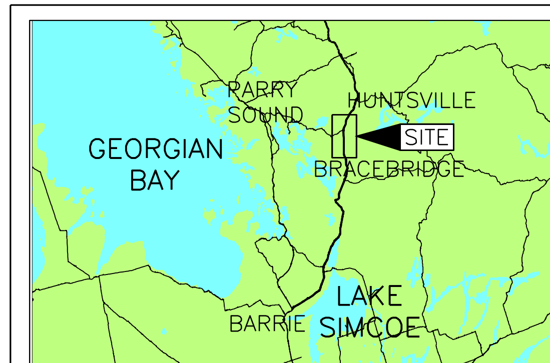
GWP No. 5462-09-00

SHEET

HIGHWAY 11

CULVERTS

INDEX PLAN



KEY PLAN

NOT TO SCALE

REFERENCE

Base data accessed in digital format from MNR LIO, obtained 2013.

NO.	DATE	BY	REVISION
.	.	.	.

Geocres No. 31E-342

HWY. 11	PROJECT NO. 14-1111-0007		DIST.
SUBM'D. MCK	CHKD. MCK	DATE: 11/5/2014	SITE: 42-342/C
DRAWN: MR	CHKD. CN	APPD. JMAC	DWG. 1

PLOT DATE: January 26, 2015

APPENDIX A

Unnamed Creek Culvert at STA 11+209 – Highway 11 – Site No. 42-342/C

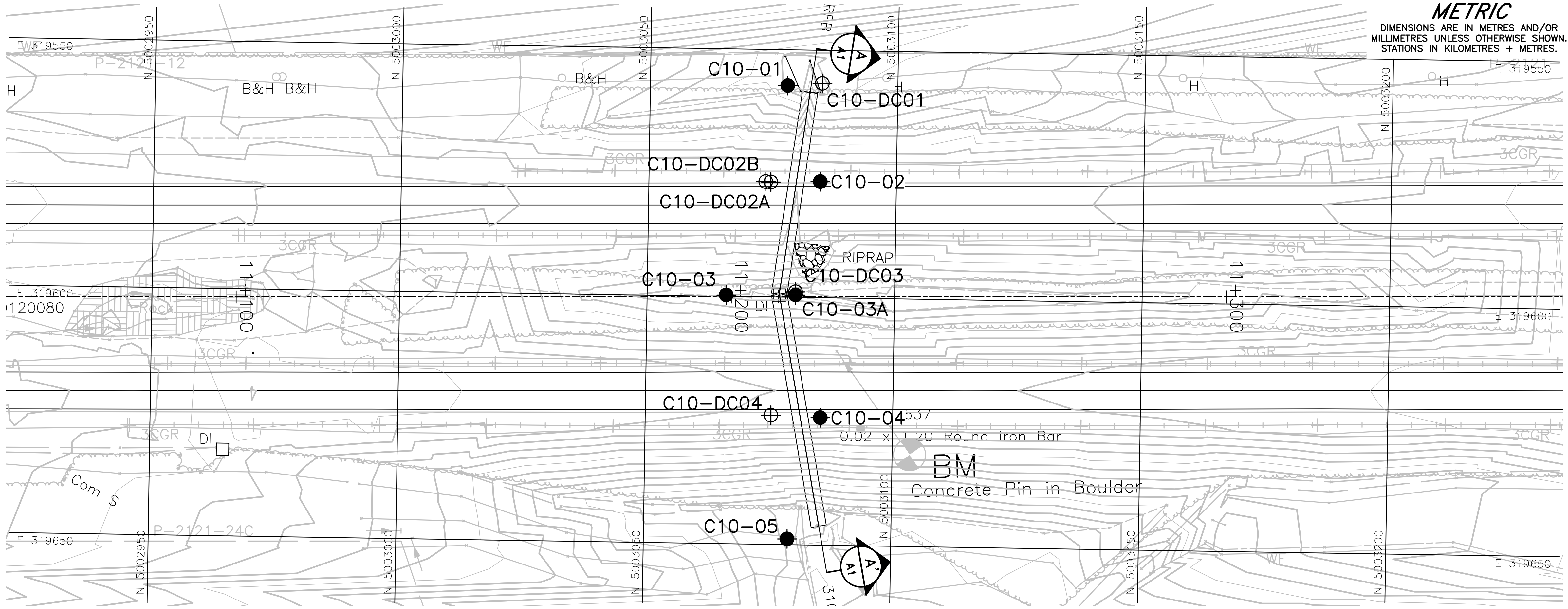
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 5462-09-00

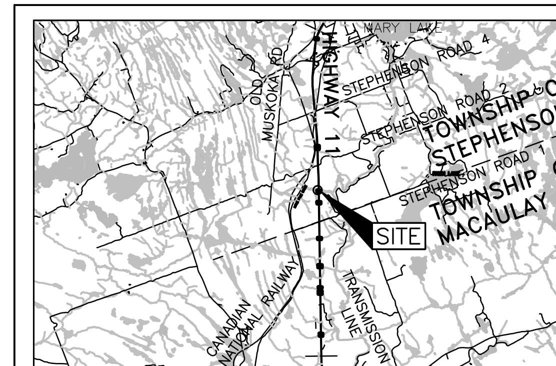
HIGHWAY 11
CULVERT STA. 11+209 (SBL AND NBL)
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET .

Golder Associates



PLAN
SCALE
10 0 10 20 m



KEY PLAN
SCALE
3 0 3 6 km

LEGEND

- ● Borehole – Current Investigation
- ⊕ Dynamic Cone Penetration Test
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)
- REC % Recovery
- ▽ WL upon completion of drilling
- R Refusal

BOREHOLE CO-ORDINATES

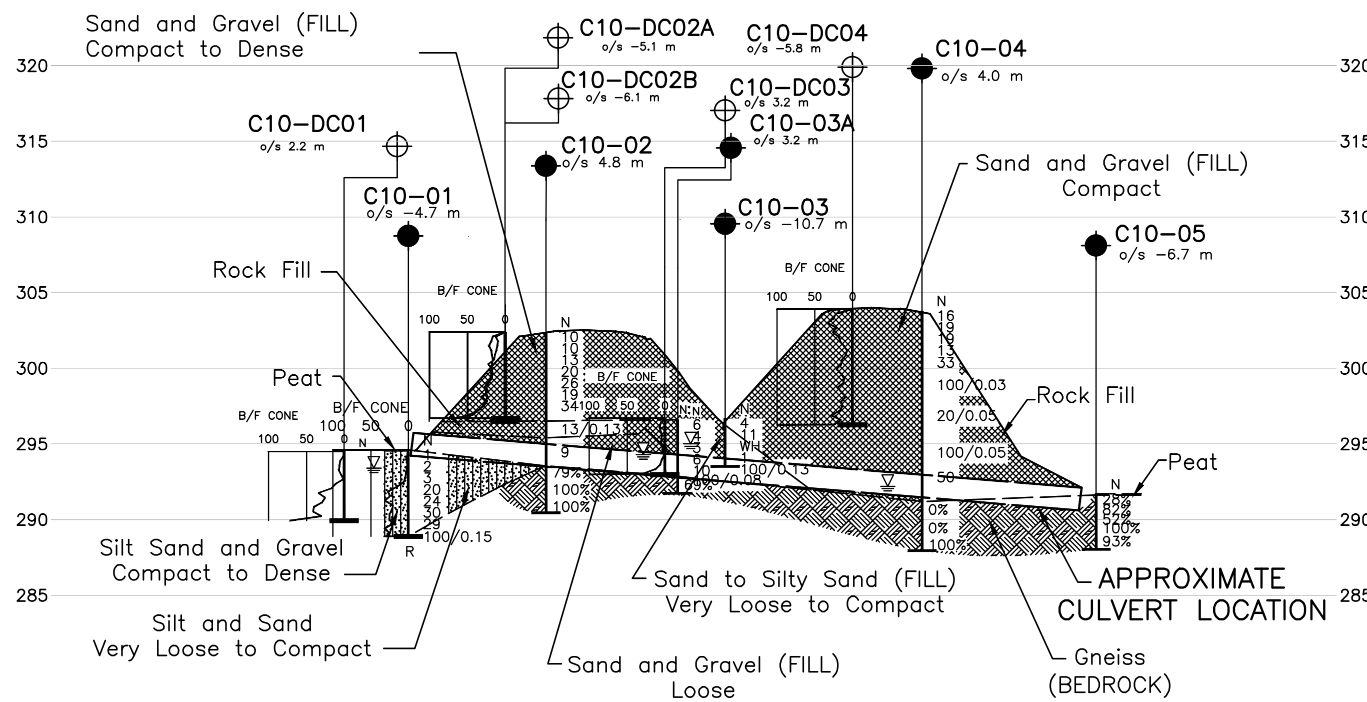
No.	ELEVATION	NORTHING	EASTING
C10-01	294.6	5003077.8	319557.2
C10-02	302.4	5003084.6	319576.6
C10-03	296.7	5003066.0	319599.8
C10-03A	296.6	5003080.0	319599.5
C10-04	303.8	5003085.4	319624.3
C10-05	291.7	5003079.1	319648.9
C10-DC01	294.5	5003084.8	319556.7
C10-DC02A	302.4	5003074.6	319576.8
C10-DC02B	302.4	5003073.6	319576.7
C10-DC03	296.7	5003080.0	319598.9
C10-DC04	303.9	5003075.4	319623.9

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.



A-A' / A1 CULVERT STA. 11+209
SECTION A-A'

HORIZONTAL SCALE
10 0 10 20 m

VERTICAL SCALE
5 0 5 10 m

REFERENCE

Base plan, sections and topographic data, provided in digital format by exp geomatics, drawing file nos. ntb-01407006.dwg and X-SECTIONS.dwg, received Oct 14, 2014.

NO.	DATE	BY	REVISION
.	.	.	

Geocres No. 31E-342			
HWY. 11	PROJECT NO. 14-1111-0007		DIST. .
SUBM'D. MCK	CHKD. MCK	DATE: 11/5/2014	SITE: 42-342/C
DRAWN: MR	CHKD. CN	APPD. JMAC	DWG. A1

Golder Associates

RECORD OF BOREHOLE No C10-01

SHEET 1 OF 1

METRIC

PROJECT 14-1111-0007

G.W.P. 5462-09-00

LOCATION N 5003077.8 ;E 319557.2

ORIGINATED BY MT

DIST ____ HWY 11

BOREHOLE TYPE Portable Equipment, Wash Boring

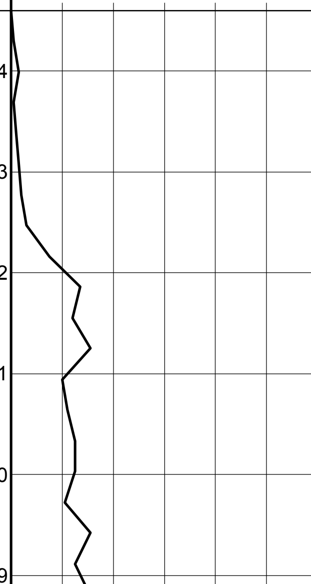
COMPILED BY MT

DATUM Geodetic

DATE June 19, 2014

CHECKED BY CN

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
294.6	GROUND SURFACE								
0.0	PEAT (Fibrous)	1A							
0.1	Silty SAND to SAND, trace organics Very loose Grey to brown Moist to wet	1B	SS	1		294			
		2	SS	2	∇		50.8		OC = 4.7%
		3	SS	3		293			
292.4 2.2	SILT, trace to some clay, trace sand Compact Grey Wet	4	SS	20		292			
		5	SS	24		291	○		0 1 93 6
		6	SS	30		290			
		7A	SS	29			○		
289.7 4.9	Silty SAND and GRAVEL, trace clay Compact to dense Grey Wet	7B							
		8	SS	100/0.15		289	○		30 41 27 2
288.9 5.7	END OF BOREHOLE SPOON REFUSAL (HAMMER BOUNCING)								



PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30

NOTES:

1. Water level in open borehole at a depth of 1.2 m below ground surface (Elev. 293.4 m) upon completion of drilling.

2. DCPT advanced 1.0 m west of Borehole C10-01.

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

Golder Associates

RECORD OF BOREHOLE No C10-02

SHEET 1 OF 2 **METRIC**

PROJECT 14-1111-0007
G.W.P. 5462-09-00
DIST
HWY 11
DATUM Geodetic
LOCATION N 5003084.6 ;E 319576.6
BOREHOLE TYPE CME 55, 108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing
DATE June 19, 2014
ORIGINATED BY ID
COMPILED BY MT
CHECKED BY CN

ELEV DEPTH	DESCRIPTION (SOIL PROFILE)	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%) (approx.)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
302.4	GROUND SURFACE					
0.0	Sand, trace to some silt, trace gravel, trace clay (FILL) Compact to dense Brown Moist to wet Asphalt mixed with sand and gravel encountered from surface to a depth of 0.1 m.	1A / 1B	SS	10		
		2	SS	10	○ (~10)	1 86 11 2
		3	SS	13		
		4	SS	20	○ (~19)	0 80 17 3
		5	SS	26		
		6	SS	19		
		7	SS	34	○ (~14)	
296.2		8	SS	13/0.13	○ (~25)	0 87 (13)
6.2	Rock fill (FILL)					
295.4 7.0	Sand and gravel (FILL) Loose Brown Wet	9	SS	9		
293.6 8.8	GNEISS (BEDROCK) Bedrock cored from depths of 8.8 m to 12.0 m. For bedrock coring details refer to Record of Drillhole C10-02.	1	RC	REC 100%		RQD = 79%
		2	RC	REC 100%		RQD = 100%
		3	RC	REC 100%		RQD = 100%
290.4 12.0	END OF BOREHOLE NOTE: 1. Open borehole dry upon completion of drilling.					

Chart headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED (20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; ELEVATION SCALE 302–291; STRAT PLOT; GROUND WATER CONDITIONS.

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

PROJECT: 1411110007

RECORD OF DRILLHOLE: C10-02

LOCATION: N 5003084.6 ;E 319576.6
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: June 19, 2014
DRILL RIG: CME 55
DRILLING CONTRACTOR: Landcore Drilling Inc.

DATUM: Geodetic

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.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	FLUSH COLOUR % RETURN	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	NOTES
		Continued from Record of Borehole C10-02	293.6				
9	NQ Coring June 19, 2014	GNEISS Strong Pinkish grey Medium to coarse grained Fresh	8.8	1	GREY 100	JN,IR,RO JN,IR,RO	
10				2	GREY 100		UCS = 76 MPa
11				3	GREY 100		
12		END OF DRILLHOLE	290.4 12.0				

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: ID
CHECKED: CN

GTA-RCK 023 S:\CLIENTS\MTO\HWY_11\02_DATA\GINT\1411110007.GPJ GAL-GTA.GDT 01/21/15

Golder Associates

RECORD OF BOREHOLE No C10-03

SHEET 1 OF 1 — METRIC

PROJECT 14-1111-0007

G.W.P. 5462-09-00 — LOCATION N 5003066.0 ;E 319599.8 — ORIGINATED BY EG

DIST ___ HWY 11 — BOREHOLE TYPE Portable Equipment, Wash Boring — COMPILED BY MT

DATUM Geodetic — DATE July 9, 2014 — CHECKED BY CN

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
296.7	GROUND SURFACE						
0.0	Sand to silty sand, some gravel, trace clay, trace organics (FILL) Very loose to compact Brown Moist	1	SS	4			
		2	SS	11		296	
		3	SS	WH	∇	295	
		4	SS	1		294	18 51 29 2
293.5		5	SS	100/0.13			
3.2	END OF BOREHOLE SPOON REFUSAL NOTE: 1. Water level in open borehole at a depth of 1.7 m below ground surface (Elev. 295.0 m) upon completion of drilling.						

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³

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

Foundation Design

Golder Associates

RECORD OF BOREHOLE No C10-03A

SHEET 1 OF 2

METRIC

PROJECT 14-1111-0007
G.W.P. 5462-09-00
LOCATION N 5003080.0 ;E 319599.5
ORIGINATED BY EG
DIST
HWY 11
BOREHOLE TYPE Portable Equipment, Wash Boring
COMPILED BY MT
DATUM Geodetic
DATE July 10, 2014
CHECKED BY CN

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L – WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
296.6	GROUND SURFACE										
0.0	Silty sand, trace gravel, trace clay (FILL) Very loose to loose Brown Wet		1	SS	6		296				
			2	SS	4						
			3	SS	3		295		○ (~22)		3 71 24 2
						▽					
			4	SS	6		294				
			5	SS	10				○ (~30)		
292.9			6	SS	100/0.08		293				
3.7	GNEISS (BEDROCK) Bedrock cored from depths of 3.7 m to 4.9 m For bedrock coring details refer to Record of Drillhole C10-03A.		1	RC	REC 97%		292				RQD = 69%
291.7 4.9	END OF BOREHOLE										

NOTE:

1. Water level in open borehole at a depth of 2.3 m below ground surface (Elev. 294.3 m) upon completion of drilling.

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

PROJECT: 1411110007

RECORD OF DRILLHOLE: C10-03A

LOCATION: N 5003080.0 ;E 319599.5

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: July 10, 2014

DRILL RIG: Aluminum Tripod and Cathead/Hitch Pull

DRILLING CONTRACTOR: George Downing Estate Drilling Ltd.

DATUM: Geodetic

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.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH / COLOUR % RETURN	RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 0.3 m	DISCONTINUITY DATA: B Angle	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY K, cm/sec	Diametral Point Load Index (MPa)	RMC -Q' AVG.
		Continued from Record of Borehole C10-03A		292.9															
4	Thin-walled BQ Coring, July 10, 2014	GNEISS Pinkish grey Medium to coarse grained Fresh		3.7 291.7 4.9	1														
5		END OF DRILLHOLE																	

Depth scale: 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: EG

CHECKED: CN

RECORD OF BOREHOLE No C10-04

SHEET 1 OF 3 **METRIC**

PROJECT 14-1111-0007
G.W.P. 5462-09-00 LOCATION N 5003085.4 ;E 319624.3 ORIGINATED BY EG
DIST HWY 11 BOREHOLE TYPE CME 75, NW Casing, NQ Coring COMPILED BY MT
DATUM Geodetic DATE June 25, 2014 CHECKED BY CN

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
303.8	GROUND SURFACE						
0.0	Sand and gravel, trace silt (FILL) Compact Grey to brown Moist to wet	1	SS	16			
		2	SS	19			
		3	SS	19		○ (approx. 7)	61 35 (4)
301.6 / 2.2	Rock fill (FILL)	4	SS	13			
		5	SS	33			
		6	SS	100/0.03			
		7	SS	20/0.05			
		8	SS	100/0.05			
		9	SS	50	▽ (approx. El. 292.3)		
291.2 / 12.6	GNEISS (BEDROCK) Bedrock cored from depths of 12.6 m to 15.9 m. For bedrock coring details refer to Record of Drillhole C10-04.	1	RC	REC 100%			RQD = 0%
		2	RC	REC 100%			RQD = 0%

Elevation scale: 303, 302, 301, 300, 299, 298, 297, 296, 295, 294, 293, 292, 291, 290, 289

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED: 20 40 60 80 100
PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30
UNIT WEIGHT γ kN/m³

Continued Next Page

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

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RECORD OF BOREHOLE No C10-04

SHEET 2 OF 3

METRIC

PROJECT 14-1111-0007
G.W.P. 5462-09-00
LOCATION N 5003085.4 ;E 319624.3
ORIGINATED BY EG
DIST
HWY 11
BOREHOLE TYPE CME 75, NW Casing, NQ Coring
COMPILED BY MT
DATUM Geodetic
DATE June 25, 2014
CHECKED BY CN

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
			3	RC	REC 100%						RQD = 100%
287.9							288				
15.9	END OF BOREHOLE NOTE: 1. Water level in open borehole at a depth of 11.6 m below ground surface (Elev. 292.2 m) upon completion of drilling.										

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

RECORD OF DRILLHOLE: C10-04

PROJECT: 1411110007

SHEET 3 OF 3

LOCATION: N 5003085.4 ;E 319624.3

DRILLING DATE: June 26, 2014

DATUM: Geodetic

DRILL RIG: CME 75

INCLINATION: -90° AZIMUTH: ---

DRILLING CONTRACTOR: Landcore Drilling Inc.

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.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	FLUSH COLOUR % RETURN	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION
		Continued from Record of Borehole C10-04	291.2			
13	NQ Coring, June 26, 2014	GNEISS Severely weathered to fresh Dark grey Fine to coarse grained	12.6	1	GREY 100	
14		Broken core encountered from 12.6 m to 15.0 m depth, likely as a result of drilling operations.		2	GREY 100	BR,,
15			287.9 / 15.9	3	GREY 100	
16		END OF DRILLHOLE				

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: EG

CHECKED: CN

GTA-RCK 023 S:\CLIENTS\MTO\HWY_11\02_DATA\GINT\1411110007.GPJ GAL-GTA.GDT 01/21/15

RECORD OF BOREHOLE No C10-05

SHEET 1 OF 2

METRIC

PROJECT 14-1111-0007

G.W.P. 5462-09-00

LOCATION N 5003079.1 ;E 319648.9

ORIGINATED BY TM

DIST

HWY 11

BOREHOLE TYPE Portable Equipment

COMPILED BY MT

DATUM Geodetic

DATE June 25, 2014

CHECKED BY CN

ELEV / DEPTH (m)	SOIL PROFILE: DESCRIPTION	SAMPLE NUMBER	SAMPLE TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%)
291.7	GROUND SURFACE					
0.0	PEAT (Fibrous)					
0.1	GNEISS (BEDROCK) Bedrock cored from depths of 0.1 m to 3.7 m For bedrock coring details refer to Record of Drillhole C10-05.	1	RC	REC 96%		RQD = 28%
		2	RC	REC 100%	291	RQD = 82%
		3	RC	REC 93%	290	RQD = 52%
		4	RC	REC 100%		RQD = 100%
288.0		5	RC	REC 97%	289	RQD = 93%
3.7	END OF BOREHOLE NOTE: 1. Water level not recorded.					

Columns with no entries: STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L, WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³; GR SA SI CL.

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

RECORD OF DRILLHOLE: C10-05

PROJECT: 1411110007
SHEET 2 OF 2

LOCATION: N 5003079.1 ;E 319648.9
DRILLING DATE: June 25, 2014
DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---
DRILL RIG: Portable Drilling Equipment
DRILLING CONTRACTOR: George Downing Estate Drilling Ltd.

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.

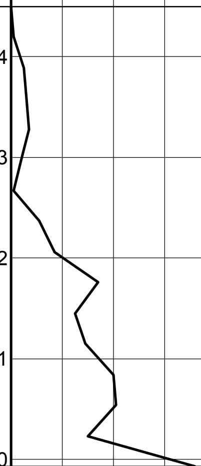
DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	COLOUR % RETURN	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION
		Continued from Record of Borehole C10-05	291.6			
	BQ Thin-walled Coring, June 25, 2014	GNEISS Pinkish grey Medium grained Slightly weathered Highly fractured zone encountered from 0.3 m to 0.4 m depth.	0.1	1	GREY 100	JN,PL,RO BR,, JN,IR,RO JN,IR,RO
1				2	GREY 100	JN,IR,RO JN,IR,RO JN,IR,RO JN,IR,RO JN,IR,RO
				3	GREY 100	JN,IR,RO JN,IR,RO JN,IR,RO
2				4	GREY 100	JN,IR,RO JN,IR,RO
3			288.0 3.7	5	GREY 100	JN,IR,RO JN,IR,RO
		END OF DRILLHOLE				
4						
5						
6						
7						
8						
9						
10						

Other column headings: SYMBOLIC LOG; FLUSH; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX PER 0.3 m; B Angle; DIP w.r.t. CORE AXIS; Jr; Ja; Jn; HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); Diametral Point Load Index (MPa); RMC -Q' AVG.

RECORD OF DCPT No C10-DC01

SHEET 1 OF 1 **METRIC**

PROJECT 14-1111-0007			
G.W.P. 5462-09-00	LOCATION N 5003084.8 ;E 319556.7		ORIGINATED BY MT
DIST	HWY 11	BOREHOLE TYPE Portable Equipment, Dynamic Cone Penetration Test	COMPILED BY MT
DATUM Geodetic	DATE June 19, 2014		CHECKED BY CN

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED) 20 40 60 80 100	PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L / WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
294.5	GROUND SURFACE										
0.0	Dynamic Cone Penetration Test (DCPT)						294 293 292 291 290				
289.9 4.6	END OF DCPT REFUSAL TO FURTHER PENETRATION (72 Blows / 0.30 m) (HAMMER BOUNCING)										

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

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RECORD OF DCPT No C10-DC02A

SHEET 1 OF 1

METRIC

PROJECT 14-1111-0007

G.W.P. 5462-09-00

LOCATION N 5003074.6 ;E 319576.8

ORIGINATED BY ID

DIST HWY 11

BOREHOLE TYPE CME 55, Dynamic Cone Penetration Test

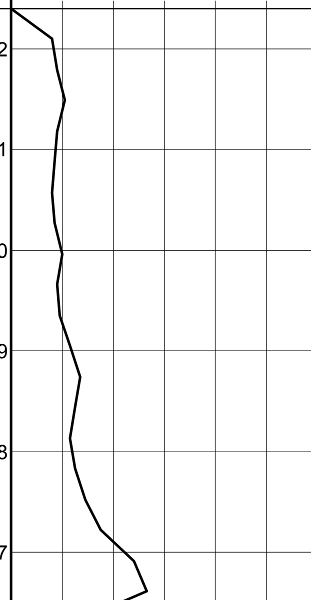
COMPILED BY MT

DATUM Geodetic

DATE June 18, 2014

CHECKED BY CN

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	STRAT PLOT	SAMPLES – NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED) 20 40 60 80 100	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L – WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
302.4	GROUND SURFACE										
0.0	Dynamic Cone Penetration Test (DCPT)						302, 301, 300, 299, 298, 297				
296.5 / 5.9	END OF DCPT REFUSAL TO FURTHER PENETRATION (42 Blows / 0.13 m) (HAMMER BOUNCING)										



$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

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Foundation Design

Golder Associates

RECORD OF DCPT No C10-DC02B

SHEET 1 OF 1

METRIC

PROJECT 14-1111-0007			
G.W.P. 5462-09-00	LOCATION N 5003073.6 ;E 319576.7		ORIGINATED BY ID
DIST	HWY 11	BOREHOLE TYPE CME 55, Dynamic Cone Penetration Test	COMPILED BY MT
DATUM Geodetic		DATE June 18, 2014	CHECKED BY CN

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
302.4	GROUND SURFACE										
0.0	Dynamic Cone Penetration Test (DCPT)						302, 301, 300, 299, 298, 297				
296.7 5.7	END OF DCPT REFUSAL TO FURTHER PENETRATION (72 Blows / 0.25 m) (HAMMER BOUNCING) NOTE: 1. DCPT C10-DC02 B advanced 1.0 m south of DCPT C10-DC02 A.										

Dynamic cone penetration resistance plot: 20 40 60 80 100
Shear strength kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED; 20 40 60 80 100
Plastic limit W_P, Natural moisture content W, Liquid limit W_L; Water content (%): 10 20 30

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

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RECORD OF DCPT No C10-DC03

SHEET 1 OF 1

METRIC

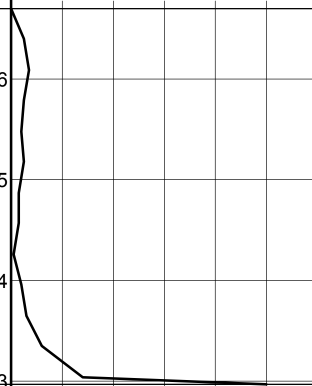
PROJECT 14-1111-0007

G.W.P. 5462-09-00 — LOCATION N 5003080.0 ;E 319598.9 — ORIGINATED BY EG

DIST ___ HWY 11 — BOREHOLE TYPE Portable Equipment, Dynamic Cone Penetration Test — COMPILED BY MT

DATUM Geodetic — DATE July 9, 2014 — CHECKED BY CN

ELEV DEPTH	SOIL PROFILE – DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
296.7	GROUND SURFACE										
0.0	Dynamic Cone Penetration Test (DCPT)						296, 295, 294, 293				
293.0 3.7	END OF DCPT REFUSAL TO FURTHER PENETRATION (100 Blows / 0.08 m) (HAMMER BOUNCING)										



Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10, 20, 30.

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

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RECORD OF DCPT No C10-DC04

SHEET 1 OF 1

METRIC

PROJECT 14-1111-0007			
G.W.P. 5462-09-00	LOCATION N 5003075.4 ;E 319623.9		ORIGINATED BY EG
DIST	HWY 11	BOREHOLE TYPE CME 75, Dynamic Cone Penetration Test	COMPILED BY MT
DATUM Geodetic	DATE June 27, 2014		CHECKED BY CN

SOIL PROFILE: ELEV DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED) 20 40 60 80 100	PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
303.9	GROUND SURFACE										
0.0	Dynamic Cone Penetration Test (DCPT)						303 302 301 300 299 298 297				
296.3 7.7	END OF DCPT REFUSAL TO FURTHER PENETRATION (100 Blows / 0.03 m) NOTE: 1. DCPT advanced 1.0 m north of C10-DC04 encountered refusal to further penetration at a depth of 0.9 m.										

GTA-MTO 001 S:\CLIENTS\MTO\HWY_11\02_DATA\GINT\1411110007.GPJ GAL-GTA.GDT 01/21/15

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

Table A1: Summary of Analytical Testing of Surface Water

Culvert Location Highway 11 (Township)	Parameter (Units, Detection Limit)				
	Chloride (mg/L, 1)	Sulfate (mg/L, 1)	Conductivity (μS/cm, 1)	Resistivity (Ω-cm)	pH
STA 11+209 (Township of Stephenson)	26	Not Detected	120	8000	6.95

Notes: 1. Samples obtained July 18, 2014
2. Analytical testing carried out by Maxxam Analytics.

Prepared by: MCK
Checked by: CN
Reviewed by: JMAC

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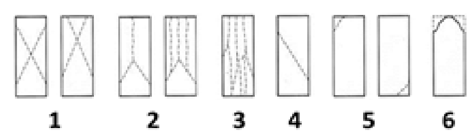
TABLE A2 - Unconfined Compressive Strength

PROJECT NO.: 14-1111-0007
JOB NAME: Unnamed Creek Culvert
TYPE OF UNIT: Bedrock Core

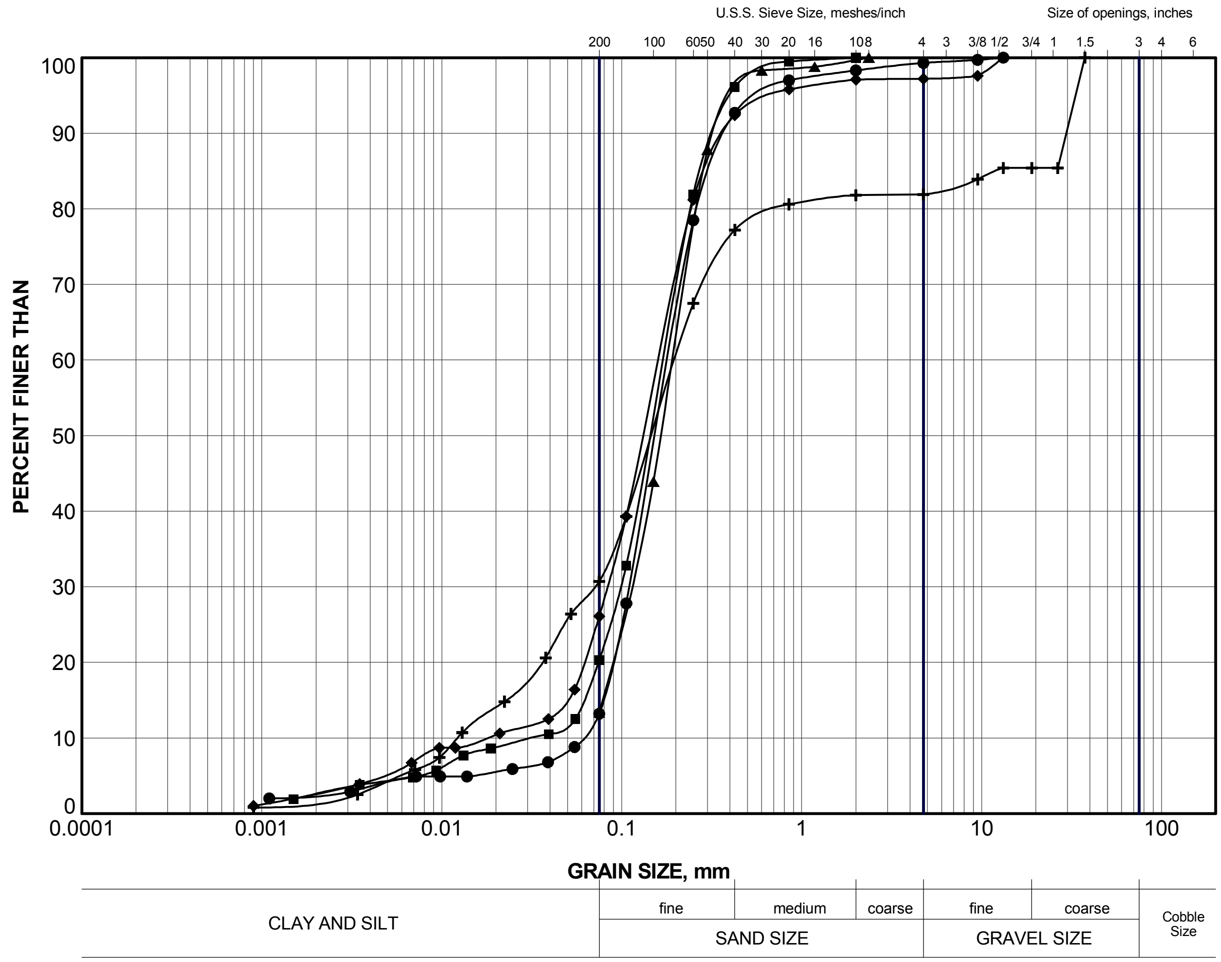
GOLDER LAB NUMBER	**G0837**
BOREHOLE	**C10-02**
DATE TESTED	**September 5, 2014**
DEPTH OF TESTED CORE (m)	10.2
LENGTH AS CUT (mm)	105.0
DIAMETER (mm)	47.5
DENSITY (kg/m3)	2758
UNIAXIAL COMPRESSIVE STRENGTH (MPa)	**76.1**
TYPE OF FRACTURE	**3**

Type of Fracture



Tested by: SA

Reviewed by : CN



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C10-02	2	301.3
■	C10-02	4	299.8
▲	C10-02	8	296.2
+	C10-03	4	294.1
◆	C10-03A	3	294.8

PROJECT

HIGHWAY 11 RESURFACING
UNNAMED CREEK CULVERT
SITE NO. 42-342/C

TITLE

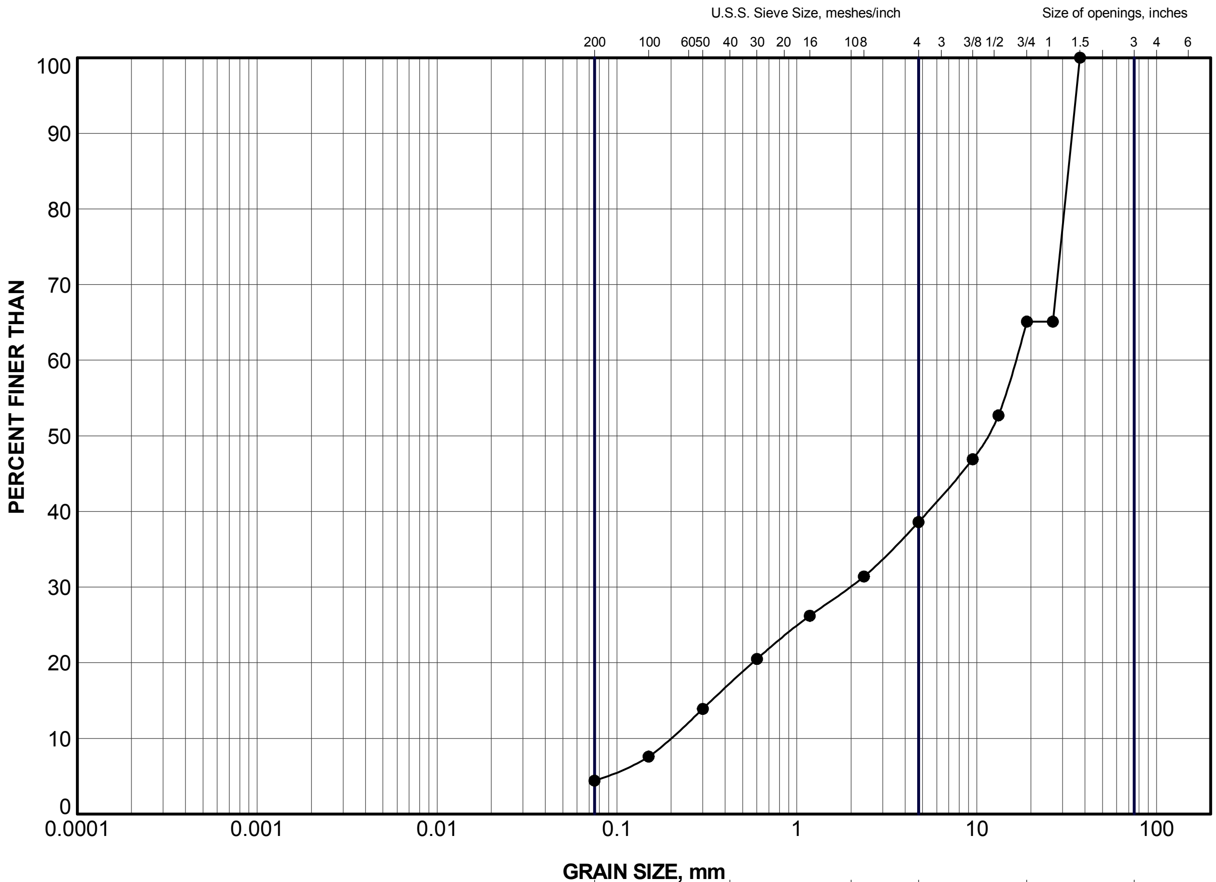
GRAIN SIZE DISTRIBUTION

SILTY SAND to SAND (FILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	14-1111-0007		FILE No.	14-1111-0007.GPJ
DRAWN	TB	Oct 2014	SCALE N/A	REV.
CHECK	MCK	Oct 2014		
APPR	CN	Oct 2014	FIGURE A1	

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)
●	C10-04	3	302.0

PROJECT

HIGHWAY 11 RESURFACING
UNNAMED CREEK CULVERT
SITE NO. 42-342/C

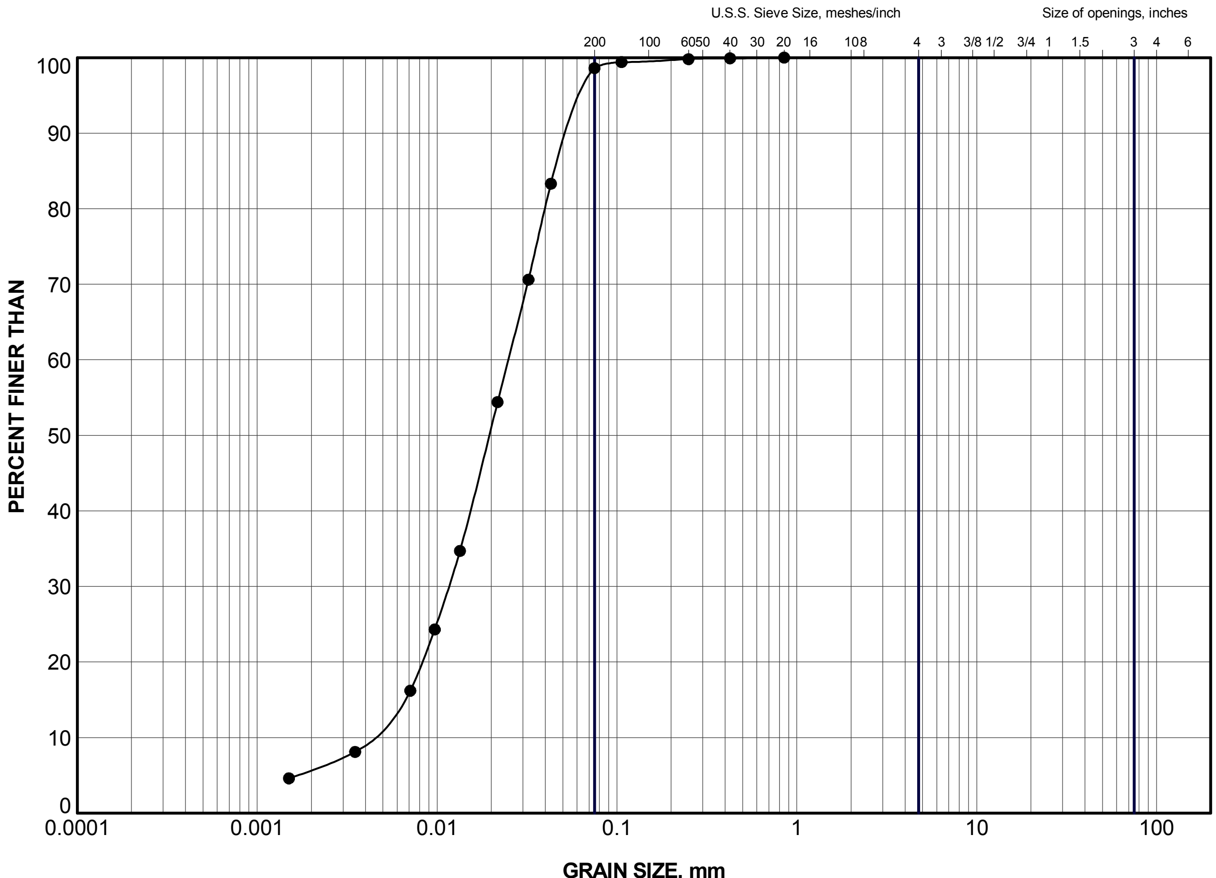
TITLE

GRAIN SIZE DISTRIBUTION

SAND and GRAVEL (FILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		14-1111-0007	FILE No.	14-1111-0007.GPJ
DRAWN	TB	Oct 2014	SCALE	N/A	REV.
CHECK	MCK	Oct 2014		
APPR	CN	Oct 2014	FIGURE A2	



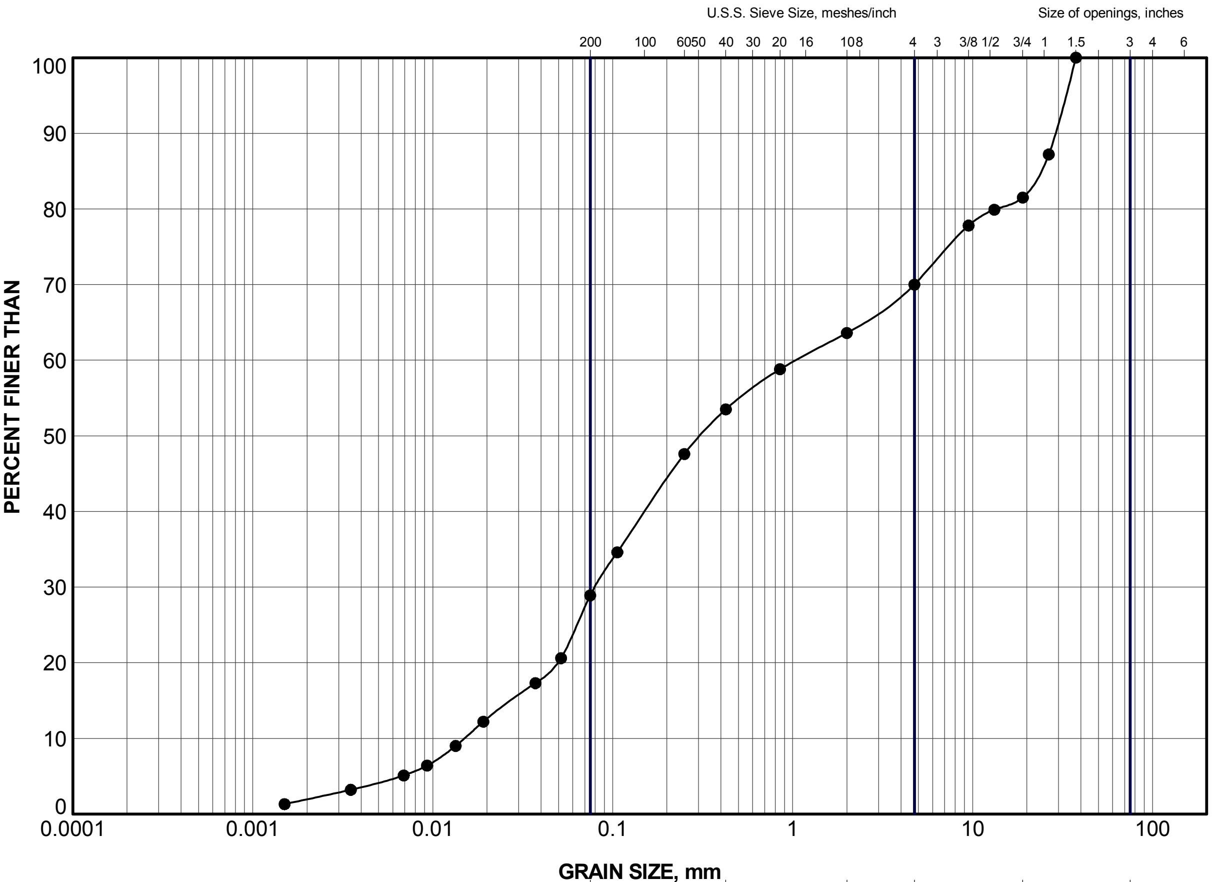
CLAY AND SILT	SAND SIZE			GRAVEL SIZE		Cobble Size
	fine	medium	coarse	fine	coarse	

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C10-01	5	291.2

PROJECT	HIGHWAY 11 RESURFACING UNNAMED CREEK CULVERT SITE NO. 42-342/C				
TITLE	**GRAIN SIZE DISTRIBUTION** SILT				
Golder Associates SUDBURY, ONTARIO	PROJECT No.	14-1111-0007		FILE No.	14-1111-0007.GPJ
	DRAWN	TB	Oct 2014	SCALE N/A	REV.
	CHECK	MCK	Oct 2014	**FIGURE A3**	
	APPR	CN	Oct 2014		

SUD-MTO GSD (NEW) GLDR_LDN.GDT



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	C10-01	8	289.1

PROJECT	HIGHWAY 11 RESURFACING UNNAMED CREEK CULVERT SITE NO. 42-342/C				
TITLE	**GRAIN SIZE DISTRIBUTION** SILTY SAND and GRAVEL				
Golder Associates SUDBURY, ONTARIO	PROJECT No.	14-1111-0007		FILE No.	14-1111-0007.GPJ
	DRAWN	TB	Oct 2014	SCALE N/A	REV.
	CHECK	MCK	Oct 2014	**FIGURE A4**	
	APPR	CN	Oct 2014		

SUD-MTO GSD (NEW) GLDR_LDN.GDT

At Golder Associates we strive to be the most respected global company providing consulting, design, and construction services in earth, environment, and related areas of energy. Employee owned since our formation in 1960, our focus, unique culture and operating environment offer opportunities and the freedom to excel, which attracts the leading specialists in our fields. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees who operate from offices located throughout Africa, Asia, Australasia, Europe, North America, and South America.

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