November 17, 2011

FOUNDATION INVESTIGATION AND DESIGN REPORT

HIGHWAY 11 NBL CULVERT REPLACEMENT AT STATION 12+824
TOWNSHIP OF NORTH HIMSWORTH, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5416-06-00

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

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REPORT

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FOUNDATION INVESTIGATION REPORT

HIGHWAY 11 NBL CULVERT REPLACEMENT AT STATION 12+824

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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 rehabilitation of the Highway 11 Northbound Lanes (NBL), including the culvert replacement at Station 12+824. This project is part of the detail design for the rehabilitation of Highway 11 Northbound Lanes (NBL) and Southbound Lanes (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 replacement of the culvert on Highway 11 NBL at Station 12+824 only. Separate reports will be submitted detailing the foundation investigations for other culverts for this project, as well as for the wildlife crossing. The drawing for the culvert alignment was provided to Golder by URS on June 4, 2010 and cross-sections showing invert information were provided on August 25, 2010.

Based on the information from URS, the culvert at Station 12+824 will be concrete and will have an opening of about 1.4 m. The inverts at the west and east ends of the culvert will be Elevation 256.3 m and 256.2 m, respectively. The embankment in the culvert area is about 2 m high and we understand that neither a grade raise nor embankment widening are required at this culvert location.

The purpose of this investigation is to establish the subsurface conditions at the location of the proposed culvert replacement 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 replacement culvert will be located on the same alignment as the existing culvert in the Township of North Himsworth on Highway 11 approximately 500 m south of Watson 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 existing culvert at Station 12+824 is a 1,370 mm diameter and 32 m long Corrugated Steel Pipe (CSP) culvert. The Preliminary Design Report (PDR) dated July 2009 indicates that the condition of the culvert is poor to fair and sedimentation was observed at left end.

The ground surface of the shoulder of the embankment is at Elevation 259 m and the creek water surface at the time of the investigation was about Elevation 257 m.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation associated with this culvert replacement at Station 12+824 was carried out on May 7, 12, and 13, 2010, during which time a total of four (4) Boreholes (BH09-06 and BH09-10 to BH09-12) and four (4) Dynamic Cone Penetration Tests (DCPTs) were advanced at the culvert location. The field investigation was carried out using a Track Mounted D-50 supplied and operated by Walker Drilling Ltd., of Utopia, Ontario. 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 and 1.5 m, using a 50 mm outer diameter (O.D.) split-spoon sampler, performed in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586-08a). Field vane shear tests were conducted in cohesive soils for determination of undrained shear strengths (ASTM D2573-08) using MTO Standard 'N' size vanes. The DCPTs were adjacent about 1 m north or south of each borehole to determine the depth to refusal. All boreholes were backfilled with bentonite upon completion in accordance with Ontario Regulation 903 Wells (as amended by Ontario Regulation 372).

The boreholes were advanced to depths ranging between 4.6 m and 6.6 m below existing ground surface. In general, boreholes and DCPTs locations were terminated on refusal to further split-spoon and/or auger advancement, or cone penetration. These depths to refusal do not confirm bedrock surface elevations, but may be inferred to indicate potential 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. It should be noted that groundwater elevations as encountered in the boreholes may not be representative of static groundwater levels since the groundwater levels in the boreholes may not have stabilized on completion of drilling. Furthermore, groundwater elevations will vary depending on seasonal fluctuations, precipitation and local soil permeability.

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 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.

A sample of the creek water was obtained during the field investigation, using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters. The results of the analytical testing are summarized in Table B-1 in Appendix B.

Survey stakes were installed near the NBL embankment east toe 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		
09-06	5113373.8	315694.6	258.8	6.5
09-10	5113368.4	315713.6	258.7	6.6
09-11	5113373.4	315721.6	257.5	6.6
09-12	5113372.8	315686.6	257.1	4.6

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.

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. Detailed 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 the profile 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 and 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.

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[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.

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

In general, the subsurface stratigraphy along the culvert alignment consists of a layer of fill at ground surface, underlain by a layer of peat and deposits of clayey silt to clay and sand and silt to sand, underlain by inferred bedrock.

The bottom of the creek was probed using a steel bar from the edge of the creek at the time of the field investigation and the depth to firm creek bottom was measured at 0.7 m and 0.8 m below water surface on the west and east side of the embankment, respectively.

4.2.1 Fill

Fill, consisting of brown to grey sand and gravel to sand trace to some silt, was encountered at ground surface in each of the boreholes. In Borehole BH09-12, the fill is mixed with topsoil and roots. The fill thickness varies between 0.2 m and 2.3 m.

The SPT 'N'-values measured within the fill are between 3 blows and 21 blows per 0.3 m of penetration, indicating a very loose to compact relative density.

The grain size distribution of two samples of the deposit is shown on Figure B-1 in Appendix B.

The measured water content on samples of this deposit varies between about 4 percent and 11 percent.

4.2.2 Peat

A deposit of black, fibrous peat was encountered below the fill in Boreholes BH09-10 to BH09-12. The top of this deposit varies between about Elevation 256.9 m and Elevation 256.4 m and the thickness of the deposit varies between about 0.1 m and 0.3 m.

4.2.3 Clayey Silt to Clay

A deposit of brown to/and grey clayey silt to clay, trace sand, was encountered underlying the fill in Borehole BH09-06 and underlying the peat in Boreholes BH09-10 to BH09-12. Trace organics were found in the upper portion of the layer. The top of the deposit was encountered between Elevation 256.8 m and Elevation 255.7 m and the thickness of the deposit ranges from 2.4 m to 3.7 m.

The SPT 'N'-values measured within this deposit range from 0 blows (weight of hammer) to 7 blows per 0.3 m of penetration. In situ field vane testing carried out within this stratum measured undrained shear strengths ranging from about 30 kPa to 38 kPa. The in situ field vane tests indicate the deposit has a firm consistency.

Atterberg limits testing was carried out on nine samples of the clayey silt to clay deposit, and the test results indicate liquid limits ranging from about 23 percent to 62 percent, plastic limits ranging from about 15 percent to 24 percent and plasticity indices ranging from about 8 percent to 38 percent. The results of the Atterberg limits tests are shown on the plasticity chart on Figure B-2 in Appendix B and indicate that the material is classified as a clayey silt of low plasticity to clay of high plasticity.

Grain size distributions for four samples of this deposit are shown on Figure B-3 in Appendix B.

The measured water content on samples of this deposit ranges between about 22 percent and 59 percent.

The organic content measured on one sample of this deposit from Borehole BH09-10 is 2.5 percent.

4.2.4 Sand and Silt to Sand

A deposit of grey, sand and silt to sand, some gravel, trace clay, was encountered below the clayey silt to clay in each of the boreholes. The top of sand and silt to sand deposit ranges from about Elevation 253.4 m and 252.9 m and the deposit is between 0.9 m and 2.0 m thick. The bottom of this deposit was defined by refusal to further auger and/or split-spoon advancement in each of the boreholes.

The SPT ‘N’-values measured within this deposit range between 18 and 45 blows per 0.3 m of penetration, indicating a loose to dense relative density.

Grain size distributions of two samples of this deposit are shown on Figure B-4 in Appendix B.

The natural water content measured on samples of this deposit is about 13 percent and 19 percent.

4.2.5 Refusal

In each of the boreholes and DCPTs, refusal to further split-spoon and/or auger advancement or cone penetration was encountered at depths between 4.6 m and 7.0 m below ground surface, corresponding to Elevation 252.5 m to 250.6 m. These depths to refusal, while they do not confirm bedrock elevations, may be inferred to indicate potential proximity to the bedrock interface.

4.2.6 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 0.6 m to 2.2 m below existing ground surface ranging between Elevation 257.3 m and 256.5 m. Groundwater/surface water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

5.0 CLOSURE

The field personnel supervising the drilling program were Mr. Ed Savard and Mr. Indulis Dumpis. 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

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PART B

FOUNDATION DESIGN REPORT

HIGHWAY 11 NBL CULVERT REPLACEMENT AT STATION 12+824

TOWNSHIP OF NORTH HIMSWORTH, ONTARIO

MINISTRY OF TRANSPORTATION, ONTARIO

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6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides an interpretation of the factual geotechnical data obtained during the investigation 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 SBL and/or NBL, which includes foundation investigation and design for the replacement of four (4) NBL culverts, three (3) SBL culverts, a new NBL and SBL wildlife crossing and the replacement of Windsor Creek NBL culvert.

This section of the report provides foundation design recommendations for the proposed culvert replacement on Highway 11 NBL at Station 12+824. The scope of work includes an assessment of stability and settlement of the embankment for the culvert replacement and 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 head walls and wing walls associated with the culvert (where applicable), construction concerns and potential geotechnical problems associated with the culvert, including localized sub-excavation of soft / organic materials, placement of new fill and requirements for erosion protection and bedding materials.

We understand from URS that the replacement culvert to be constructed under the NBL embankment at Station 12+824 will be precast concrete and will have a diameter of 1.4 m. The new section of embankment at the replacement culvert location will be reconstructed to the same elevation as the existing embankment, approximately 2 m high, and there will not be any embankment widening. The new culvert will be about 32 m long and the west and east inverts of the culvert will be Elevation 256.3 m and 256.2 m, respectively, and head walls and wing walls will not be required.

The subsoils along the culvert alignment generally consist of fill materials overlying peat, silt (where encountered) clayey silt to clay and sand and silt to sand deposits. Refusal was encountered between Elevation 252.5 m and 250.6 m. Details of the subsurface conditions along this culvert are presented in Section 4.2 and shown on Drawing 1 following the text of this report.

6.2 Culvert Types

The analysis and recommendations in this report assume that a concrete circular culvert will be installed at the site. However, foundation design recommendations for a concrete box culvert are also provided in the event that an alternative culvert type is considered.

6.3 Culvert Construction Options

We understand that the existing embankment will not be widened or raised. Should a widening or grade raise of the embankment be required, the timing of culvert construction will be an essential factor in determining the preferred mitigation option as the foundation strata at the culvert crossing will undergo settlement as a result of any additional loading from widening of the embankment or raising the embankment grade. The following alternatives for culvert construction can be considered (where applicable, giving due consideration to the recommended foundation mitigation option for the embankment):

- concurrent with phased embankment construction between the two sides of the roadway; or
- following full sub-excavation of soft soils along the culvert alignment and concurrent with embankment construction.

Where relatively small settlements are estimated to occur as a result of the embankment construction, culvert construction may be carried out concurrently with the embankment. If required, the culvert design could include a camber. Should an embankment widening or grade raise be identified at this location, additional analysis will be required to address settlement and stability for the revised embankment geometry and to provide recommendations for possible alternatives for culvert construction to mitigate settlements and improve long-term performance.

At this site, the recommended construction alternative is to remove all organic materials, backfill the sub-excavated area with MTO Special Provision (SP) 110S13 (Aggregates) Granular ‘B’ Type II material and bedding and construct the culvert concurrent with embankment construction.

6.4 Stability, Settlement and Horizontal Strain

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

The analyses assume that all organic soils beneath the culvert alignment will be removed prior to construction as discussed in Section 6.6.1.1 and that granular fill (i.e. SP 110S13 (Aggregates) Granular ‘B’ Type II) will be used for replacement of sub-excavated material. The piezometric conditions required in the analyses were based on the groundwater levels observed during drilling.

6.4.1 Stability

The methodology used to evaluate embankment stability at the culvert location 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 7.13), 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 roadway. 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 location.

6.4.1.2 Parameter Selection

The embankment cross-section modelled in the analyses is assumed to be constructed of granular fill (such as 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 2 m high above the surrounding ground surface.

The subsoils encountered below the culvert alignment are generally composed of cohesive soils underlain by cohesionless soils.

For the cohesive layers, total stress parameters were employed in the analysis. The total stress parameters (i.e. average mobilized undrained shear strength – s_u) for the cohesive soils were assessed based on the results of the in situ field vane tests and estimated from correlations with the SPT results and other laboratory test data. The native clayey silt to clay modelled in the analysis is assumed to have a unit weight of 17 kN/m^3 and undrained shear strength of 30 kPa.

For the cohesionless layers, effective stress parameters were employed in the analyses assuming drained conditions. The native sand and silt to sand modelled in the analyses is assumed to have a unit weight of 20 kN/m^3 and an effective friction angle of 30°.

6.4.1.3 Results of Analysis

The stability analysis performed on the proposed embankment at the culvert location indicates that after completion of construction, the embankment 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.

6.4.2 Settlement

As the existing embankment will not be raised or widened at the location of the culvert replacement, settlement of the foundation soils is not anticipated. Should the embankment require widening or an increase to the grade, settlement analysis will be required and recommendations provided for mitigation as appropriate.

It is recommended that consideration be given to the use of SP 110S13 (Aggregates) Granular 'B' Type I or II for embankment reconstruction at the culvert location. Where granular fill will be placed below the water level, Granular 'B' Type II should be used. The material placed below the water level will compress/settle under its selfweight 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. It is recommended that the fines content of the Granular 'B' Type II fill used for embankment construction be restricted to a maximum of 5 percent passing the No. 200 sieve, to reduce the potential for segregation of fines during placement and to reduce the potential post-construction settlement and associated maintenance needs.

6.4.3 Horizontal Strain

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

6.5 Design Recommendations for Concrete Box Culvert

6.5.1 Geotechnical Resistance

If a concrete box culvert is considered, a factored geotechnical axial resistance at Ultimate Limits States (ULS) of 200 kPa is recommended for design for an assumed 1.4 m wide box culvert founded on a properly prepared subgrade of granular fill overlying the firm clayey silt to clay deposit. The geotechnical resistance given is 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*.

It is noted that at this site, the loading on the foundation soils below the culvert and the associated total settlement at the culvert location will be governed by the design height of the overlying embankment fill. As such, it is recommended that the structural engineer exercise caution when utilizing the value of the geotechnical axial resistance at Serviceability Limit States (SLS) in the design of the culvert and that consideration be given to the sequence and staging of construction. Based on the above, the geotechnical resistance at SLS (for 25 mm settlement) for a 1.4 m wide box culvert constructed on the properly prepared Granular 'B' Type II subgrade overlying the firm clayey silt to clay deposit may be taken as 100 kPa.

6.5.2 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 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 'A' or 'B' Type II	tan δ = 0.45
Cast-in-Place Concrete Box Culvert on Compacted Granular 'A' or 'B' Type II	tan Φ' = 0.58

6.5.3 Lateral Earth Pressures

The lateral earth pressures acting on the side walls of the culvert (head walls and/or wing walls will not be required) 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 culvert walls.

The following recommendations are made concerning the design of the box culvert.

- Select, free draining granular fill meeting the specifications of SP 110S13 (Aggregates) Granular 'A' or Granular 'B' Type II but with less than 5 percent passing the No. 200 (0.075 mm) sieve should be used as backfill behind the culvert. Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS 501 (Compacting). Backfill should be placed with a maximum of 200 mm loose lift thickness. Other aspects of the granular backfill requirements for concrete culverts should be in accordance with OPSD 803.010 (Backfill and Cover for Concrete Culverts).
- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the culvert, in accordance with *CHBDC* Section 6.9.3 and Figure 6.6. Other surcharge loadings should be accounted for in the design, as required.
- For a box culvert, granular fill should be placed in a zone with the width equal to at least 2.0 m behind the back of the culvert (in accordance with Figure C6.20(a) of the *Commentary* to the *CHBDC*).
- For a box culvert, 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 granular fill:

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

If the box culvert design allows for lateral yielding, active earth pressures may be used in the geotechnical design of the structure. If the culvert does 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 a restrained structure, may be taken as presented in Table C6.6 of the *Commentary* to the *CHBDC*.

6.6 Culvert Construction Considerations

6.6.1 Subgrade Preparation and Excavation

The following sections discuss general aspects of subgrade preparation and embankment construction at the culvert, 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 Type 3 soil. In addition, provisions for traffic control measures should be included in the Contract Documents to maintain the safe operation of the existing Highway 11 and any associated side roads or detours during excavation operations, where applicable.

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.

6.6.1.1 Removal of Organics

Based on the information from the boreholes advanced during the field investigation, the thickness of organic deposits (i.e. peat) at the culvert location is up to 0.3 m and underlying up to about 2.3 m of fill. 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 – New Construction).

6.6.1.2 Replacement/Backfill below Base of Culvert

For replacement of sub-excavated material below the water level along the culvert alignment, it is assumed that Granular ‘B’ Type II will be used to backfill the excavation. In addition, in this instance (i.e. typically backfill 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).

6.6.2 Bedding and Backfill above Base of Culvert

The bedding, levelling pad and backfill requirements for a circular concrete pipe culvert should be in accordance with OPSD 802.031 (Rigid Pipe, Bedding Cover and Backfill, Type 3 Soil - Earth Excavation) and culvert construction should be in accordance with OPSS 421 (Pipe Culvert Installation in Open Cut). It is important that the backfill at the haunches be well compacted.

A precast box culvert, if used as an alternative to the circular concrete pipe culvert, should be constructed in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts). The box culvert should be constructed on a minimum 300 mm thick layer of SP 110S13 (Aggregates) Granular ‘B’ Type II material for bedding purposes and partial frost protection.

In dry conditions, the bedding should be placed in lifts not exceeding 200 mm in loose thickness, and compacted to at least 95 percent of the Standard Proctor maximum dry density (SPMDD) of the material as specified in

OPSS 501 (Compaction). Where bedding material is placed in wet conditions, Granular 'B' Type II should be used. The structural design of the culvert should take into consideration the conditions for bedding placement and compaction such that where the invert level is located at or below the groundwater table, the structural design should assume that the bedding material will only achieve 90 percent of the SPMDD during placement.

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.

Inspection should be carried out by qualified geotechnical personnel during all engineered fill placement operations to ensure that appropriate materials are used, and that field density testing be carried out on fills placed above the water level to check that adequate levels of compaction have been achieved.

6.6.3 Erosion Protection

Provision should be made for scour and erosion protection (suitable non-woven geotextiles and/or rip-rap) at the culvert location. In order to prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring) or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a clay seal or concrete cut-off wall should be provided at the upstream end of the culvert. If a clay seal is adopted, the clay material should meet the requirements of OPSS 1205 (Clay Seal), and the seal should be a minimum 1 m thick if constructed of natural clay or soil-bentonite mix and extend from a depth of 1 m below the scour level to a minimum horizontal distance of 2 m on either side of the culvert inlet opening, and a minimum vertical height equivalent to the high water level including along the embankment slope. Alternatively, a 0.6 m thick clay blanket (if constructed of natural clay or a soil-bentonite mix) may be constructed, extending upstream three (3) times the culvert height and along the adjacent slopes to a height of two (2) times the culvert height or the high water level, whichever is greater.

The requirements for and design of erosion protection measures for the inlet and outlet of the culvert should be assessed by the hydraulics design engineer. As a minimum, rip-rap treatment for the outlet of the culvert should be consistent with the standard presented in OPSD 810.010 (Rip-Rap Treatment for Sewer and Culvert Outlets). Erosion protection for the inlet of the culverts should follow the standard presented in OPSD 810.010 similar to the outlet but with the rip-rap placed up to the toe of slope level, in combination with the cut-off measures noted above. Similarly, rip-rap should be provided over the full extent of the clay blanket, including the creek side slopes and fill slope over the culvert.

6.6.4 Control of Groundwater and Surface Water

Excavation within the plan limits of the proposed culvert alignment will be required to remove organic and/or soft deposits prior to placement of backfill/embankment fill, bedding material and the actual culvert structure. Creek/ditch flows via the culvert at the time of construction of the replacement culvert will need to be diverted/piped away from the excavation area during the construction period. As a result of the excavation, groundwater flow into the excavation can be expected to occur due to the relatively permeable subsoils and high groundwater levels observed at the culvert location. A precast concrete circular pipe culvert can be placed and the associated bedding materials constructed 'in-the-wet' and, as such, control of surface water and groundwater would not be required at this culvert location under such conditions.

6.6.5 Analytical Testing for Construction Materials

The analytical test results on a sample of creek water taken adjacent to the culvert site are presented in Table B-1. The suite of parameters tested is intended to allow the structural engineer to assess the requirements for the appropriate type of cement to be used in construction and the need for corrosion protection.

7.0 CLOSURE

This report was prepared by Mr. André Bom, P.Eng., a geotechnical engineer with Golder. 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 an independent 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

AB/JMAC/lb

n:\active\2009\1190 sudbury\1191\09-1191-0042 urs hwy 11 culverts powassan\reporting\final\r03 - nbl 12+824\09-1191-0042-r03 final rpt 11nov17 hwy 11 nbl 12824.docx

REFERENCES

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 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.

STANDARDS:

ASTM International:

ASTM D1586-08a	Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils
ASTM D2573-08	Standard Test Method for Field Vane Shear Test in Cohesive Soil

Contract Design Estimating and Documentation (CDED):

Special Provision 110S13	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material. Amendment to OPSS 1010. May 2010.

Ontario Occupational Health and Safety Act:

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

Ontario Provincial Standard Drawing:

OPSD 203.010	Embankments Over Swamp – New Construction.
OPSD 802.031	Rigid Pipe Bedding, Cover and Backfill Type 3 Soil - Earth Excavation.
OPSD 803.010	Backfill and Cover for Concrete Culverts With Spans less than or equal to 3.0 m.
OPSD 810.010	Rip-Rap Treatment for Sewer and Culvert Outlets.

Ontario Provincial Standard Specification:

OPSS 209	Construction Specification for Embankments Over Swamps and Compressible Soils.
OPSS 421	Construction Specification For Pipe Culvert Installation In Open Cut.
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.
OPSS 1002	Material Specification for Aggregates – Concrete.
OPSS 1205	Material Specification for Clay Seal.

Ontario Water Resources Act:

Ontario Regulation 372/97	Amendment to Ontario Regulation 903

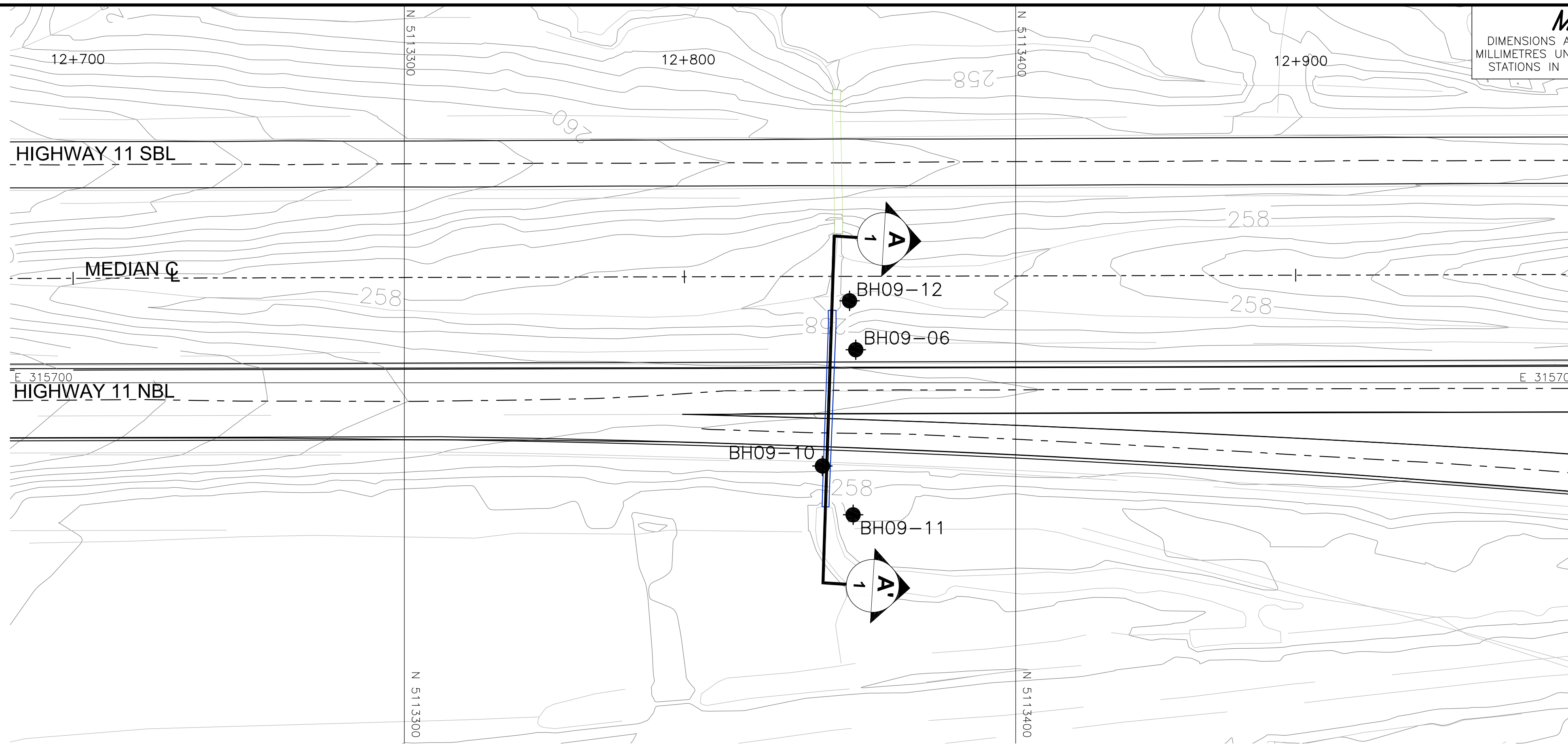
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5416-06-00

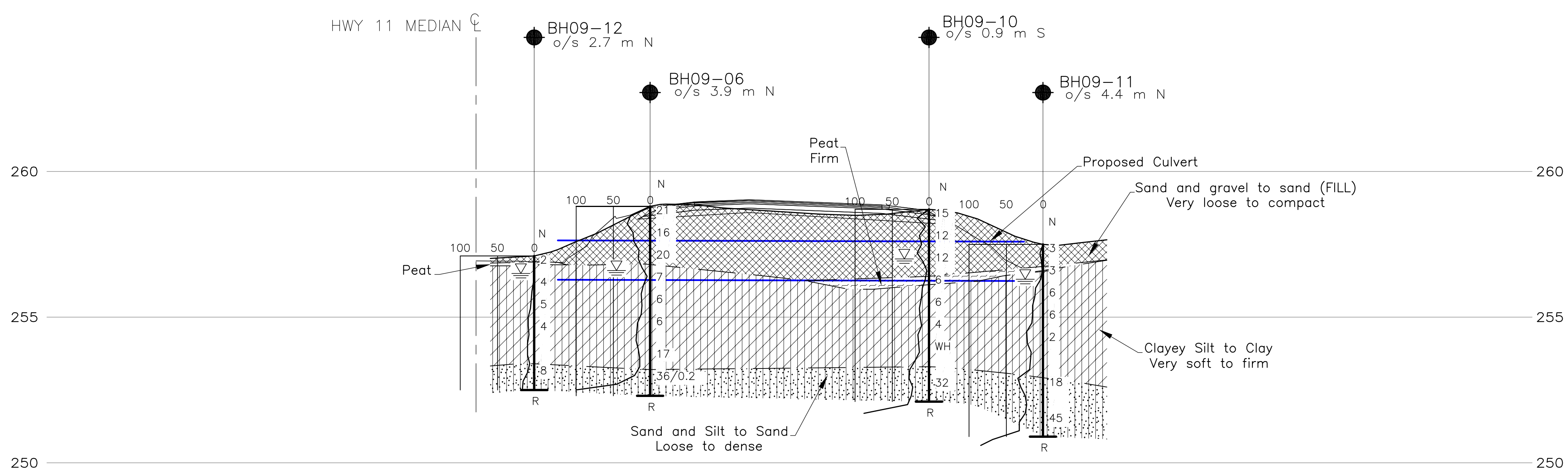
SHEET

HIGHWAY 11
CULVERT AT STA 12+824 NBL
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates
Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA

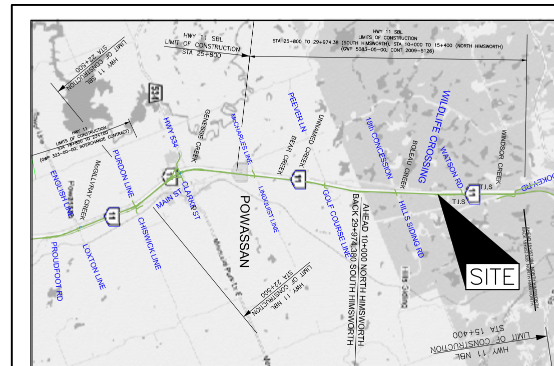


PLAN
SCALE
10 0 10 20 m



A–A' 1 CULVERT PROFILE STA. 12+824 (NBL)
HIGHWAY 11

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

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
BH09–06	258.8	5113373.8	315694.6
BH09–10	258.7	5113368.4	315713.6
BH09–11	257.5	5113373.4	315721.6
BH09–12	257.1	5113372.8	315686.6

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 received June 04, 2010, Keyplan received June 03, 2011.

LICENSED PROFESSIONAL ENGINEER A.J.K. BOM 100075715 NOV 17, 2011 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER J.M.A.COSTA NOV 17, 2011 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 31L–144

HWY. 11	PROJECT NO. 09–1191–0042		DIST.
SUBM'D. LG	CHKD. AB	DATE: NOV 2011	SITE:
DRAWN: JJL	CHKD.	APPD. JMAC	DWG. 1

APPENDIX A

Record of Boreholes

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
v	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 ($\gamma' = \gamma$-γ_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 δ
c′	effective cohesion
c_u, s_u	undrained shear strength (ϕ = 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	Sand and Gravel
	With (cohesive)	Silty Clay with sand / Clayey Silt with sand

Golder Associates

RECORD OF BOREHOLE No BH09-06

 METRIC

PROJECT 09-1191-0042

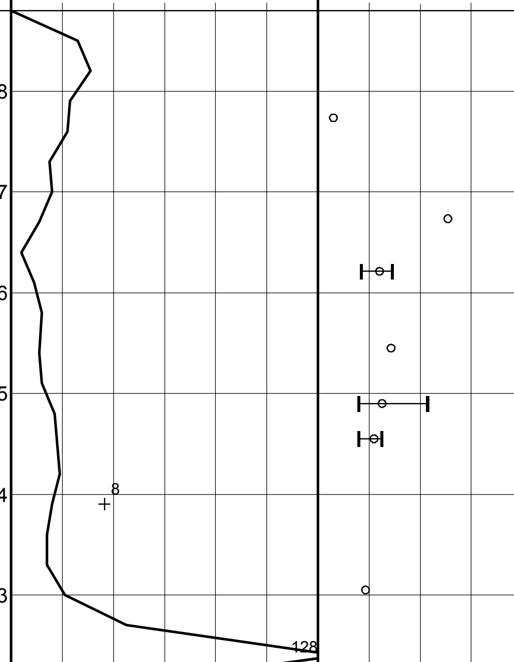
W.P. 5416-06-00 LOCATION N 5113373.8; E 315694.6 ORIGINATED BY EHS

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

DATUM Geodetic DATE May 7, 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
258.8	GROUND SURFACE					
0.0	Sand and gravel to sand, trace to some silt (FILL) Compact Brown Moist	1	SS	21		
		2	SS	16		5 83 (12)
		3a	SS	20		
256.8 / 2.0	CLAYEY SILT to SILTY CLAY, trace sand Firm Brown to grey Wet	3b			∇	
		4	SS	7		
	Trace organics to 3.2 m depth	5	SS	6		
		6a / 6b	SS	6		
		7a	SS	17		
253.2 / 5.6	SAND and SILT to SAND, some gravel, trace to some clay Dense Grey Wet	7b				12 50 31 7
		8	SS	36/0.2		
252.3 / 6.5	END OF BOREHOLE SPOON AND AUGER REFUSAL					

DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20 40 60 80 100); ELEVATION SCALE 258–253



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 2.2 m below ground surface (Elev. 256.6 m) upon completion of drilling.

2. Advanced DCPT 1 m north of Borehole BH09-06. Refusal at a depth of 6.5 m (hammer bouncing) below ground surface (Elev. 252.3 m).

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

Golder Associates

RECORD OF BOREHOLE No BH09-10

 METRIC

PROJECT 09-1191-0042 | LOCATION N 5113368.4; E 315713.6 | ORIGINATED BY ID

W.P. 5416-06-00 | BOREHOLE TYPE 108 mm I.D. Continous Flight, Hollow Stem Augers | COMPILED BY LG

DIST ___ HWY 11 | DATE May 12. 2010 | CHECKED BY AB

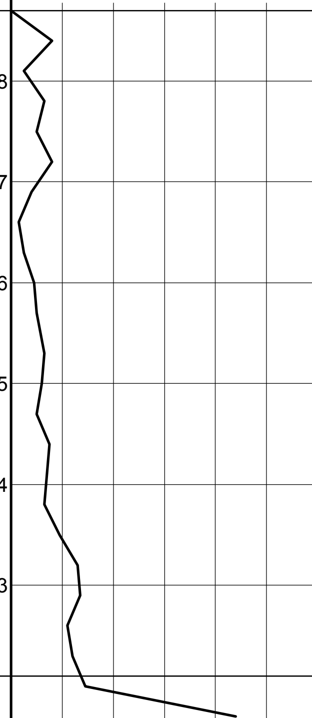
DATUM Geodetic

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT	UNIT WEIGHT	GR SA SI CL
258.7	GROUND SURFACE								
0.0	Sand and gravel to sand, some gravel, trace to some silt (FILL) Compact Brown to grey Moist to wet	1	SS	15					
		2	SS	12		258	o		
		3	SS	12	▽	257			
256.4 / 256.1	PEAT (Fibrous) Firm Black Wet	4a	SS	6					
2.6	CLAYEY SILT to CLAY Very soft to firm Brown and grey Wet	4b				256	o	OC=2.5%	
	Trace organics in upper 0.4 m.	5	SS	6			⊢o⊣		0 5 60 35
		6	SS	4		255	⊢o⊣		
	Could not push vane to 5.4 m depth.	7	SS	WH		254	⊢—o⊣		
253.3 / 5.4	SAND, some gravel Dense Grey Wet					253			
252.1		8	SS	32					
6.6	END OF BOREHOLE SPOON AND AUGER REFUSAL								

Notes:

1. Water level at a depth of 1.7 m below ground surface (Elev. 257.0 m) upon completion of drilling.

2. Advanced DCPT 1 m north of Borehole BH09-10. Refusal at a depth of 7.0 m (hammer bouncing) below ground surface (Elev. 251.7 m).



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

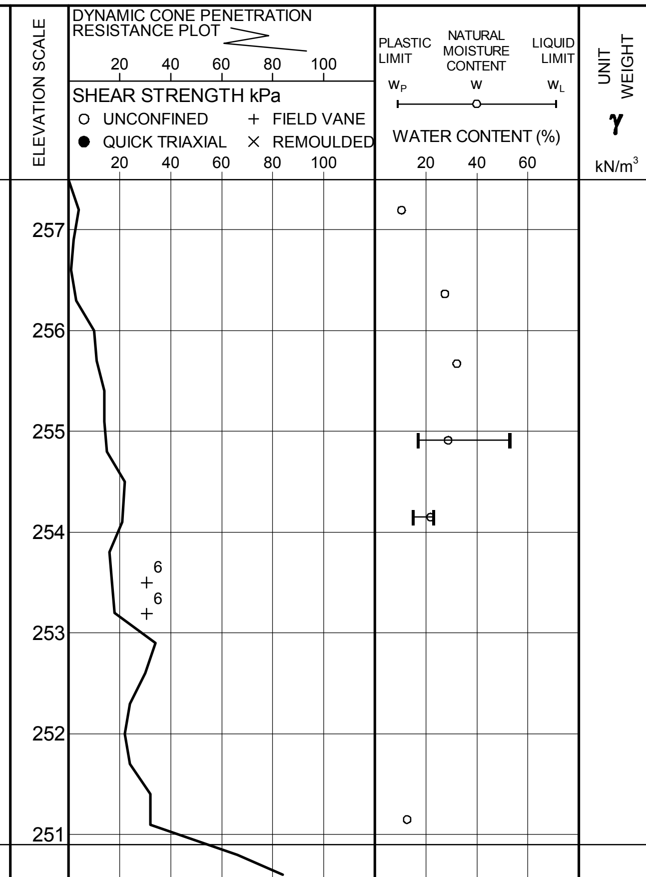
Golder Associates

RECORD OF BOREHOLE No BH09-11

 METRIC

PROJECT 09-1191-0042
W.P. 5416-06-00
LOCATION N 5113373.4; E 315721.6
ORIGINATED BY ID
DIST HWY 11
BOREHOLE TYPE 108 mm I.D. Continous Flight, Hollow Stem Augers
COMPILED BY LG
DATUM Geodetic
DATE May 12. 2010
CHECKED BY AB

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
257.5	GROUND SURFACE					
0.0	Sand, some gravel, trace to some silt (FILL) Very loose Brown Moist	1	SS	3		18 73 (9)
256.7 / 0.9	PEAT (Fibrous) Black Moist	2a				
	CLAYEY SILT to CLAY, trace to some sand Firm Brown to grey Wet. Trace organics in upper 0.6 m.	2b	SS	3	∇	0 8 69 23
		3	SS	6		
		4	SS	6		0 6 39 55
		5	SS	2		
252.9 / 4.6	SAND, some silt, some gravel, trace clay Compact to dense Grey Wet	6	SS	18		
		7	SS	45		16 61 (23)
250.9 / 6.6	END OF BOREHOLE SPOON AND AUGER REFUSAL					



Notes:

1. Water level at a depth of 1.2 m below ground surface (Elev. 256.3 m) upon completion of drilling.

2. Advanced DCPT 1 m north of Borehole BH09-11. Refusal at a depth of 6.9 m (hammer bouncing) below ground surface (Elev. 250.6 m).

3. Borehole advanced on north side of creek; water surface at Elev. 257.0 m. Creek bed measured at about 0.6 m below water surface and probed to fim bottom at about 0.8 m below water surface.

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

SUD-MTO 001 09-1191-0042-4000.GPJ GAL-MISS.GDT 16/11/11 DATA INPUT:

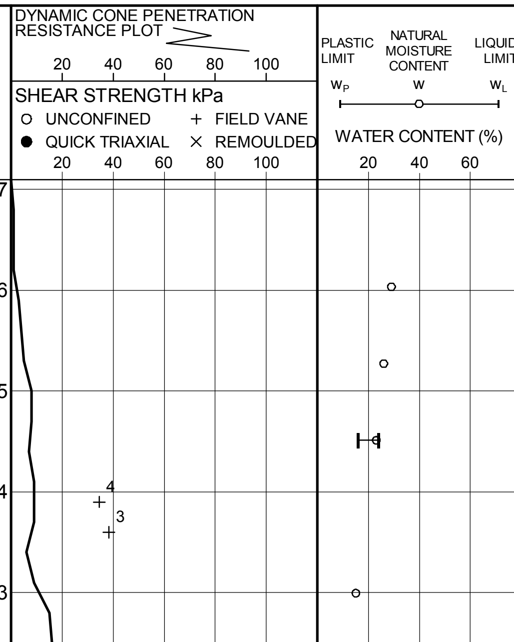
Golder Associates

RECORD OF BOREHOLE No BH09-12

 METRIC

PROJECT 09-1191-0042
W.P. 5416-06-00
DIST
HWY 11
DATUM Geodetic
LOCATION N 5113372.8; E 315686.6
BOREHOLE TYPE 108 mm I.D. Continous Flight, Hollow Stem Augers
DATE May 13, 2010
ORIGINATED BY ID
COMPILED BY LG
CHECKED BY AB

ELEV DEPTH	SOIL PROFILE DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
257.1	GROUND SURFACE					257		
0.0	Gravelly sand mixed with topsoil and roots (FILL) Brown Moist	1	SS	2	▽			
0.3	PEAT (Fibrous) Black Moist	2	SS	4		256		0 5 66 29
	CLAYEY SILT to SILTY CLAY, trace sand Firm Brown to grey Wet Trace organics to 1.5 m depth	3	SS	5		255		
		4	SS	4		254		
253.4 3.7	SAND, some gravel, some silt Loose Grey Wet	5	SS	8		253		
252.5 4.6	END OF BOREHOLE AUGER REFUSAL							



Notes:

1. Water level at a depth of 0.6 m below ground surface (Elev. 256.5 m) upon completion of drilling.

2. Advanced DCPT 1 m south of Borehole BH09-12. Refusal at a depth of 4.6 m (hammer bouncing) below ground surface (Elev. 252.5 m).

3. Borehole advanced on north side of creek; water surface at Elev. 257.0 m. Creek bed measured at about 0.5 m below water surface and probed to fim bottom at about 0.7 m below water surface.

UNIT WEIGHT γ kN/m³

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

APPENDIX B

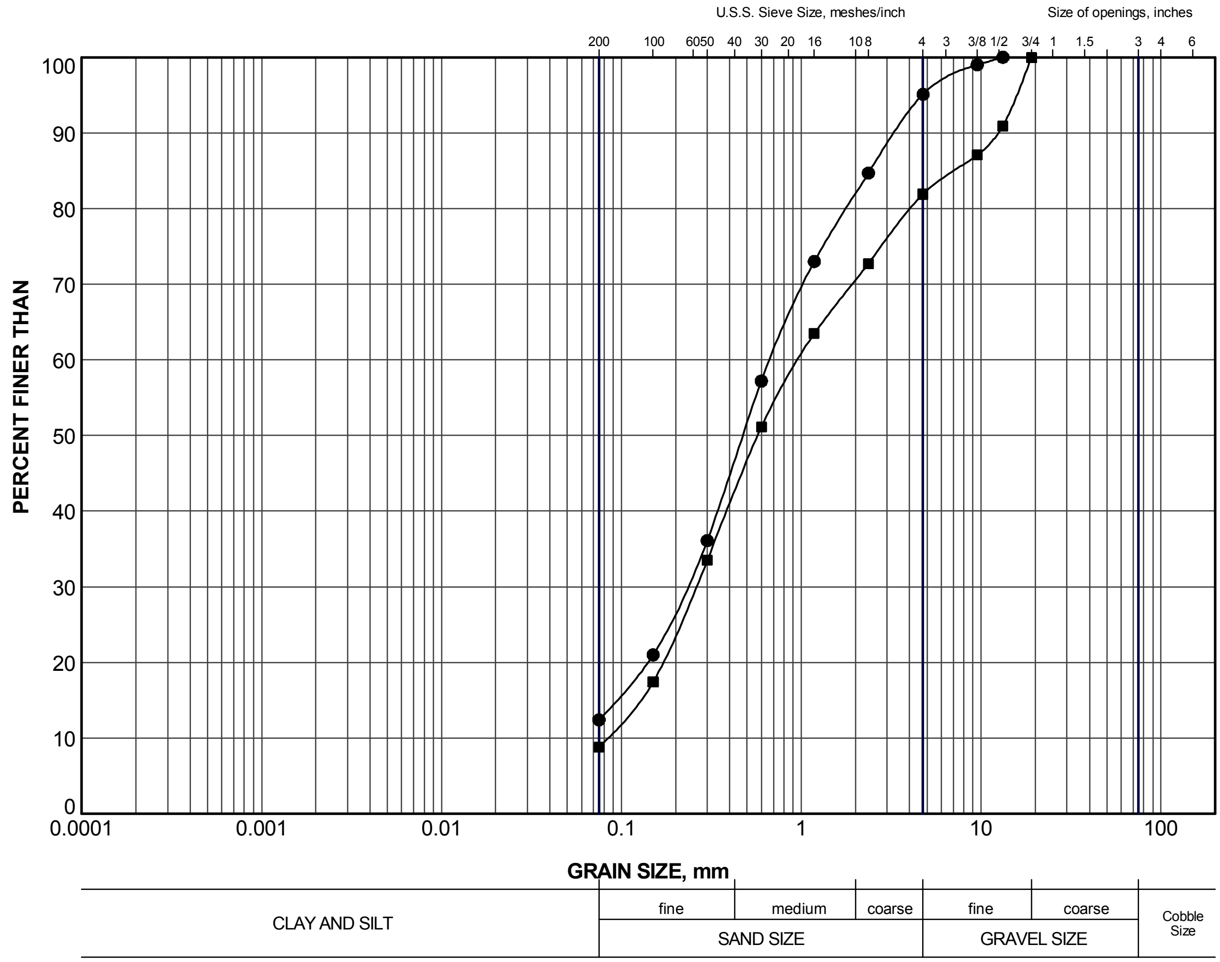
Laboratory Test Results

Table B-1 - Summary of Analytical Testing of Creek Water

Parameter	Units	Method Detection Limit	Result
Chloride	mg/L	0.2	177
Sulphate	mg/L	1	1.7
Conductivity	µS/cm	1	603
Resistivity	Mohm-cm	n/a	0.00166
pH	n/a	n/a	7.04

Notes: 1. Samples obtained May 17, 2010.
2. Analytical testing carried out by Testmark Laboratory Ltd.

Compiled by: AB
Checked by: LG



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH09-06	2	257.7
■	BH09-11	1	257.2

PROJECT

HIGHWAY 11 NBL CULVERT 12+824

TITLE

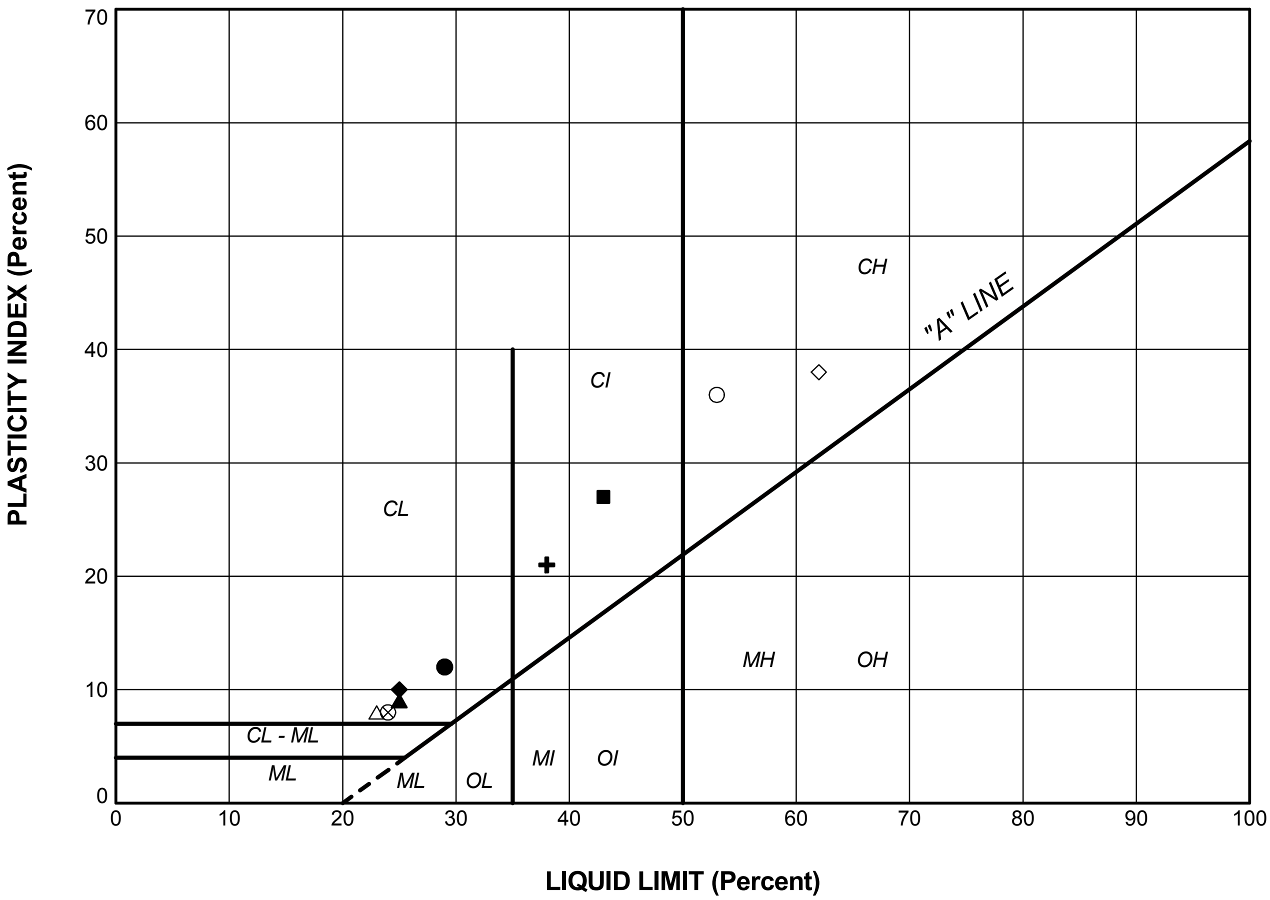
GRAIN SIZE DISTRIBUTION

SAND (FILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		09-1191-0042	FILE No. 09-1191-0042-4000.GPJ	
DRAWN	JJL	Nov 2011	SCALE N/A	REV.
CHECK	AB	Nov 2011	**FIGURE B-1**	
APPR	JMAC	Nov 2011		

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
●	BH09-06	4	29.0	17.0	12.0
■	BH09-06	6a	43.0	16.0	27.0
▲	BH09-06	6b	25.0	16.0	9.0
✚	BH09-10	5	38.0	17.0	21.0
◆	BH09-10	6	25.0	15.0	10.0
◇	BH09-10	7	62.0	24.0	38.0
○	BH09-11	4	53.0	17.0	36.0
△	BH09-11	5	23.0	15.0	8.0
⊗	BH09-12	4	24.0	16.0	8.0

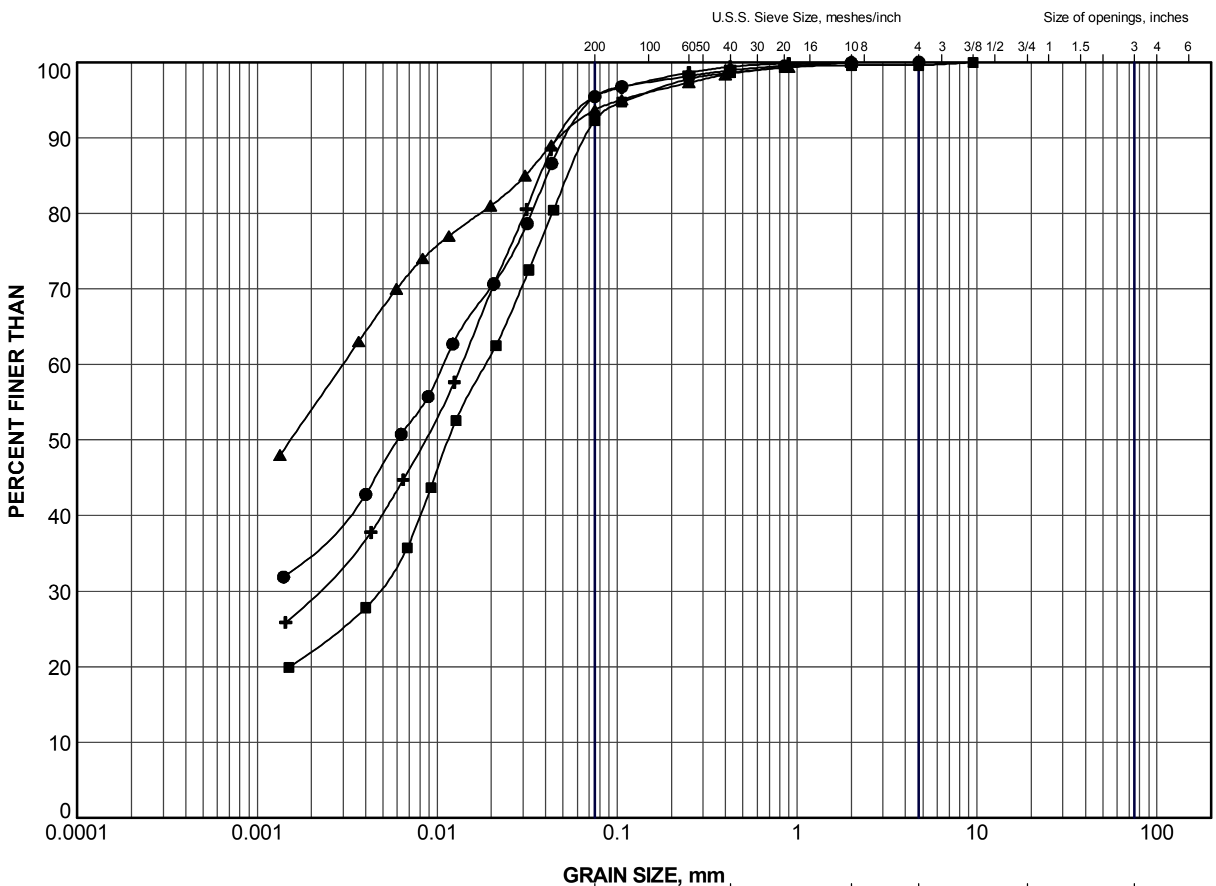
PROJECT
HIGHWAY 11 NBL CULVERT 12+824

TITLE
PLASTICITY CHART
CLAYEY SITL TO CLAY

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	09-1191-0042		FILE No.	09-1191-0042-4000.GPJ
DRAWN	JJL	Nov 2011	SCALE N/A	REV.
CHECK	AB	Nov 2011		
APPR	JMAC	Nov 2011	**FIGURE B-2**	

MTO_PI GLDR_LDN.GDT



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH09-10	5	255.4
■	BH09-11	2b	256.4
▲	BH09-11	4	254.9
✚	BH09-12	2	256.0

PROJECT

HIGHWAY 11 NBL CULVERT 12+824

TITLE

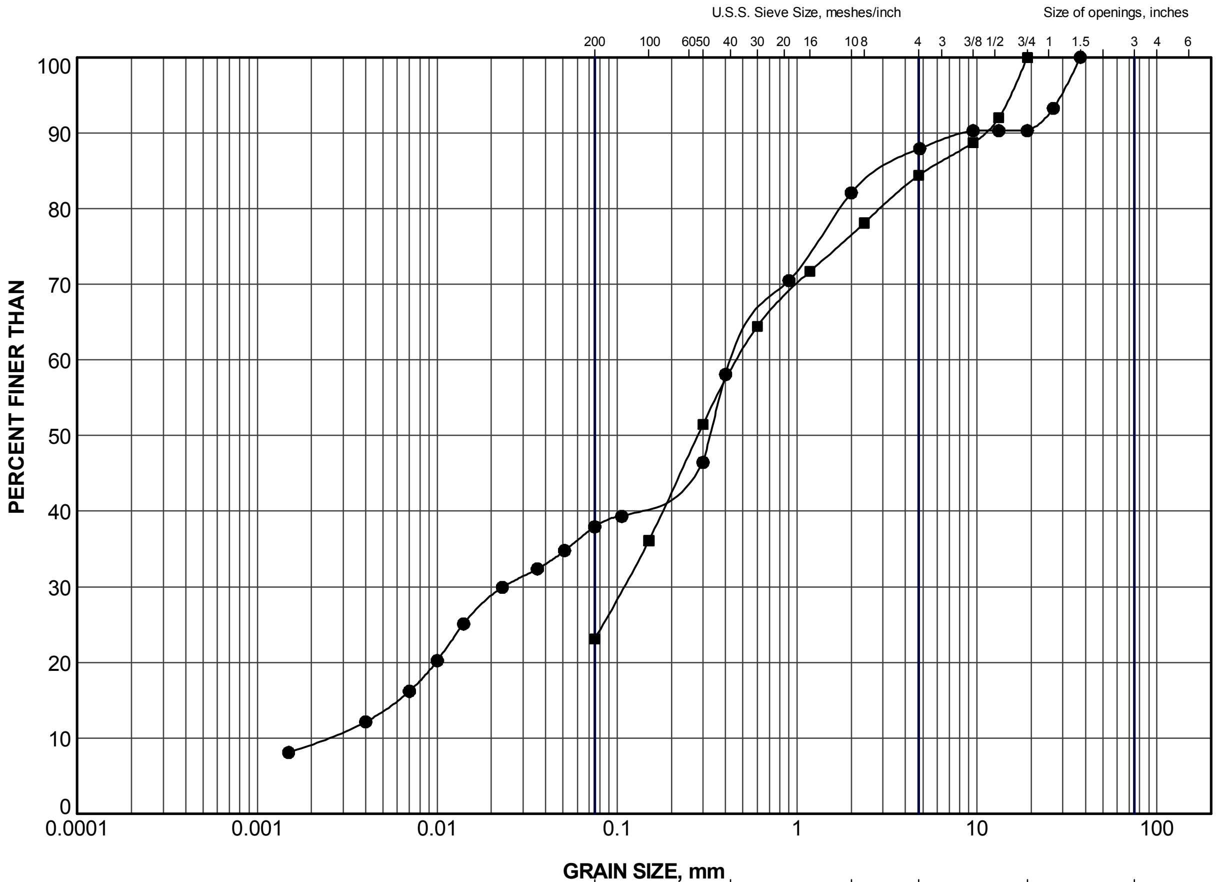
GRAIN SIZE DISTRIBUTION

CLAYEY SILT TO CLAY

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		09-1191-0042	FILE No. 09-1191-0042-4000.GPJ	
DRAWN	JJL	Nov 2011	SCALE N/A	REV.
CHECK	AB	Nov 2011	**FIGURE B-3**	
APPR	JMAC	Nov 2011		

LDN_MTO_NEW GLDR_LDN.GDT



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH09-06	7b	253.1
■	BH09-11	7	251.2

PROJECT

HIGHWAY 11 NBL CULVERT 12+824

TITLE

GRAIN SIZE DISTRIBUTION

SAND AND SILT TO SAND

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		09-1191-0042
DRAWN	JJL	Nov 2011
CHECK	AB	Nov 2011
APPR	JMAC	Nov 2011

FILE No. 09-1191-0042-4000.GPJ

SCALE N/A | REV.

FIGURE B-4

LDN_MTO_NEW GLDR_LDN.GDT

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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

Golder Associates