January 17, 2012

FOUNDATION INVESTIGATION AND DESIGN REPORT

HIGHWAY 11 NBL AND SBL WILDLIFE CROSSING CULVERT
AT STATION 12+169 (NBL) AND STATION 12+181 (SBL), SITE 43-371
TOWNSHIP OF NORTH HIMSWORTH, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5416-06-00, WP 5415-11-01/02

Submitted to:
URS Canada Inc.
75 Commerce Valley Drive East
Markham, ON L3T 7N9

GEOCRES NO. 31L-156

REPORT

Report Number: 09-1191-0042-R05

Distribution:

5 Copies: Ministry of Transportation, Ontario, North Bay, Ontario (Northeastern Region)
1 Copy: Ministry of Transportation, Ontario, Downsview, Ontario (Foundations Section)
2 Copies: URS Canada Inc., Markham, Ontario
2 Copies: Golder Associates Ltd., Sudbury, Ontario

Golder Associates

Table of Contents

PART A

FOUNDATION INVESTIGATION REPORT
HIGHWAY 11 NBL AND SBL WILDLIFE CROSSING CULVERT
AT STATION 12+169 (NBL) AND STATION 12+181 (SBL), SITE 43-371
TOWNSHIP OF NORTH HIMSWORTH, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5416-06-00

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by URS Canada Inc. (URS) on behalf of Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the proposed Wildlife Crossing under the Highway 11 Northbound Lanes (NBL) at Station 12+169 and Southbound Lanes (SBL) at Station 12+181 north of Powassan, Ontario. This project is part of the rehabilitation of Highway 11 NBL and SBL from 1.5 km south of Highway 534, northerly 3.5 km and NBL only from 2.0 km north of Highway 534 northerly 9.5 km to 1.5 km south of Highway 654 in the Township of North Himsworth. The general location of this section of the Highway 11 alignment is shown on the Key Plan on Drawing 1 following the text of this report.

The terms of reference and scope of work for the foundation investigation are outlined in MTO's Request for Proposal dated July 23, 2009. Golder's proposal (P9-1191-0042, dated August 14, 2009) for foundation engineering services associated with the rehabilitation/replacement of culverts is contained in Section 6.8 of URS's Technical Proposal that forms part of the Consultant's Agreement (Purchase Order Number 5008-E-0061) for this project. The work was carried out in accordance with Golder's Supplemental Specialty Quality Control Plan for this project dated August 17, 2010.

This report addresses the investigation carried out for the proposed Wildlife Crossing on Highway 11 NBL at Station 12+169 and SBL at Station 12+181 only. Separate reports will be submitted detailing the foundation investigations for other culverts for this project. The final General Arrangement (GA) drawing for the proposed Wildlife Crossing was provided to Golder by URS.

Based on the information from URS, the Wildlife Crossing will consist of a 4 m (inside dimension) square concrete box culvert aligned beneath each of the Highway 11 NBL and SBL embankments. Each culvert will have a length of about 14 m. A 1.7 m grade raise and associated embankment widening (i.e. about 3 m on each side) will be required for the NBL embankment to accommodate the new culvert. The existing SBL embankment geometry will generally remain unchanged. The NBL and SBL embankments in the proposed culvert area are about 2 m and 4 m high, respectively, relative to the ground surface at the median. The invert of the NBL culvert at the east and west ends will be Elevation 258.7 m and 258.5 m, respectively, and the invert of the SBL culvert at the east and west ends will be Elevation 258.4 m and 258.3 m, respectively.

The purpose of this investigation is to establish the subsurface conditions at the location of the proposed Wildlife Crossing by borehole drilling, in situ testing and laboratory testing on selected samples.

The culvert alignment was located in the field by Golder relative to stakes installed by Callon Dietz Inc. (Callon Dietz), a professional surveying company retained by URS, and referencing plan drawings provided by URS. The investigated area is shown in plan on Drawing 1 following the text of this report.

2.0 SITE DESCRIPTION

The proposed Wildlife Crossing will be located in the Township of North Himsworth on Highway 11, approximately 1 km north of Hills Siding Road.

In general, the topography in the area of the overall project limits is flat with numerous bedrock outcrops separated by swamps in low-lying areas or creeks. The ground surface at the borehole locations advanced at the Wildlife Crossing site ranges between Elevations 263.7 m and 259.8 m. The existing NBL and SBL embankments are about 2 m and 4 m high, respectively, and the SBL embankment is constructed of rock fill and covered in sections of the exterior slopes with granular material. While there appears to be signs of surficial erosion of the granular material due to surface water runoff, the embankments appear to be stable and there do not appear to be any signs of pavement distress of the roadway surface at the location of the proposed culvert crossing.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation associated with the proposed Wildlife Crossing was carried out between November 22 and 25, 2010, and on June 1, 2011, during which time a total of eight (8) boreholes (WL-1 to WL-8) and five (5) Dynamic Cone Penetration Tests (DCPTs) were advanced at the proposed Wildlife Crossing location. Further, as discussed below, on June 22, 2011, one piezometer was installed adjacent to Borehole WL-5. The field investigation was carried out using a Track Mounted D-50 supplied and operated by Walker Drilling Ltd., of Utopia, Ontario, or Track Mounted CME-55 operated by Landcore Drilling (Landcore), of Sudbury, Ontario (for the boreholes at the toes of the embankments) and a Truck Mounted CME-55 supplied and operated by Landcore (for the boreholes at the roadway lanes/shoulders). The location of the boreholes is shown on Drawing 1 following the text of this report.

The boreholes were advanced through the overburden using 108 mm inside diameter hollow-stem augers. Soil samples were obtained continuously or at intervals of depth of about 0.75 m, using a 50 mm outer diameter (O.D.) split-spoon sampler, carried out in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586-08a). DCPTs were advanced generally within about 1.5 m of Boreholes WL-1 to WL-5 (one DCPT for each borehole) to determine the depth to refusal. Samples of the bedrock were obtained using either ‘NQ’ or ‘HQ’ size rock core barrel in three of the boreholes (WL-1, WL-5 and WL-8). All boreholes were backfilled with bentonite upon completion in accordance with Ontario Regulation 903 (as amended).

The boreholes were advanced to depths ranging between 3.8 m and 8.3 m below existing ground surface. Between 2.3 m and 3.1 m of bedrock was cored in Boreholes WL-1, WL-5 and WL-8, while Boreholes WL-2 to WL-4 were advanced to auger refusal. Boreholes WL-6 and WL-7 were terminated as no further casing penetration was noted, likely on or in proximity to the bedrock surface.

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. On June 22, 2011, a piezometer was installed in an unsampled borehole advanced about 1.5 m west of Borehole WL-5 to permit monitoring of the groundwater level at this location. The piezometer consists of a 19 mm diameter PVC pipe with a 1.5 m long slotted screen sealed within the clayey silt and sand and gravel deposit as encountered at Borehole WL-5. The borehole annulus surrounding the piezometer screen was backfilled with sand and the remainder of the borehole was backfilled with bentonite. The piezometer details and water level readings are described on the Record of Borehole sheet in Appendix A.

The fieldwork was supervised throughout by a member of our 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 and bedrock samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Sudbury geotechnical laboratory where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. Classification testing (water content, Atterberg limits and grain size distribution) was carried out on selected soil samples. The results of the laboratory testing are included in Appendix B.

Survey stakes were installed near the east toe of the NBL embankment by Callon Dietz prior to drilling. The as-drilled borehole locations, in stations and offsets, were measured in reference to the stakes 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 the horizontal control points along Highway 11. The borehole locations shown on Drawing 1 are positioned relative to MTM NAD 83 northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum.

The as-drilled borehole locations, ground surface elevations at the drilled locations and borehole depths are summarized below.

Borehole	Location (m)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
WL-1	5112708.7	315701.2	260.3	6.5
WL-2	5112712.6	315692.7	262.2	5.9
WL-3	5112715.9	315684.5	262.3	5.9
WL-4	5112718.4	315672.8	259.8	3.8
WL-5	5112724.2	315667.3	259.9	7.6
WL-6	5112726.1	315655.5	263.6	7.5
WL-7	5112729.5	315646.9	263.7	7.7
WL-8	5112730.3	315640.9	261.9	8.3

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

As delineated in The Physiography of Southern Ontario (Chapman and Putnam, 1984)[1], this section of Highway 11 lies within the physiographic region known as the Number 11 Strip, which extends along Highway 11 from Gravenhurst to North Bay. This part of the Number 11 Strip physiographic region is near the southwest shoreline of glacial Lake Algonquin. As a result, the streams entering Lake Algonquin deposited sand as delta features and silt and clay settled in deeper offshore water. Sand and gravel was also deposited as an esker which follows the strip from Bondfield to Gravenhurst.

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

The bedrock in the area consists typically of crystalline granite gneisses of the Powassan Domain of the Central Gneiss Belt, a subdivision of the Grenville Structural Province, as described in Geology of Ontario, OGS Special Volume 4[2].

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced for this investigation, together with the results of the laboratory tests carried out on selected soil samples, are given on the attached Record of Borehole sheets in Appendix A. The results of the laboratory testing are provided in Appendix B. The inferred stratigraphy as encountered in the boreholes is shown on Drawing 1. The stratigraphic boundaries shown on the Record of Borehole sheets and in profile on Drawing 1 are inferred from non-continuous sampling, observations of drilling progress and the results of SPTs and in situ testing. 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.

It should be noted that the orientation (i.e. north, south, east, west) stated in the text of the report is typically referenced to project north (along the Highway 11 alignment) and therefore may differ from that shown on the drawing which represents magnetic north.

In general, the subsurface stratigraphy along the proposed Wildlife Crossing alignment consists of pavement surface layer of asphalt, granular fill and rock fill in the existing embankment footprint, and peat at ground surface in the highway median, underlain by deposits of silts, sands, clayey silt to silty clay and/or sand and gravel, underlain by bedrock.

4.2.1 Fill

The following boreholes were advanced through the existing embankments and encountered fill material from ground surface:

- Boreholes WL-2 and WL-3 were advanced through the east and west shoulders of the NBL embankment, respectively;
- Boreholes WL-6 and WL-7 were advanced through the east and west shoulders of the SBL embankment, respectively; and
- Borehole WL-8 was advanced on the SBL embankment west slope.

[2] Geology of Ontario, 1991. Ontario Geological Society Special Volume 4, Part 2. Ministry of Northern Development and Mines, Ontario.

The ground surface at Boreholes WL-2, WL-3 and WL-6 to WL-8 ranges between Elevation 263.7 m and 261.9 m.

Boreholes WL-3, WL-6 and WL-7 encountered a layer of asphalt between 65 mm and 210 mm thick from pavement surface. In Borehole WL-3, a second lift of asphalt about 75 mm thick was encountered below a 260 mm thick layer of sand and fill layer. Underlying the asphalt in Boreholes WL-3, WL-6 and WL-7 and from ground surface in Borehole WL-2, a layer of fill comprised of sand and gravel to sand, trace to some silt was encountered, ranging in thickness between 0.5 m and 3.8 m. In Borehole WL-3, the sand and gravel to sand fill contains cobbles at various depths.

The SPT 'N'-values measured within the fill are between 9 blows and 45 blows per 0.3 m of penetration, indicating a loose to dense relative density.

The grain size distribution of four samples of the fill deposit is shown on Figure B1 in Appendix B.

The measured water content on samples of this deposit varies between about 2 percent and 15 percent.

Underlying the sand and gravel to sand fill in Boreholes WL-6 and WL-7 and from ground surface in Borehole WL-8, the boreholes penetrated through a layer of blast rock fill between 4.7 m and 6.0 m thick. The top of the blast rock was encountered between Elevation 262.9 m and 261.8 m. The total core recovery of the rock fill pieces is between 30 percent and 70 percent.

4.2.2 Peat

A 0.6 m thick deposit of fibrous or amorphous peat was encountered at ground surface corresponding to Elevation 259.8 m and 259.9 m in Boreholes WL-4 and WL-5 advanced in the median, respectively.

The SPT 'N'-values measured within the peat deposit are 2 blows and 6 blows per 0.3 m of penetration, suggesting a soft to firm consistency.

4.2.3 Sand

A 1.4 m thick deposit of brown sand, trace to some gravel, some silt, slightly organic was encountered from ground surface (Elevation 260.3 m) in Borehole WL-1.

An SPT 'N'-value measured within this deposit is 6 blows per 0.3 m of penetration, indicating a loose relative density.

The grain size distribution of one sample of the deposit is shown on Figure B2 in Appendix B.

The natural water content measured on one sample of this deposit is about 15 percent.

4.2.4 Silt to Sand and Silt

A deposit of brown to grey silt to sand and silt was encountered below the sand in Borehole WL-1 and below the peat in Boreholes WL-4 and WL-5. The top of this deposit was encountered between Elevation 259.3 m and 258.9 m and the deposit ranges in thickness between 0.8 m and 1.5 m. Borehole WL-4 further encountered an approximately 0.9 m thick layer of grey sandy silt underlying a clay silt to silty clay deposit (described below) at Elevation 257.7 m.

The SPT 'N'-values measured within this deposit range between 4 blows and 17 blows per 0.3 m of penetration, indicating a loose to compact relative density.

The grain size distribution of two samples of the deposit is shown on Figure B3 in Appendix B.

The natural water content measured on three samples of this deposit ranges between 17 percent and 22 percent.

4.2.5 Clayey Silt to Silty Clay

A deposit of grey to brown clayey silt to silty clay, trace to some sand was encountered underlying the fill in Boreholes WL-2 and WL-3 and below the sand and silt deposit in Boreholes WL-4 and WL-5. The top of this deposit is at Elevation 258.5 m and 258.4 m and the thickness of the deposit ranges from 0.7 m to 1.0 m.

SPT 'N'-values measured within the clayey silt to silty clay deposit are between 5 blows and 10 blows per 0.3 m of penetration, suggesting a firm to stiff consistency.

Atterberg limits testing was carried out on three samples of this deposit and the test results are shown on Figure B4 in Appendix B. The test results indicate liquid limits between about 30 percent and 36 percent, plastic limits of about 16 percent or 17 percent and plasticity indices between about 14 percent and 20 percent. The results of the Atterberg limits testing indicate that the material is classified as clayey silt of low plasticity to silty clay of intermediate plasticity.

The grain size distribution of four samples of the deposit is shown on Figure B5 in Appendix B.

The natural water content measured on four samples of the clayey silt to silty clay deposit is between about 22 percent and 31 percent.

4.2.6 Sand and Gravel

A deposit of brown and grey sand and gravel, some silt was encountered underlying the silt to sandy silt deposit in Boreholes WL-1 and WL-4, below the clayey silt to silty clay deposit in Boreholes WL-2, WL-3 and WL-5 and below the blast rock fill in Boreholes WL-6 and WL-7. The top of the deposit was encountered between Elevation 257.8 m and 256.8 m and the thickness of the deposit ranges from about 0.4 m to 2.4 m. The bottom of the deposit is defined by refusal to further auger advancement or no further casing penetration or by bedrock coring.

The SPT 'N'-values measured within this deposit range between 9 blows and 57 blows per 0.3 m of penetration, indicating a loose to dense relative density, while an 'N'-value of 13 blows per 0.08 m of penetration was recorded at the contact with bedrock.

A grain size distribution of two samples of this deposit is shown on Figure B6 in Appendix B.

The natural water content measured on four samples of this deposit ranges between 11 percent and 19 percent.

4.2.7 Bedrock/ Refusal

Bedrock was encountered and cored in Boreholes WL-1, WL-5 and WL-8. The bedrock surface was inferred from auger refusal or resistance to casing advancement in the remaining boreholes. These refusal depths, while they do not confirm bedrock elevations, may be inferred to indicate potential proximity to the bedrock interface. The bedrock surface (inferred or actual) was encountered at depths and elevations presented below.

Borehole No.	Depth to Bedrock Surface (m)	Bedrock Surface Elevation (m)	Refusal Type
WL-1	3.3	257.0	Bedrock Cored
WL-2	5.9	256.3	Auger Refusal
WL-3	5.9	256.4	Auger Refusal
WL-4	3.8	256.0	Auger Refusal
WL-5	4.5	255.4	Bedrock Cored
WL-6	7.5	256.1	No further Casing Penetration
WL-7	7.7	256.0	No further Casing Penetration
WL-8	6.0	255.9	Bedrock Cored

Based on the bedrock core samples, the bedrock generally consists of gneiss, and may be described as fresh, medium to coarse grained, pinkish grey. The Rock Quality Designation (RQD) measured on the core samples ranges from 68 percent to 100 percent, but is typically greater than 80 percent, indicating a rock mass of fair but generally good to excellent quality (as per Table 3.10, CFEM 2006). The Total Core Recovery (TCR) of the samples recovered is 100 percent.

4.2.8 Groundwater Conditions

In general, the samples taken in the boreholes were wet with free water noted in some samples of cohesionless material. Water levels observed in the boreholes upon completion of drilling range from 0.9 m to 5.2 m below existing ground surface, ranging between Elevation 259.0 m and 256.6 m. The water level in the standpipe piezometer installed in a borehole immediately adjacent to Borehole WL-5 after installation on June 22, 2011, was measured at 1.0 m below ground surface, corresponding to Elevation 258.9 m and on July 6, 2011, the water level in the standpipe was measured at 0.6 m below existing ground surface, corresponding to Elevation 259.3 m. Groundwater elevations will vary depending on seasonal fluctuations, precipitation and local soil permeability.

5.0 CLOSURE

The field personnel supervising the drilling program were Mr. Ed Savard and Mr. Mathew Riopelle. This report was prepared by Mr. Luigi Gianfrancesco, EIT, and the technical aspects were reviewed by Mr. André Bom, P.Eng. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project, carried out a quality control review of the report.

Report Signature Page

GOLDER ASSOCIATES LTD.

LICENSED PROFESSIONAL ENGINEER
A. J. K. BOM
100075715
PROVINCE OF ONTARIO

André Bom, P.Eng.
Geotechnical Engineer

LICENSED PROFESSIONAL ENGINEER
J. M. A. COSTA
PROVINCE OF ONTARIO

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

LG/AB/JMAC/lb/cl

n:\active\2009\1190 sudbury\1191\09-1191-0042 urs hwy 11 culverts powassan\reporting\final\r05 - wildlife crossing\09-1191-0042-r05 final rpt 12jan17 wlc.docx

PART B

FOUNDATION DESIGN REPORT

HIGHWAY 11 NBL AND SBL WILDLIFE CROSSING CULVERT

AT STATION 12+169 (NBL) AND STATION 12+181 (SBL) , SITE 43-371

TOWNSHIP OF NORTH HIMSWORTH, ONTARIO

MINISTRY OF TRANSPORTATION, ONTARIO

GWP 5416-06-00

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides an interpretation of the factual geotechnical data obtained during the investigation, and conclusions and recommendations on the foundation aspects of design of the proposed works. The recommendations provided are intended for the guidance of the design engineer. Where comments are made on construction, they are provided to highlight aspects of construction that could affect the design of the project. Those requiring information on aspects of construction must make their own interpretation of the subsurface information provided as such interpretation may affect their proposed construction methods, costs, equipment selection, scheduling and the like.

6.1 General

The overall project involves the rehabilitation of a 13.0 km section of Highway 11, which includes foundation investigation and design for the Wildlife Crossing, replacement of four (4) NBL culverts and three (3) SBL culverts and a culvert below the NBL embankment crossing Windsor Creek.

This section of the report provides foundation design recommendations for the proposed Wildlife Crossing spanning beneath the NBL embankment at Station 12+169 and beneath the SBL embankment at Station 12+181. The scope of work includes: an assessment of stability and settlement of the embankment for the Wildlife Crossing; providing recommendations on a preferred mitigation option that may be required as a means to minimize total and differential settlements (if applicable); geotechnical resistances (as applicable); and estimates of horizontal and vertical strains and maximum joint opening allowances along the culvert. The work also includes: addressing foundation aspects for the final design and construction of Retained Soil System (RSS) walls associated with the culvert; addressing concerns; and providing recommendations associated with sub-excavation of soft / organic materials, placement of new fill, and requirements for erosion protection and bedding materials.

We understand from URS that the proposed NBL and SBL Wildlife Crossing will consist of a separate 14 m long, 4 m (inside dimension) square concrete box culvert beneath each embankment. The new portion of the SBL embankment at the culvert location will be re-constructed to the same elevation as the existing embankment, approximately 4 m high relative to the ground surface at the median. The new portion of the NBL embankment at the culvert location will be re-constructed to about 1.7 m higher than the existing embankment to approximately 4 m high relative to the existing ground surface at the median. The NBL embankment will also be widened by about 3 m (horizontal distance) on both sides of the existing embankments to accommodate the proposed grade raise. The invert of the NBL culvert will be Elevation 258.7 m and 258.5 m at the east and west ends, respectively, and the invert of the SBL culvert will be Elevation 258.4 m and 258.3 m at the east and west ends, respectively. RSS walls between 7.5 m and 10.7 m long will be required at each end of the two culverts on both sides of the culvert walls. Further details (i.e. heights) and recommendations for the RSS walls are provided in Section 6.7.

The subsoils along each culvert alignment generally consist of fill materials (sand and gravel to sand and/or blast rock), or peat, underlain by a clayey silt to silty clay deposit (where encountered) and cohesionless deposits, underlain by bedrock. Bedrock was encountered between Elevations 257.0 m and 255.4 m at Boreholes WL-1, WL-5 and WL-8 and was cored for a length of between 2.3 m and 3.2 m. Refusal was encountered at the remaining boreholes between Elevation 256.4 m and 256.0 m. Details of the subsurface conditions along this culvert are presented in Section 4.2 and shown in profile on Drawing 1 following the text of this report.

6.2 Culvert Types

The analysis and recommendations presented in this report assume that the two Wildlife Crossing culverts will consist of either a concrete box culvert, or an open footing concrete culvert. Table 1 presents a comparison of the two alternatives. From a foundations perspective, a precast concrete box culvert is considered slightly advantageous over an open bottom cast-in-place concrete culvert.

6.3 Culvert Construction Options

As discussed in Section 6.1, the existing SBL embankment geometry will not be widened or raised and the NBL embankment will require a grade raise of approximately 1.7 m in the approach areas to the culvert which will require widening of the embankment by about 3 m (horizontal distance) on both sides of the existing slopes. The portion of the NBL embankment to be widened will require sub-excavation of soft soils, to a depth of about 1.3 m prior to culvert construction. The Wildlife Crossing structure under both the NBL and SBL embankments may be constructed concurrent with embankment re-construction.

Where relatively small settlements are estimated to occur as a result of the embankment re-construction due to the grade raise, the design of the culverts could include a camber. Should embankment widening or a grade raise be identified in the future at the SBL location (or additional grade raise at the NBL embankment), additional analysis will be required to assess settlement and stability for the revised embankment geometry and to provide recommendations for possible alternatives for construction to mitigate settlements and improve long-term performance.

At this site, the recommended construction alternative is to remove all existing fill (where applicable) and organic material and cohesive deposit (below NBL), backfill the sub-excavated area with Granular ‘B’ Type II material and bedding, and construct the culvert concurrent with embankment re-construction.

6.3.1 Frost Protection

The estimated frost penetration depth for the Powassan area is 2.0 m, as per OPSD 3090.101 (Foundation Frost Penetration Depths for Southern Ontario).

Box culverts are typically not provided with frost protection where water flows year-round through the culvert. At this site, where the culvert will function as a wildlife crossing rather than a hydraulic structure and frost protection may extend to 2.0 m below the invert, it is recommended that the fine-grained subsoils (i.e. clayey silt) present below the proposed NBL culvert alignment be sub-excavated (to about 1 m below the culvert invert) and replaced with non frost susceptible SP 110S13 (Aggregates) Granular ‘A’ or Granular ‘B’ Type II material as further discussed in Section 6.8.2.

Spread footings for an open footing concrete culvert should be provided with a minimum of 2.0 m of conventional soil cover for frost protection, as per OPSD 3090.101 (Foundation Frost Penetration Depths for Southern Ontario). For spread footings founded directly on the bedrock (i.e. potentially the east end of the NBL culvert, as discussed in Section 6.4), frost susceptibility is not an issue.

6.4 Stability, Settlement and Horizontal Strain

The following sections summarize the methods utilized to carry out analyses of stability and settlement of the culverts and methods utilized to evaluate horizontal strains along the culverts beneath the influence of the proposed embankment loading.

The analyses are based on the conditions that all organic soils beneath the culvert alignments will be removed prior to construction as discussed in Section 6.8.1.1 and that granular fill (i.e. sand and gravel material such as Granular 'B' Type II) will be used for replacement of sub-excavated material. The piezometric conditions required in the analyses are based on the groundwater levels observed during drilling and the piezometer installed in the median.

6.4.1 Stability

The methodology used to evaluate embankment stability at the culvert locations is described below and the results of the analyses are discussed in Section 6.4.1.3.

6.4.1.1 Methodology

Limit equilibrium slope stability analyses were performed using the commercially available program GeoStudio 2007 (Version 7.17), produced by Geo-Slope International Ltd., employing the Morgenstern-Price method of analysis. For all analyses, the Factor of Safety of numerous potential failure surfaces was computed in order to establish the minimum Factor of Safety. The Factor of Safety is defined as the ratio of the forces tending to resist failure to the driving forces tending to cause failure. A target minimum Factor of Safety of 1.3 is normally adopted for the design of embankment slopes under static conditions. This Factor of Safety is considered adequate for the embankment at this site considering the design requirements and the field data available and is based on deep-seated, global failure surfaces that would affect the operation of the roadways. The stability analyses were performed to check that the target minimum Factor of Safety was achieved for the embankment height and geometry at the culvert locations.

6.4.1.2 Parameter Selection

The embankment cross-section at the culvert locations modelled in the analyses is assumed to be constructed of granular fill (such as MTO SP 110S13 (Aggregates) Granular 'B' Type I or Type II), having a unit weight of 21 kN/m^3 above the water level and 20 kN/m^3 below the water level and an effective friction angle of 35° and is constructed with 2H:1V side slopes to 4 m high relative to the ground surface at the median.

For the 0.7 m to 1.0 m thick layer of clayey silt to silty clay, the analysis were carried out for two cases: the first case assuming total stress parameters for the undrained condition; and the second case using effective stress parameters for the drained condition. The total stress parameters (i.e. average mobilized undrained shear strength – s_u) and effective stress parameters (i.e. effective friction angle) for the clayey silt to silty clay stratum were estimated from correlations with the SPT results. The clayey silt to silty clay stratum modelled in the analysis is assumed to have a unit weight of 17 kN/m^3, an undrained shear strength of 50 kPa for the undrained analysis and an effective friction angle of 28° for the drained analysis.

For the very loose to very dense cohesionless soils, the effective stress parameters employed in the analysis were estimated from empirical correlations (such as suggested by NAVFAC [1982]) based on the results of the in situ SPT, in conjunction with engineering judgment based on experience in similar soil conditions. The native surficial sands and silts modelled in the analysis were assumed to have a unit weight of 19 kN/m^3 and an effective friction angle of 28°. The underlying sand and gravel was assumed to have a unit weight of 20 kN/m^3 and effective friction angle of 32°.

6.4.1.3 Results of Analysis

The stability analysis performed on the proposed NBL and SBL embankments at the culvert locations indicates that after completion of construction, the embankments will have a Factor of Safety of 1.3 or greater for deep-seated, global failure surfaces that would impact the operation of the roadway, as shown on Figure 1 (NBL).

6.4.2 Settlement

Settlement of the NBL embankment in the culvert area can be expected as a result of the loading on the cohesive and cohesionless foundations soils from the approximately 1.7 m grade raise and the approximately 3 m embankment widening (on each side). As discussed in Section 6.3.1 and 6.8.2, we recommend that the cohesive soils below the NBL culvert be sub-excavated and replaced with Granular ‘B’ Type II which will mitigate the settlement. The following sections outline the methods used to conduct the settlement analyses at the culvert. The results of the analyses for the culvert are discussed in Section 6.4.2.4.

As the existing SBL embankment will not be raised or widened at the location of the new culvert, settlement of the foundation soils is not anticipated. Should the embankment require widening or a raising of the grade in the future, settlement analysis will be required and recommendations provided for mitigation, as appropriate.

6.4.2.1 Methodology

To estimate the magnitude of the expected settlements, analyses were carried out along the Wildlife Crossing alignment using hand calculations as per CFEM (2006) Section 11.3.4.

6.4.2.2 Parameter Selection

The subsoils encountered in the NBL culvert area are composed of a relatively thin deposit of clayey silt to silty clay (0.7 m to 1.0 m thick) and cohesionless soils (sands and silts and sand and gravel). For the box culvert, it has been assumed that the upper clayey material and sands and silts will be removed and replaced with new granular fill below the culvert, as recommended in Section 6.3.1. The new granular backfill below the box culvert will generally be placed over the native sand and gravel deposit. For the open bottom culvert, the footings will generally be founded on the native sand and gravel deposit.

The immediate compression of the sand and gravel deposit was modelled by estimating an elastic modulus of deformation (E') based on empirical correlations to SPT 'N'-values, as suggested by Kulhawy and Mayne (1990). The sand and gravel layer was assigned an E' value of 20 MPa.

6.4.2.3 Settlement of Embankment Fill

It is recommended that the embankments at the location of the Wildlife Crossing be re-constructed using SP 110S13 (Aggregates) Granular 'B' Type I or Type II. Under the culverts and where granular fill will be placed below the water level, Granular 'B' Type II but containing less than 5 percent passing the No. 200 sieve should be used to reduce the potential for segregation of fines during placement and to reduce the potential for post-construction settlement and associated maintenance needs. The material placed below the water level will compress/settle under its self-weight as additional fill is placed over it. The material placed above the water level should be compacted in accordance with OPSS 501 (Compacting). The magnitude of compression settlement from the fill placed below water and from properly compacted embankment fill above water is expected to occur during construction.

6.4.2.4 Results of Analysis

The total immediate settlement of the native foundation soils along the NBL box culvert alignment and below the footings for the open bottom culvert due to the new embankment loading (after culvert construction) is estimated to be less than 10 mm.

Based on these results, culvert construction concurrent with embankment construction can be carried out without the need for any additional foundation mitigation measures, as long as the structural design of the culvert can accommodate this estimated settlement.

It should also be noted that the sections of embankment on both sides of the NBL culvert will also require a gradual grade raise from the existing embankment grade further away from the culvert to the higher level of the roadway over the culvert. These sections of the NBL embankment may also undergo settlement potentially differential in magnitude, due to the increased loading on the subsoils and of the embankment fill itself if rock fill is used. Therefore, future maintenance (padding), of these sections of the roadway may be required.

6.4.3 Horizontal Strain

Horizontal strain along the SBL culvert is not expected to occur provided the proposed embankment geometry does not change from the current geometry. Should the SBL embankment be widened or raised compared with the existing geometry, a reassessment of the potential magnitude of horizontal strain will be required.

As the estimated settlement along the NBL culvert is relatively minor (i.e. 10 mm or less as discussed in Section 6.4.2.4), the horizontal strain along the 15 m long culvert is considered to be negligible and the maximum joint opening will be negligible (i.e. <5 mm).

6.5 Geotechnical Resistance

For a box culvert constructed under the SBL, a factored geotechnical axial resistance at Ultimate Limits States (ULS) of 600 kPa is recommended for design for the assumed 4.6 m (outside dimension) wide box culvert founded on a properly prepared subgrade of granular fill overlying the native soils. For the NBL culvert, following the removal of the clayey silt to silty clay deposit and re-placement with Granular 'B' Type II likely placed in the wet, we recommend that a factored geotechnical axial resistance at ULS of 400 kPa be used for design for an assumed 4.6 m wide box culvert founded on a properly prepared subgrade overlying native soils. However, if the native cohesive soils under the NBL culvert are replaced with Granular 'B' Type II to a depth of 1.3 m below the culvert invert, a ULS value of 600 kPa may be used under the NBL culvert design. The geotechnical resistances are given for loads applied perpendicular to the surface of the base of the culvert. Where loads are not applied perpendicular to the base of the culvert, inclination of the loads should be taken into account in accordance with Section 6.7.4 and Section C6.7.4 of the *Canadian Highway Bridge Code (CHBDC)* and its *Commentary*. For the estimation of the factored ULS value, a minimum culvert embedment depth of 1.5 m and a groundwater level below the culvert invert elevation were used.

In the event that an open footing culvert is chosen for the Wildlife Crossing, the strip footings should be designed on the basis of a factored geotechnical axial resistance at ULS of 400 kPa for both the SBL and NBL culverts, assuming a 0.6 m wide strip footing founded on the compact cohesionless deposits. Based on providing 2.0 m of cover for frost protection below the invert of the culverts, as discussed with URS, the footing subgrade will be between Elevation 256.3 m at the west end of the SBL culvert and Elevation 256.7 m at the east end of the NBL culvert. It should be noted that at the east end of the NBL culvert, at Borehole WL-1, bedrock was encountered at Elevation 257.0 m whereas Borehole WL-2 auger refusal was encountered at Elevation 256.3 m; the footing on the east half of NBL culvert will likely be founded on bedrock whereas the remainder of the culvert to the west may be founded on a soil subgrade. For strip or spread footings bearing directly on the bedrock surface, a factored geotechnical resistance at ULS of 10 MPa may be used for design. Dewatering may be required to construct the footings in the dry, as discussed further in Section 6.8.3.

It is noted that at this site, the loading on the foundation soils below the culverts and the associated total settlement at the culvert locations will be governed by the design height of the overlying and adjacent widening embankment fills. As such, it is recommended that the structural engineer exercise caution when utilizing the value(s) of the geotechnical axial resistance at Serviceability Limit States (SLS) in the design of the culverts and that consideration be given to the sequence and staging of construction. At the SBL culvert location, little to no settlement along the culvert alignment is expected due to the embankment geometry remaining unchanged. At the NBL culvert location, the total settlement of the foundation soils is expected to be up to about 10 mm upon completion of embankment construction and the settlement will vary along the length of the culvert. Based on the above, the geotechnical resistance at SLS (for 25 mm settlement) for a 4.6 m wide box culvert (for both the SBL and NBL culverts) constructed on the properly prepared granular subgrade overlying the native soils may be taken as 250 kPa, and for a 0.6 m wide strip footing for an open footing culvert founded on the native soil may be taken as 200 kPa.

6.5.1 Resistance to Lateral Loads/Sliding Resistance

Resistance to lateral forces/sliding resistance between the base of a concrete box culvert and the granular fill/bedding placed following sub-excavation or cast-in-place footings for an open culvert on the native cohesionless soils should be calculated in accordance with Section 6.7.5 of the *CHBDC*. The following summarizes the coefficient of friction for the interface materials for a precast and cast-in-place culvert.

Interface Materials	Coefficient of Friction
Precast Concrete Box Culvert on Compacted Granular 'B' Type II	$\tan \delta = 0.45$
Cast-in-Place Concrete on Compacted Granular 'B' Type II or native cohesionless soils (assuming native cohesive soils removed)	$\tan \Phi' = 0.58$

6.6 Lateral Earth Pressures – Culverts and Retaining Walls

The lateral earth pressures acting on the side walls and retaining walls of the culverts 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 retaining 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 SP110S13 (Aggregates) Granular 'A' or Granular 'B' Type II but with less than 5 percent passing the 200 sieve (0.075 mm) should be used as backfill behind the culverts. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Other aspects of the granular backfill requirements with respect to sub drains and frost taper should be in accordance with OPSD 3101.150 (Wall, Abutment, Backfill) and OPSD 3121.150 (Walls Retaining, Backfill).

- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the culverts and retaining walls, in accordance with *CHBDC* Section 6.9.3 and Figure 6.6. Compaction equipment should be used in accordance with OPSS 501 (Compacting). Other surcharge loadings should be accounted for in the design as required.
- Granular fill may be placed either in a zone with the width equal to at least 2.0 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 horizontal to 1 vertical (1.5H: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*).
- For a restrained wall condition, the pressures are based on the proposed embankment fill materials and the existing overburden soils and the following parameters (unfactored) may be used assuming the use of earth fill or rock fill:

	Granular Fill	**Rock Fill**
Soil unit weight:	21 kN/m^3	19 kN/m^3
Coefficients of static lateral earth pressure: Active, K_a At rest, K_o	 0.31 0.47	 0.22 0.36

- For an unrestrained wall condition, the pressures are based on the granular fill as placed and the following parameters (unfactored) may be assumed:

	Granular 'A'	**Granular 'B' Type II**
Soil unit weight:	22 kN/m^3	21 kN/m^3
Coefficients of static lateral earth pressure: Active, K_a At rest, K_o	 0.27 0.43	 0.27 0.43

If the retaining walls and culvert structures allow for lateral yielding, active earth pressures may be used in the geotechnical design of the structures. If the retaining walls and culvert structures do not allow lateral yielding, at rest earth pressures should be assumed for geotechnical design. The movement to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure, may be taken as presented in Table C6.6 of the *Commentary* to the *CHBDC*.

6.7 Retained Soil System (RSS) Wall

We understand that RSS walls are required at each side of the ends of the SBL and NBL culverts to accommodate the embankment side slopes, for a total of eight (8) walls. The RSS walls will extend to lengths between 7.5 m and 10.7 m from the ends of the SBL culvert and to lengths between 7.5 m and 9.9 m from the ends of the NBL culvert. We understand from URS that the height of the RSS walls will be variable as follows:

- Immediately at the ends of the culvert, the walls will be between about 4.6 m and 4.7 m high decreasing in height away from the end of the culvert as follows:
  - At the end of the NBL walls, the height of the walls will be between 1.2 m and 2.7 m; and
  - At the end of the SBL walls, the height of the walls will be between 1.9 m and 3.9 m.

An RSS wall consists generally of granular fill placed and compacted in layers, and reinforced with fabric strips or geogrids. A facing material, typically pre-cast concrete panels mechanically fastened to the reinforcing strips or geogrids, is used to form the vertical face of the retained soil structure and to prevent loss of fill material. A typical RSS wall has the front facing supported on a strip footing placed at shallow depth below the ground surface in front of the wall.

As discussed in Section 6.8.2, the SBL culvert should be founded on a 300 mm thick Granular 'B' Type II pad placed on the surface of the rock fill which will comprise the primary embankment fill over the native sand and gravel deposit. At the west end of the SBL culvert, the 300 mm thick pads will likely be constructed on the existing rock fill without the need for sub-excavation provided organic material has been removed from the footprint of the wall. Preparation of the rock fill subgrade may be required including grading/chinking of the rock fill surface.

Below the NBL culvert, we recommend that the clayey silt to silty clay deposit be sub-excavated. For consistency between the founding soils below the NBL culvert and the NBL RSS walls, we recommend that the NBL RSS walls be founded on a 1 m thick pad of Granular 'B" Type II material.

The final grading design should be checked to provide approximately 0.3 m of embedment for the facing footing of the RSS walls. A minimum 150 mm thick granular fill levelling pad comprised of Granular 'A' or Granular 'B' Type II should be provided under each footing.

The granular fill levelling pads should extend a minimum of 1 m beyond the edges of the footings and soil mass.

Assuming that the RSS wall acts as a unit and utilizes the full width of the reinforced soil mass, which has been taken as 0.8 times the height of the height of the wall, the factored geotechnical resistance at ULS and the geotechnical resistance at SLS (25 mm of settlement) given below for the RSS walls at each culvert end may be used for assessment of the reinforced mass founded on the properly prepared granular fill pad constructed over the native cohesionless soils.

Culvert	Maximum Wall Height (m)	Assumed Maximum Reinforced Width* (m)	Factored Geotechnical Resistance at ULS	Geotechnical Resistance at SLS
SBL	4.7	3.8	700 kPa	350 kPa
NBL	4.7	3.8	700 kPa	350 kPa

* Assumed equivalent to 80% of the wall height.

The resistance to lateral forces / sliding resistance between the compacted fill of the RSS wall and the subgrade should be calculated in accordance with Section 6.7.5 of the CHBDC. The coefficient of friction, tan φ', between the compacted granular fills of the RSS wall and the properly prepared subgrade may be taken as 0.6.

Based on the results of the stability and settlement analysis discussed in Section 6.4, the static global stability of the RSS wall has a Factor of Safety greater than 1.3 and the settlement of the culverts (and adjacent RSS walls) is expected to be nominal (i.e. 10 mm or less). The internal stability of the wall should be checked by the RSS supplier/designer.

6.8 Culvert Construction Considerations

6.8.1 Subgrade Preparation and Excavation

The following sections discuss general aspects of subgrade preparation and embankment construction at the culverts, including removal of organic materials.

All excavations must be carried out in accordance with Ontario Regulation 213 Ontario Occupational Health and Safety Act for Construction Projects (as amended by Ontario Regulation 443). In addition, provisions for traffic control measures should be included in the Contract Documents to maintain the safe operation of the existing Highway 11.

Where required, temporary excavation support systems should be designed and constructed in accordance with OPSS 539 (Temporary Protection Systems). Temporary excavation support systems should be designed to Performance Level 2 for any excavation adjacent to existing roadways and Performance Level 3 for excavations in other areas. Given the presence of rock fill within the SBL embankment, it may not be possible to install conventional shoring through these deposits to facilitate construction.

6.8.1.1 Removal of Organics

Based on the information from the boreholes advanced during the field investigation, the thickness of organic deposits (i.e. fibrous/amorphous peat) at the culvert locations is up to 0.6 m, encountered in the highway median area. Prior to the placement of any bedding material and fill for new construction, all organic soils should be stripped from the plan limits of the proposed works. Construction of the embankment section in sub-excavated areas should be in accordance with OPSD 203.010 (Embankments Over Swamp).

6.8.1.2 Replacement/Backfill Below Base of Culvert

For replacement of sub-excavated material below the water level along the culvert alignment, it is recommended that Granular 'B' Type II be used to backfill the excavation. In addition, in this instance (i.e. typically backfill placed below the water table), the granular fill should to be end-dumped simultaneously as the excavation advances in accordance with OPSS 209 (Embankments Over Swamps and Compressible Soils).

6.8.1.3 Subgrade Protection

The native subgrade soils may be susceptible to disturbance from construction traffic and/or ponded water. In order to limit this degradation, for the footings of an open bottom culvert, it is recommended that a concrete working slab be placed on the subgrade if the footings are not constructed within four (4) hours after preparation, inspection and approval of the subgrade. A sample Non-Standard Special Provision (NSSP) to address this requirement is included in Appendix C.

6.8.2 Bedding and Backfill Above Base of Culvert

If a precast box culvert is chosen as the method of construction, it should be constructed in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts) and could be installed in wet conditions depending on the season of construction and water level at the time of installation. Due to the variable composition of underlying subsoils at the site, we recommend that the bedding for the box culvert be constructed as follows:

- Below the SBL, where blast rock fill was encountered overlying native sand and gravel, the SBL box culvert should be constructed on a minimum 300 mm thick layer of SP110S13 (Aggregates) Granular 'B' Type II material for bedding purposes and partial frost protection; and
- Below the NBL, we recommend that the clayey silt to silty claydeposit be sub-excavated (to at least Elevation 257.4 m in Borehole WL-2) and replaced with Granular 'B' Type II material such that the NBL box culvert will be constructed on a minimum 1 m thick layer of Granular 'B' Type II material for bedding purposes and partial frost protection.

The Granular 'B' Type II will likely be placed in the wet and when nominally compacted should achieve a density of 90 percent of the Standard Proctor Maximum Dry Density (SPMDD). The structural design of the culvert should take into consideration the conditions for bedding placement and compaction in accordance with the requirements of Section 7.8.3.6 of the *CHBDC*.

The culverts should be designed for the full overburden stress and appropriate live loads, assuming a fill unit weight of 22 kN/m^3 for Granular 'A' and 21 kN/m^3 for Granular 'B' Type II backfill above and surrounding the culvert. Compaction of the fill adjacent to the culvert should be in accordance with culvert and embankment specifications.

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.

6.8.3 Control of Groundwater and Surface Water

Excavation to remove peat, existing rock fill and granular fill and cohesive (clayey) soils within the plan limits of the proposed Wildlife Crossing alignment and RSS walls will be required prior to construction of the open bottom culvert and front facing footings, placement of backfill/embankment fill, bedding material and the actual culvert structures. Depending on the season of construction, groundwater flow into the excavation may be expected to occur due to the relatively permeable subsoils.

A precast concrete box culvert and the associated bedding materials may be constructed 'in-the-wet', although at this site, control of surface water and groundwater is not anticipated to be required within the culvert footprint.

However, footings for an open footing culvert will be cast-in-place and, as such, dewatering will likely be required for footing construction in-the-dry. Surface water should be directed away from the excavations areas to prevent ponding of water that could result in disturbance and weakening of the foundation subgrades. Where the excavations will be advanced through existing fill and cohesive soils to terminate within cohesive soils at shallow depths (i.e. no excavation through water-bearing granular soils), seepage into the excavation should be adequately controlled by pumping from properly filtered sumps. However, more likely at this site, the excavations will be advanced through or into water-bearing cohesionless soils and appropriate unwatering of the water-bearing granular soil deposits will be required to maintain the water level below the founding level for the culverts during excavation and construction. It is recommended that an NSSP be included in the Contract to address unwatering for the culvert sites; a sample NSSP is included in Appendix C.

7.0 CLOSURE

This report was prepared by Mr. Luigi Gianfrancesco, EIT, and Mr. André Bom, P.Eng. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and a Principal with Golder, reviewed the technical aspects of and conducted a quality control review of the report.

Report Signature Page

GOLDER ASSOCIATES LTD.

LICENSED PROFESSIONAL ENGINEER
A. J. K. BOM
100075715
PROVINCE OF ONTARIO

André Bom, P.Eng.
Geotechnical Engineer

LICENSED PROFESSIONAL ENGINEER
J. M. A. COSTA
PROVINCE OF ONTARIO

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

LG/AB/JMAC/lb/cl

n:\active\2009\1190 sudbury\1191\09-1191-0042 urs hwy 11 culverts powassan\reporting\final\r05 - wildlife crossing\09-1191-0042-r05 final rpt 12jan17 wlc.docx

REFERENCES

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

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

Chapman, L.J., and Putnam, D.F., 1984. The Physiography of Southern Ontario. Ontario Geological Survey, Special Volume 2, 3rd Edition. Ontario Ministry of Natural Resources.

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.

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

NAVFAC Design Manual, DM-7.2. Soil Mechanics, Foundation and Earth Structures. U.S. Navy, 1982, Alexandria, Virginia.

STANDARDS

ASTM International:

ASTM D1586-08a	Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

Contract Design Estimating and Documentation (CDED)

Special Provision 110S13	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

Ontario Occupational Health and Safety Act

Ontario Regulation 213/91	Construction Projects
Ontario Regulation 443/09	Amendment to Ontario Regulation 213

Ontario Provincial Standard Drawing

OPSD 203.010	Embankments Over Swamp – New Construction
OPSD 3101.150	Walls, Abutment, Backfill, Minimum Granular Requirement
OPSD 3121.150	Walls, Retaining, Backfill, Minimum Granular Requirement

Ontario Provincial Standard Specification

OPSS 209	Construction Specification for Embankments Over Swamps and Compressible Soils
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS 501	Construction Specification for Compacting
OPSS 539	Construction Specification for Temporary Protection Systems

Ontario Water Resources Act

Ontario Regulation 372/97	Amendment to Ontario Regulation 903

Table 1: Evaluation of Wildlife Crossing Culvert Types

Options	Rank	Advantages	Disadvantages	Relative Costs
Box Culvert (concrete)	1	■ Straightforward construction. ■ Installation for pre-cast culvert is relatively quick compared with cast-in-place open bottom culvert. ■ Dewatering/unwatering likely not required for culvert bedding. ■ Greater tolerances for differential settlement below NBL culvert from embankment loading (i.e. grade raise) than open footing culvert.	■ Excavation for and bedding placement (fine grain soils) required to full frost penetration depth, under entire culvert base.	■ Additional costs incurred due to transportation of pre-cast culvert units. ■ Additional cost for sub-excavation and replacement of native cohesive soils with granular fill to 1.3 m below invert under entire base of culvert.
Open Bottom Culvert (concrete)	2	■ Bedding not required, footings can be founded on native subgrade provided concrete is placed in the dry. ■ Better suited to sites where reduced impact to creek beds is required. ■ Protection of footings from frost penetration can be provided by in-situ soils as footings are founded below frost penetration depth.	■ Deeper excavation required for footings ■ Dewatering/unwatering likely required for cast-in-place footings. ■ Lower tolerances for differential settlement along NBL culvert footings from embankment loading (i.e. grade raise) than box culvert; however, at this site, settlements of foundation soils from grade raise are estimated to be 20 mm or less along length of culvert.	■ Additional cost for form work for concrete placement. ■ Additional cost for dewatering for footing construction in-the-dry.

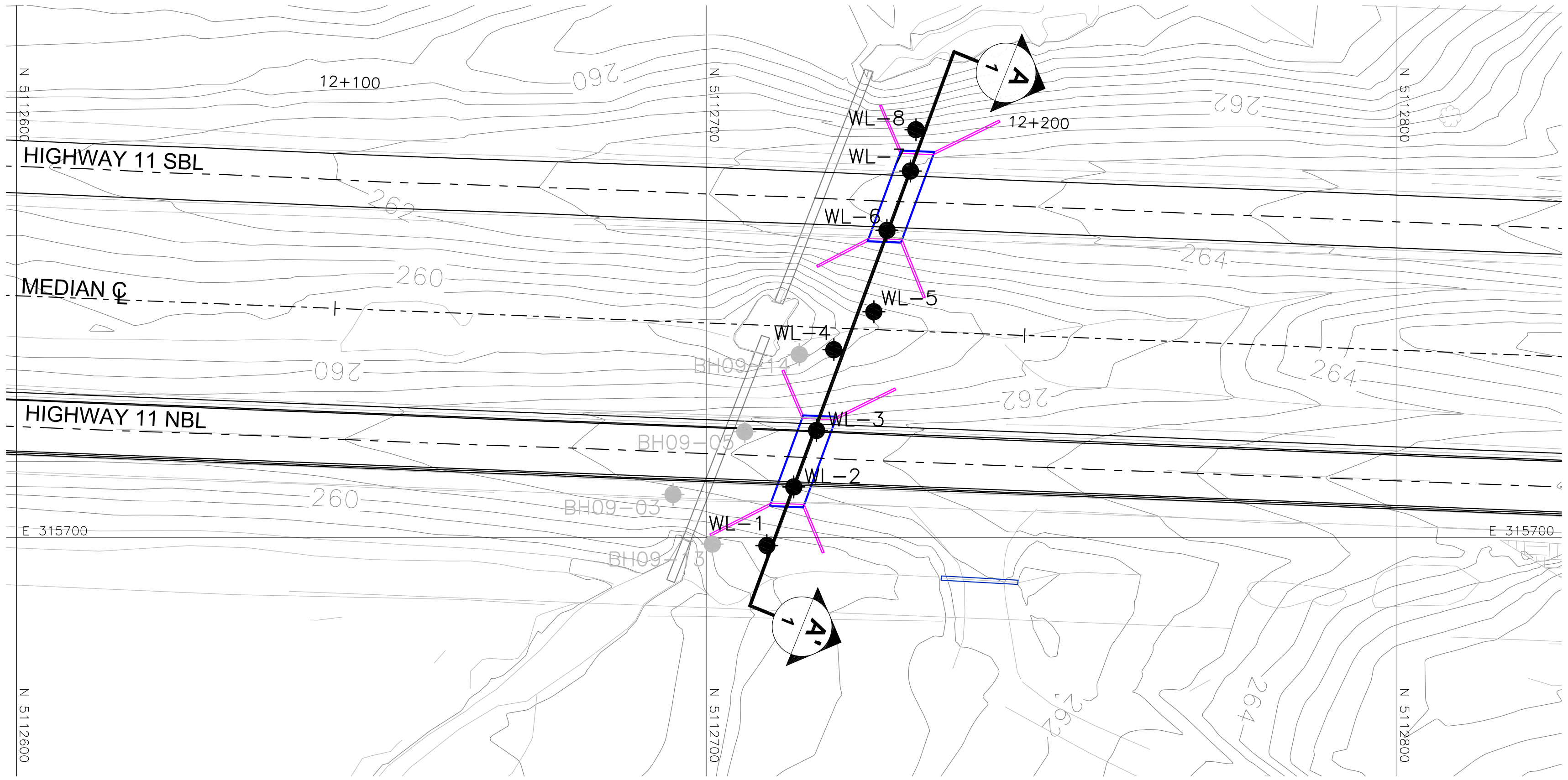
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5415–11–01/02

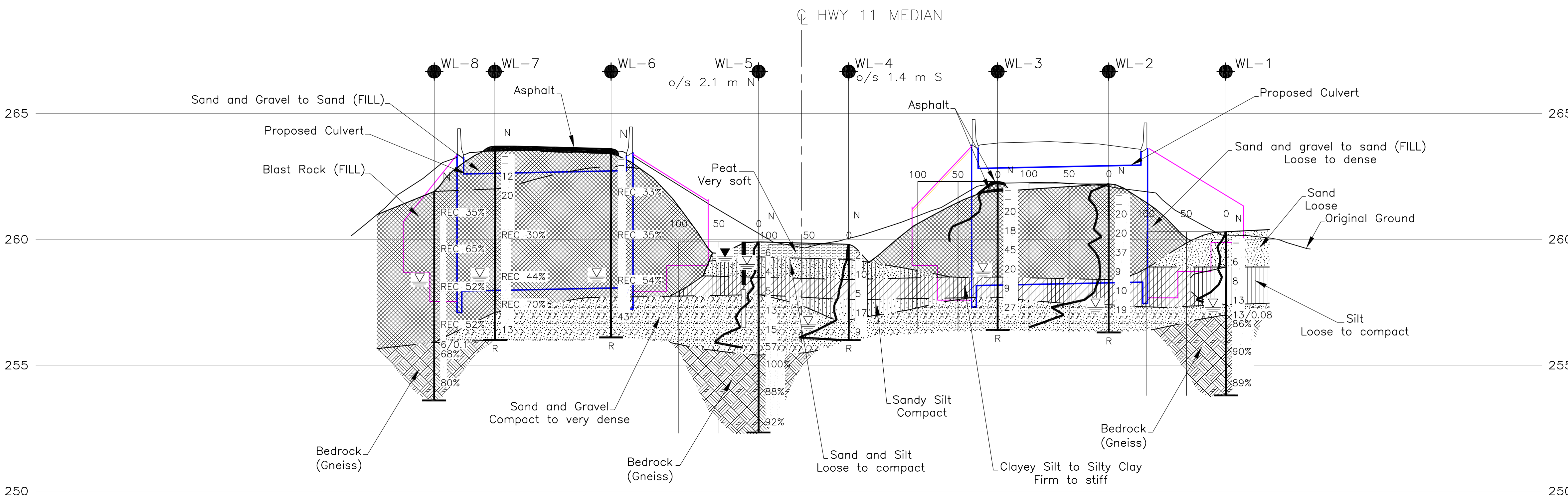
SHEET

HIGHWAY 11
WILDLIFE CROSSING NBL AT STA 12+169 AND SBL AT STA 12+181
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates
Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA

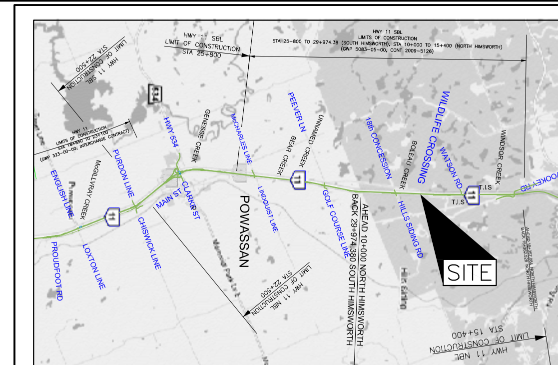


PLAN
SCALE
10 0 10 20 m



A–A' / 1 WILDLIFE CROSSING PROFILE STA. 12+168 AND STA. 12+181
HIGHWAY 11 (NBL AND SBL)

HORIZONTAL SCALE
4 0 4 8 m
2 0 2 4 m
VERTICAL SCALE



KEY PLAN
SCALE
2.5 0 2.5 km

LEGEND

- Borehole – Current Investigation
- N — Standard Penetration Test Value
- R — Refusal
- 100% — Rock Quality Designation (RQD)
- 16 — Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL upon completion of drilling
- WL in piezometer, measured on JULY 06, 2011
- Seal
- Piezometer

BOREHOLE CO–ORDINATES

No.	ELEVATION	NORTHING	EASTING
WL–1	260.3	5112708.7	315701.2
WL–2	262.2	5112712.6	315692.7
WL–3	262.3	5112715.9	315684.5
WL–4	259.8	5112718.4	315672.8
WL–5	259.9	5112724.2	315667.3
WL–6	263.6	5112726.1	315655.5
WL–7	263.7	5112729.5	315646.9
WL–8	261.9	5112730.3	315640.9

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.

REFERENCE

Base plans provided in digital format by URS, drawing file nos. BasePlan HWY 11.dwg dated JUNE 04, 2010, drawing file Wild Life Crossing_GA.dwg recieved Jan 12, 2012. Drawing file Keyplan.dwg recieved June 3, 2011.

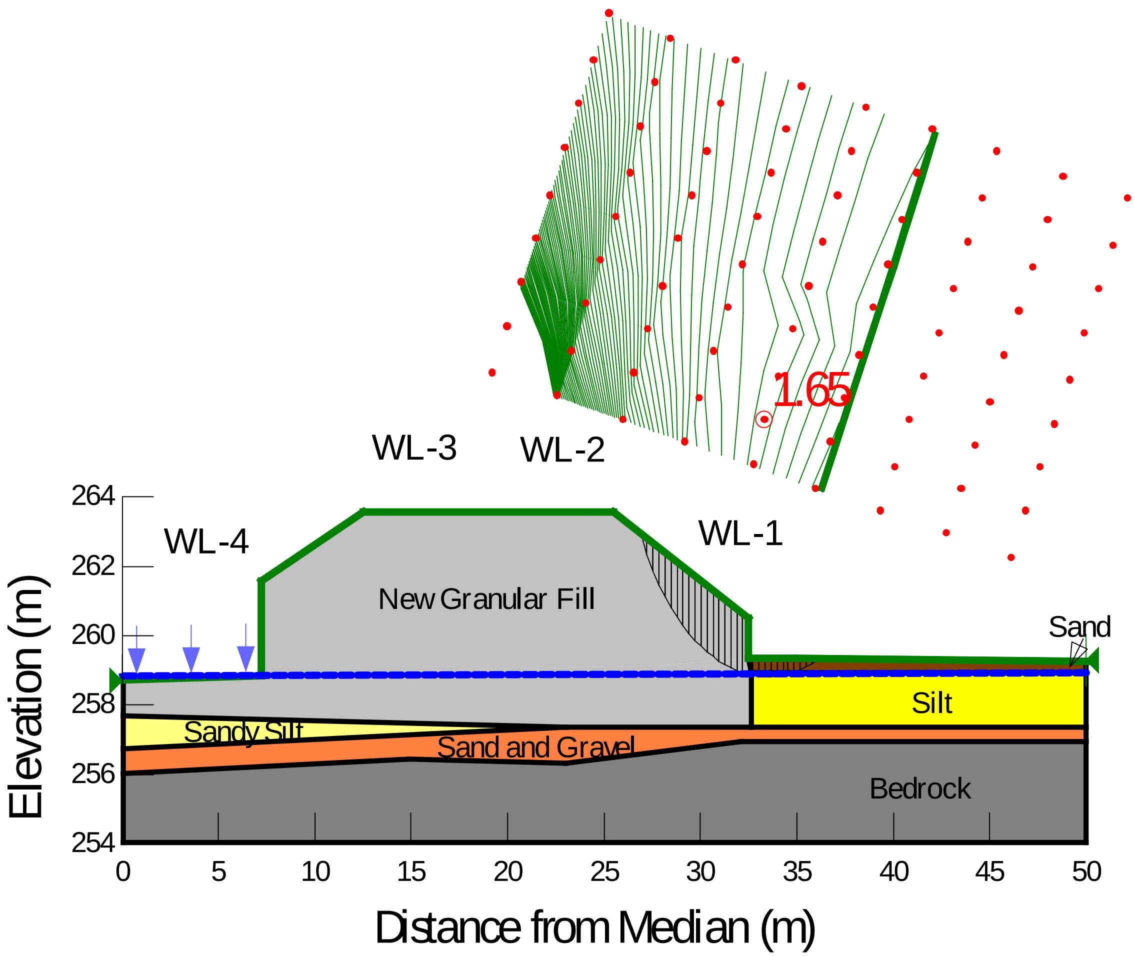
LICENSED PROFESSIONAL ENGINEER A.J.K. BOM 100075715 JAN 17, 2012 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER J.M.A.COSTA JAN 17, 2012 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 31L–156

HWY. 11	PROJECT NO. 09–1191–0042		DIST.
SUBM'D. LG	CHKD. AB	DATE: JAN 2012	SITE: 43–371
DRAWN: JJL	CHKD.	APPD. JMAC	DWG. 1



New Granular Fill
Unit Weight: 21 kN/m^3
Phi: 35°

Sand and Gravel
Unit Weight: 20 kN/m^3
Phi: 35°

Sand, Silt, Sandy Silt
Unit Weight: 19 kN/m^3
Phi: 28°

PROJECT	HIGHWAY 11 NBL and SBL Wildlife Crossing Culvert			
TITLE	**SLOPE STABILITY - NBL**			
Golder Associates	PROJECT No. 09-1191-0042		FILE No. ----	
	DESIGN		SCALE AS SHOWN	REV.
	CADD	--	**Figure 1**	
	CHECK	AB	Jan. 2012	
	REVIEW			

APPENDIX A

Record of Boreholes and Drillholes

LIST OF SYMBOLS

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

1. GENERAL

π	3.1416
in 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
V	volume
W	weight

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. 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

* 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	liquid limit
w_p	plastic limit
I_p	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_a	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation pressure
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

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
SS	Split-spoon
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
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) Cohesionless 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**	**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

Percent 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 (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 texture and structure are preserved.

BEDDING THICKNESS

Description	Bedding Plane Spacing
Very thickly bedded	> 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	< 6 mm

JOINT OR FOLIATION SPACING

Description	Spacing
Very wide	> 3 m
Wide	1 – 3 m
Moderately close	0.3 – 1 m
Close	50 – 300 mm
Very close	< 50 mm

GRAIN SIZE

Terms	Size*
Very Coarse Grained	> 60 mm
Coarse Grained	2 – 60 mm
Medium Grained	60 microns – 2 mm
Fine Grained	2 – 60 microns
Very Fine Grained	< 2 microns

* Note: Grains > 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 varies 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 separation) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

Dip with Respect to (W.R.T.) 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 abbreviated description of the discontinuities, whether naturally occurring separation such as fractures, bedding planes and foliation planes or mechanically induced fractures 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

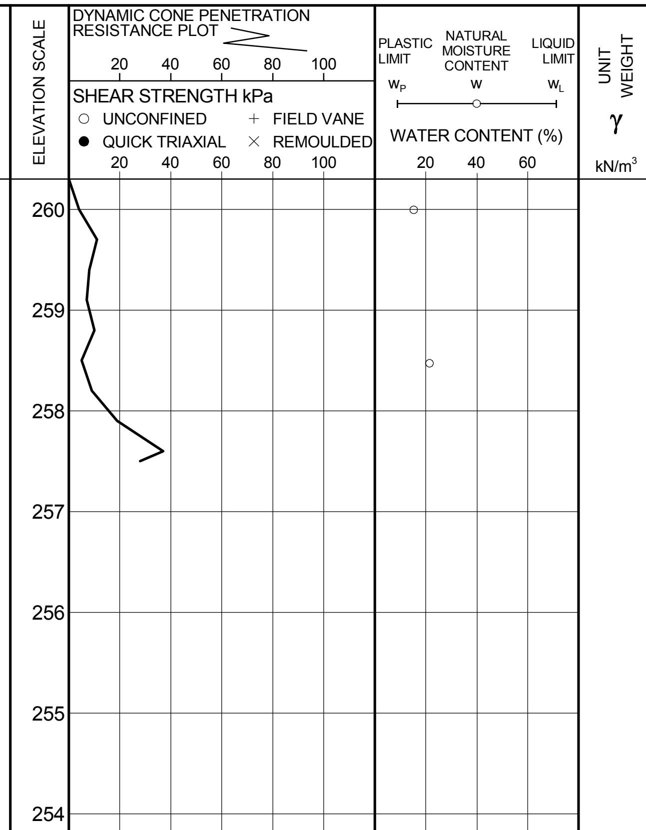
B - Bedding	⊥ - Perpendicular To
FO - Foliation / Schistosity	∥ - Parallel To
CL - Cleavage	P - Polished
SH - Shear Plane / Zone	K - Slickensided
VN - Vein	SM - Smooth
F - Fault	R - Rough
CO - Contact	ST - Stepped
J - Joint	PL - Planar
FR - Fracture	U - Undulating
MF - Mechanical Fracture	C - Curved

RECORD OF BOREHOLE No WL-1

 METRIC

PROJECT	09-1191-0042				
W.P.	5416-06-00	LOCATION	N 5112708.7; E 315701.2	ORIGINATED BY	MR
DIST		HWY 11	BOREHOLE TYPE 108 mm I.D. Continous Flight, Hollow Stem Augers	COMPILED BY	AMW
DATUM	Geodetic	DATE	November 22, 2010	CHECKED BY	AB

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
260.3	GROUND SURFACE					
0.0	SAND, trace to some gravel, some silt, slightly organic Loose Brown Moist	1	AS	-		14 67 (19)
		2	SS	6		
258.9 / 1.4	SILT, some sand, trace to some clay Loose to compact Grey to brown Moist	3	SS	8		0 18 69 13
		4	SS	13	∇	
257.4	SAND and GRAVEL, some silt Compact Brown Wet	5	SS	13/0.08		
257.0 / 3.3	GNEISS (BEDROCK) Bedrock cored from 3.3 m depth to 6.5 m depth. For coring details see Record of Drillhole WL-1.	1	RC	REC 100%		RQD = 86%
		2	RC	REC 100%		RQD = 90%
		3	RC	REC 100%		RQD = 89%
253.8 / 6.5	END OF BOREHOLE					



Notes:

1. Water level at a depth of 3.0 m below ground surface (Elev. 257.3 m) upon completion of drilling.

2. Advanced DCPT 1 m west of Borehole WL-1. Refusal (hammer bouncing) at a depth of 2.8 m below ground surface (Elev. 257.5 m).

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

PROJECT: 09-1191-0042

RECORD OF DRILLHOLE: WL-1

SHEET 1 OF 1

LOCATION: N 5112708.7 ;E 315701.2

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: November 22, 2010

DRILL RIG: D-50 Turbo Track

DRILLING CONTRACTOR: Walker Drilling

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 METRES	DISCONTINUITY DATA B Angle	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	HYDRAULIC CONDUCTIVITY k, cm/s	Diametral Point Load Index (MPa)	RMC -Q' AVG.	NOTES WATER LEVELS INSTRUMENTATION
		Refer to Previous Page																		
	November 22, 2010 HQ Coring	GNEISS Medium to coarse grained Fresh Pinkish grey		257.0 3.3	1	GREY 100%							JIR							
4					2	GREY 100%							JIR JIR							
5					3	GREY 100%							JIR JIR							
6				253.8 6.5																
		END OF DRILLHOLE																		
7																				
8																				
9																				
10																				
11																				
12																				
13																				

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: MR

CHECKED: AB

Golder Associates

RECORD OF BOREHOLE No WL-2

 METRIC

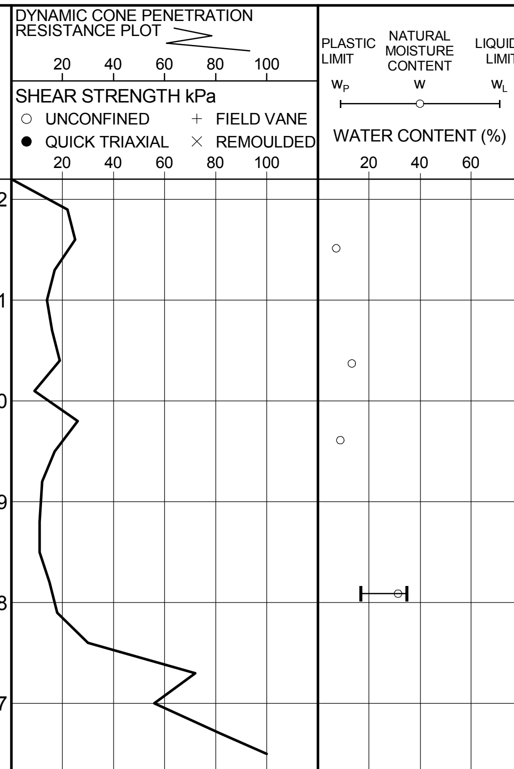
PROJECT 09-1191-0042

W.P. 5416-06-00 LOCATION N 5112712.6; E 315692.7 ORIGINATED BY EHS

DIST HWY 11 BOREHOLE TYPE 108 mm I.D. Continous Flight, Hollow Stem Augers COMPILED BY AMW

DATUM Geodetic DATE November 23, 2010 CHECKED BY AB

ELEV / DEPTH (m)	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
262.2	GROUND SURFACE					
0.0	Sand and gravel to sand, trace to some silt (FILL) Loose to dense Brown Moist	1	AS	-		
		2	AS	-		
		3	SS	20		
		4	SS	20		16 60 (24)
		5	SS	37		
		6	SS	9		
258.4 3.8	CLAYEY SILT, trace to some sand, slightly organic Stiff Grey Moist	7	SS	10		0 9 67 24
257.4 4.8	SAND and GRAVEL, trace to some silt Compact Grey Wet	8	SS	19	∇	
256.3 5.9	END OF BOREHOLE AUGER REFUSAL					



UNIT WEIGHT γ kN/m³

Notes:

1. Water level at a depth of 4.9 m below ground surface (Elev. 257.3 m) upon completion of drilling.

2. Advanced DCPT 0.5 m south of Borehole WL-2. Refusal (hammer bouncing) at a depth of 5.7 m below ground surface (Elev. 256.5 m).

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

SUD-MTO 001 09-1191-0042-4000.GPJ GAL-MISS.GDT 17/01/12 DATA INPUT:

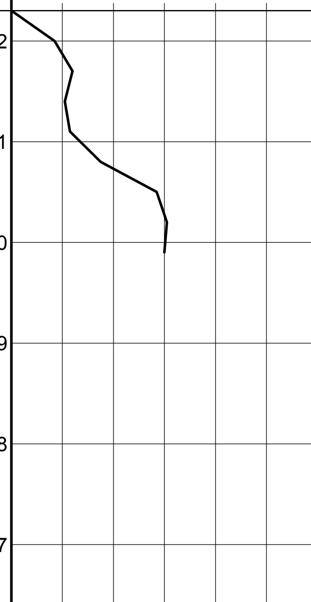
Golder Associates

RECORD OF BOREHOLE No WL-3

 METRIC

PROJECT	09-1191-0042		
W.P.	5416-06-00	LOCATION	N 5112715.9; E 315684.5
DIST		HWY	11
BOREHOLE TYPE	108 mm I.D. Continous Flight, Hollow Stem Augers		
DATUM	Geodetic	DATE	November 23, 2010
ORIGINATED BY	EHS	COMPILED BY	AMW
CHECKED BY	AB		

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
262.3	GROUND SURFACE				
0.0	ASPHALT (65 mm)				
	Sand and gravel, trace silt (FILL) Brown Moist	1	AS	-	
0.4	ASPHALT (75 mm)	2	AS	-	
	Sand and gravel to sand, trace to some silt, containing cobbles (FILL) Loose to dense Brown Moist Cobbles at 1.5 m and 1.8 m depth.	3	SS	20	21 69 (10)
		4	SS	18	
		5	SS	45	
		6	SS	20	
258.5 3.8	CLAYEY SILT, trace to some sand Stiff Grey to brown Moist	7	SS	9	1 16 65 18
257.7 4.6	SAND and GRAVEL, some silt Compact Brown Wet	8	SS	27	
256.4 5.9	END OF BOREHOLE AUGER REFUSAL				



Notes:

1. Water level at a depth of 3.6 m below ground surface (Elev. 258.7 m) upon completion of drilling.

2. Advanced DCPT 1.5 m north of Borehole WL-3. Refusal (hammer bouncing) at a depth of 2.4 m below ground surface (Elev. 259.9 m).

SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED

WATER CONTENT (%): PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L

UNIT WEIGHT γ kN/m³

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

Foundation Design

RECORD OF BOREHOLE No WL-4

1 OF 1 **METRIC**

PROJECT 09-1191-0042

W.P. 5416-06-00 | LOCATION N 5112718.4; E 315672.8 | ORIGINATED BY MR

DIST ___ HWY 11 | BOREHOLE TYPE 108 mm I.D. Continous Flight, Hollow Stem Augers | COMPILED BY AMW

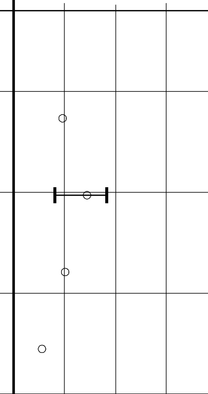
DATUM Geodetic | DATE November 23, 2010 | CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
259.8	GROUND SURFACE						
0.0	PEAT (Amorphous), some silt, trace clay, trace sand Soft Brown Moist	1	SS	2			
259.2 / 0.6	SAND and SILT, trace gravel, slightly organic Loose Grey Moist to wet	2	SS	10		259	
258.4 / 1.4	SILTY CLAY, trace to some sand Firm Grey Moist	3	SS	5		258	0 9 67 24
257.7 / 2.1	Sandy SILT, trace gravel Compact Grey Wet	4	SS	17		257	
256.8 / 3.0	SAND and GRAVEL, some silt Loose Grey Wet	5	SS	9	▽		33 49 (18)
256.0 / 3.8	END OF BOREHOLE AUGER REFUSAL					256	

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 (%) (20 40 60)



UNIT WEIGHT γ kN/m³

Notes:

1. Water level at a depth of 3.2 m below ground surface (Elev. 256.6 m) upon completion of drilling.

2. Advanced DCPT 1 m north of Borehole WL-4. Refusal (hammer bouncing) at a depth of 3.8 m below ground surface (Elev. 256.0 m)

SUD-MTO 001 09-1191-0042-4000.GPJ GAL-MISS.GDT 17/01/12 DATA INPUT:

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

Golder Associates

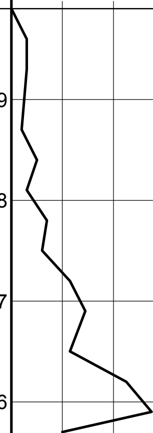
RECORD OF BOREHOLE No WL-5

 METRIC

PROJECT	09-1191-0042				
W.P.	5416-06-00	LOCATION	N 5112724.2; E 315667.3	ORIGINATED BY	MR
DIST	HWY 11	BOREHOLE TYPE	108 mm I.D. Continous Flight, Hollow Stem Augers	COMPILED BY	AMW
DATUM	Geodetic	DATE	November 23, 2010	CHECKED BY	AB

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	NATURAL MOISTURE CONTENT	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
259.9	GROUND SURFACE						
0.0	PEAT(Fibrous), some sand, some silt, Firm, Brown, Moist	1	SS	6			
259.3 / 0.6	SAND and SILT, trace clay, slightly organic, Loose, Grey, Wet	2	SS	4	259	○	1 36 57 6
258.5 / 1.4	CLAYEY SILT, some sand, Firm, Grey, Wet	3	SS	5	258	○	0 16 66 18
257.8 / 2.1	SAND and GRAVEL, some silt, Compact to very dense, Grey to brown, Wet	4	SS	13	257	○	
		5	SS	15	256		
		6	SS	57			
255.4 / 4.5	GNEISS (BEDROCK). Bedrock cored from 4.5 m depth to 7.6 m depth. For coring details see Record of Drillhole WL-5.	1	RC	REC 100%	255		RQD = 100%
		2	RC	REC 100%	254		RQD = 88%
		3	RC	REC 100%	253		RQD = 92%
252.3 / 7.6	END OF BOREHOLE						

Column headings also include: 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 (%) 20 40 60; UNIT WEIGHT γ kN/m³.



Notes:

1. Water level at a depth of 0.9 m below ground surface (Elev. 259.0 m) upon completion of drilling.

2. Advanced DCPT 1 m south of Borehole WL-5. Refusal at a depth of 4.2 m (hammer bouncing) below ground surface (Elev. 255.7 m).

3. On June 22, 2011, a piezometer was installed about 1.5 m west of Borehole WL-5. The water level measured in the piezometer after the installation was 1.0 m below ground surface (Elev. 258.9 m). On July 6, 2011, the water level was measured at a depth of 0.6 m below ground surface (Elev. 259.3 m).

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

PROJECT: 09-1191-0042

RECORD OF DRILLHOLE: WL-5

LOCATION: N 5112724.2 ;E 315667.3

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: November 23, 2010

DRILL RIG: D-50 Turbo Track

DRILLING CONTRACTOR: Walker Drilling

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	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
		Refer to Previous Page		255.4				
5	November 23, 2010 HQ Coring	GNEISS Medium to coarse grained Fresh Pinkish grey		4.5	1	GREY 100%		
6					2	GREY 100%	JIR JIR JIR JIR JIR JIR	
7				252.3 / 7.6	3	GREY 100%	JIR JIR JIR	
		END OF DRILLHOLE						

Depth scale: 8, 9, 10, 11, 12, 13, 14

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: MR

CHECKED: AB

SUD-RCK 09-1191-0042-4000.GPJ GAL-MISS.GDT 17/01/12 DATA INPUT:

Golder Associates

Foundation Design

RECORD OF BOREHOLE No WL-6

1 OF 1 **METRIC**

PROJECT 09-1191-0042
W.P. 5416-06-00
LOCATION N 5112726.1; E 315655.5
ORIGINATED BY MR
DIST HWY 11
BOREHOLE TYPE 108 mm I.D. Continous Flight, Hollow Stem Augers, NW Casing, NQ Coring
COMPILED BY AMW
DATUM Geodetic
DATE November 24, 2010
CHECKED BY AB

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
263.6	GROUND SURFACE							
0.0	ASPHALT (210 mm)							
0.2	Sand and gravel to sand, trace silt (FILL) Brown Moist	1	AS	-		263	plotted	
		2	AS	-				
262.9 / 0.7	Blast rock (FILL)		RC	REC 33%		262		
			RC	REC 35%		261, 260		
			RC	REC 54%	∇	259, 258		
257.7 / 5.9	SAND and GRAVEL, some silt, trace clay Dense Grey Wet	3	SS	43		257	plotted	32 44 (24)
256.1 / 7.5	END OF BOREHOLE NO FURTHER CASING PENETRATION							

Note:

1. Water level at a depth of 5.1 m below ground surface (Elev. 258.5 m) upon completion of drilling.

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 (%) 20 40 60; UNIT WEIGHT γ kN/m³

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

SUD-MTO 001 09-1191-0042-4000.GPJ GAL-MISS.GDT 17/01/12 DATA INPUT:

Golder Associates

RECORD OF BOREHOLE No WL-7

 METRIC

PROJECT 09-1191-0042
W.P. 5416-06-00
LOCATION N 5112729.5; E 315646.9
ORIGINATED BY MR
DIST ___ HWY 11
BOREHOLE TYPE 108 mm I.D. Continous Flight, Hollow Stem Augers, NW Casing, NQ Coring
COMPILED BY AMW
DATUM Geodetic
DATE November 25, 2010
CHECKED BY AB

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
263.7	GROUND SURFACE					
0.0	ASPHALT (180 mm)					
0.2	Sand and gravel to sand, trace to some silt (FILL) Compact Brown Moist	1	AS	-		46 49 (5)
		2	AS	-		
		3	SS	12		3 90 (7)
		4	SS	20		
261.8 / 1.9	Blast rock (FILL)		RC	REC 30%		
			RC	REC 44%	▽	
			RC	REC 70%		
257.1 / 6.6	SAND and GRAVEL, some silt Compact Grey Wet	5	SS	13		
256.0 / 7.7	END OF BOREHOLE NO FURTHER CASING PENETRATION					

Note:

1. Water level at a depth of 5.2 m below ground surface (Elev. 258.5 m) upon completion of drilling.

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; ELEVATION SCALE (263, 262, 261, 260, 259, 258, 257, 256); 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 (%) 20 40 60; UNIT WEIGHT γ kN/m³

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

Golder Associates

RECORD OF BOREHOLE No WL-8

 METRIC

PROJECT 09-1191-0042
W.P. 5416-06-00
LOCATION N 5112730.3; E 315640.9
ORIGINATED BY EHS
DIST HWY 11
BOREHOLE TYPE 108 mm I.D. Continous Flight, Hollow Stem Augers, NW Casing, NQ Coring
COMPILED BY JJL
DATUM Geodetic
DATE June 1, 2011
CHECKED BY AB

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%)
261.9	GROUND SURFACE							
0.0	Blast rock (FILL)			RC	REC 35%		261	
				RC	REC 65%		260	
				RC	REC 52%	▽	259 / 258	
				RC	REC 52%		257	
255.9				SS	6/0.1		256	
6.0	GNEISS (BEDROCK) Bedrock cored from 6.0 m depth to 8.3 m depth. For coring details see Record of Drillhole WL-8.		1	RC	REC 100%		255	RQD = 68%
			2	RC	REC 100%		254	RQD = 80%
253.6 / 8.3	END OF BOREHOLE Notes: 1. Water level at a depth of 3.6 m below ground surface (Elev. 258.3 m) upon completion of drilling.							

Plot columns (no data plotted): 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 (%) (20, 40, 60); UNIT WEIGHT γ kN/m³; GR SA SI CL.

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

PROJECT: 09-1191-0042

RECORD OF DRILLHOLE: WL-8

SHEET 1 OF 1

LOCATION: N 5112730.3 ;E 315640.9

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: June 1, 2011

DRILL RIG: CME 55

DRILLING CONTRACTOR: Landcore Drilling

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.	DISCONTINUITY TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
		Refer to Previous Page		255.9			
6	June 1, 2011 / NQ Coring	GNEISS Medium to coarse grained Fresh Pinkish grey		6.0	1	JIR JPLR JIR JPLR	
7		Broken core between 6.9 m and 7.2 m depth.			2	JPLR JPLR	
8				253.6 8.3		JIR	
		END OF DRILLHOLE					

Column headers also include: COLOUR % RETURN; FLUSH; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX METRES; DISCONTINUITY DATA (B Angle, DIP w.r.t. CORE AXIS, TYPE AND SURFACE DESCRIPTION, Jr, Ja, Jn); HYDRAULIC CONDUCTIVITY k, cm/s; Diametral Point Load Index (MPa); RMC -Q' AVG.

Depth scale: 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16

SUD-RCK 09-1191-0042-4000.GPJ GAL-MISS.GDT 17/01/12 DATA INPUT:

DEPTH SCALE

1 : 50

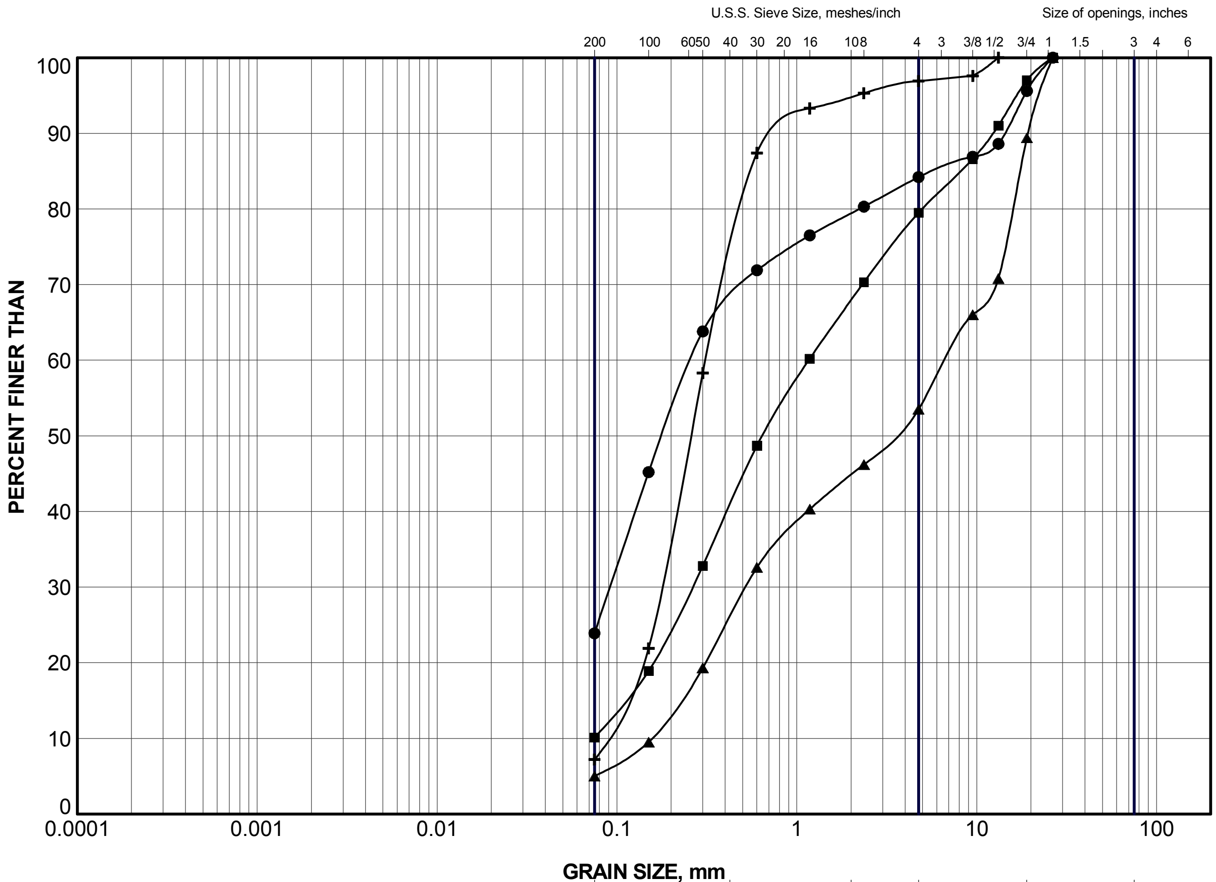
Golder Associates

LOGGED: EHS

CHECKED: AB

APPENDIX B

Laboratory Test Results



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	WL-2	4	260.4
■	WL-3	3	261.2
▲	WL-7	1	263.5
+	WL-7	3	262.6

PROJECT

HIGHWAY 11 WILDLIFE CROSSING
12+169 NBL & 12+181 SBL

TITLE

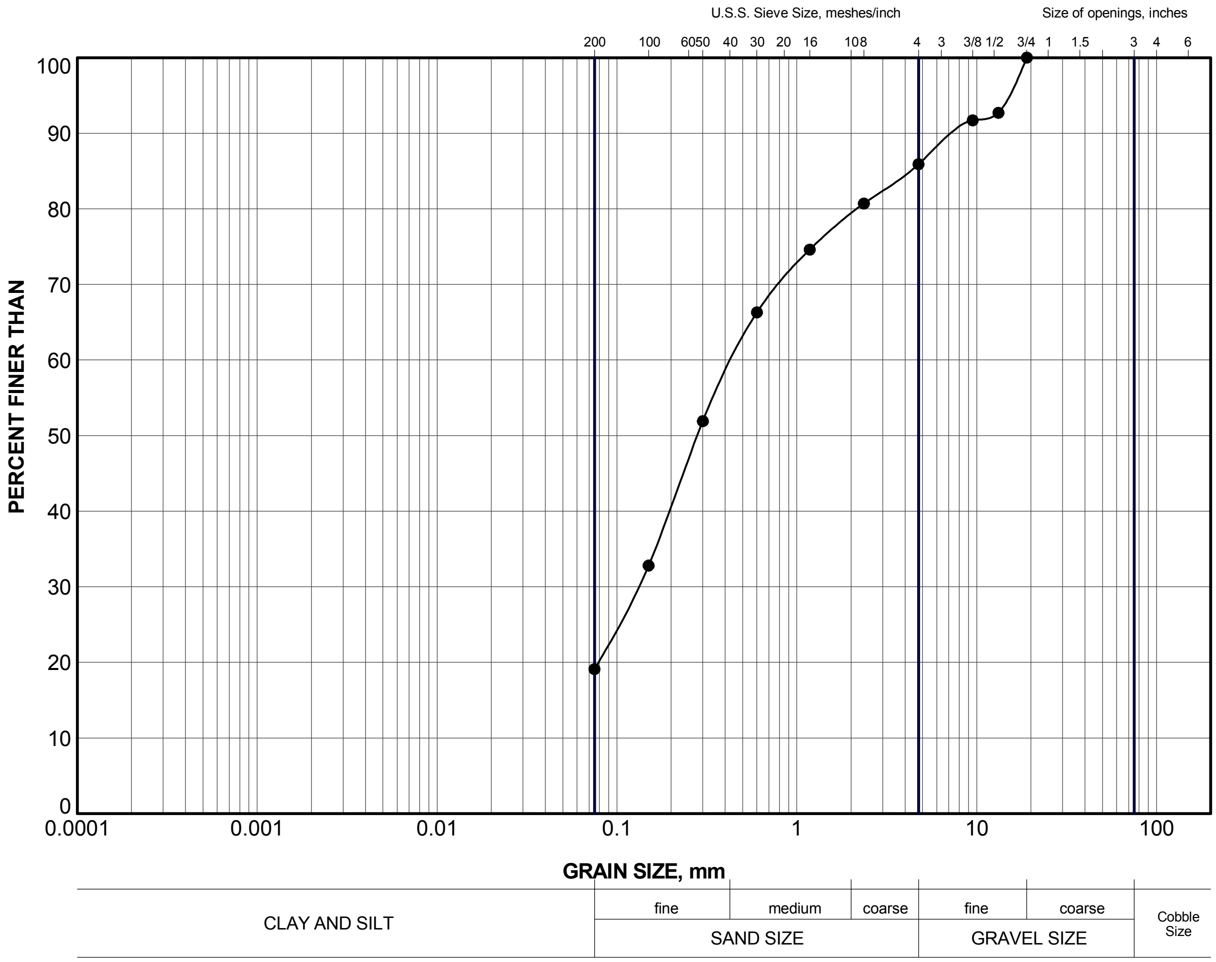
GRAIN SIZE DISTRIBUTION

SAND AND GRAVEL TO SAND (FILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	09-1191-0042		FILE No. 09-1191-0042-4000.GPJ	
DRAWN	JJL	Jan 2012	SCALE N/A	REV.
CHECK	AB	Jan 2012	**FIGURE B1**	
APPR	JMAC	Jan 2012		

LDN_MTO_NEW GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	WL-1	1	260.0

PROJECT

HIGHWAY 11 WILDLIFE CROSSING
12+169 NBL & 12+181 SBL

TITLE

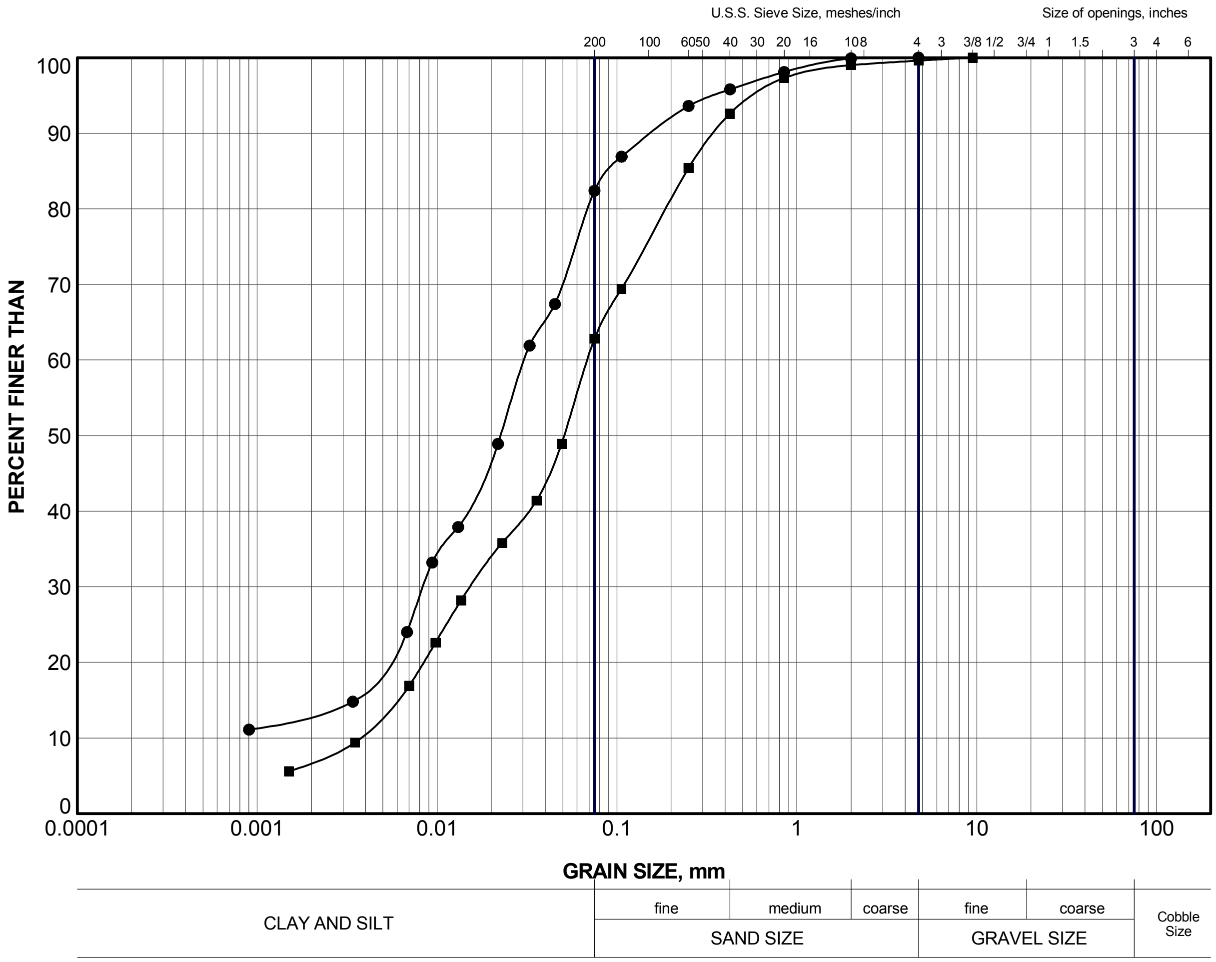
GRAIN SIZE DISTRIBUTION

SAND

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		09-1191-0042	FILE No. 09-1191-0042-4000.GPJ
DRAWN	JJL	Jan 2012	SCALE N/A REV.
CHECK	AB	Jan 2012	FIGURE B2
APPR	JMAC	Jan 2012	

LDN_MTO_NEW GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	WL-1	3	258.5
■	WL-5	2	258.8

PROJECT

HIGHWAY 11 WILDLIFE CROSSING
12+169 NBL & 12+181 SBL

TITLE

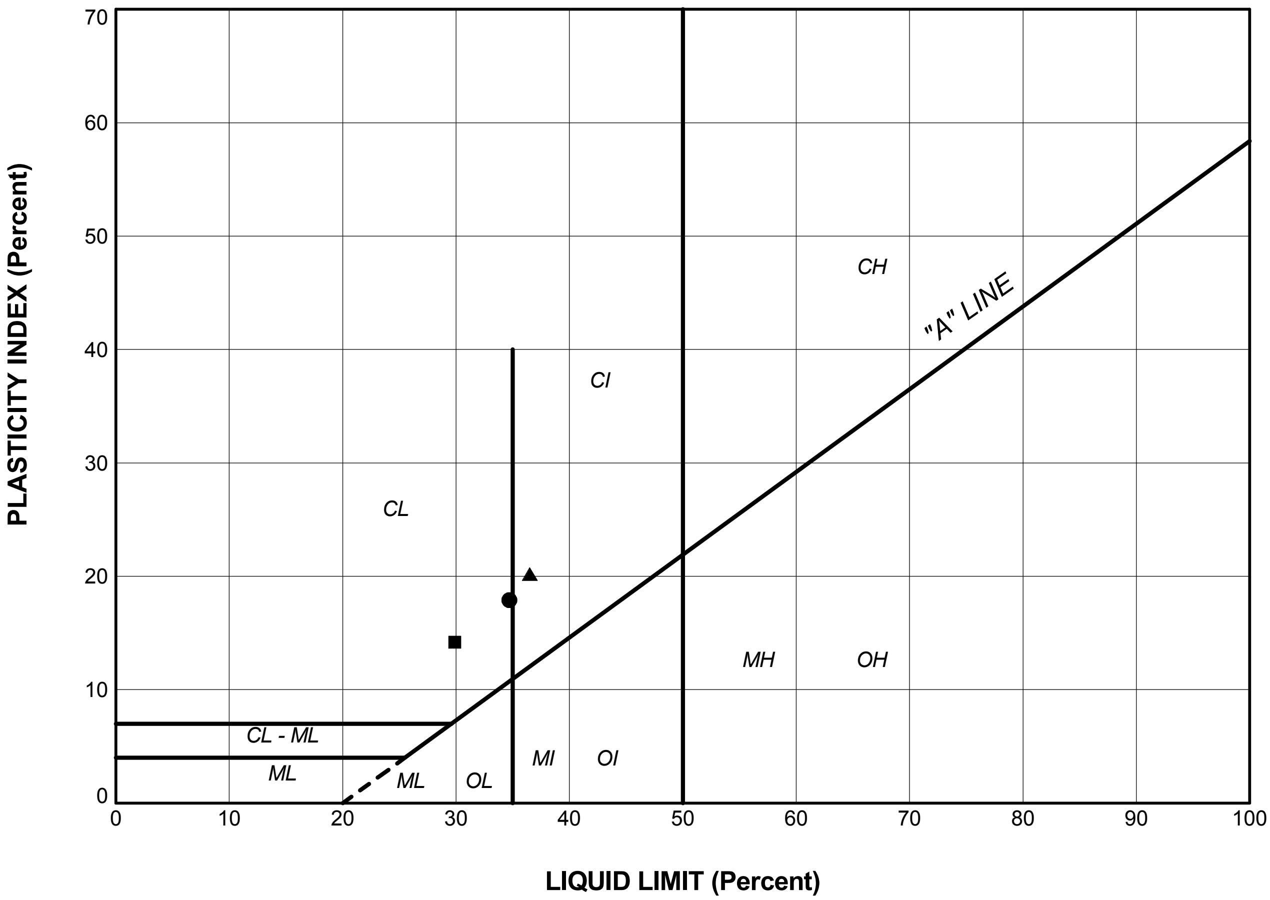
GRAIN SIZE DISTRIBUTION

SILT TO SAND AND SILT

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		09-1191-0042	FILE No. 09-1191-0042-4000.GPJ	
DRAWN	JJL	Jan 2012	SCALE N/A	REV.
CHECK	AB	Jan 2012	FIGURE B3	
APPR	JMAC	Jan 2012		

LDN_MTO_NEW GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	WL-2	7	34.7	16.8	17.9
■	WL-3	7	29.9	15.7	14.2
▲	WL-4	3	36.5	16.3	20.2

PROJECT

HIGHWAY 11 WILDLIFE CROSSING
12+169 NBL & 12+181 SBL

TITLE

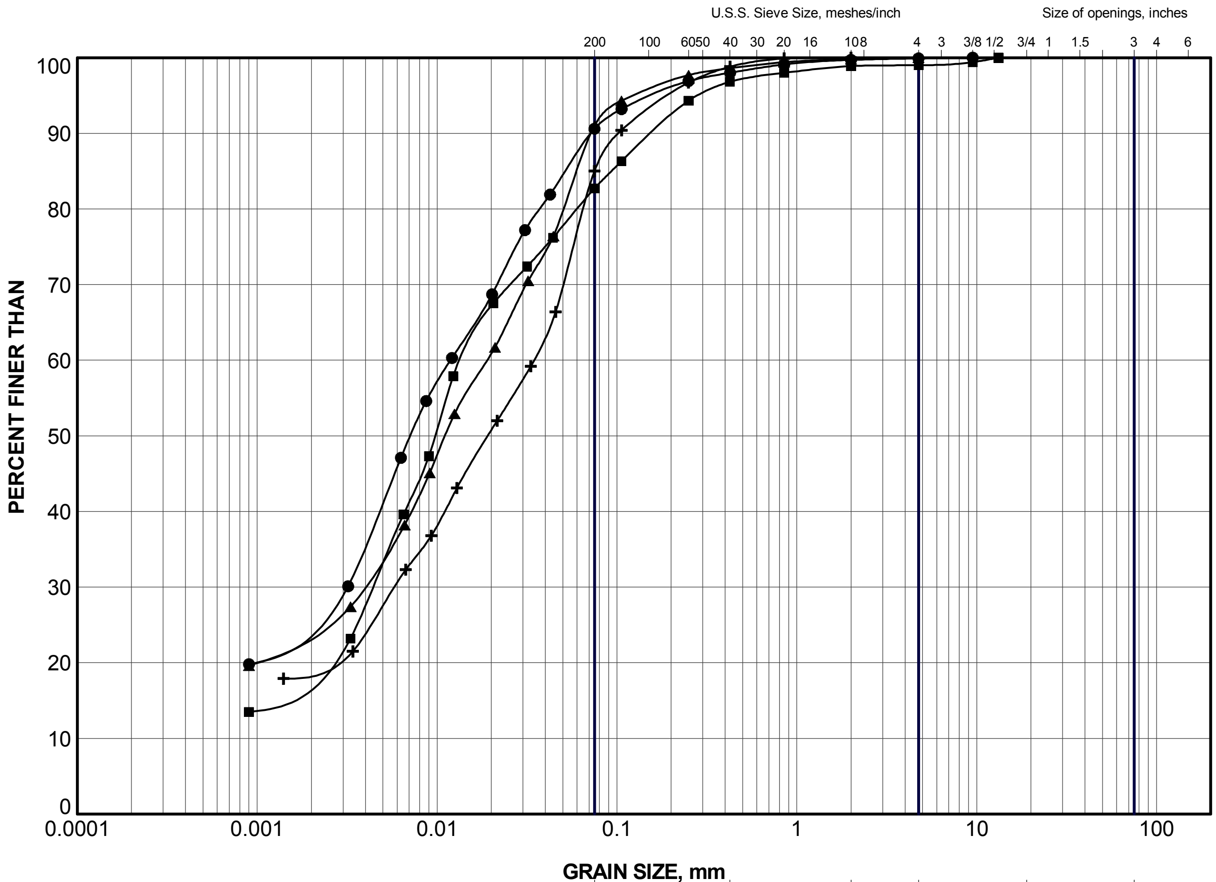
PLASTICITY CHART

CLAYEY SILT TO SILTY CLAY

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	09-1191-0042		FILE No.	09-1191-0042-4000.GPJ
DRAWN	JJL	Jan 2012	SCALE N/A	REV.
CHECK	AB	Jan 2012		
APPR	JMAC	Jan 2012	**FIGURE B4**	

MTO_PI GLDR_LDN.GDT



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	WL-2	7	258.1
■	WL-3	7	258.2
▲	WL-4	3	258.0
+	WL-5	3	258.1

PROJECT

HIGHWAY 11 WILDLIFE CROSSING
12+169 NBL & 12+181 SBL

TITLE

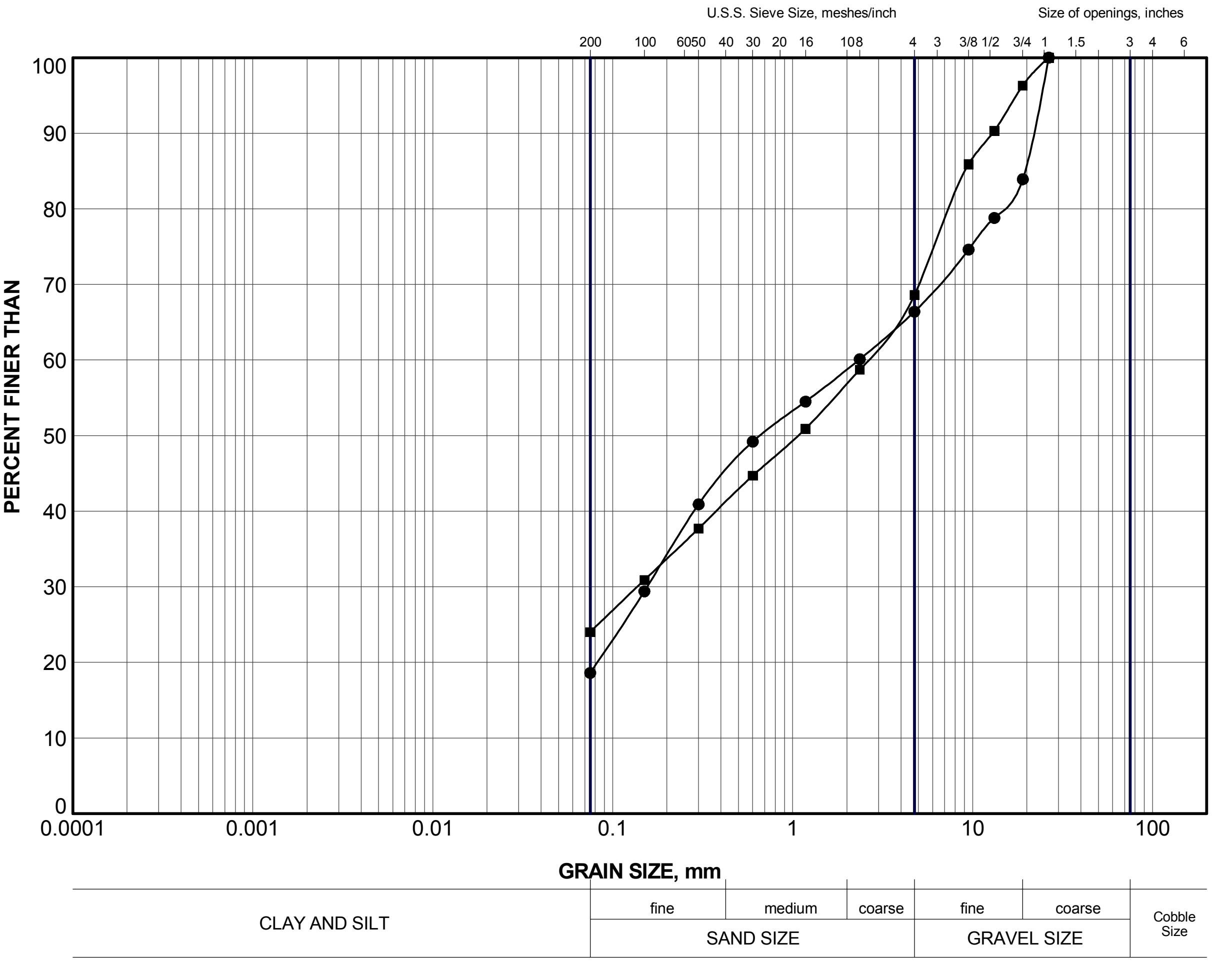
GRAIN SIZE DISTRIBUTION

CLAYEY SILT TO SILTY CLAY

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		09-1191-0042	FILE No. 09-1191-0042-4000.GPJ	
DRAWN	JJL	Jan 2012	SCALE N/A	REV.
CHECK	AB	Jan 2012	FIGURE B5	
APPR	JMAC	Jan 2012		

LDN_MTO_NEW GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	WL-4	5	256.4
■	WL-6	3	257.0

PROJECT	HIGHWAY 11 WILDLIFE CROSSING 12+169 NBL & 12+181 SBL			
TITLE	**GRAIN SIZE DISTRIBUTION** SAND AND GRAVEL			
Golder Associates SUDBURY, ONTARIO	PROJECT No.	09-1191-0042		FILE No. 09-1191-0042-4000.GPJ
	DRAWN	JJL	Jan 2012	SCALE N/A REV.
	CHECK	AB	Jan 2012	**FIGURE B6**
	APPR	JMAC	Jan 2012	

LDN_MTO_NEW GLDR_LDN.GDT

APPENDIX C

Non-Standard Special Provisions

WORKING SLAB, Item No.

Non-Standard Special Provision

Scope

This Special Provision covers the requirements for the supply and placement of a concrete working slab under the structure foundations. The purpose of the working slab is to protect the subgrade from disturbance and loosening due to construction traffic and ponded water and also to provide a level working surface.

Construction

Protection of Founding Soil:

- Following inspection and approval of the prepared subgrade, a working slab with a minimum thickness of 100 mm shall be placed on the foundation subgrade as per the contract drawings and documents. The concrete shall have a minimum 28-day compressive strength of 20 MPa.

Unwatering of the excavation for the footing construction, including the construction of the working slab, may be required and is covered under separate Tender Item. The dewatering scheme shall be done in such a manner as to prevent any disturbance to the surrounding original soil.

Basis of Payment

Payment at the contract price for this Tender Item shall include full compensation for all labour, equipment and material required to do the work.

GROUNDWATER CONTROL - Item No.

Non-Standard Special Provision

Foundations for the new Wildlife Crossing open bottom culvert will require excavations to extend below the groundwater level at the sites. Cohesionless soils (sand, silty sand, gravel and gravelly sand) that are present below the groundwater table will slough, run, boil or cave into the excavation unless appropriate groundwater controls are in place. The Contractor is to design and install an appropriate dewatering system for the culvert sites to enable construction in dry conditions, and prevent disturbance to the founding soils.

Basis of Payment

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

END OF SECTION

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.

Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

solutions@golder.com
www.golder.com

Golder Associates Ltd.
1010 Lorne Street
Sudbury, Ontario, P3C 4R9
Canada
T: +1 (705) 524 6861