



September 2011

DRAFT FOUNDATION INVESTIGATION AND DESIGN REPORT

**HYDRO TOWERS AND RETAINING WALL
HIGHWAY 404 EXTENSION FROM QUEENSVILLE
SIDEROAD TO RAVENSHOE ROAD
TOWN OF EAST GWILLIMBURY
MINISTRY OF TRANSPORTATION, ONTARIO
W.P 2005-07-00**

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DRAFT REPORT



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PART A

**DRAFT FOUNDATION INVESTIGATION REPORT
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the proposed new hydro towers and associated retaining wall structure required as part of the relocation of two existing hydro towers located on the proposed alignment of Highway 404 (about 500 m north of Holborn Road) as part of the Highway 404 Extension project in the Town of East Gwillimbury, Ontario.

The requirements for the subsurface investigation for the hydro towers are presented in Hydro One's "Technical Specification for Geotechnical Investigation" document, provided to us on December 3, 2010. The scope of work addressing Hydro One's Terms of Reference for this specific assignment is outlined in our letter to AECOM entitled "Addendum No. 2, Foundation Engineering Services for Relocation of Hydro Towers, Hwy 404 Extension from Queensville Sideroad to Ravenshoe Road, MTO, W.P. 2005-07-00", dated December 13, 2010.

The purpose of this investigation is to establish the subsurface soil and shallow groundwater conditions at the proposed hydro towers and retaining wall sites by borehole drilling, in situ testing and laboratory testing on selected samples.

2.0 SITE DESCRIPTION

The site of the proposed hydro towers and retaining wall structure is located approximately 1 km west of Woodbine Avenue and 500 m north of Holborn Road in the Town of East Gwillimbury in the Region of York (see key plan on Drawing 1). The two existing hydro towers (located in the median of the proposed Highway 404 extension) are to be removed and replaced with two sets of hydro towers west and east of the current location as shown on Drawing 1. A retaining wall is also proposed to separate the hydro tower platform grade and the Highway 404 NBL grade (to be constructed in cut) on the east side of the Highway from about Station 35+415 to 35+515.

The overall surface topography in the area of the proposed hydro towers and retaining wall is generally gently sloping, with rolling hills present through the area. The site is currently an open field and slopes downward from the south-east to the north-west. The existing ground surface in the immediate vicinity of the proposed structures varies from about Elevation 255 m to 249 m. Two sets of high voltage transmission lines currently cross the site at about Station 35+425.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the current investigation was carried out between December 20 and 22, 2010, at which time five boreholes (Borehole 1 to 5) were advanced at the locations shown on Drawing 1.

The field investigation was carried out using a track-mounted drill rig supplied and operated by Walker Drilling Ltd. of Utopia, Ontario. The boreholes were advanced using 108 mm inner diameter hollow stem augers and 108 mm outer diameter solid stem augers. Soil samples were obtained at 0.75 m and 1.5 m intervals of depth using 50 mm outside diameter split-spoon samplers driven by an automatic hammer in accordance with the Standard Penetration Test (SPT) (ASTM D1586) procedure.

The groundwater conditions in the open boreholes were observed throughout the drilling operations and piezometers were installed in Boreholes 1 and 5 to monitor the groundwater level at the site. The piezometers consist of 50 mm diameter PVC pipe, with a slotted screen sealed at a select depth within the borehole. The



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open boreholes and the annulus surrounding the piezometer pipe above the sand pack were backfilled to the ground surface with bentonite pellets in accordance with Ontario Regulation (O.Reg.) 903 as amended by O.Reg. 372/07. The piezometer installation details and water level readings are described on the Record of Borehole sheets in Appendix A.

The field work was monitored on a full-time basis by a member of Golder's engineering staff who arranged for service clearances, supervised the drilling, sampling and in-situ testing operations, logged the boreholes and examined and cared for the soil samples. The soil samples were identified in the field, placed in labelled containers and transported to Golder's laboratory in Mississauga for further examination and 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 select soil samples and the results of the Atterberg limits and grain size distribution tests are presented in Appendix B. Environmental testing (according to Ontario Regulation 153 – Metals and Inorganics) was carried out on select soil samples as per Hydro One requirements. The results of the geo-environmental testing are presented in Appendix C together with the Chain of Custody documentation.

Boreholes 1, 3, 4, and 5 were advanced in the vicinity of the proposed hydro towers and retaining walls located on the east side of the proposed Highway 404 NBL roadway alignment. Borehole 2 was advanced in the vicinity of the hydro towers located on the west side of the proposed Highway 404 SBL alignment. The borehole locations were measured and staked in the field by Golder relative to on-site features (i.e. the existing hydro towers). The ground surface elevations and coordinates were determined from the digital terrain model (DTM) for the project provided by AECOM. The approximate as-drilled borehole locations (referenced to MTM NAD83 co-ordinate system) and ground surface elevations (referenced to Geodetic datum) are summarized below.

Borehole	Location (MTM NAD 83)		Ground Elevation (m)	Depth Drilled (m)
	Northing	Easting		
1	4891446.1	309297.6	254.8	10.8
2	4891441.9	309216.6	249.5	15.8
3	4891494.5	309283.2	252.5	9.2
4	4891504.8	309279.4	252.0	9.8
5	4891545.2	309270.6	251.6	9.6



4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

The study area for this investigation lies within or near two physiographic regions, delineated in *The Physiography of Southern Ontario*¹ as:

- Simcoe Lowlands; and
- Peterborough Drumlin Field

The surficial soils in the Simcoe Lowlands, to the south and southeast of Lake Simcoe, consist of sands, silts and clays that were deposited within a former glacial lake. It is noted that several areas of drumlinized till break the continuity of the Simcoe Lowlands plain.

The surficial soils in the Peterborough Drumlin Field consist of sandy drumlinized till. Some of the drumlins in this area have shallow coverings of silt and fine sand of thickness between about 0.5 m and 2.5 m. "Wave-washed" drumlins, with exposed bouldery surfaces, are also present near the Simcoe Lowlands immediately south and east of Lake Simcoe. Localized deposits of silt, clay and peat are found in the low-lying areas between drumlins.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of the in-situ and laboratory tests are given on the Record of Borehole sheets and laboratory test plots provided in Appendices A and B, respectively. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling, observations of drilling progress and the results of Standard Penetration Tests (SPTs). These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Subsoil conditions will vary between and beyond the borehole locations.

In summary, the subsoil conditions encountered at the site generally consist of a surficial layer of topsoil or slightly organic clayey silt underlain by an interlayered sequence of sand and silt till and clayey silt till, sandy silt, sand and gravel, silty sand, sand, clayey silt and silt deposits.

A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Topsoil and Slightly Organic Clayey Silt

Topsoil or slightly organic clayey silt deposits, trace to some sand, trace gravel and containing rootlets throughout were encountered at the existing ground surface in all Boreholes (1 to 5). The thickness of the topsoil and slightly organic clayey silt layers vary between 0.3 m and 0.7 m.

Standard Penetration Test (SPT) 'N' values recorded within the topsoil or slightly organic clayey silt layers range between 4 and 11 blows per 0.3 m of penetration suggesting a soft to stiff consistency. The investigation was performed during the winter months during which time the topsoil and near surface soils may have been frozen, therefore, the SPT "N" values may not be representative of thawed conditions.

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



The measured water content on three samples of this layer range from 14 percent to 22 percent.

4.2.2 Sand and Silt to Silt and Sand Till

Underlying the topsoil or slightly organic clayey silt layers, Boreholes 1, 4 and 5 encountered a stratum of sand and silt to silt and sand till at between 0.3 m and 0.7 m below ground surface corresponding to between Elevation 254.1 m and 251.3 m. In Boreholes 2 and 3, the silt and sand till stratum was encountered underlying a clayey silt till stratum and a sandy silt stratum, respectively, at 4.1 m and 1.5 m below ground surface, corresponding to Elevation 245.4 m and Elevation 251.0 m, respectively. The sand and silt to silt and sand till deposit typically contains trace to some gravel and is between 0.8 m and 1.7 m thick.

Standard Penetration Test (SPT) 'N'- values recorded within the sand and silt to silt and sand till deposit range between 18 and 71 blows per 0.3 m of penetration, with one 'N'- value of 102 blows per 0.08 m of penetration suggesting a compact to very dense relative density.

The results of four grain size distribution tests performed on samples of the sand and silt to silt and sand till deposit are shown on Figure 1. Atterberg limit testing carried out on two samples of the sand and silt till stratum measured plastic limits of 12 per cent and liquid limits of 16 and 19 per cent, with corresponding plasticity indices of 4 and 7 per cent. These test results, which are plotted on a plasticity chart on Figure 2, indicate that the fine material of this deposit is silt of low plasticity. The measured water content on samples of the sand and silt to silt and sand till deposit range from 8 percent to 13 percent.

4.2.3 Sandy Silt to Gravelly Sandy Silt

A stratum of sandy silt to silty sand, trace clay, trace gravel to gravelly sandy silt was encountered underlying the topsoil and slightly organic clayey silt layers in Boreholes 2 and 3 and below the sand and silt till deposit in Borehole 1. The thickness of the sandy silt stratum ranges from 0.8 m to 2.5 m thick and the surface of the layer was encountered at a depth between 0.5 m and 1.5 m below ground surface corresponding to between Elevation 249.0 m and Elevation 253.3 m. In Borehole 2, the sandy silt layer contained rootlets, zones of oxidation staining and clayey silt interlayers.

Standard Penetration Test (SPT) 'N'- values measured within the sandy silt range between 17 and 37 blows per 0.3 m of penetration, indicating a compact to dense relative density. One SPT 'N'- value of 100 blows per 0.1 m of penetration was measured at the bottom of the stratum in Borehole 1.

The results of two grain size distribution tests on samples of the sandy silt to gravelly sandy silt deposits are shown on Figure 3. The higher clay content in the sample from Borehole 2 (Sample 3) is due to the presence of clayey silt interlayers, whereas the gap-graded nature of the results from Borehole 1 (Sample 4) is due to the presence of gravel in the sample.

The measured water content on three samples of the sandy silt deposit range from 9 to 18 percent.

4.2.4 Clayey Silt Till

A clayey silt till stratum was encountered underlying the sandy silt in Borehole 2. The surface of the till was encountered at a depth of 2.6 m below ground surface corresponding to Elevation 246.9 m and the stratum is 1.5 m thick.



The SPT 'N'- values recorded within the clayey silt till are 13 and 17 blows per 0.3 m of penetration, suggesting a stiff to very stiff consistency.

The measured water content on one sample of the clayey silt till deposit is 27 percent.

4.2.5 Sand and Gravel

A deposit of sand and gravel was encountered underlying the gravelly sandy silt layer in Borehole 1. The surface of the sand and gravel deposit was encountered at a depth of 4.0 m below ground surface corresponding to Elevation 250.8 m and the borehole was terminated within the deposit after penetrating 6.8 m into the deposit. A 2.5 m thick interlayer of silty sand was encountered within the sand and gravel deposit at a depth of 7.3 m below ground surface corresponding to Elevation 247.5 m.

Standard Penetration Test (SPT) 'N' values measured within the sand and gravel deposit were greater than 100 blows per 0.3 m of penetration, indicating a very dense relative density.

The result of one grain size distribution test performed on a sample of the sand and gravel is shown on Figure 4.

The measured water content on one sample of this deposit was 5 percent.

4.2.6 Sand to Silty Sand

A deposit of sand to silty sand was encountered within the sand and gravel layer in Borehole 1, underlying the silt and sand till in Boreholes 3 and 4 and underlying the sand and silt till in Borehole 5. The surface of the deposit was encountered at between 2.0 m and 7.3 m below ground surface, corresponding to Elevations 249.6 m and 247.5 m, respectively, and the deposit is between 2.1 m and 3.0 m thick. In Borehole 4, the deposit contains silt interlayers.

Standard Penetration Test (SPT) 'N' values recorded within the sand to silty sand deposit range from 66 to greater than 100 blows per 0.3 m of penetration, indicating a very dense relative density.

The result of a grain size distribution test performed on a sample of the sand deposit is shown on Figure 5.

The natural water content measured on two samples of this deposit were 3 and 17 percent.

4.2.7 Silt

A deposit of silt was encountered underlying the silty sand stratum in Boreholes 3 and 4 at Elevation 245.6 m and 246.6 m, respectively. The silt deposit is 1.6 m thick in Borehole 4, and Borehole 3 was terminated within the silt deposit at a depth of 9.2 m below ground surface corresponding to Elevation 243.3 m, after penetrating 2.3 m into the deposit.

Standard Penetration Test (SPT) 'N' values measured within the silt deposit are 50 and 55 blows per 0.08 m of penetration, indicating a very dense relative density.

The results of two grain size distribution tests performed on samples of the silt deposit are shown on Figure 6.

The measured water content on three samples of this deposit range from 19 percent to 20 percent.



4.2.8 Clayey Silt

A stratum of clayey silt was encountered underlying the silt and sand till stratum in Borehole 2, the silt deposit in Borehole 4 and the sand deposit in Borehole 5. The clayey silt deposit contains silty clay interlayers and in Borehole 2, a 1.1 m thick interlayer of sand and gravel, trace clay was encountered within the clayey silt deposit at Elevation 234.9 m. The surface of this deposit was encountered at between Elevation 247.5 m and 244.1 m and the boreholes terminated within the deposit at depths ranging from 9.6 m to 15.8 m below existing ground surface after penetrating between 2.8 m and 10.4 m into the deposit.

Standard Penetration Test (SPT) 'N' values measured within the clayey silt deposit range between 39 and greater than 100 blows per 0.3 m of penetration, suggesting a hard consistency.

The results of three grain size distribution tests performed on samples of the clayey silt deposit are shown on Figure 7.

Atterberg limits testing was carried out on five samples of the clayey silt deposit and measured plastic limits between 15 and 17 per cent, liquid limits between 22 and 32 per cent, with corresponding plasticity indices between 6 and 16 per cent. These test results, which are plotted on a plasticity chart on Figure 8, confirm that the material is a clayey silt of low plasticity.

The measured water content on seven samples of the clayey silt deposit range from 18 percent to 31 percent.

4.2.9 Groundwater Conditions

Water levels were noted in the boreholes during and shortly after the drilling operations. Piezometers were installed in Boreholes 1 and 5 to permit monitoring of the groundwater level. Details of the piezometer installations are shown on the Record of Borehole sheets in Appendix A. The water levels recorded in the boreholes and piezometers are summarized below:

Borehole No.	Ground Surface Elevation (m)	Groundwater Elevation (m)	Date of Measurement	Notes
BH 1	254.8	248.2	December 22, 2010	Piezometer
BH 2	249.5	236.7	December 20, 2010	Open Borehole
BH 3	252.5	245.9	December 21, 2010	Open Borehole
BH 4	252.0	246.2	December 22, 2010	Open Borehole
BH 5	251.6	Dry	December 22, 2010	Piezometer

The water levels do not represent stabilized groundwater conditions. An attempt to obtain stabilized water levels was made on January 17, 2011, however permission to enter the private property was denied by the property owner.

It should also be noted that groundwater levels are expected to fluctuate seasonally and are expected to rise during wet periods of the year.



4.2.10 Chemical Analysis of Soil Samples

As a part of the Hydro One requirements, environmental testing was performed on three soil samples obtained in Boreholes 1, 2 and 5 at depths ranging from 0.8 m to 2.4 m below ground surface. The samples were collected during the geotechnical investigation and delivered under chain of custody protocol to an independent CAIAL accredited laboratory (Maxxam Analytical Inc. in Mississauga, Ontario) for analysis of Ontario Regulation 153/04 metals and inorganics. Copies of the chain-of-custody and Certificate of Analysis are included in Appendix C.

In order to characterize the material for potential transfer to another site requiring fill, the results were compared to the Table 1 ("Full Depth Background Site Condition Standards" for non-agricultural property use) standards provided in the document entitled "Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act (MOE, March 2004)". For excess soil that is to be transferred to another site as inert fill, the MOE generally requires that the analytical data meet MOE's Table 1 standards. These soil standards are considered background values derived from the Ontario Typical Range values for the specified land uses and are considered by the MOE to be representative of upper limits of typical province-wide background concentrations in soils that are not considered by point sources.

Based on the results of chemical analysis and the standard comparison, the concentrations of the inorganic and metal parameters meet the 2004 MOE's Table 1 standards for "All Other Types of Property Uses."



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5.0 CLOSURE

This Foundation Investigation Report was prepared by Mr. Antony Tomory, EIT, and reviewed by Mr. Kevin Bentley, P.Eng., an Associate and Senior Geotechnical Engineer with Golder. Mr. Jorge M.A. Costa, P.Eng., a Principal of Golder and a Designated MTO Contact for Foundations carried out a quality control review of this report for conformance with the project Terms of Reference.

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PART B

**DRAFT FOUNDATION DESIGN REPORT
HYDRO TOWERS AND RETAINING WALL
HIGHWAY 404 EXTENSION FROM QUEENSVILLE SIDEROAD TO
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6.0 FOUNDATION ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides foundation engineering design parameters and recommendations for the proposed four hydro towers and associated retaining wall structure to be located adjacent to the proposed alignment of Highway 404 (about 500 m north of Holborn Road) as part of the Highway 404 Extension project in East Gwillimbury, Ontario. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current subsurface investigation. The discussion and recommendations presented are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and to carry out the design of the structure foundations. Where comments are made on construction, they are provided in order to highlight those aspects which could affect the design of the project. Those requiring information on the aspects of construction should make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

Based on drawings of the proposed hydro towers and retaining wall entitled “New Construction” and “Highway 404 Hydro Tower Relocation Retaining Walls”, dated February 2011 provided by AECOM, the existing hydro towers will need to be removed from the highway median and replaced with two sets of towers on the east and west sides of the proposed Highway 404. The proposed ditch grade of Hwy 404 NBL in this area ranges from about Elevation 249 m to 250 m resulting in a cut section up to about 2.5 m below the existing ground surface. A retaining wall is proposed to separate the platform of the east hydro towers and the depressed Highway 404 NBL ditchline. The required soil parameters for design of the tower foundations are present in Hydro One’s “Technical Specification for Geotechnical Investigation” document dated December 3, 2010.

6.2 Hydro Tower Foundation Options

At the proposed hydro tower locations, the upper 0.3 m to 0.7 m thick soil layer is comprised of topsoil or slightly organic clayey silt and is not suitable to support the anticipated foundation loading. Although the hydro tower foundations are to be designed by others (i.e. Hydro One), it is considered that spread footings or drilled circular footings (i.e. caissons) are feasible foundation options at the site. Piles are not considered to be a practical option at this site. Advantages, disadvantages, relative costs and associated risks for each foundation option are provided in Table 1. Based on telephone conversations with Hydro One, we understand that drilled circular footings (i.e. caissons) are the preferred option by Hydro One. From a geotechnical perspective, caissons are considered to be the preferred option and design recommendations are provided below. As required in Hydro One’s Terms of Reference, Table 2 provides a summary of geotechnical design parameters at the proposed hydro tower locations for final design of the hydro tower foundations.

6.2.1 Caissons

Based on telephone conversations with Hydro One, caissons 6.0 m long and 1.8 m diameter are being considered for the hydro towers foundations’ design. Based on the subsoil conditions encountered in the area of the proposed hydro towers, drilled caissons with base 6.0 m below ground surface (base between Elevation 249.0 m and 243.5 m) will be founded within the hard clayey silt or very dense silty sand, very dense silt or very dense sand and gravel. Based on the measured water levels during the investigation, the base of the caissons will be at or near the water level; however stabilized water levels could not be determined and the groundwater level at the time of caisson construction should be confirmed as it may affect installation methods to ensure a



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stable subgrade is maintained. Although not encountered in the boreholes, cobbles and boulders may be present within the till soils encountered in Boreholes 2, 3 and 4 between depths of 0.7 m and 4.0 m below ground surface. Caisson drilling equipment must be capable of penetrating such obstacles.

For 1.8 m diameter caissons drilled to found within the undisturbed hard/very dense materials between the base elevations indicated above, the factored geotechnical axial resistance at ULS may be taken as 1,000 kN and the geotechnical resistance at SLS for 25 mm of settlement may be taken as 800 kN.

The geotechnical axial geotechnical resistance will be obtained through a combination of shaft friction and resistance at the caisson base. If permanent liners are used during installation, the factored geotechnical axial resistance value at ULS and the geotechnical resistance at SLS should be reduced to account for the reduction in shaft resistance.

The resistance to lateral loading in front of vertical caissons may be calculated using subgrade reaction theory where the coefficient of horizontal subgrade reaction (k_h in MPa/m) is determined based in the equations given below (CFEM 1992² as noted in CHBDC C6.8.7.1):

For cohesionless soils:

$$k_h = \frac{n_h z}{B} \quad \text{where} \quad \begin{array}{l} n_h \text{ is the constant of subgrade reaction (MPa/m);} \\ z \text{ is the depth (m); and} \\ B \text{ is the pile diameter / width (m).} \end{array}$$

For cohesive soils:

$$k_h = \frac{67 S_u}{B} \quad \text{where} \quad \begin{array}{l} S_u \text{ is the undrained shear strength of the soil (MPa); and} \\ B \text{ is the pile diameter / width (m).} \end{array}$$

The values of n_h and S_u provided in Table 2 can be assumed for design in the structural analysis. The upper 1.5 m of soil resistance should not be included in the design to account for frost action. Group action for lateral loading should be considered when caisson spacing in the direction of loading is less than six to eight caisson diameters. Group action can be evaluated by reducing the coefficient of horizontal subgrade reaction in the direction of loading by a reduction factor, R (NAVFAC DM-7.2, 1982) as follows:

Pile Spacing in direction of Loading (D = Pile Diameter)	Subgrade Reaction Reduction Factor (R)
8D	1.0
6D	0.7
4D	0.4
3D	0.25

² Canadian Foundation Engineering Manual, 1992, 3rd Edition, Canadian Standards Association



6.2.2 Spread Footings

Based on the subsurface conditions in the area of the proposed hydro towers, spread footings founded lower than 1.5 m below present ground surface would be supported on a variety of subsoils consisting of either very stiff to hard clayey silt, dense to very dense silt and sand till and compact to very dense sandy silt. Assuming a minimum 2 m wide spread footing, a factored geotechnical resistance value at ULS of 350 kPa and a geotechnical resistance value at SLS (for 25 mm of settlement) of 250 kPa may be used for design.

The geotechnical resistances provided above are for loads applied perpendicular to the surface of the footing. Where the load is not applied perpendicular to the surface of the footing, inclination of the load should be taken into account in accordance with Section 6.7.4 of the CHBDC and its Commentary.

If the concrete for the footing cannot be placed on the soil immediately after inspection of the prepared subgrade excavation, it is recommended that a concrete working slab be placed to protect the integrity of the bearing stratum. A Non-standard Special Provision should be included in the Contract Documents for a working slab and an example is provided in Appendix D.

Resistance to lateral forces / sliding resistance between the cast-in-place concrete footings and the undisturbed subgrade soils should be calculated in accordance with Section 6.7.5 of the CHBDC. The following summarises the coefficient of friction, $\tan \phi'$, for the various interface materials.

Interface Materials	Coefficient of Friction ($\tan \phi'$)
Cast-in-Place Concrete footing or working slab on Dense to Very Dense Sand and Silt Till / Compact to Very Dense Sandy Silt and Very Stiff to Hard Clayey Silt with Sand	0.45

This value represents an unfactored value.

6.3 Frost Protection

All footings should be provided with a minimum 1.5 m of soil cover or equivalent thickness of insulation below the footing (or caisson cap) for frost protection.

6.4 Retaining Wall Options

Based on the drawings provided by AECOM, a retaining wall is required to separate the Highway 404 NBL ditchline (which is constructed in a cut) and the ground surface level at the proposed hydro towers located east of the Highway 404 NBL.

The proposed retaining wall is 100 m long and the exposed face is up to 2.5 m high. Based on the relatively competent subsurface conditions encountered at the site, consideration could be given to designing the wall as a concrete cantilever wall or mechanically reinforced wall (retained soil system or RSS wall). A summary of the advantages, disadvantages, relative costs and associated level of risk for each option is provided in Table 3. From a foundations perspective, a concrete cantilever wall is the preferred alternative.



6.4.1 Concrete Cantilever Wall

The drawings provided by AECOM indicate that the top of the retaining wall footings are up to about 6 m below existing ground surface, that is about 4 m below proposed ground surface at the back of the retaining wall and 1.4 m below proposed grade at the front of the wall. Assuming that the footings will be about 400 mm thick (according to the AECOM drawings), the founding subgrade of the concrete walls ranges from about Elevation 247 m to 248 m, and therefore the wall footings will be founded on very dense sand and gravel, silty sand to silt, or hard clayey silt. The groundwater measured during drilling in December 2010 was 5.6 m to 6.8 m below existing ground surface (Elevation 245.9 m to 248.3 m), suggesting the water level is near or slightly above (about 0.3 m) the proposed foundation level. It should be noted that stabilized water levels in the piezometer were not measured because access to the property was denied.

For the design founding elevations indicated above, the factored geotechnical axial resistance values at ULS and SLS (for 25 mm of settlement) of 350 kPa and 250 kPa may be used assuming a minimum 1.8 m wide spread footing founded at least 1.5 m below the lowest adjacent proposed ground surface (i.e. below frost depth)

The geotechnical resistance values provided above are given for loads that will be applied perpendicular to the surface of the footing. Where the load is not applied perpendicular to the surface of the footing, inclination of the load should be taken into account in accordance with Section 6.7.4 if the CHBDC and its Commentary.

If the concrete for the footing cannot be placed on the soil immediately after inspection of the properly prepared subgrade excavation, it is recommended that a working concrete slab be placed to protect the integrity of the bearing stratum. A Non-standard Special Provision should be included in the Contract Documents for use of a working slab and an example is provided in Appendix D.

6.4.1.1 Resistance to Lateral Loads

Resistance to lateral forces / sliding resistance between the retaining wall cast-in-place concrete footing and the undisturbed subgrade soils should be calculated in accordance with Section 6.7.5 of the CHBDC and its commentary. The following summarizes the coefficient of friction, $\tan \phi'$, for the various interface materials.

Interface Materials	Coefficient of Friction ($\tan \phi'$)
Cast-in-Place Concrete footing or working slab on Very Dense Sand and Gravel / Silty Sand	0.45
Cast-in-Place Concrete footing or working slab on Hard Clayey Silt	0.40

These values represent unfactored values.

6.4.2 Reinforced Soil System (RSS) Wall

An RSS wall system could be considered as an option for the retaining wall. Subexcavation of native soils up to about 6 m below the existing ground surface (4 m below proposed ground surface) would be required as the retaining wall is to be constructed in cut. The subexcavated soils would need to be replaced with the reinforced soil mass placed and compacted as per SP 206S03. Typically an RSS wall has a front facing supported on a strip footing placed at shallow depth below the ground surface in front of the wall.



Assuming the base of the strip footing and reinforced soil mass is at the same elevation as the base of the alternative concrete cantilever wall (i.e. base level ranging from Elevation 247 m to 248 m), the estimated geotechnical resistance values provided in Section 6.3.1 can be used for design. It should be noted that the internal stability of a reinforced earth structure is to be assessed by the proprietary product designer to ensure that the external and internal stability of the wall is adequate.

6.5 Seismic Site Coefficient

The peak zonal acceleration ratio is 0.05g for the Town of Bradford, Ontario (CHBDC Table A3.1.1). The Site Coefficient (S) may be taken as 1.2, consistent with Soil Profile Type II in accordance with Section 4.4.6 and Table 4.4 of the CHBDC (2006).

6.6 Lateral Earth Pressures

The lateral earth pressures acting on the retaining wall will depend on the type and method of placement of the backfill materials, the nature of the soils behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the wall. Seismic (earthquake) loading must also be taken into account in the design.

The following recommendations are made concerning the design of the retaining wall. It should be noted that these design recommendations and parameters are applicable for level backfill and ground surface behind the wall. Where there is sloping ground behind the wall, the coefficient of lateral earth pressure must be adjusted to account for the slope.

- 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 200 sieve should be used as backfill behind the wall. Transverse 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 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 wall stem, in accordance with *CHBDC* Section 6.9.3 and Figure 6.6. Compaction equipment should be used in accordance with Special Provision 105S10 (Compaction). Other surcharge loadings should be accounted for in the design as required.
- The granular fill may be placed either in a zone with the width equal to at least 1.5 m behind the back of the walls (Case I on 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 footing (see Case II on Figure C6.20(b) of the *Commentary* to the *CHBDC*).



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- For Case I, the pressures are based on the existing native soils and the following parameters (unfactored) may be used:

	Native Granular Soil/Clayey Silt with Sand
Soil unit weight:	21 kN/m ³
Coefficients of static lateral earth pressure:	
Active, K_a	0.31
At rest, K_o	0.47

- For Case II, 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	0.27	0.27
At rest, K_o	0.43	0.43

If the wall support allows lateral yielding of the stem, active earth pressures may be used in the geotechnical design of the structure. If the wall support does not allow lateral yielding, at-rest earth pressures should be assumed for geotechnical design. The movement required to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure for design, should be calculated in accordance with Section C6.9.1 and Table C6.6 of the *Commentary* to the *CHBDC*.

A restrained structure is typically a concrete box culvert or a rigid frame bridge structure where the rotational and/or horizontal movement is not sufficient to mobilize the active pressure condition. For this condition, an at-rest pressure plus any compaction surcharge should be included in the design of the structure.

Seismic (earthquake) loading must also be taken into account in the design in accordance with Section 4.6 of the *CHBDC*. In this regard, the following should be included in the assessment of lateral earth pressures:

- Seismic loading will result in increased lateral earth pressures acting on the retaining wall. The wall should be designed to withstand the combined lateral loading for the appropriate static pressure conditions given above, plus the earthquake-induced dynamic earth pressure. According to Table C4.2 of the *Commentary* to the *CHBDC*, this site is located in Seismic Zone 1. The site specific zonal acceleration ratio for Bradford is 0.05. For the thickness and competent overburden soils encountered at this site, an amplification factor of the ground



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motion is recommended for design (i.e. Site Coefficient, $S=1.2$). As such, the recommended ground surface acceleration will increase to $0.06g$. The seismic lateral earth pressure coefficients given below have been derived based on a design zonal acceleration ratio of $A = 0.06$.

- In accordance with Sections 4.6.4 and C.4.6.4 of the *CHBDC* and its *Commentary* (employing the methodology suggested by Mononobe-Okabe), for structures which allow lateral yielding, the horizontal seismic coefficient, k_h , used in the calculation of the seismic active pressure coefficient, is taken as 0.5 times the zonal acceleration ratio (i.e. $k_h = 0.03$). For structures that do not allow lateral yielding, k_h is taken as 1.5 times the zonal acceleration ratio (i.e. $k_h = 0.09$). The seismic active earth pressure coefficient is also dependent on the vertical component of the earthquake acceleration, k_v . Three discrete values of vertical acceleration are typically selected for analysis, corresponding to $k_v = +2/3 k_h$, $k_v = 0$, and $k_v = -2/3 k_h$.
- The following seismic active pressure coefficients (K_{AE}) for the two cases (Case I and Case II) may be used in design. These coefficients reflect the maximum K_{AE} obtained using the k_h and three values of k_v as described above. It should be noted that these seismic earth pressure coefficients assume that the back of the wall is vertical and the ground surface behind the wall is flat.

SEISMIC ACTIVE PRESSURE COEFFICIENTS, K_{AE}

	Case I	Case II	
	Earth Fill (Granular Materials)	Granular 'A'	Granular 'B' Type II
Yielding wall	0.32	0.26	0.26
Non-yielding wall	0.37	0.30	0.30

Note : These *CHBDC* seismic K_{AE} values include the effect of wall friction ($\delta=\Phi'/2$) and are less than the static values of K_a and K_o reported above for the very low zonal acceleration ratio for this site.

- The above K_{AE} values for yielding walls are applicable provided that the wall can move up to 250A (mm), where A is the design zonal acceleration ratio of 0.06. This corresponds to displacements of up to 15 mm at this site.
- The earthquake-induced dynamic pressure distribution, which is to be added to the static earth pressure distribution, is a linear distribution with maximum pressure at the top of the wall and minimum pressure at its toe (i.e. an inverted triangular pressure distribution). The total pressure distribution (static plus seismic) may be determined as follows:

$$\sigma_h(d) = K \gamma' d + (K_{AE} - K) \gamma' (H - d)$$

Where $\sigma_h(d)$ is the lateral earth pressure at depth (d) below the top of the wall (kPa)
 K is either the static active earth pressure coefficient (K_a)
or the static at rest earth pressure coefficient (K_o);
 K_{AE} is the seismic active earth pressure coefficient;



- γ' is the effective unit weight of the soil (kN/m^3)
- taken as soil unit weights given above for fill materials
 - taken as 21 kN/m^3 for the native materials
- d is the depth below the top of the wall (m); and
- H is the total height of the wall above the toe (m).

6.7 Global Stability

The global slope stability of the retaining wall was analyzed using the commercially available program SLIDE (Version 5.0), produced by Rocscience Inc., employing the Morgenstern-Price method of analysis. The factor of safety of numerous potential failure surfaces was computed in order to establish the minimum Factor of Safety. A target factor of safety of 1.5 against deep-seated global instability of the retaining wall was used for design under static conditions. This factor of safety is considered appropriate for the retaining wall at this site, considering the design requirements and the field data available (CFEM, 2006).

The soil parameters used in the analyses, as given below, were estimated from empirical correlations proposed by Kulhawy and Mayne (1990) using the results of in situ Standard Penetration Tests, visual classification, our experience and the results of laboratory testing. The piezometric conditions used in the analysis are based on the highest groundwater levels measured during drilling (or shortly after drilling) being at Elevation 248.5 m.

Soil Unit	Unit Weight (kN/m^3)	Undrained Shear Strength (kPa)	Effective Cohesion (c') (kPa)	Effective Angle of Internal Friction, ϕ' (degrees)
Compact to Very Dense Sand and Silt to Silt and Sand Till	20	-	0	32
Compact to Very Dense Sandy Silt, Silty Sand, Sand	20	-	0	32
Very Dense Silty Sand, Sand and Gravel, Silt	21	-	0	35
Hard Clayey Silt	19	200	-	-

A critical section (maximum wall height) was analyzed for the retaining wall based on drawings and the topographic plan provided by AECOM.

Based on the results of the analysis, a factor of safety of greater than 1.5 is achieved against deep-seated global instability for the proposed concrete wall configuration, as shown on Figure 1. A factor of safety equal to or greater than 1.5 is anticipated for a similar RSS wall configuration assuming any new embankment fill/backfill is properly placed and compacted as per SP 206S03.

6.8 Settlement

The proposed Highway 404 profile will result in lowering the existing ground surface adjacent to the retaining wall by up to about 2.5 m. As a result, there is no additional embankment loading on the retaining wall foundation soils. Provided the wall foundation subgrade is properly prepared (by removing loosened soil from the base of the excavation) and confirmed to be founded on the subsurface soils noted above, the total settlement is expected to be less than 25 mm.



There may be some grading/fill placed behind the retaining walls to level the ground surface in the vicinity of the hydro towers; however, it is expected that less than 2.5 m of additional fill will be required based on the drawings. Assuming that surficial soils containing organics are removed prior to any fill placement, and the fill is placed/compacted to engineering fill standards, settlements resulting from the new fill are expected to be less than 25 mm. To minimize fill handling operations, consideration could be given to leaving the surficial slightly organic clayey silt layer (up to 0.7 m thick) in place and placing engineered fill directly on top of this layer where no settlement sensitive structures (to be confirmed by Hydro One) will be supported on this layer.

6.9 Design and Construction Considerations

6.9.1 Subgrade Preparation and Excavation

The base of the excavation for retaining wall construction is expected to be up to 6.4 m below existing ground surface and about 1.8 m below the proposed Highway 404 ditchline. Therefore, it is recommended that the Highway 404 NBL road grade be established prior to constructing the retaining wall foundations to reduce the temporary excavation depth to about 1.8 m below ground surface and reduce dewatering efforts.

The excavation will extend mainly through deposits of slightly organic clayey silt, compact sand and silt till, compact to very dense sand, silty sand, sandy silt, silt and sand till, sand and gravel and hard clayey silt. For temporary excavations made within these soils, the soils are considered to be Type 3 according to the Occupational Health and Safety Act Ontario Regulation 213 for Construction Projects (OHSA). As such, temporary excavations in Type 3 soils should be carried out with walls sloped no steeper than 1H:1V provided groundwater seepage is allowed to drain and surface water is directed around the excavation. All excavations must be carried out in accordance with the latest edition of the OHSA.

6.9.2 Control of Groundwater and Surface Water

Control of surface water and groundwater may be necessary for the construction of the retaining wall foundations to allow subexcavation and concrete placement to be carried out in dry conditions. If scheduling permits, construction of the foundations should be carried out during drier periods of the year.

The groundwater level was measured to be up to 0.3 m above the base of the retaining wall foundation, however depending on stabilized water levels, precipitation events, and seasonal fluctuations in the water table, groundwater may be higher than measured during the borehole investigation. Based on the measured groundwater levels, it is expected that groundwater seepage into the excavation can be adequately controlled by pumping from properly filtered sumps.

Surface water should be directed away from the excavation areas, to prevent ponding of water that could result in disturbance and weakening of subgrade soils. As noted in Section 6.3.1, a concrete working slab should be placed on the base of the proposed subgrade to protect the integrity of the bearing stratum if concrete foundations cannot be poured immediately after subexcavation, inspection and approval of the foundation subgrade.

For the hydro tower caisson foundations, temporary or permanent liners are recommended to reduce ground loss during drilling and to permit cleaning and inspection of the caisson base. Depending on groundwater levels at the time of construction, the use of drilling mud and / or tremie methods for concrete placement may be necessary.



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6.9.3 Removal of Existing Hydro Towers

Although the sequencing of the removal of the existing hydro towers and construction of the new towers and proposed Highway 404 profile is not known, care should be taken to ensure that the existing hydro tower foundations (while the existing hydro towers are in operation) are not compromised during grading/construction operations. Considering the proposed Highway 404 grade will result in lowering the existing ground surface by up to about 2.5 m, it is recommended that a safe working / excavation limit be provided around the existing hydro tower foundations to ensure adequate vertical and lateral soil resistance is maintained throughout construction until the hydro towers are removed.

7.0 CLOSURE

This Foundation Design Report was prepared by Mr. Antony Tomory, EIT, and reviewed by Mr. Kevin Bentley, P.Eng., a geotechnical engineer and Associate with Golder. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and Principle with Golder, conducted an independent quality control review of this report.

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REFERENCES

- Canadian Geotechnical Society, 2006. *Canadian Foundation Engineering Manual*, 4th Edition. The Canadian Geotechnical Society, BiTech Publisher Ltd., British Columbia.
- Canadian Standards Association, 2006. Canadian Highway Bridge Design Code (CHBDC) and Commentary on CAN/CSA-S6-06. CSA Special Publication, S6.1 06.
- Chapman, L.J., and Putnam, D.F., 1984. *The Physiography of Southern Ontario*, 3rd Edition. Ontario Geological Survey, Special Volume 2. Ontario Ministry of Natural Resources.
- 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, 1982. *Design Manual DM 7.2: Soil Mechanics, Foundation and Earth Structures*. U.S. Navy. Alexandria, Virginia.
- Ministry of the Environment, March 2004. "Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act (MOE, March 2004)".

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)

- | | |
|-----------|--------------------------------------------------------------------------------------------|
| SP 110S13 | Material Specification for Aggregate Base, Sub-base, Select Subgrade and Backfill Material |
| SP 206S03 | Earth Excavation, Grading. |
| SP 105S10 | Construction Specifications for Compaction |

Ontario Occupational Health and Safety Act:

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

Ontario Provincial Standard Drawings (OPSD)

- | | |
|---------------|------------------------------------------------------------|
| OPSD 3090.101 | Foundation Frost Penetration Depths for Southern Ontario |
| OPSD 3121.150 | Walls – Retaining, Backfill, Minimum Granular Requirement. |

Ontario Water Resources Act:

- | | |
|---------------------------|-------------------------------------|
| Ontario Regulation 372/97 | Amendment to Ontario Regulation 903 |
| Ontario Regulation 903/90 | Wells |
| Ontario Regulation 153/04 | Records of Site Condition |



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TABLE 1 - EVALUATION OF FOUNDATION ALTERNATIVES
Proposed Hydro Towers – Highway 404 Extension
W.P. 2005-07-00

Footing Option	Rank	Advantages	Disadvantages	Relative Costs ¹	Risks/Consequences
<i>Caissons founded within hard clayey silt or very dense silty sand, silt or sand and gravel</i>	1	<ul style="list-style-type: none"> Large axial/lateral resistance. Relative ease of construction with conventional Hydro One equipment 	<ul style="list-style-type: none"> May require temporary / permanent steel liner to mitigate loosening of caisson walls by groundwater and allow for inspection of the base of the caisson. 	<ul style="list-style-type: none"> Comparable cost to spread footings if Hydro One can use their own equipment. (\$900/m length) 	<ul style="list-style-type: none"> Risk of "heaving" or "softening" of end-bearing stratum if water level is significantly above the design tip level.
<i>Spread Footings founded on very stiff to hard clayey silt, stiff to very stiff clayey silt till, dense to very dense silt and sand till and compact to very dense sandy silt to silty sand</i>	2	<ul style="list-style-type: none"> Relative ease of construction with conventional equipment. 	<ul style="list-style-type: none"> Lower geotechnical resistance and limited uplift/lateral resistance. Larger volume of soil spoil and backfill required. 	<ul style="list-style-type: none"> Cost (\$600/m³) however significant volume may be required to resist uplift forces. 	<ul style="list-style-type: none"> May require significant footing size/embedment depth to resist design uplift/lateral loadings
<i>Steel H-piles founded within hard clayey silt or very dense silty sand, silt and sand and gravel</i>	NP	<ul style="list-style-type: none"> Excavation required for pile cap(s) only Large axial resistance compared to spread footing but smaller than for a caisson foundation Groundwater not an issue 	<ul style="list-style-type: none"> Unconventional method for Hydro One Hydro One may not have pile Driving Equipment 	<ul style="list-style-type: none"> High relative costs compared to other options. (\$250/m of pile for HP 310x110 piles) 	<ul style="list-style-type: none"> Hydro One may not have pile driving equipment Pile caps could end up being same size and at same depth for frost protection as for a spread footing.

Notes:

1. The actual costs will depend on Hydro One resources and availability of equipment.



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**TABLE 2 - GEOTECHNICAL DESIGN PARAMETERS FOR HYDRO TOWERS AND RETAINING WALLS
W.P. 2220-03-00**

Structure	Borehole No.	Stratum	Depth ¹ (m)	Elevation (m)	Groundwater Elevation (m)*	N _{avg}	S _u kPa	φ'	γ kN/m	γ' kN/m	K _p	n _h (MPa)
West Hydro Towers	BH 2	Compact sandy silt	0.5 – 2.6	249.0 – 246.9	243	19	-	32°	20	10	3.3	10
		Stiff to Very Stiff Clayey Silt Till	2.6 – 4.1	246.9 – 245.4		15	100	30°	21	11	3.0	-
		Very Dense Silt and Sand Till	4.1 – 5.4	245.4 – 244.1		70	-	35°	21	11	3.7	20
		Hard Clayey Silt	5.4 – 15.8	244.1 – 233.7		50	200	28°	20	10	2.8	-
East Hydro Towers	BH 3 (Southeast Tower)	Compact sandy silt	0.7 – 1.5	251.8 – 251.0	246	21	-	32°	20	10	3.3	10
		Dense to Very Dense sand and silt till	1.5 – 4.1	251.0 – 248.4		77	-	35°	21	11	3.7	20
		Very Dense silty sand/silt	4.1 – 9.2	248.4 – 243.3		>100	-	35°	21	11	3.7	15
Retaining Wall	BH 5 (Northeast Tower)	Compact to Dense Silt and Sand Till	0.3 – 2.0	251.3 – 249.6	246	28	-	32°	20	10	3.0	10
		Very Dense Sand	2.0 – 4.1	249.6 – 247.5		>100	-	35°	20	10	3.7	20
		Hard Clayey Silt	4.1 – 9.6	247.5 – 242.0		66	200	28°	20	10	2.8	-

* Groundwater level estimated relative to the depth below ground surface as recorded in the standpipe piezometer in Borehole 1

NOTES:

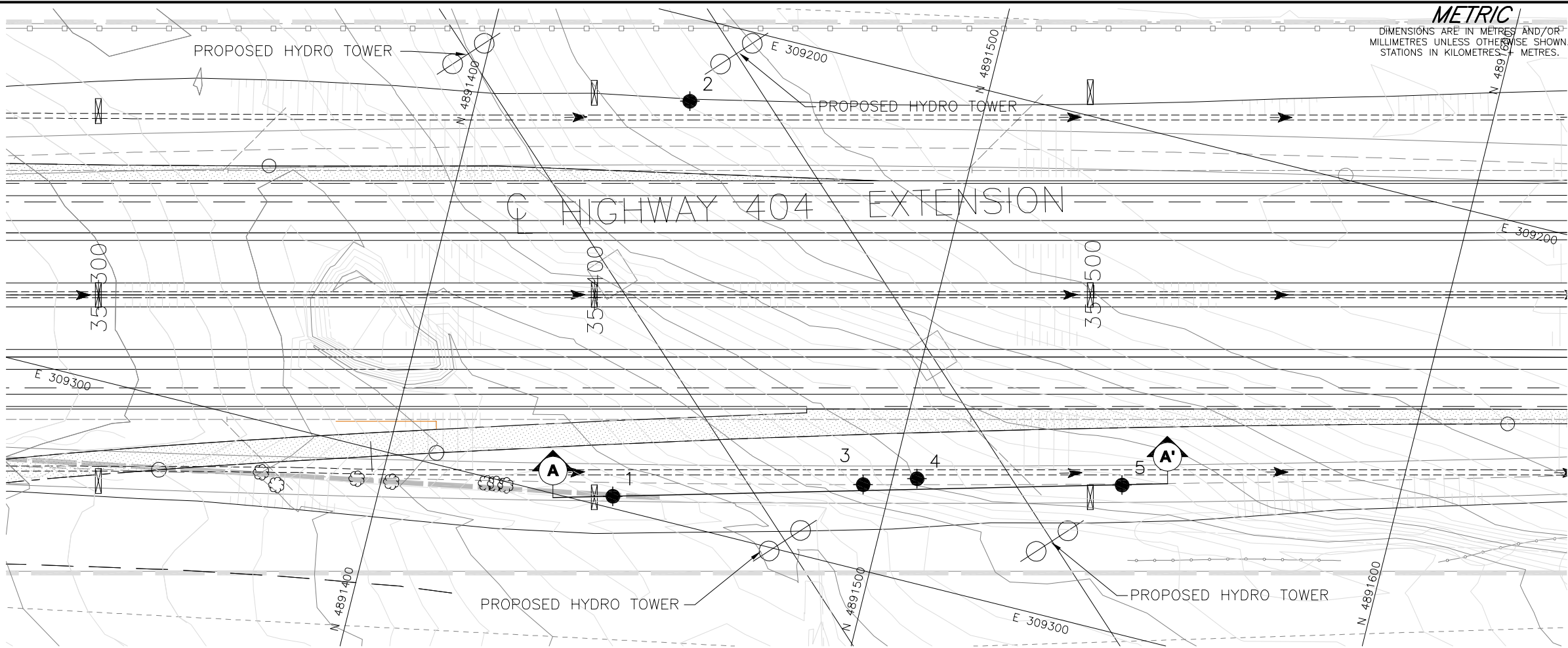
1. Depths are given for the borehole location; the ground surface elevation at the borehole location should be compared to the ground surface elevation at the actual Tower support location, and the depths of the soil strata adjusted accordingly.
2. Design parameters:
 - N_{avg} = average Standard Penetration Test (SPT) value for stratum
 - S_u = undrained shear strength (kPa);
 - φ' = effective friction angle (degrees);
 - γ = bulk unit weight (kN/m³);
 - γ' = effective unit weight below the groundwater level (kN/m³); and
 - K_p = passive earth pressure coefficient.
3. The passive resistance in the upper 1.5 m below ground surface should be neglected to account for frost action.
4. Groundwater levels were measured during drilling operations and may not represent stabilized conditions. Where groundwater level was not measured in the borehole, the measured water level from an adjacent borehole has been provided.



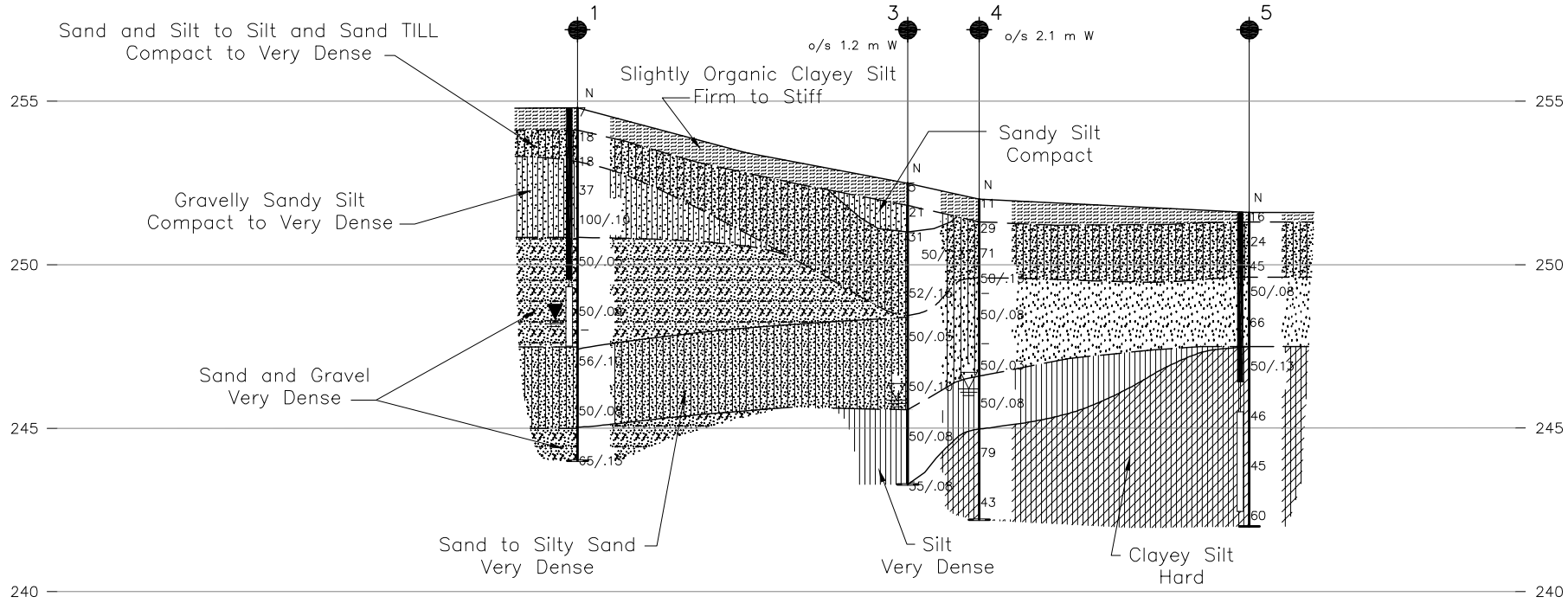
DRAFT FOUNDATION REPORT HYDRO TOWERS AND RETAINING WALL, W.P. 2005-07-00

TABLE 3 - EVALUATION OF RETAINING WALL ALTERNATIVES
Highway 404 Extension
W.P. 2005-07-00

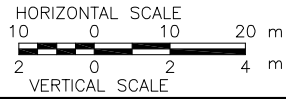
Wall Option	Rank	Advantages	Disadvantages	Relative Costs ¹	Risks/Consequences
<i>Concrete Cantilever Wall</i>	1	<ul style="list-style-type: none">• Potentially easier and faster construction using conventional cast-in-place methods.• Conventional construction methods	<ul style="list-style-type: none">• Base to be founded below depth of frost penetration (1.5 m below final grade) requires deeper excavation then for RSS wall front-facing footing.	<ul style="list-style-type: none">• Higher costs relative to RSS Wall	<ul style="list-style-type: none">• Low risk of problems using conventional excavation and construction techniques but cannot tolerate differential settlement.
<i>RSS Wall</i>	2	<ul style="list-style-type: none">• Can tolerate some differential settlement.	<ul style="list-style-type: none">• Slightly larger temporary excavation footprint required to install reinforcing strips• Proprietary system requires construction by specialist contractor.	<ul style="list-style-type: none">• Less expensive than concrete cantilever wall	<ul style="list-style-type: none">• Low risk of problems using conventional construction methods.



PLAN



SECTION A-A'



DRAFT

CONT No. 2010-2055
GWP No. 2005-07-00

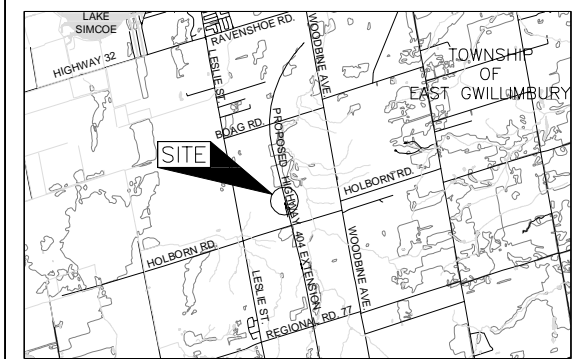


HIGHWAY 404 EXTENSION
PROPOSED HYDRO TOWERS AND RETAINING WALL
BOREHOLE LOCATIONS AND SOIL STRATA

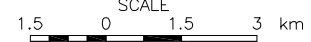
SHEET



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MISSISSAUGA, ONTARIO, CANADA



KEY PLAN



LEGEND

- Borehole - Current Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL in piezometer, measured on Dec. 22, 2010
- WL upon completion of drilling

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
1	254.8	4891446.1	309297.6
2	249.5	4891441.9	309216.6
3	252.5	4891494.5	309283.2
4	252.0	4891504.8	309279.4
5	251.6	4891545.2	309270.6

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 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.

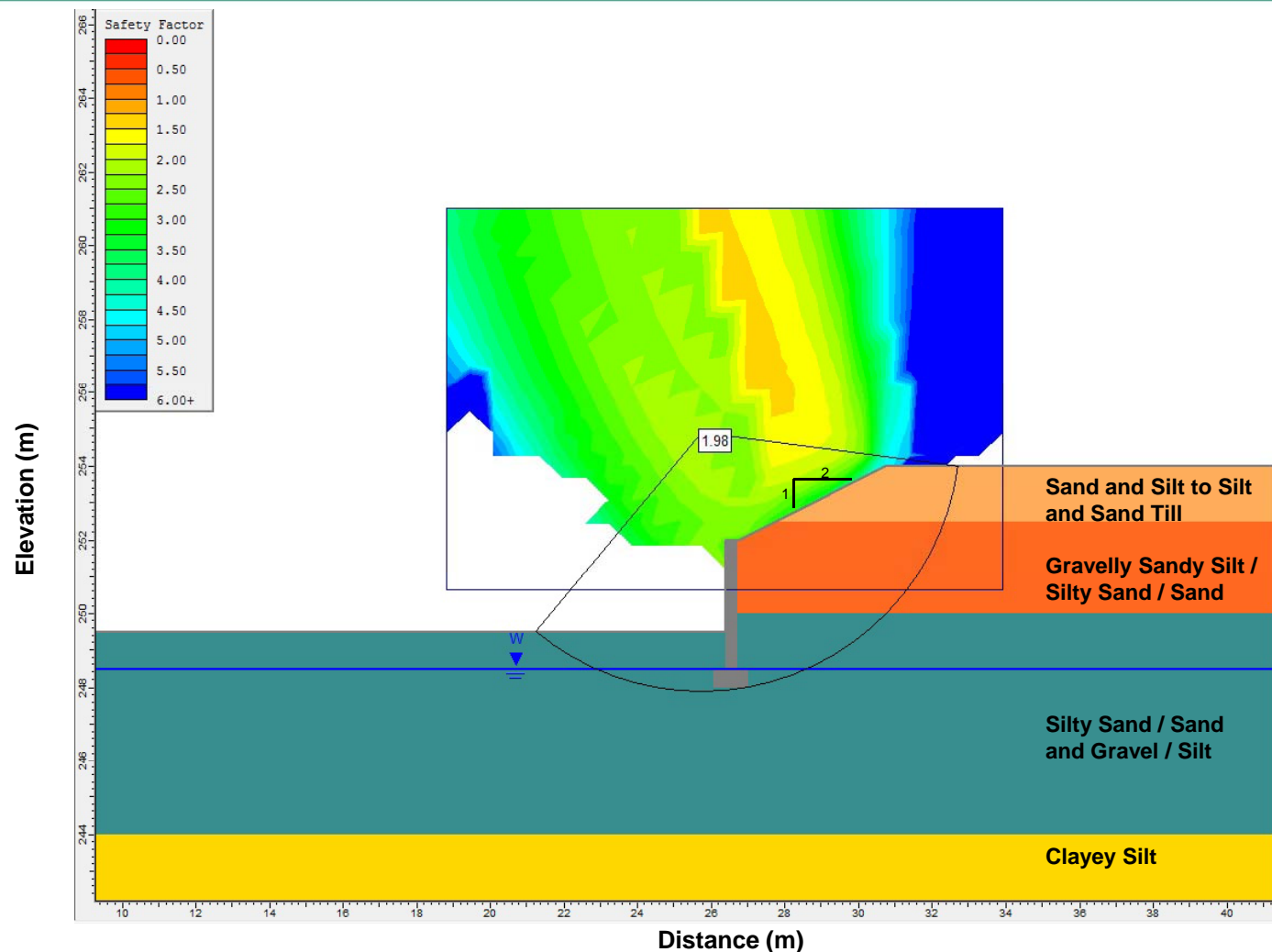
REFERENCE

Base plans provided in digital format by AECOM, drawing files "76808.dwg" and "76809.dwg", received, November, 16, 2009, drawing file "2538-199-00_00-ST-1001-To Golder-091126.dwg", received November 26, 2009 and 2538-199-00_CT-XDesign-To Accommodate Hydro Towers Within ROW-Option2 (2011-01-05).dwg, received January 06, 2011.

NO.	DATE	BY	REVISION
Geocres No.			
HWY. 404		PROJECT NO. 08-1111-0022	DIST.
SUBM'D.	CHKD.	DATE: Mar. 24, 2011	SITE:
DRAWN: JFC	CHKD. KJB	APPD. JMAC	DWG. 1



**Figure 1 - Results of Global Static Stability Analysis
Retaining Wall (Station 35+425)**



Material Properties

Sand and Silt to Silt and Sand Till

Unit Weight: 20 kN/m³

Cohesion: 0 kPa

Friction Angle: 32 degrees

Gravelly Sandy Silt / Silty Sand / Sand

Unit Weight: 20 kN/m³

Cohesion: 0 kPa

Friction Angle: 32 degrees

Silty Sand / Sand and Gravel / Silt

Unit Weight: 21 kN/m³

Cohesion: 0 kPa

Friction Angle: 35 degrees

Clayey Silt

Unit Weight: 19 kN/m³

Cohesion: 200 kPa

Friction Angle: 0 degrees



APPENDIX A

RECORD OF BOREHOLES



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, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

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

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Cohesionless Soils

Density Index	N
Relative Density	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils Consistency

	C_u, S_u	
	kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO ₄	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

V. MINOR SOIL CONSTITUENTS

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



LIST OF SYMBOLS

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

I. GENERAL

π	3.1416
$\ln x$,	natural logarithm of x
\log_{10}	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
F	factor of safety
V	volume
W	weight

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ϵ	linear strain
ϵ_v	volumetric strain
η	coefficient of viscosity
ν	poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - \mu$)
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
μ	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight*)
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

(a) Index Properties (continued)

w	water content
w_l	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 $= \sigma'_p / \sigma'_{vo}$

(d) Shear Strength

T_p, T_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction $= \tan \delta$
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 + \sigma_3)/2$ or $(\sigma'_1 + \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 + \sigma_3)$
S_t	sensitivity

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

Notes: 1 $\tau = c' + \sigma' \tan \phi'$
2 shear strength = (compressive strength)/2



PROJECT 08-1111-0022			RECORD OF BOREHOLE No 1			1 OF 1 METRIC															
G.W.P. 2005-07-00			LOCATION N 4891446.1 ; E 309297.6			ORIGINATED BY CS															
DIST _____ HWY 404			BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers			COMPILED BY MAS															
DATUM Geodetic			DATE December 20, 2010			CHECKED BY KJB/CS															
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC NATURAL LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ			GR SA SI CL		
254.8	GROUND SURFACE							20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					W _p — W — W _L 10 20 30			kN/m ³					
0.0	CLAYEY SILT, slightly organic, some sand and gravel, containing rootlets		1	SS	7																
254.1	Firm																				
0.7	Brown Moist		2	SS	18		254													19 35 32 14	
253.3	SAND and SILT, some clay and gravel (TILL)																				
1.5	Compact Brown Moist		3	SS	18		253														
	Gravelly Sandy SILT, trace to some clay																				
	Compact to very dense		4	SS	37		252													22 20 50 8	
	Brown Moist		5	SS	100/10																
250.8							251														
4.0	SAND and GRAVEL, some silt, trace clay		6	SS	50/05		250														
	Very dense																				
	Brown Moist		7	SS	50/00		249														
			7A	AS			248													47 35 14 4	
247.5																					
7.3	Silty SAND, trace clay		8	SS	56/10		247														
	Very dense																				
	Brown Wet		9	SS	50/08		246														
245.0							245														
9.8	SAND and GRAVEL, trace clay																				
	Very dense																				
	Brown Wet		10	SS	65/13		244														
244.0																					
10.8	END OF BOREHOLE																				
NOTES:																					
1. Water level in piezometer at a depth of 6.6 m below ground surface (Elev. 248.2 m) on December 22, 2010.																					
2. No PTE on January 17, 2011 to obtain water level.																					

PROJECT 08-1111-0022				RECORD OF BOREHOLE No 2				1 OF 2 METRIC					
G.W.P. 2005-07-00				LOCATION N 4891441.9 ; E 309216.6				ORIGINATED BY CS					
DIST HWY 404				BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers				COMPILED BY MAS					
DATUM Geodetic				DATE December 20, 2010				CHECKED BY KJB/CS					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _p W W _L			
249.5	GROUND SURFACE												
0.0	TOPSOIL		1	SS	4								
249.0			2	SS	17								
0.5	Sandy SILT, some clay, containing rootlets and oxidation staining, containing clayey silt interlayers at a depth of 1.5 m Compact Brown Moist		3	SS	21								
246.9			4A	SS	17								
2.6	CLAYEY SILT, trace sand, trace gravel (TILL) Stiff to very stiff Brown to grey Moist		4B										
			5	SS	13								
245.4													
4.1	SILT and SAND, trace to some clay, trace gravel (TILL) Very dense Grey Moist		6	SS	102/08								
244.1													
5.4	CLAYEY SILT, trace sand, trace to some gravel, containing interlayers of silty clay Hard Grey Moist		7	SS	44								
			8	SS	52								
			9	SS	103/28								
			10	SS	39								
			11	SS	39								
			12	SS	65/13								
234.9													
14.6													

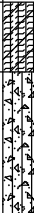
Continued Next Page

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

PROJECT <u>08-1111-0022</u>		RECORD OF BOREHOLE No 2		2 OF 2 METRIC	
G.W.P. <u>2005-07-00</u>		LOCATION <u>N 4891441.9 ; E 309216.6</u>		ORIGINATED BY <u>CS</u>	
DIST <u> </u> HWY <u>404</u>		BOREHOLE TYPE <u>108 mm I.D. Hollow Stem Augers</u>		COMPILED BY <u>MAS</u>	
DATUM <u>Geodetic</u>		DATE <u>December 20, 2010</u>		CHECKED BY <u>KJB/CS</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE LIQUID CONTENT LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED									
	--- CONTINUED FROM PREVIOUS PAGE ---						20	40	60	80	100	W _p	W	W _L			
233.8	SAND and GRAVEL, trace clay, trace silt Dense Grey Wet		13A	SS	45												
15.8	CLAYEY SILT, trace sand Hard Grey Wet END OF BOREHOLE NOTES: 1. Borehole caved to a depth of 13.5 m below ground surface (Elev. 236.0 m) upon completion of drilling. 2. Water level in open borehole at a depth of 12.8 m below ground surface (Elev. 236.7 m) upon completion of drilling.		13B														

PROJECT		08-1111-0022		RECORD OF BOREHOLE No 3				1 OF 1 METRIC						
G.W.P.		2005-07-00		LOCATION		N 4891494.5 ; E 309283.2		ORIGINATED BY						
DIST		HWY 404		BOREHOLE TYPE		108 mm O.D. Solid Stem Augers		COMPILED BY						
DATUM		Geodetic		DATE		December 21, 2010		CHECKED BY						
								KJB/CS						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
252.5	GROUND SURFACE													
0.0	CLAYEY SILT, slightly organic, some sand, containing rootlets Firm Brown Moist		1	SS	5									
251.8														
0.7	Sandy SILT, trace gravel, trace clay Compact Brown Moist		2	SS	21									
251.0														
1.5	SILT and SAND, trace to some clay, trace gravel (TILL) Dense to very dense Brown Moist		3	SS	31									
			4	SS	50/13									
			5	SS	52/15									
248.4														
4.1	Silty SAND, trace to some clay, trace gravel Very dense Brown Moist		6	SS	50/06									
			7	SS	50/10									
245.6														
6.9	SILT, some sand, trace to some clay Very dense Brown Wet		8	SS	50/08									
243.3														
9.2	END OF BOREHOLE		9	SS	55/08									
NOTE: 1. Water level in open borehole at a depth of 6.6 m below ground surface (Elev. 245.9 m) upon completion of drilling.														

PROJECT		08-1111-0022		RECORD OF BOREHOLE No 4		1 OF 1 METRIC																
G.W.P.		2005-07-00		LOCATION		N 4891504.8 ; E 309279.4																
DIST		HWY 404		BOREHOLE TYPE		108 mm O.D. Solid Stem Augers																
DATUM		Geodetic		DATE		December 22, 2010																
				ORIGINATED BY		CS																
				COMPILED BY		MAS																
				CHECKED BY		KJB/CS																
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%) W _p — W — W _L			γ			GR SA SI CL			
252.0	GROUND SURFACE							20 40 60 80 100														
0.0	CLAYEY SILT, slightly organic, trace to some sand, trace to some gravel		1	SS	11																	
251.3	Stiff		2	SS	29																	
0.7	Brown Moist		3	SS	71																	
	SILT and SAND, trace to some clay, trace gravel (TILL) Compact to very dense		4	SS	50/13																	
249.6	Silty SAND, some gravel, trace clay, containing silt interlayers		5A	AS	-																	
2.4	Very dense		5	SS	50/08																	
	Brown Moist		6A	AS	-																	
			6	SS	50/03																	
246.6	SILT, some sand, trace to some clay, trace gravel		7	SS	50/08																	
5.4	Very dense																					
	Brown Wet		8	SS	79																	
245.0	CLAYEY SILT, trace sand, trace to some gravel, containing interlayers of silty clay		9	SS	43																	
7.0	Hard Grey Moist to wet																					
242.2	END OF BOREHOLE																					
9.8	NOTE: 1. Water level in open borehole at a depth of 5.8 m below ground surface (Elev. 246.2 m) upon completion of drilling.																					

PROJECT 08-1111-0022		RECORD OF BOREHOLE No 5		1 OF 1 METRIC	
G.W.P. 2005-07-00		LOCATION N 4891545.2 ; E 309270.6		ORIGINATED BY CS	
DIST HWY 404		BOREHOLE TYPE 108 mm O.D. Solid Stem Augers		COMPILED BY MAS	
DATUM Geodetic		DATE December 22, 2010		CHECKED BY KJB/CS	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _p	W	W _L		
251.6	GROUND SURFACE													
0.0	CLAYEY SILT, slightly organic, some sand, trace gravel, containing rootlets Brown Moist		1	SS	16									
251.3														
0.3	SAND and SILT, trace clay and gravel (TILL) Compact to dense Brown Moist		2	SS	24									
249.6			3	SS	45									
2.0	SAND, some silt, trace gravel, trace clay Very dense Brown Moist		4	SS	50/08									
			5	SS	66									
247.5														
4.1	CLAYEY SILT, containing interlayers of silty clay Hard Grey Moist to wet		6	SS	50/13									
			7	SS	46									
			8	SS	45									
			9	SS	60									
242.0														
9.6	END OF BOREHOLE													
NOTES: 1. Piezometer dry after installation on Dec. 22, 2010. 2. No PTE on January 17, 2011 to obtain water level.														



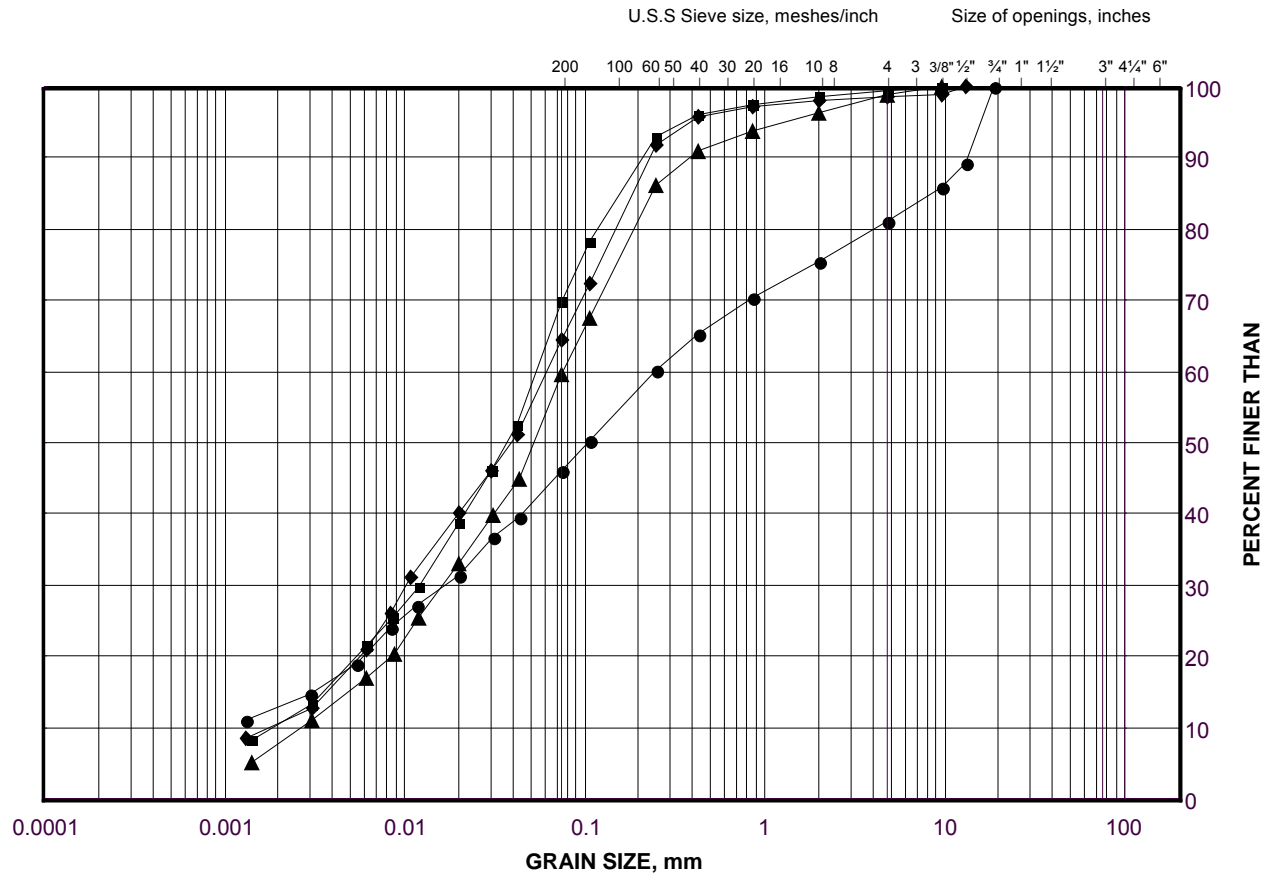
APPENDIX B

LABORATORY TEST RESULTS

GRAIN SIZE DISTRIBUTION

Sand and Silt Till

FIGURE 1



SILT AND CLAY SIZES		FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED		SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

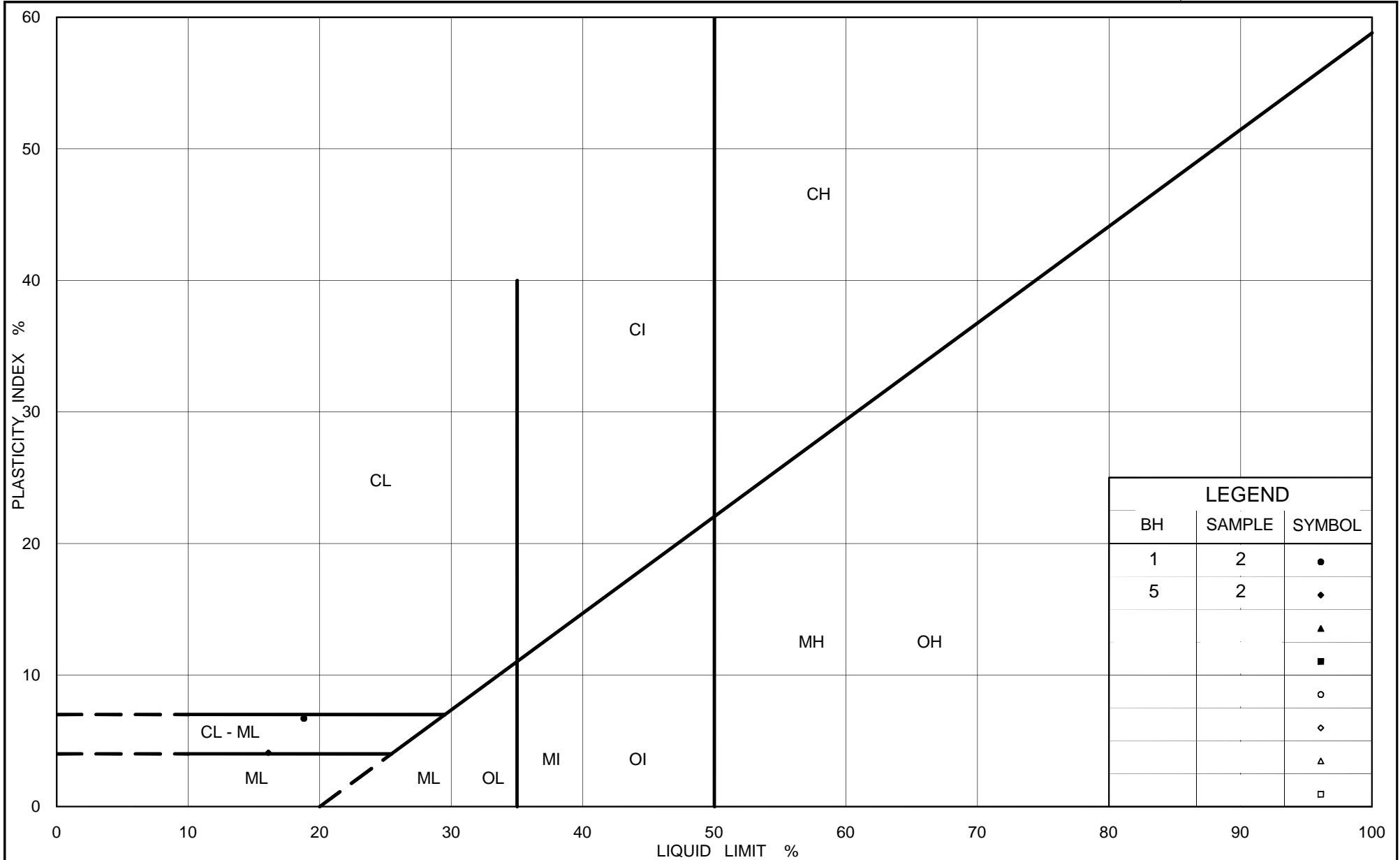
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	1	2	253.7
■	4	3	250.3
◆	3	3	250.7
▲	2	6	244.8

Project Number: 08-1111-0022F

Checked By: KJB

Golder Associates

Date: 30-May-11



Ministry of Transportation

Ontario

PLASTICITY CHART

Sand and Silt Till

Figure No. 2

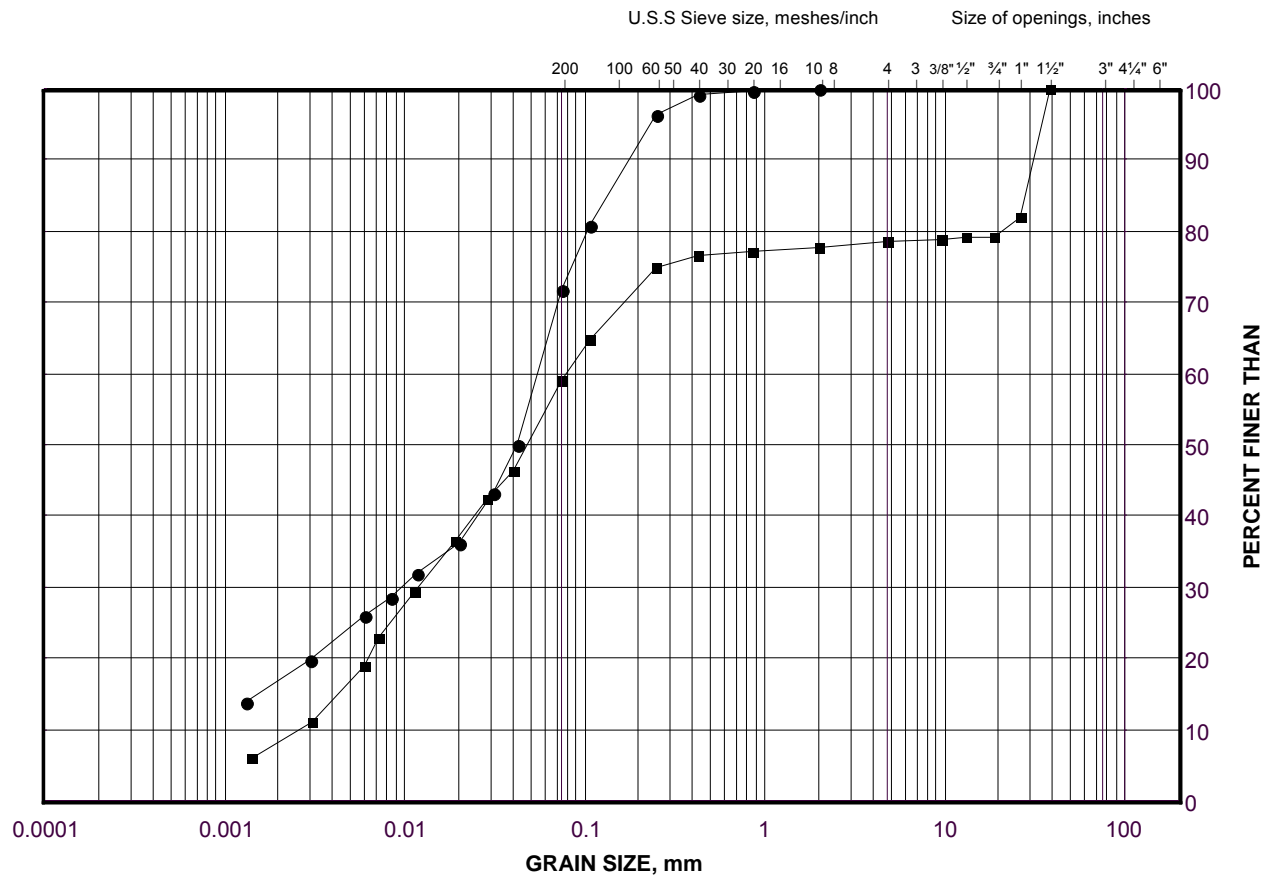
Project No. 08-1111-0022F

Checked By: KJB

GRAIN SIZE DISTRIBUTION

Sandy Silt to Gravelly Sandy Silt

FIGURE 3



SILT AND CLAY SIZES		FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED		SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	2	3	247.7
■	1	4	252.2

Project Number: 08-1111-0022F

Checked By: KJB

Golder Associates

Date: 30-May-11

Sand and Gravel

U.S.S Sieve size, meshes/inch

Size of openings, inches

PERCENT FINER THAN

GRAIN SIZE, mm

Grain Size (mm)	U.S.S Sieve Size (meshes/inch)	Size of Opening (inches)	Percent Finer (%)
0.075	No. 20	1 1/2"	100
0.15	No. 10	3/4"	95
0.3	No. 60	3/8"	78
0.6	No. 30	1/2"	65
1.2	No. 15	1"	55
2.5	No. 8	3/4"	42
5.0	No. 4	3/8"	38
10.0	No. 2	1/2"	35
20.0	No. 1	1"	32
40.0	No. 1/2	3/4"	30
80.0	No. 1/4	3/8"	28
150.0	No. 1/16	3/16"	25
300.0	No. 1/32	1/32"	22
600.0	No. 1/64	1/64"	18
1200.0	No. 1/128	1/128"	15
2500.0	No. 1/256	1/256"	12
5000.0	No. 1/512	1/512"	10
10000.0	No. 1/1024	1/1024"	8
20000.0	No. 1/2048	1/2048"	5
40000.0	No. 1/4096	1/4096"	2
80000.0	No. 1/8192	1/8192"	0

SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		SIZE

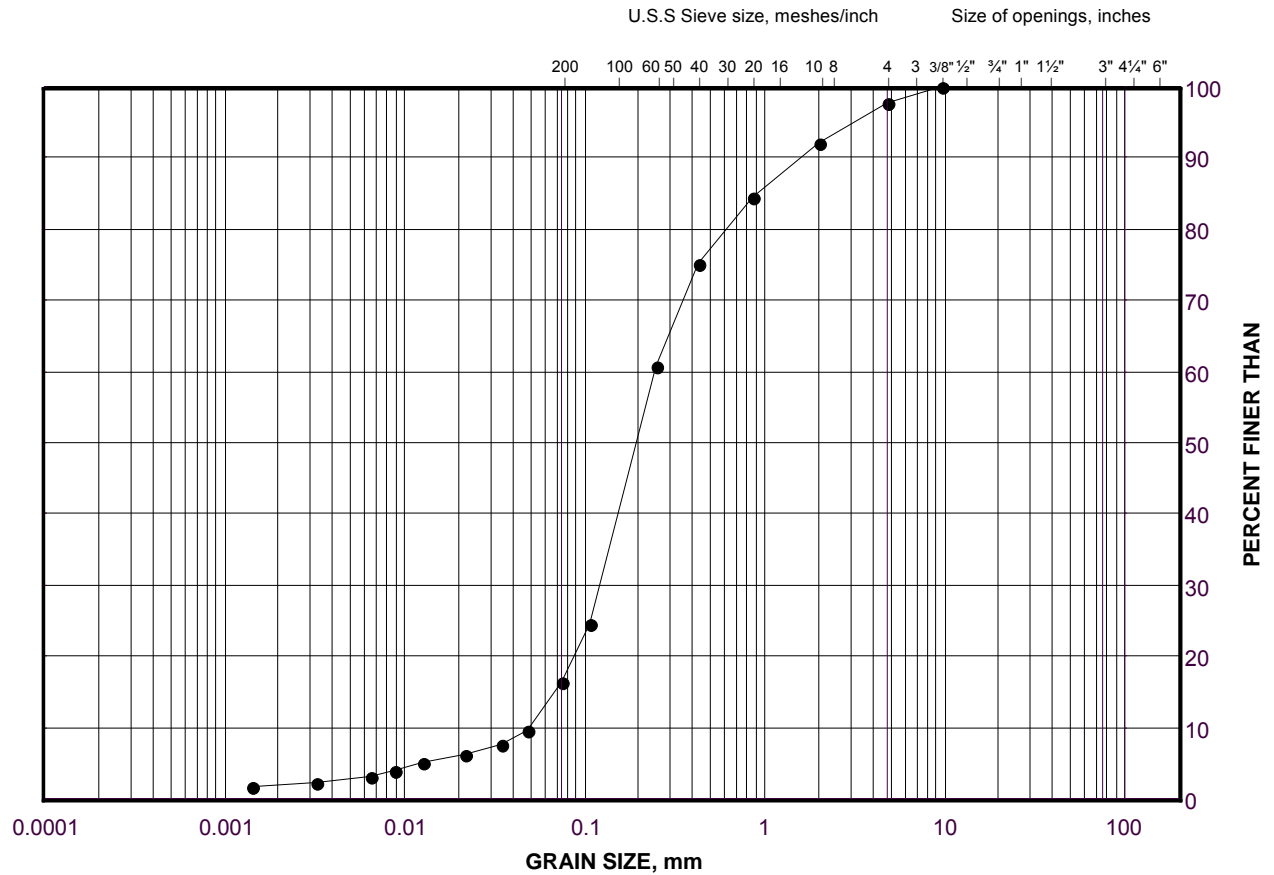
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	1	7A	248.4

Date: 30-May-11

GRAIN SIZE DISTRIBUTION

Sand

FIGURE 5



SILT AND CLAY SIZES			FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED			SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	5	4	249.1

Project Number: 08-1111-0022F

Checked By: KJB

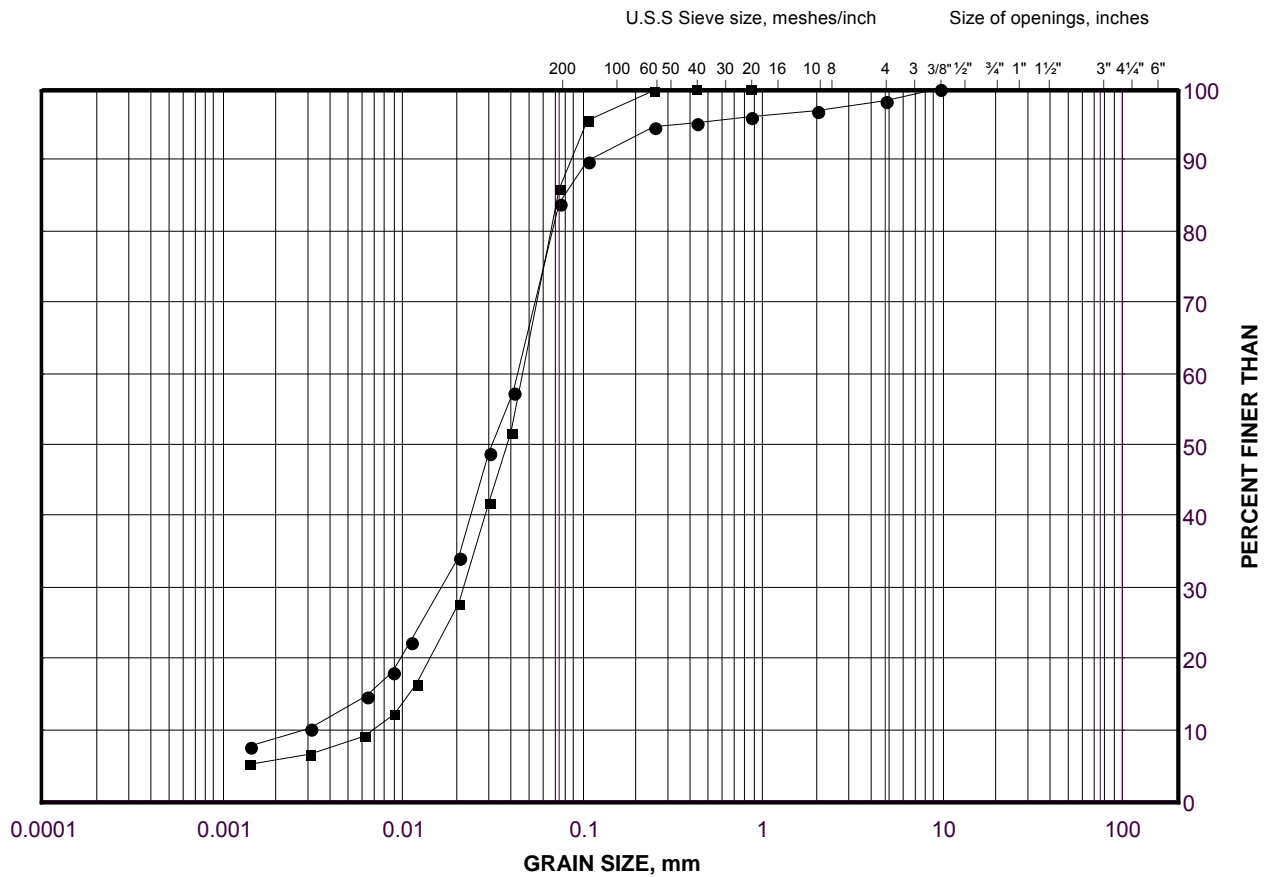
Golder Associates

Date: 30-May-11

GRAIN SIZE DISTRIBUTION

Silt

FIGURE 6



SILT AND CLAY SIZES		FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED		SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	4	7	245.8
■	3	8	244.8

Project Number: 08-1111-0022F

Checked By: KJB

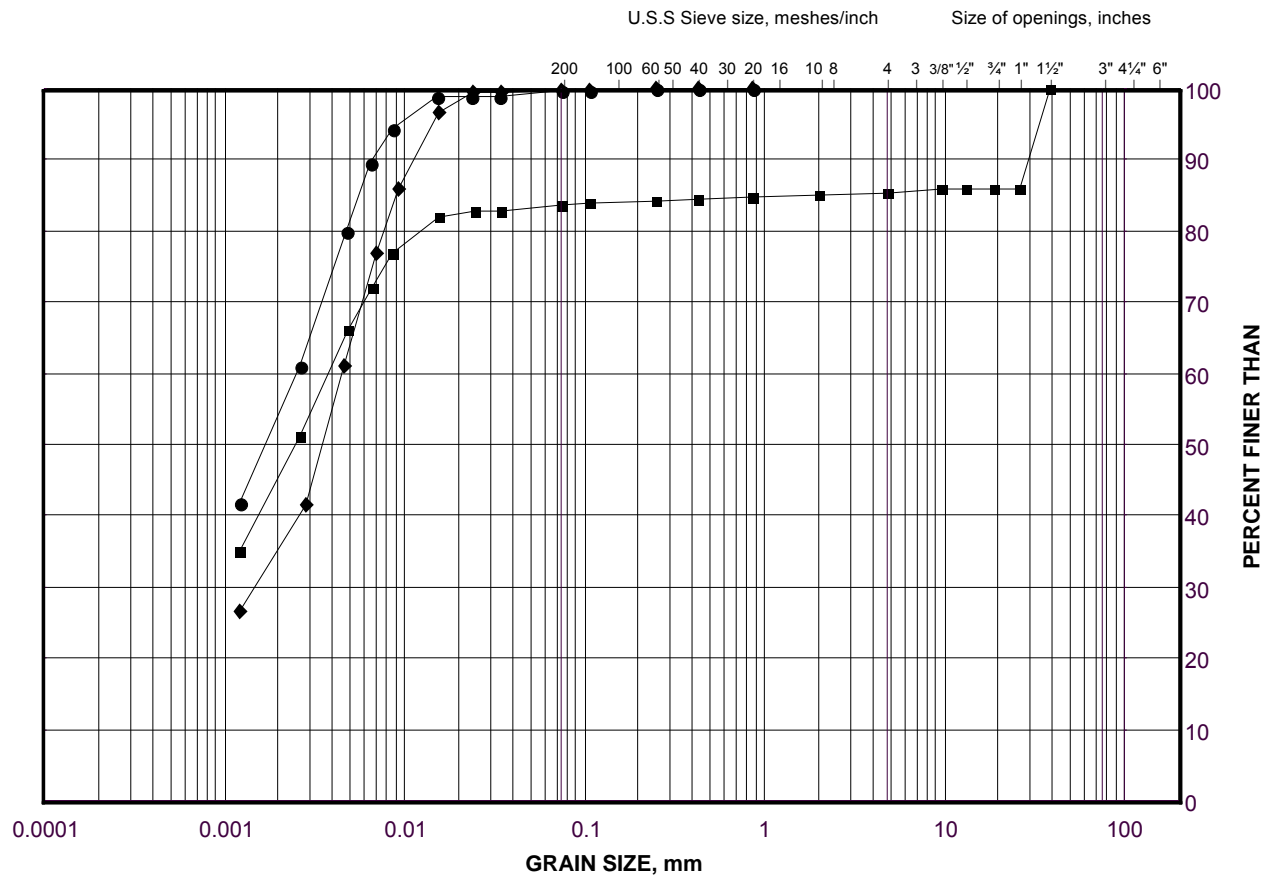
Golder Associates

Date: 30-May-11

GRAIN SIZE DISTRIBUTION

Clayey Silt

FIGURE 7



SILT AND CLAY SIZES		FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED		SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

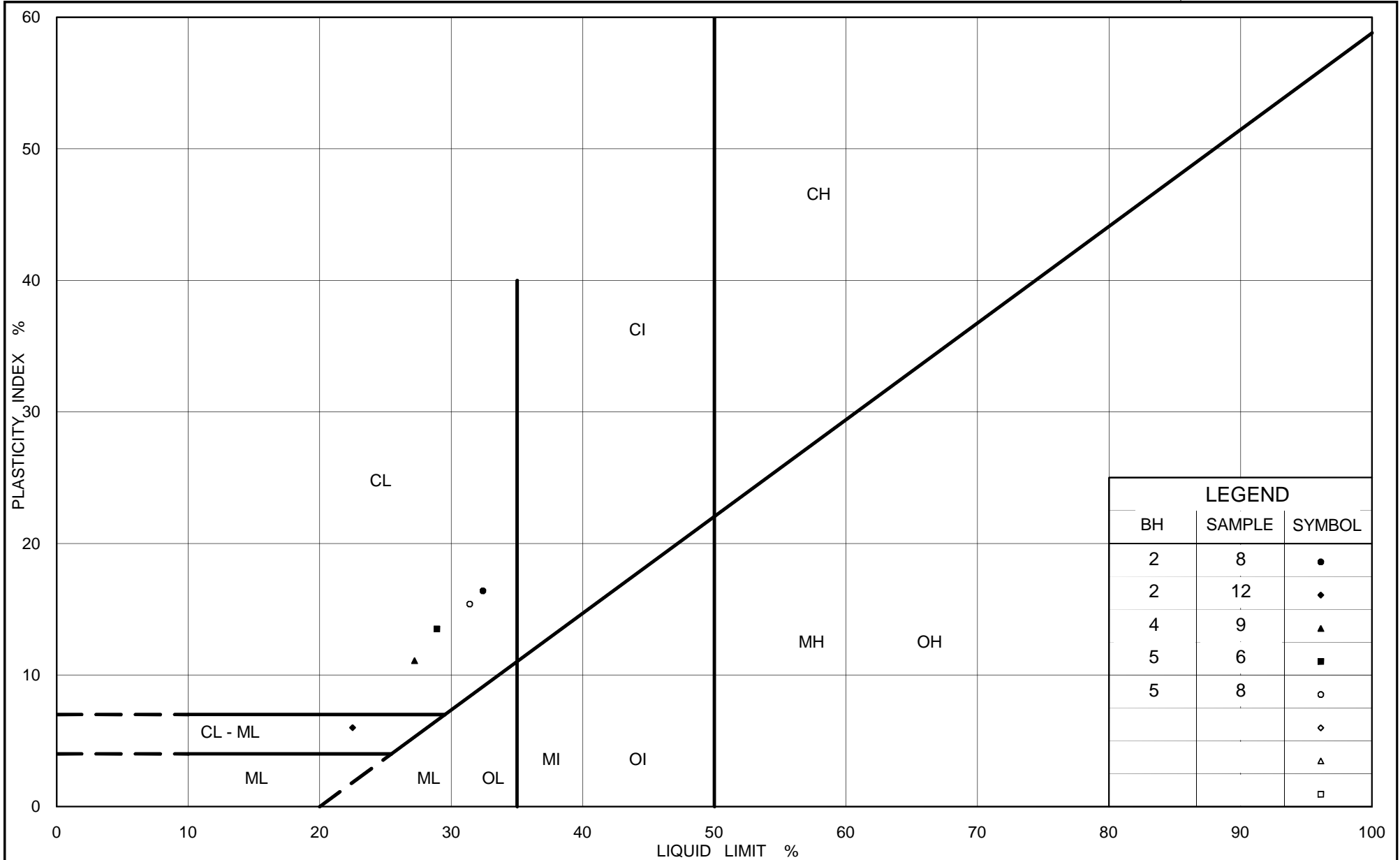
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	5	8	243.7
■	2	8	241.6
◆	4	9	242.7

Project Number: 08-1111-0022F

Checked By: KJB

Golder Associates

Date: 30-May-11



Ministry of Transportation

Ontario

PLASTICITY CHART

Clayey Silt

Figure No. 8

Project No. 08-1111-0022F

Checked By: KJB



APPENDIX C

ENVIRONMENTAL TEST RESULTS

Your Project #: 08-1111-0022
 Site Location: HWY 404 EXTENSION HYDRO TOWERS
 Your C.O.C. #: 24418

Attention: Christ Sternik
 Golder Associates Ltd
 Mississauga - Standing Offer
 2390 Argentia Rd
 Mississauga, ON
 L5N 5Z7

Report Date: 2011/01/06

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B0I6234
Received: 2010/12/29, 12:03

Sample Matrix: Soil
 # Samples Received: 3

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Method Reference
Hot Water Extractable Boron	3	2011/01/05	2011/01/05	CAM SOP-00408	R153 Ana. Prot. 2004
Chloride (20:1 extract)	3	N/A	2011/01/05	CAM SOP-00463	
Free Cyanide	3	N/A	2011/01/05	CAM SOP-00457	SM 4500CN-I
Conductivity	3	N/A	2011/01/05	CAM SOP-00414	APHA 2510
Hexavalent Chromium in Soil by IC Ø	3	N/A	2011/01/05	CAM SOP-00436	EPA SW846-3060/7199
Acid Extr. Metals (aqua regia) by ICPMS	3	2011/01/05	2011/01/05	CAM SOP-00447	EPA 6020
Moisture	3	N/A	2011/01/04	CAM SOP-00445	McKeague 2nd ed 1978
Nitrate (NO3) and Nitrite (NO2) in Soil	3	N/A	2011/01/05	CAM SOP-00440	SM 4500 NO3/NO2B
pH CaCl2 EXTRACT	3	2011/01/05	2011/01/05	CAM SOP-00413	SM 4500 H
Sodium Adsorption Ratio (SAR)	3	2010/12/29	2011/01/05	CAM SOP-00102	EPA 6010
Total Kjeldahl Nitrogen - Soil	3	2011/01/04	2011/01/04	CAM SOP-00454	EPA 351.2 Rev 2

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.
 * Results relate only to the items tested.

(1) Soils are reported on a dry weight basis unless otherwise specified.

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

MATHURA THIRUKKUMARAN, CS Rep
 Email: MThirukkumaran@maxxam.ca
 Phone# (905) 817-5700

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Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Total cover pages: 1

Maxxam Job #: B016234
Report Date: 2011/01/06

Golder Associates Ltd
Client Project #: 08-1111-0022
Project name: HWY 404 EXTENSION HYDRO TOWERS
Sampler Initials: C.S

O'REG 153 METALS & INORGANICS, TABLE 1 (SOIL)

Maxxam ID		IG6500	IG6500	IG6501		IG6502	IG6502		
Sampling Date		2010/12/21	2010/12/21	2010/12/20		2010/12/22	2010/12/22		
	Units	BH# 1, SA# 3	BH# 1, SA# 3 Lab-Dup	BH# 2, SA# 2	QC Batch	BH# 5, SA# 3	BH# 5, SA# 3 Lab-Dup	RDL	QC Batch
Calculated Parameters									
Sodium Adsorption Ratio	N/A	0.38		0.56	2369476	0.43			2369476
Inorganics									
Soluble (20:1) Chloride (Cl)	ug/g	<20	<20	46	2373031	<20		20	2373031
Chromium (VI)	ug/g	<0.2		<0.2	2371993	<0.2		0.2	2371993
Conductivity	mS/cm	0.12		0.19	2372870	0.091		0.002	2372870
Free Cyanide	ug/g	<0.01		<0.01	2372818	<0.01		0.01	2372818
Moisture	%	13		14	2372207	9	9	1	2372009
Available (CaCl2) pH	pH	7.70		7.71	2372869	7.81			2372869
Total Kjeldahl Nitrogen	ug/g	90		109	2371936	57	56	10	2371936
Nitrite (N)	ug/g	<0.5	<0.5	<0.5	2373030	0.5		0.5	2373030
Nitrate (N)	ug/g	<2	<2	<2	2373030	<2		2	2373030
Nitrate + Nitrite	ug/g	<3	<3	<3	2373030	<3		3	2373030
Metals									
Acid Extractable Antimony (Sb)	ug/g	<0.2		<0.2	2372808	<0.2		0.2	2372808
Acid Extractable Arsenic (As)	ug/g	2		2	2372808	1		1	2372808
Acid Extractable Barium (Ba)	ug/g	35		41	2372808	22		0.5	2372808
Acid Extractable Beryllium (Be)	ug/g	0.4		0.3	2372808	<0.2		0.2	2372808
Acid Extractable Cadmium (Cd)	ug/g	<0.1		<0.1	2372808	<0.1		0.1	2372808
Acid Extractable Chromium (Cr)	ug/g	10		10	2372808	8		1	2372808
Acid Extractable Cobalt (Co)	ug/g	4.4		3.6	2372808	3.1		0.1	2372808
Acid Extractable Copper (Cu)	ug/g	9.4		8.8	2372808	5.9		0.5	2372808
Acid Extractable Lead (Pb)	ug/g	4		3	2372808	3		1	2372808
Acid Extractable Molybdenum (Mo)	ug/g	<0.5		<0.5	2372808	<0.5		0.5	2372808
Acid Extractable Nickel (Ni)	ug/g	8.1		8.3	2372808	5.3		0.5	2372808
Acid Extractable Selenium (Se)	ug/g	<0.5		<0.5	2372808	<0.5		0.5	2372808
Acid Extractable Silver (Ag)	ug/g	<0.2		<0.2	2372808	<0.2		0.2	2372808
Acid Extractable Thallium (Tl)	ug/g	0.05		<0.05	2372808	<0.05		0.05	2372808
Acid Extractable Vanadium (V)	ug/g	20		22	2372808	22		5	2372808
Acid Extractable Zinc (Zn)	ug/g	21		17	2372808	14		5	2372808
Acid Extractable Mercury (Hg)	ug/g	<0.05		<0.05	2372808	<0.05		0.05	2372808

N/A = Not Applicable

RDL = Reportable Detection Limit

QC Batch = Quality Control Batch

Maxxam Job #: B016234
Report Date: 2011/01/06

Golder Associates Ltd
Client Project #: 08-1111-0022
Project name: HWY 404 EXTENSION HYDRO TOWERS
Sampler Initials: C.S

ELEMENTS BY ATOMIC SPECTROSCOPY (SOIL)

Maxxam ID		IG6500	IG6501	IG6502		
Sampling Date		2010/12/21	2010/12/20	2010/12/22		
	Units	BH# 1, SA# 3	BH# 2, SA# 2	BH# 5, SA# 3	RDL	QC Batch
Metals						
Hot Water Ext. Boron (B)	ug/g	<0.05	0.05	<0.05	0.05	2372735

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

Maxxam Job #: B016234
Report Date: 2011/01/06

Golder Associates Ltd
Client Project #: 08-1111-0022
Project name: HWY 404 EXTENSION HYDRO TOWERS
Sampler Initials: C.S

QUALITY ASSURANCE REPORT

QC Batch	Parameter	Date	Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	Units	Value (%)	QC Limits	% Recovery	QC Limits
2371936	Total Kjeldahl Nitrogen	2011/01/04	87	75 - 125			<10	ug/g	1.2	40	83	75 - 125
2371993	Chromium (VI)	2011/01/05	101	75 - 125	103	80 - 120	<0.2	ug/g	NC	25	105	75 - 125
2372009	Moisture	2011/01/04							3.2	20		
2372207	Moisture	2011/01/04							4.0	20		
2372735	Hot Water Ext. Boron (B)	2011/01/05					<0.05	ug/g			99	85 - 115
2372808	Acid Extractable Antimony (Sb)	2011/01/05	102	75 - 125			<0.2	ug/g	NC	35	98	75 - 125
2372808	Acid Extractable Arsenic (As)	2011/01/05	104	75 - 125			<1	ug/g	NC	35	96	75 - 125
2372808	Acid Extractable Barium (Ba)	2011/01/05	NC	75 - 125			<0.5	ug/g	1.3	35	95	75 - 125
2372808	Acid Extractable Beryllium (Be)	2011/01/05	101	75 - 125			<0.2	ug/g	NC	35	97	75 - 125
2372808	Acid Extractable Cadmium (Cd)	2011/01/05	105	75 - 125			<0.1	ug/g	NC	35	98	75 - 125
2372808	Acid Extractable Chromium (Cr)	2011/01/05	106	75 - 125			<1	ug/g	6.8	35	97	75 - 125
2372808	Acid Extractable Cobalt (Co)	2011/01/05	101	75 - 125			<0.1	ug/g	10.3	35	98	75 - 125
2372808	Acid Extractable Copper (Cu)	2011/01/05	101	75 - 125			<0.5	ug/g	4.5	35	98	75 - 125
2372808	Acid Extractable Lead (Pb)	2011/01/05	101	75 - 125			<1	ug/g	NC	35	98	75 - 125
2372808	Acid Extractable Molybdenum (Mo)	2011/01/05	103	75 - 125			<0.5	ug/g	NC	35	96	75 - 125
2372808	Acid Extractable Nickel (Ni)	2011/01/05	103	75 - 125			<0.5	ug/g	0.3	35	98	75 - 125
2372808	Acid Extractable Selenium (Se)	2011/01/05	103	75 - 125			<0.5	ug/g	NC	35	98	75 - 125
2372808	Acid Extractable Silver (Ag)	2011/01/05	101	75 - 125			<0.2	ug/g	NC	35	97	75 - 125
2372808	Acid Extractable Thallium (Tl)	2011/01/05	99	75 - 125			<0.05	ug/g	NC	35	96	75 - 125
2372808	Acid Extractable Vanadium (V)	2011/01/05	107	75 - 125			<5	ug/g	NC	35	100	75 - 125
2372808	Acid Extractable Zinc (Zn)	2011/01/05	NC	75 - 125			<5	ug/g	3.0	35	98	75 - 125
2372808	Acid Extractable Mercury (Hg)	2011/01/05	108	75 - 125			<0.05	ug/g	NC	35	102	75 - 125
2372818	Free Cyanide	2011/01/05	38 ⁽¹⁾	75 - 125	108	75 - 125	<0.01	ug/g	NC	35		
2372870	Conductivity	2011/01/05					<0.002	mS/cm	0.8	35	99	75 - 125
2373030	Nitrite (N)	2011/01/05	116	75 - 125	107	80 - 120	<0.5	ug/g	NC	25		
2373030	Nitrate (N)	2011/01/05	107	75 - 125	105	80 - 120	<2	ug/g	NC	25		
2373030	Nitrate + Nitrite	2011/01/05					<3	ug/g	NC	25		
2373031	Soluble (20:1) Chloride (Cl)	2011/01/05	100	75 - 125	109	85 - 115	<20	ug/g	NC	35		

N/A = Not Applicable

RPD = Relative Percent Difference

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

QC Standard: A blank matrix to which a known amount of the analyte has been added. Used to evaluate analyte recovery.

Spiked Blank: A blank matrix to which a known amount of the analyte has been added. Used to evaluate analyte recovery.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spiked amount was not sufficiently significant to permit a reliable recovery calculation.

NC (RPD): The RPD was not calculated. The level of analyte detected in the parent sample and its duplicate was not sufficiently significant to permit a reliable calculation.

(1) - Recovery or RPD for this parameter is outside control limits. The overall quality control for this analysis meets acceptability criteria.

Validation Signature Page

Maxxam Job #: B0I6234

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).




 EWA PRANJIC, M.Sc., C.Chem, Scientific Specialist

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INVOICE INFORMATION		REPORT INFORMATION (if differs from invoice)		PROJECT INFORMATION		MAXXAM JOB NUMBER	
Company Name: <u>Golden Associates Ltd.</u>		Company Name:		Quotation #:		00	
Contact Name: <u>Chris Sternik</u>		Contact Name:		P.O. #:			
Address: <u>2390 Argentinia Rd</u>		Address:		Project #: <u>08-1111-0022</u>			
<u>Mississauga, ON L5N 5Z7</u>				Project Name: <u>Hwy 404 Extension</u>			
Phone: <u>905-567-4444</u> Fax: <u>905-567-6561</u>		Phone: Fax:		Location: <u>Hydro Towers</u>			
Email: <u>chris_sternik@golder.com</u>		Email:		Sampled By: <u>Chris Sternik</u>		CHAIN OF CUSTODY #	

REGULATORY CRITERIA				ANALYSIS REQUESTED (Please be specific)				TURNAROUND TIME (TAT) REQUIRED			
<p>Note: For regulated drinking water samples - please use the Drinking Water Chain of Custody Form.</p> <p>Reg. 153</p> <p><input type="checkbox"/> MISA <input checked="" type="checkbox"/> 2004 <input type="checkbox"/> 2011</p> <p><input type="checkbox"/> PWQO <input checked="" type="checkbox"/> Table 1 <input type="checkbox"/> Residential / Parkland <input type="checkbox"/> Sanitary</p> <p><input type="checkbox"/> Reg. 558 <input checked="" type="checkbox"/> Table 2 <input type="checkbox"/> Industrial / Commercial <input type="checkbox"/> Storm</p> <p><input type="checkbox"/> Table 3 <input type="checkbox"/> Medium / Fine Municipality: _____</p> <p><input type="checkbox"/> Table 6 <input type="checkbox"/> Coarse</p> <p>Other (specify): _____ Report Criteria on C of A? <input checked="" type="checkbox"/></p>				<p>Regulated Drinking Water? (Y / N)</p> <p>Metals Field Filtered? (Y / N)</p> <p><u>Reg 153 Metals & Inorganics</u></p>				<p>PLEASE PROVIDE ADVANCE NOTICE FOR RUSH PROJECTS.</p> <p>Regular (Standard) TAT: <input checked="" type="checkbox"/> 5 to 7 Working Days</p> <p>Rush TAT: Rush Confirmation #: _____ (call Lab for #)</p> <p><input type="checkbox"/> 1 day <input type="checkbox"/> 2 days <input type="checkbox"/> 3 days</p> <p>DATE Required: _____</p> <p>TIME Required: _____</p> <p>Please note that TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details.</p>			
SAMPLES MUST BE KEPT COOL (<10°C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM.											
Sample Identification	Date Sampled	Time Sampled	Matrix (GW, SW, Soil, etc.)	Regulated Drinking Water? (Y / N)	Metals Field Filtered? (Y / N)			# of Cont.	COMMENTS / TAT COMMENTS		
1 BH #1 SA #3	Dec 21/10	AM	Soil					1			
2 BH #2 SA #2	Dec 20/10	AM	Soil					1			
3 BH #5 SA #3	Dec 22/10	AM	Soil					1			
4											
5											
6											
7											
8											
9											
10											
11											
12											

29-Dec-10 12:03

ENV-189 SEL

B016234

RELINQUISHED BY (Signature/Print)	RECEIVED BY (Signature/Print)	Date	Time	# JARS USED AND NOT SUBMITTED	Laboratory Use Only Temperature (°C) on Receipt
<u>Chris Sternik</u>	<u>Maxxam</u>	<u>Dec 29/10</u>	<u>12:03</u>	<u>3</u>	<u>5/6/5°C</u>



APPENDIX D

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 a 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.

END OF SECTION

At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. 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 now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

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