Golder Associates

FOUNDATION INVESTIGATION AND DESIGN REPORT PROCTOR'S CREEK CULVERT 2 NORTH EXTENSION/REPLACEMENT HIGHWAY 401-COUNTY ROAD 30 INTERCHANGE BRIGHTON, ONTARIO G.W.P. 256-98-00, W.P. 4141-07-00

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HIGHWAY 401-COUNTY ROAD 30 INTERCHANGE
BRIGHTON, ONTARIO
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Giffels Associates Limited (Giffels) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for culvert extensions and new culverts along Proctor’s Creek, and for embankments 4.5 m or more in height within a section of the realigned W-N/S ramp, at the Highway 401-County Road 30 interchange near Brighton, Ontario.

This report addresses the replacement of an existing corrugated steel pipe (CSP) culvert extension at the north (inlet) end of Culvert 2 with a new concrete culvert extension.

The terms of reference and scope of work for the foundation investigation are outlined in MTO’s Request for Proposal, dated May 2006, and in Section 6.8 of Giffels’ Technical Proposal for this assignment, which were subsequently amended to included the extension of Culvert 2 as outlined in Golder’s letter to Giffels dated January 3, 2008.

2.0 SITE DESCRIPTION

Culvert 2 is located north of Highway 401 and conveys Proctor's Creek under the N-S Ramp, County Road 30 and Telephone Road. The existing Culvert 2 consists of a 2.4 m wide by 1.7 m high concrete open footing structure, with a 12.7 m long, 2.3 m wide by 1.6 m high corrugated steel pipe (CSP) arch extension at the north end. The overall culvert invert declines from approximately Elevation 193.0 m at the north end to Elevation 192.8 m at the south end.

The natural ground surface immediately adjacent to Proctor's Creek is at approximately Elevation 193 m to 193.5 m at the north (upstream) end of Culvert 2, and at about Elevation 192.5 m to 193 m at and beyond the south (downstream) end. The N-S Ramp, County Road 30 and Telephone Road embankments are up to about 7 m high relative to the natural ground surface, with the pavement grade at approximately Elevation 199.5 m on County Road 30 at the ramp terminus/Telephone Road intersection.

The natural ground surface in the area is generally grass-covered, with scattered trees and shrubs.

3.0 INVESTIGATION PROCEDURES

3.1 Geotechnical Investigation

The field work for this subsurface investigation was carried out in May and July 2007 and in January 2008, during which time three boreholes were advanced adjacent to Culvert 2. Borehole 07-12B was drilled in near the north end of Culvert 2, to supplement Boreholes 07-12 and 07-13, which were drilled near the south end of this culvert. Boreholes 07-12B and 07-13 were advanced using a CME-55 track-mounted drill rig, and Borehole 07-12 was advanced using portable drilling equipment (due to access limitations), all supplied and operated by Marathon Drilling Company Ltd. of Ottawa, Ontario.

The borehole locations are shown on Drawing 1. Boreholes 07-12B and 07-13 were advanced with full-size drilling equipment to depths of 14.2 m and 18.9 m, respectively, and Borehole 07-12 was advanced with portable drilling equipment to a depth of 4.9 m. All boreholes terminated within very dense soils.

Soil samples were obtained at 0.75 m and 1.5 m intervals of depth, using 50 mm outside diameter split-spoon samplers in accordance with the Standard Penetration Test (SPT) procedure. The groundwater conditions in the open boreholes were observed throughout the drilling operations and are noted on the borehole logs following the text of this report. Following completion, the boreholes were backfilled to ground surface using bentonite pellets, mixed in places with auger cuttings, in accordance with the requirements of Ontario Regulation 903.

The field work was supervised on a full-time basis by members of Golder's staff, who located the boreholes in the field, directed the drilling, sampling, and in situ testing operations, and logged the boreholes. The soil samples were identified in the field, placed in labelled containers and transported to Golder's laboratory in Mississauga for further examination and laboratory testing. Index and classification tests consisting of water contents, Atterberg limits and grain size distributions were carried out on selected soil samples.

The borehole locations were measured in the field relative to the existing culvert and the roadway, and the ground surface elevation at the borehole locations was determined using the digital terrain mapping for this project. The borehole locations (northing and easting coordinates referenced to MTM NAD83 coordinate system) and ground surface elevations (referenced to geodetic datum) are summarized in the following table and are shown on Drawing 1.

Borehole Number	*Northing (m)*	*Easting (m)*	*Ground Surface Elevation (m)*
07-12	4,882,564.2	203,060.1	195.1
07-12B	4,882,635.5	203,105.0	195.5
07-13	4,882,574.5	203,055.2	199.4

3.2 Previous Hydrogeological Investigation

Two boreholes (MW1-08 and MW2-09) were advanced and completed as monitoring wells in November 2008 and January 2009 as part of a hydrogeological investigation by Golder to assess the need for a Permit to Take Water (PTTW) for this site.

Boreholes MW1-08 and MW2-09 were drilled to depths of 6.7 m and 4.1 m, respectively, by Geo-Environmental Drilling Inc. and Strata Soil Sampling Inc. The approximate borehole/monitoring well locations are shown on Drawing 1, and the records for these boreholes are contained in Appendix A of this report for reference. Soil samples were obtained at 0.75 m and 1.5 m intervals of depth using split-spoon samplers as part of the SPT procedure. The soil samples obtained during this investigation were transported to Golder’s geotechnical laboratory in Whitby, Ontario for further examination and classification testing (water contents and grain size distributions).

The boreholes were completed with 50 mm diameter PVC screen and riser pipe. A filter sand pack was placed around the screened portion of each monitoring well and the remaining annular space was sealed with bentonite. The monitoring well installation details are shown on the borehole records in Appendix A.

4.0 SITE GEOLOGY AND STRATIGRAPHY

4.1 Regional Geological Conditions

The area of Highway 401 and County Road 30 lies within the Iroquois Plain physiographic region, as delineated in *The Physiography of Southern Ontario*[1]; the Iroquois Plain extends around the western and northern shores of Lake Ontario. The soils within this physiographic region represent the flat to undulating lake bed and beaches of the former glacial Lake Iroquois, which occupied the Lake Ontario basin during the last glacial recession.

The soils in the Iroquois Plain are typically comprised of glaciolacustrine clays and silts, though deposits of sand to sand and gravel are also known to be present. The overburden soils are underlain by limestone bedrock of the Trenton Group.

4.2 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of the in situ and laboratory testing are given on the Record of Borehole sheets; the results of the laboratory testing are also shown on Figures 1 to 4 following the text of this report. The borehole records and laboratory test results from a hydrogeological investigation at this site are shown in Appendix A. The stratigraphic boundaries shown on the borehole records are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

In summary, the subsoil conditions encountered in Boreholes 07-12, 07-12B and 07-13 at the Culvert 2 site consist of existing sand and silt to silty sand embankment fill overlying a deposit of compact to very dense sand and silt to sandy silt till and/or loose to very dense silt. A more detailed description of the subsoil conditions encountered in the boreholes at the Culvert 2 site is provided in the following sections.

4.2.1 Fill

Approximately 2.6 m and 8.2 m of fill materials were encountered in Boreholes 07-12 and 07-13, respectively, which were drilled near the toe and through the shoulder of the Telephone Road embankment in the northwest quadrant of the Highway 401-County Road 30 interchange; the base of the fill was encountered in these boreholes at Elevations 192.5 m and 191.2 m. Approximately 3.1 m of fill was encountered in Borehole 07-12B, which was drilled adjacent to

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

the north end of Culvert 2; the base of the fill was encountered in this borehole at approximately Elevation 192.5 m.

The fill as encountered in these boreholes consists of sand and silt to silty sand containing trace to some gravel and trace clay. A 1.5 m thick layer of cohesive fill, consisting of clayey silt containing trace to some sand and trace gravel, was encountered below the sand and silt fill in Borehole 07-13. The results of grain size distribution testing carried out on two selected samples of the sand and silt fill are shown on Figure 1. Atterberg limits testing was completed on one sample of the clayey silt fill from Borehole 07-13, and measured a plastic limit of 14 per cent, a liquid limit of 19 per cent, and a plasticity index of 5 per cent; this result, which is plotted on a plasticity chart on Figure 2, confirms that the cohesive portion of the fill is a clayey silt of low plasticity.

The measured SPT "N" values within the sand and silt to silty sand fill vary from 2 to 38 blows per 0.3 m of penetration. The fill as encountered in Boreholes 07-12 and 07-12B, which were advanced near the toes of existing embankments, has a very loose to compact relative density, based on measured SPT "N" values of 2 to 21 blows per 0.3 m of penetration. The County Road 30/Telephone Road embankment fill as encountered in Borehole 07-13, which was drilled through the shoulder of this local road, has a loose to dense (but generally compact) relative density, based on measured SPT "N" values of 6 to 38 blows per 0.3 m of penetration (but typically 13 to 17 blows per 0.3 m of penetration).

The measured SPT "N" values within the clayey silt fill were 5 and 8 blows per 0.3 m of penetration, indicating that the cohesive fill has a firm to stiff consistency.

4.2.2 Peat

A 400 mm thick layer of peat was encountered below the existing fill in Borehole 07-12. The base of the peat was encountered at approximately Elevation 192.1 m in this borehole.

4.2.3 Sand and Silt to Sandy Silt Till

A glacial till deposit was encountered below the fill and peat in Borehole 07-12, and below the fill in Borehole 07-12B; this deposit was not encountered in Borehole 07-13. Based on the results from these boreholes, and from boreholes advanced along Proctor's Creek as part of subsurface investigations for other culvert locations, the till deposit is discontinuous in the vicinity of the Proctor's Creek channel.

The surface of the till, where present, was encountered at approximately Elevation 192.5 m in Borehole 07-12B, near the upstream end of Culvert 2, and at approximately Elevation 192.1 m in

Borehole 07-12, near the downstream end of the culvert. The till deposit was full penetrated in Borehole 07-12B, where it was approximately 6.0 m in thickness.

The till deposit varies in composition from sand and silt to sandy silt, containing trace to some gravel and trace clay. The results of grain size distribution testing conducted on two samples of the sand and silt to sandy silt till are shown on Figure 3. An Atterberg limits test was conducted on one sample of the till from Borehole 07-12B, and this sample was found to be non-plastic as noted on the borehole record.

The measured SPT "N" values within the sand and silt to sandy silt till ranged from 14 to 53 blows per 0.3 m of penetration, with one SPT "N" value of 30 blows per 0.15 m of penetration. The sand and silt to sandy silt till is therefore considered to have a compact to very dense relative density.

4.2.4 Silt

A deposit of silt was encountered below the sand and silt to sandy silt till in Borehole 07-12B, and below the fill in Borehole 07-13. The surface of this deposit was encountered at about Elevation 186.4 m in Borehole 07-12B near the upstream end of Culvert 2, and at about Elevation 191.2 m in Borehole 07-13 near the downstream end of the culvert. The silt deposit was not fully penetrated in these boreholes; it extends for a thickness of at least 5.1 m in Borehole 07-12B and at least 10.7 m in Borehole 07-13.

The deposit consists of silt containing trace sand, gravel and clay. The results of grain size distribution testing carried out on five selected samples of this deposit are shown on Figure 4.

The measured SPT "N" values within the silt deposit range from 7 to 104 blows per 0.3 m of penetration. The lower recorded SPT "N" values of 7 and 16 blows per 0.3 m of penetration were measured near the upper portion of the water-bearing silt deposit in Borehole 07-12B, and are considered to have resulted from sample disturbance due to groundwater inflow to the borehole. All other SPT "N" values are greater than 36 blows per 0.3 m of penetration. The deposit is, therefore, considered to have a generally dense to very dense relative density, except in the upper portion as encountered in Borehole 07-12B where it is interpreted to have a compact relative density.

4.3 Groundwater Conditions

The water levels were observed in the boreholes following completion of drilling, and these observations are noted on the borehole records following the text of this report. Based on the moisture conditions and water levels observed during drilling, the groundwater level near the north end of Culvert 2 is at approximately Elevation 193.2 m as encountered in Borehole 07-12B.

This water level is near the original ground surface in this area, and near the water level in the adjacent Proctor's Creek channel.

Two monitoring wells were installed near the north end of Culvert 2 (see Appendix A) as part of an independent hydrogeological investigation to support a Permit to Take Water (PTTW) assessment. The water levels in these standpipe piezometers were measured at depths of 1.3 m and 1.8 m below ground surface in January 2009.

The groundwater level at the culvert sites should be expected to fluctuate as a result of seasonal variations in precipitation and the Proctor's Creek water levels.

5.0 CLOSURE

This Foundation Investigation Report was prepared Ms. Lisa Coyne, P. Eng., an Associate and geotechnical engineer with Golder. Mr. Jorge Costa, P.Eng., a Principal of and Designated MTO Contact for Golder, conducted an independent review of the report.

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PART B

FOUNDATION DESIGN REPORT
PROCTOR'S CREEK CULVERT 2
NORTH EXTENSION/REPLACEMENT
HIGHWAY 401-COUNTY ROAD 30 INTERCHANGE
BRIGHTON, ONTARIO
G.W.P. 256-98-00, W.P. 4141-07-00

6.0 ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides foundation design recommendations for the north extension/replacement of Culvert 2, in the northeast quadrant of the Highway 401-County Road 30 interchange. The recommendations are based on interpretation of the factual data obtained from Borehole 07-12B, together with the results from Boreholes 07-12 and 07-13 at the south end of Culvert 2. The interpretation and recommendations are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and to design the foundations for the proposed culvert extension/replacement.

Where comments are made on construction, they are provided to highlight those aspects which could affect the design of the project, and for which special provisions or operational constraints may be required in the Contract Documents. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods, scheduling and the like.

6.2 Foundation Options for North Extension/Replacement of Culvert 2

The existing Culvert 2 structure consists of a 2.4 m wide by 1.7 m high concrete open footing structure (footing dimensions and founding elevations unknown), with a 12.7 m long, 2.3 m wide by 1.6 m high corrugated steel pipe (CSP) arch extension at the north end. The existing concrete structure is in good condition, but the CSP arch culvert extension is in poor condition and requires replacement.

The Proctor’s Creek channel and culvert invert level are at approximately Elevation 193.0 m at the upstream end of the Culvert 2, and approximately Elevation 192.8 m at the downstream end of the existing culvert.

Either a box culvert or an “open footing” (shallow foundation) culvert is feasible for the replacement of the existing CSP arch extension at the north end of Culvert 2. Deep foundations are not required for the extension/replacement as shallow foundations will provide sufficient bearing resistance and acceptable settlement performance under the widened embankment loading.

The advantages and disadvantages associated with both open footing and box culvert extensions/replacements are summarized in Table 1 following the text of this report. From a foundations perspective, a box culvert extension has an advantage over an open footing extension in terms of minimizing the depth of excavation and groundwater control requirements compared with open footings; in addition, pre-cast box culvert segments can often be installed more expeditiously than cast-in-place open footing culverts, resulting in shorter durations for dewatering and surface water pumping. However, a box culvert extension/replacement may not satisfy fisheries requirements, or may result in compatibility problems with the existing open footing culvert channel. Since both foundations options are geotechnically feasible, an open footing extension/replacement option is considered an acceptable alternative to a box culvert.

Recommendations for both a box culvert extension and a shallow foundation (open footing) culvert extension are provided in the following sections.

6.3 Box Culvert Extension/Replacement

6.3.1 Founding Elevation

A box culvert extension/replacement does not need to be founded below the depth of frost penetration, but the culvert should be designed to structurally withstand the frost pressures and frost treatment (i.e., backfill) should be provided as per OPSD 803.010.

It has been assumed that the concrete base slab for a box culvert extension, if adopted, would have a thickness of about 300 mm, and that approximately 400 mm of fill would be placed on top of the concrete base slab to create a soil-lined channel, to satisfy fisheries requirements. Therefore, the base slab for a new box culvert extension/replacement at the north end of Culvert 2 would be founded as follows, on the compact to very dense sand and silt till deposit:

Culvert Number	*Channel Invert Elevation*	*Maximum Founding Elevation*
2 – North Extension	193.0 m	192.3 m

Based on this founding elevation, the box culvert extension will require excavation to a depth of about 0.9 m below the groundwater level at the north end of Culvert 2, within fine-grained (sand and silt fill, sand and silt till) soils. Groundwater control will be required for construction of the box culvert extension and, as discussed further in Section 6.8, it is recommended that an NSSP be included in the Contract Documents to address dewatering for the box culvert extension.

The sand and silt till subgrade for a box culvert extension/replacement will be susceptible to loosening and degradation on exposure to water and construction traffic. It is recommended that a 100 mm thick layer of mass concrete be placed on the subgrade within the culvert extension footprint to form a working mat for construction of the culvert extension, to protect the subgrade from degradation; this aspect is discussed further in Section 6.8. In this case, a 75 mm thick levelling pad of Granular A (meeting the gradation requirements set out in Ontario Provincial Standard Specification (OPSS) 1010) or concrete fine aggregate (meeting the gradation requirements set out in OPSS 1002) could be provided on top of the concrete mat to provide a "levelling pad" for the box culvert extension/replacement.

6.3.2 Geotechnical Resistances

A box culvert extension/replacement placed on the properly prepared subgrade, at or below the elevation identified above, should be designed based on the following factored geotechnical resistances at Ultimate Limit States (ULS) and geotechnical resistances at Serviceability Limit States (SLS):

Culvert Number	***Culvert Span***	***Factored Geotechnical Resistance at ULS***	***Geotechnical Resistance at SLS****
2 – North Extension	2.4 m	300 kPa	250 kPa

* For 25 mm of total settlement, assuming the box culvert extension has a width of approximately 2.4 m to match the existing Culvert 2.

The ULS resistance and settlement are dependent on the footing size, configuration and applied loads; the geotechnical resistances should, therefore, be reviewed if the culvert span or founding elevation differs significantly from those given above.

The geotechnical resistances provided above are given under the assumption that the loads will be applied perpendicular to the surface of the footings. 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 6.7.2 of the *Canadian Highway Bridge Design Code (CHBDC).*

6.3.3 Resistance to Lateral Loads

Resistance to lateral forces / sliding resistance between the base slab for the culvert extension/replacement and the subgrade should be calculated in accordance with Section 6.7.5 of the *CHBDC*. For design, the coefficient of friction (tan φ') between a pre-cast concrete box culvert extension/replacement and the bedding and/or concrete mat should be taken as 0.55, and the coefficient of friction (tan φ') between the cast-in-place concrete mat and the underlying sand and silt till deposit should be taken as 0.60. These values are unfactored; in accordance with the *CHBDC,* a factor of 0.8 is to be applied in calculating the horizontal resistance.

6.4 Strip Footings for Open Footing Culvert and Wing Walls/Retaining Walls

6.4.1 Founding Elevations

An open footing culvert extension/replacement, and any associated wing walls/retaining walls, can be supported on strip footings founded below the fill on the compact to very dense sand and silt till deposit. Strip footings should be founded at a minimum depth of 1.5 m below the lowest surrounding grade, to provide adequate protection against frost penetration. The following founding elevation is recommended for strip footings for support of the north extension of Culvert 2, and any associated wing walls/retaining walls:

Culvert Number	***Channel Invert Elevation***	***Maximum Founding Elevation***
2 – North Extension	193.0 m	191.5 m

The maximum founding level identified above will require excavation to a depth of up to about 1.7 m below the groundwater level at the north end of Culvert 2, within the fine-grained (sand and silt fill, sand and silt till) soils. Groundwater control will be required for construction of the open footing culvert extension and any wing walls/retaining walls and, as discussed further in Section 6.8, it is recommended that an NSSP be included in the Contract Documents to address dewatering for the footing construction.

The sand and silt till subgrade for the culvert extension footings will be susceptible to loosening and degradation on exposure to water and construction traffic. It is recommended that a 100 mm thick layer of mass concrete be placed on the footing subgrade to form a working mat for construction of the extension footings, to protect the subgrade from degradation; this aspect is discussed further in Section 6.8.

6.4.2 Geotechnical Resistance

Strip footings placed on the properly prepared subgrade, at or below the maximum founding elevations identified above, should be designed based on the following factored geotechnical resistances at ULS and geotechnical resistances at SLS.

Culvert Number	***Footing Width***	***Factored Geotechnical Resistance at ULS***	***Geotechnical Resistance at SLS****
2	0.6 m	300 kPa	250 kPa
	0.9 m	325 kPa	250 kPa

* For 25 mm of total settlement for the given footing width.

The ULS resistance and settlement are dependent on the footing size, configuration and applied loads; the geotechnical resistances should, therefore, be reviewed if the selected footing width or founding elevation differs significantly from those given above.

The geotechnical resistances provided above are given under the assumption that the loads will be applied perpendicular to the surface of the footings. 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 6.7.2 of the *CHBDC.*

6.4.3 Resistance to Lateral Loads

Resistance to lateral forces / sliding resistance between the concrete footings for the culvert extensions or culvert replacement and the subgrade should be calculated in accordance with Section 6.7.5 of the *CHBDC*. The following values for the coefficient of friction, tan ϕ' or tan δ, can be used for cast-in-place and pre-cast concrete footings founded on the properly prepared, compact to very dense sand and silt till:

Footing Type	***Coefficient of Friction***
Cast-in-place concrete footing	tan $\phi' = 0.6$
Pre-cast concrete footing	tan $\delta = 0.45$

The above values are unfactored; in accordance with the *CHBDC*, a factor of 0.8 is to be applied in calculating the horizontal resistance.

6.5 Settlement and Culvert Connection Requirements

If additional fill is placed to widen County Road 30 and widen or realign the N-S and N/S-W Ramps, some settlement of the foundation soils will occur below the north extension/replacement of Culvert 2. Assuming placement of up to 6 m of fill above the northward culvert extension, it is predicted that approximately 10 mm of settlement will occur; this settlement will be completed relatively quickly during and immediately following any embankment widening work. It is recommended that the structural designer determine, based on this predicted magnitude of settlement and the actual change in embankment loading, whether a rigid connection or an articulation is required between the existing concrete open footing culvert and the culvert extension/replacement.

The settlement analyses were carried out using the commercially-available program Unisettle (Version 3.0), using the elastic deformation moduli given below based on correlations (Bowles, 1982)[2] with the SPT "N" values and engineering judgement from experience with similar soils in southern Ontario.

Soil Unit	***Bulk Unit Weight***	***Elastic Modulus***
Embankment fill	20 kN/m^3	-
Compact to very dense sand and silt till/Compact to very dense silt	21 kN/m^3	40 MPa

[2] Bowles, J.E. 1982. *Foundation Analysis and Design*. Third Edition, McGraw-Hill Book Company.

6.6 Culvert Backfill and Erosion Protection

Backfill to the culvert extension/replacement walls should consist of granular fill meeting the requirements of OPSS 1010 Granular A or Granular B Type II, but with less than 5 per cent passing the No. 200 sieve. The backfill should be placed and compacted in accordance with MTO's Special Provision SP105S10. The fill depth during placement should be maintained equal on both sides of the culvert walls, with one side not exceeding the other by more than 500 mm.

Backfill above the culvert could consist of OPSS 1010 Granular A or Granular B Type II fill, or select earth fill. The new culvert extension/replacement should be designed for the full overburden pressure and live load, assuming an embankment fill unit weight of 22 kN/m^3 for Granular A, and 21 kN/m^3 for Granular B Type II backfill or select earth fill.

If the Proctor's Creek flow velocities are sufficiently high, provision should be made for scour and erosion protection. To prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring) or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a clay seal or concrete cut-off wall should be provided at the upstream end of the new extension/replacement. If a clay seal is adopted, the clay material should meet the requirements of OPSS 1205. The clay seal should have a thickness of 1 m, and should extend from a depth of 1 m below the scour level to a minimum horizontal distance of 2 m on either side of the inlet opening, and a minimum vertical height equivalent to the high water level, including along the embankment slope. Alternatively, a clay blanket may be constructed, extending upstream for a length of three times the culvert height and along the adjacent slope to a height of two times the culvert height or the high water level, whichever is greater.

The requirements for and design of erosion protection measures for the inlet of this culvert extension/replacement should be assessed by the hydraulic design engineer. As a minimum, erosion protection for the inlet of the culvert extension should follow the standard presented in OPSD 810.010, similar to Rip Rap Treatment Type A with the rip-rap placed up to the toe of slope level, in combination with the clay seal or cut-off measures recommended above. Similarly, rip-rap should be provided over the full extent of the clay blanket, including the creek side slopes and fill slope over the culverts.

6.7 Lateral Earth Pressures for Design

The lateral earth pressures acting on the culvert extension/replacement walls and any associated headwalls or retaining walls will depend on the type and method of placement of the backfill materials, on the nature of the soils behind the backfill, on the magnitude of surcharge including construction loadings, on the freedom of lateral movement of the structure, and on the drainage conditions behind the walls.

The following recommendations are made concerning the design of the walls. As discussed in Section 6.6, these recommendations assume that the backfill to the culvert walls consists of free-draining granular fill meeting the requirements of OPSS Granular A or B Type II, placed and compacted in accordance with MTO's Special Provision SP105S10, with longitudinal drains and weep holes installed as necessary to provide positive drainage of the granular backfill.

- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the walls, in accordance with *CHBDC* Section 6.9.3 and Figure 6.6. Other surcharge loadings should be accounted for in the design, as required.

- The granular fill may be placed either in a zone with width equal to at least 1.5 m behind the back of the wall stem (Case I, Figure C6.20(a) of the *Commentary on 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 (Case II, Figure C6.20(b) of the *Commentary on CHBDC)*.

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

Soil unit weight:	20 kN/m^3
Coefficients of static lateral earth pressure:	
Active, K_a	0.33 (level ground)
	0.53 (2H:1V slope)
At rest, K_o	0.50 (level ground)
	0.80 (2H:1V slope)

- For Case II, the pressures are based on granular fill 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 (level ground)	
	0.38 (2H:1V slope)	
At rest, K_o	0.43 (level ground)	
	0.61 (2H:1V slope)	

- Where the wing wall/retaining wall support allows lateral yielding of the stem, active earth pressures should be used in the geotechnical design of the structure. Where the wall support does not allow lateral yielding (which typically applies to a culvert or rigid frame structure), at-rest earth pressures should be assumed for the geotechnical design. The movement to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure, may be taken as follows:

- Rotation of approximately 0.002 about the base of a vertical wall;
- Horizontal translation of 0.001 times the height of the wall; or
- A combination of both.

6.7.1 Seismic Considerations

Seismic (earthquake) loading must also be taken into account in the design in accordance with Section 4.6 of the *CHBDC*. 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 walls should be designed to withstand the combined lateral loading for the appropriate static pressure conditions given above, plus the applicable earthquake-induced dynamic earth pressure, as given in the equation below.

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

where K is either the static active earth pressure coefficient (K_a) or the static at rest earth pressure coefficient (K_o), as applicable;
K_{AE} is the seismic active earth pressure coefficient determined in accordance with Sections 4.6.4 and C.4.6.4 of the CHBDC and its *Commentary*;
γ' is the effective unit weight of the soil (kN/m^3) taken as 20 kN/m^3 for granular fill above the water level, and 10 kN/m^3 for fill/native soils below the water table;
d is the investigated depth below the top of the wall (m); and
H is the total height of the wall above the underside of footing or toe (m).

Using the amplified zonal acceleration ratio of 0.06g obtained for this site, the seismic lateral earth pressure coefficients (K_{AE}) for both yielding and non-yielding walls, considering earth and granular fills, were determined in accordance with Sections 4.6.4 and C4.6.4 of the *CHBDC* and its *Commentary,* and these are presented below. These seismic earth pressure coefficients assume that the back of the wall is vertical and the ground surface behind the wall is essentially flat.

SEISMIC ACTIVE PRESSURE COEFFICIENTS, K_{AE}

Wall Condition	Case I	Case II	
		Granular A	Granular B Type II
Yielding wall	0.32	0.26	0.30
Non-yielding wall	0.37	0.30	0.34

Note: These 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 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.

6.8 Construction Considerations

6.8.1 Groundwater and Surface Water Control

Control of the surface water and groundwater will be necessary for the north extension/replacement of Culvert 2, to allow excavation and foundation construction to be carried out in dry conditions.

Depending on the Proctor's Creek flow at the time of construction, the surface water flow could be passed through the culvert area by means of a temporary pipe, or diverted by pumping from behind a temporary cofferdam. Surface water should be directed away from the excavation areas, to prevent ponding of water that could result in disturbance and weakening of the foundation subgrade soils; further discussion on this aspect is provided in Section 6.8.3.

As discussed previously, foundations for the north extension/replacement of Culvert 2 will require excavation to nearly 2 m below the groundwater level at the site. Appropriate groundwater control will be required to allow excavation and foundation subgrade preparation in the water-bearing sand and silt till; this could involve the use of interlocking steel sheet piles extended to sufficient depth to avoid piping, and/or the use of a specialized eductor system designed and installed by a specialist contractor. It is recommended that an NSSP be included in the Contract Documents to warn the Contractor of the soil conditions and the requirement for design and installation of a groundwater control system for this culvert extension/replacement site. An example NSSP is given in Appendix B.

6.8.2 Excavations and Temporary Roadway Protection

Temporary excavations for the north extension/replacement of Culvert 2 will extend through existing loose to compact sand and silt fill, into the compact to very dense sand and silt till. Excavation works must be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act and Regulations for Construction Projects. The existing fill is classified as Type 3 soil, according to the OHSA. Where space permits, and provided that appropriate dewatering is in place and operating to maintain the water level below the base of the foundation excavations, temporary open-cut excavations through these materials should be made with side slopes formed no steeper than 1 horizontal to 1 vertical (1H:1V).

Depending on the construction staging sequence and schedule, temporary roadway protection may be required along the north side of the N/S Ramp and/or the east side of County Road 30 to facilitate the construction of the culvert extension/replacement. The temporary excavation support system should be designed and constructed in accordance with MTO's Special Provision 105S19. The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in SP105S19, provided that any utilities that may remain present adjacent to the excavation can tolerate this level of deformation.

6.8.3 Subgrade Protection

The sand and silt till soils that will be exposed at the footing or box culvert subgrade level will be susceptible to disturbance from construction traffic and/or ponded water. To limit this degradation, it is recommended that a working mat of mass concrete be placed on the subgrade within four hours after preparation, inspection and approval of the subgrade. This requirement can be addressed either with a note on the General Arrangement drawing as well as with an NSSP; a sample NSSP is included in Appendix B.

7.0 CLOSURE

This Foundation Design Report was prepared by Ms. Lisa Coyne, P. Eng., an Associate and geotechnical engineer with Golder. Mr. Jorge Costa, P.Eng., a Principal of and Designated MTO Contact for Golder, conducted an independent review of the report.

GOLDER ASSOCIATES LTD.

Lisa C. Coyne, P.Eng.
Associate, Geotechnical Engineer

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

LCC/JMAC/lcc
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TABLE 1
COMPARISON OF FOUNDATION ALTERNATIVES
PROCTOR'S CREEK CULVERT 2 – NORTH EXTENSION/REPLACEMENT
HIGHWAY 401-COUNTY ROAD 30 INTERCHANGE
BRIGHTON, ONTARIO
G.W.P. 256-98-00, W.P. 4141-07-00

Option	*Advantages*	*Disadvantages*	*Risks/Consequences*
Box culvert extension/ replacement	• Minimizes depth of excavation and dewatering requirements compared to open footing option • Pre-cast box sections may allow faster construction than cast-in-place open footings, with shorter time duration for dewatering and surface water pumping	• Excavation would still extend to about 0.9 m below groundwater level, and groundwater control would still be required • Compatibility of box culvert extension with existing open footing culvert channel; box culvert may not satisfy fisheries requirements	• Small risk related to effective dewatering in fine-grained cohesionless fill and till deposits at this site
Open footing culvert extension/replacement	• Matches existing culvert foundation type and would satisfy any fisheries requirements, if applicable • May be feasible to build culvert extension/replacement on pre-cast footing sections, to accelerate construction schedule and reduce time for dewatering and surface water pumping	• Excavation would extend about 1.7 m below groundwater level through sand and silt fill and sand and silt till; dewatering will be required	• Slightly greater risk associated with effective dewatering in fine-grained fill and till deposits as compared to box culvert extension/replacement, due to greater drawdown required

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 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Cohesionless Soils

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

(b) Cohesive Soils

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

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

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

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LIST OF SYMBOLS

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

I. General

π	3.1416
in x,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
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
v	poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma$-u)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1+\sigma_2+\sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight*)
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_{w}$))
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_1	liquid limit
w_p	plastic limit
l_p	plasticity index $= (w_1 - w_p)$
w_s	shrinkage limit
I_L	liquidity index $= (w - w_p)/I_p$
I_C	consistency index $= (w_1 - w) / I_p$
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

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

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

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

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RECORD OF BOREHOLE No 07-12

 METRIC

PROJECT 06-1111-057
W.P. 256-98-00
LOCATION N 4882564.2 ;E 203060.1
ORIGINATED BY SB
DIST HWY 401
BOREHOLE TYPE Portable Drilling Equipment, NQ Casing
COMPILED BY MWK
DATUM Geodetic
DATE May 15, 2007
CHECKED BY LCC

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	GR	SA	SI	CL
195.1	GROUND SURFACE									
0.0	Sand and silt, trace to some gravel, containing rootlets and organics (FILL) Very loose to loose Brown to grey at 1.5m Moist	1	SS	2	∇					
		2	SS	5						
		3	SS	3		o	11	45	39	6
192.5 / 2.6	PEAT	4	SS	5						
192.1 / 3.0	Sandy SILT, some gravel, trace clay (TILL) Compact to very dense Grey Moist to wet	5	SS	14		o	16	29	46	9
		6	SS	30/.15						
		7	SS	25/.15		o				
190.2 / 4.9	END OF BOREHOLE									

Notes:

1. Borehole advanced using portable drilling equipment with a half-weight hammer. SPT "N" values shown on this log have been adjusted to reflect "N" values that would be obtained using a standard - weight hammer.

2. Water level in open borehole at a depth of 0.4 m (Elev. 194.7 m) on completion of drilling.

Column headings: SOIL PROFILE; SAMPLES; STRAT PLOT; ELEVATION SCALE (195, 194, 193, 192, 191); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED, 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%).

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

Golder Associates

RECORD OF BOREHOLE No 07-12B

 METRIC

PROJECT 06-1111-057

W.P. 256-98-00 LOCATION N 4882635.5 ;E 203105.0 ORIGINATED BY GPD

DIST HWY 401 BOREHOLE TYPE Track-Mounted CME-55, 108 mm Diameter Solid Stem Augers COMPILED BY VO

DATUM Geodetic DATE January 14, 2008 CHECKED BY LCC

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
195.5	GROUND SURFACE						
0.0	Silty sand, containing grass, rootlets and organic matter (FILL)	1	SS	5			
195.2 0.3	Sand and silt to silty sand, trace to some gravel, trace clay, containing rootlets (FILL) Loose to compact Brown to grey Moist	2	SS	19			
		3	SS	10			
	Becoming wet below 2.3 m depth	4	SS	21	▽		
192.5 3.1	SAND and SILT, trace clay and gravel (TILL) Compact to very dense Grey to brown Moist	5	SS	23		○	NP
		6	SS	29		○	6 40 46 8
		7	SS	38			
		8	SS	53			
		9	SS	31			
186.4 9.1	SILT, trace sand and gravel, trace clay Loose to very dense Brown to grey Moist to wet	10	SS	7*		○	7 3 88 2
		11	SS	16		○	0 1 93 6
		12	SS	36			
		13	SS	73			
181.3 14.2	END OF BOREHOLE						

Elevation scale: 195, 194, 193, 192, 191, 190, 189, 188, 187, 186, 185, 184, 183, 182

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

Continued Next Page

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

RECORD OF BOREHOLE No 07-12B

 METRIC

PROJECT 06-1111-057
W.P. 256-98-00
LOCATION N 4882635.5 ;E 203105.0
ORIGINATED BY GPD
DIST HWY 401
BOREHOLE TYPE Track-Mounted CME-55, 108 mm Diameter Solid Stem Augers
COMPILED BY VO
DATUM Geodetic
DATE January 14, 2008
CHECKED BY LCC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED (20 40 60 80 100)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	--- CONTINUED FROM PREVIOUS PAGE ---										
	Notes: 1. * Low SPT "N" value is the result of sample disturbance due to groundwater inflow to the borehole. 2. Water level in open borehole at a depth of 2.3 m (Elevation 193.2 m) on completion of drilling opreations.										

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

Golder Associates

RECORD OF BOREHOLE No 07-13

 METRIC

PROJECT 06-1111-057

W.P. 256-98-00

LOCATION N 4882574.5 ;E 203055.2

ORIGINATED BY PKS

DIST HWY 401

BOREHOLE TYPE Track-Mounted CME-55, 108mm I.D. Hollow Stem Augers

COMPILED BY MWK

DATUM Geodetic

DATE July 4, 2007

CHECKED BY LCC

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
199.4	GROUND SURFACE					
0.0	Sand and silt, trace gravel, trace clay (FILL) Loose to dense Brown to grey Moist to wet	1	SS	15		
		2	SS	16		
		3	SS	13		
		4	SS	17		2 38 51 9
		5	SS	6		
		6	SS	38		
192.7 6.7	Clayey silt, some sand, trace gravel (FILL) Stiff Grey-brown Moist	7	SS	8		
191.2 8.2	SILT, trace sand and clay Dense to very dense Brown to grey Wet	8	SS	40		0 3 90 7
					∇ (approx. El. 188.8)	
		9	SS	104		
		10	SS	80		0 0 93 7
		11	SS	68		

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

Elevation scale: 199, 198, 197, 196, 195, 194, 193, 192, 191, 190, 189, 188, 187, 186, 185

Continued Next Page

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

RECORD OF BOREHOLE No 07-13

 METRIC

PROJECT 06-1111-057
W.P. 256-98-00 LOCATION N 4882574.5 ;E 203055.2 ORIGINATED BY PKS
DIST HWY 401 BOREHOLE TYPE Track-Mounted CME-55, 108mm I.D. Hollow Stem Augers COMPILED BY MWK
DATUM Geodetic DATE July 4, 2007 CHECKED BY LCC

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	SILT, trace sand and clay Dense to very dense Brown to grey Wet		12	SS	50		184		o		
							183				
			13	SS	52						0 0 94 6
							182				
			14	SS	102		181				
180.5 18.9	END OF BOREHOLE 1. Water level in open borehole at a depth of 10.7 m (Elev. 188.7 m) on completion of drilling.										

Legend: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L

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

MINISTRY OF TRANSPORTATION, ONTARIO

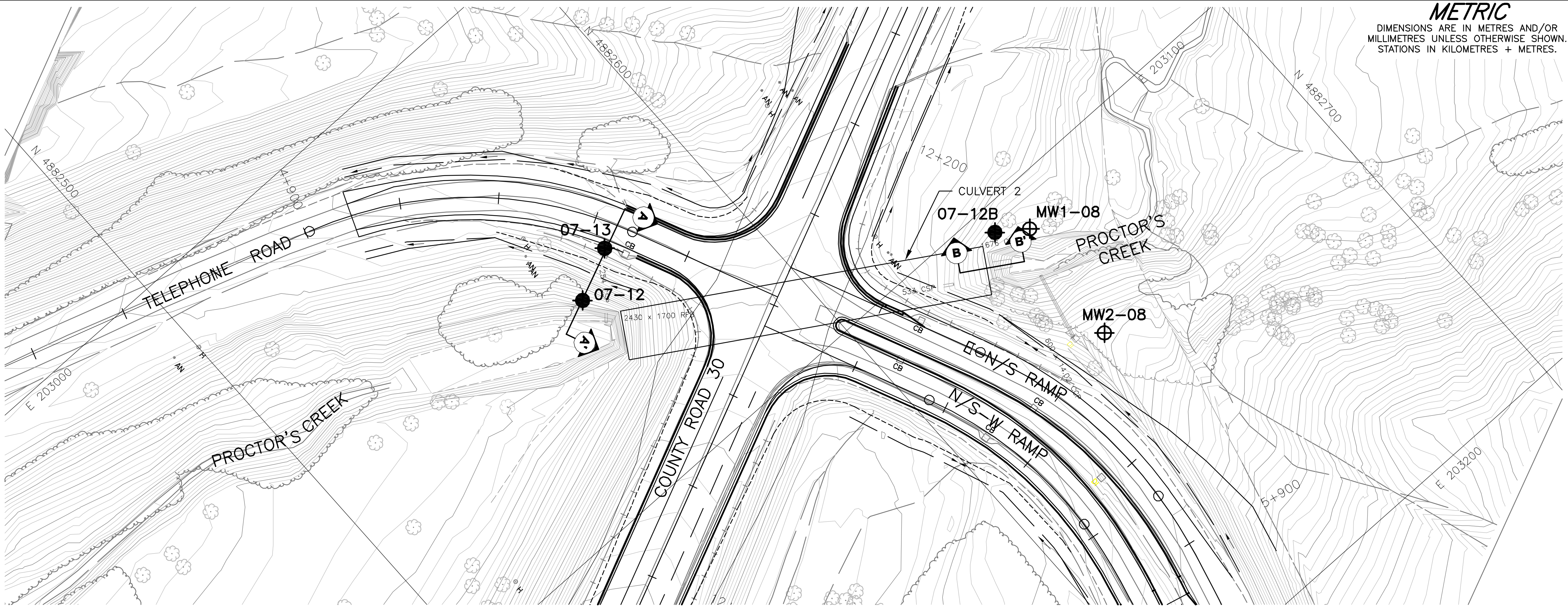
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No. 2009–4268
WP No. 4141–07–00

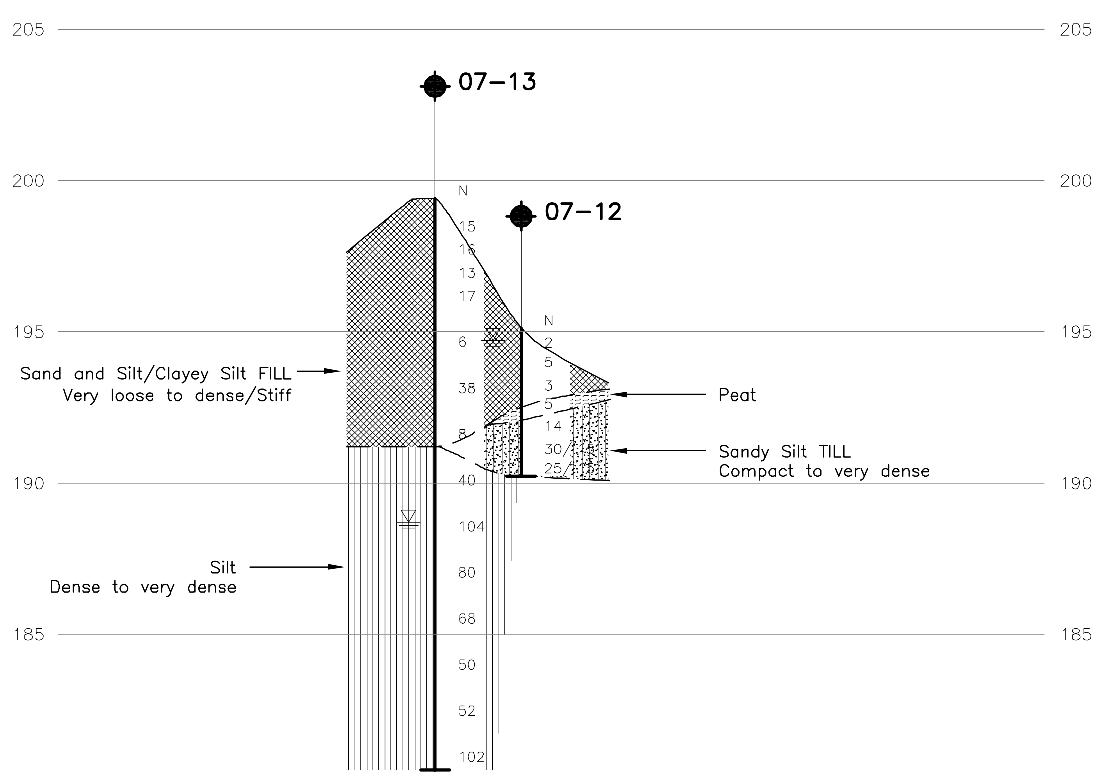
HIGHWAY 401 – COUNTY ROAD 30
CULVERT 2 NORTH EXTENSION/REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET 3

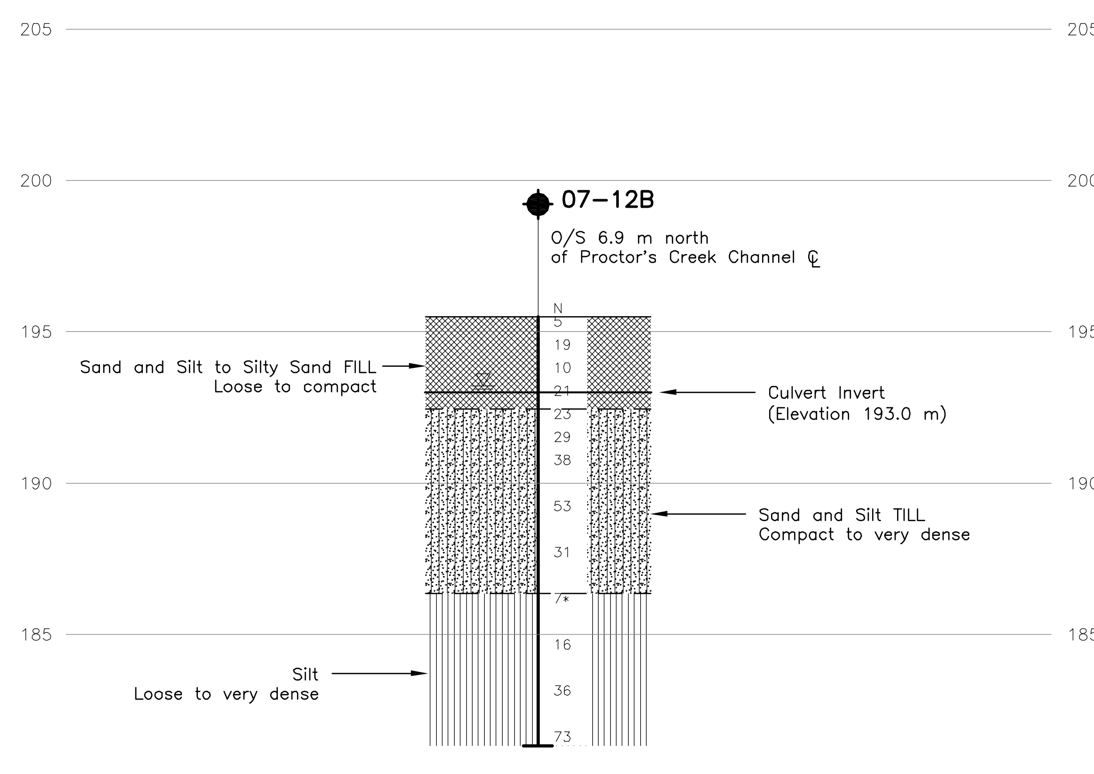
Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



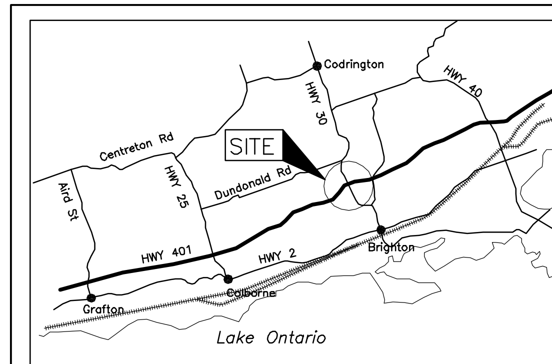
PLAN
SCALE 10 0 10 20 m



SECTION A–A' : CULVERT 2–SOUTH END
SCALE 10 0 10 20 m
VERT. 2.5 0 2.5 5 m



SECTION B–B' : CULVERT 2–NORTH END
SCALE 10 0 10 20 m
VERT. 2.5 0 2.5 5 m



KEY PLAN
SCALE 6 0 6 12 km

LEGEND

- Borehole – Current Investigation
- Borehole – PTTW Investigation (See Appendix A of Contract Foundation Investigation Report) – Approximate Location Only
- N — Standard Penetration Test Value
- 16 — Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL upon completion of drilling

No.	ELEVATION	CO–ORDINATES	
		NORTHING	EASTING
07–12	195.1	4882564.2	203060.1
07–12B	195.5	4882635.5	203105.0
07–13	199.4	4882574.5	203055.2

NOTES

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

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

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

REFERENCE

Base plan provided in digital format by Giffels (drawing file name "+401_30NEWC.dwg", received May 23, 2007).

LICENSED PROFESSIONAL ENGINEER J.M.A. COSTA May 29, 2009 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER L.C. COYNE May 29, 2009 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

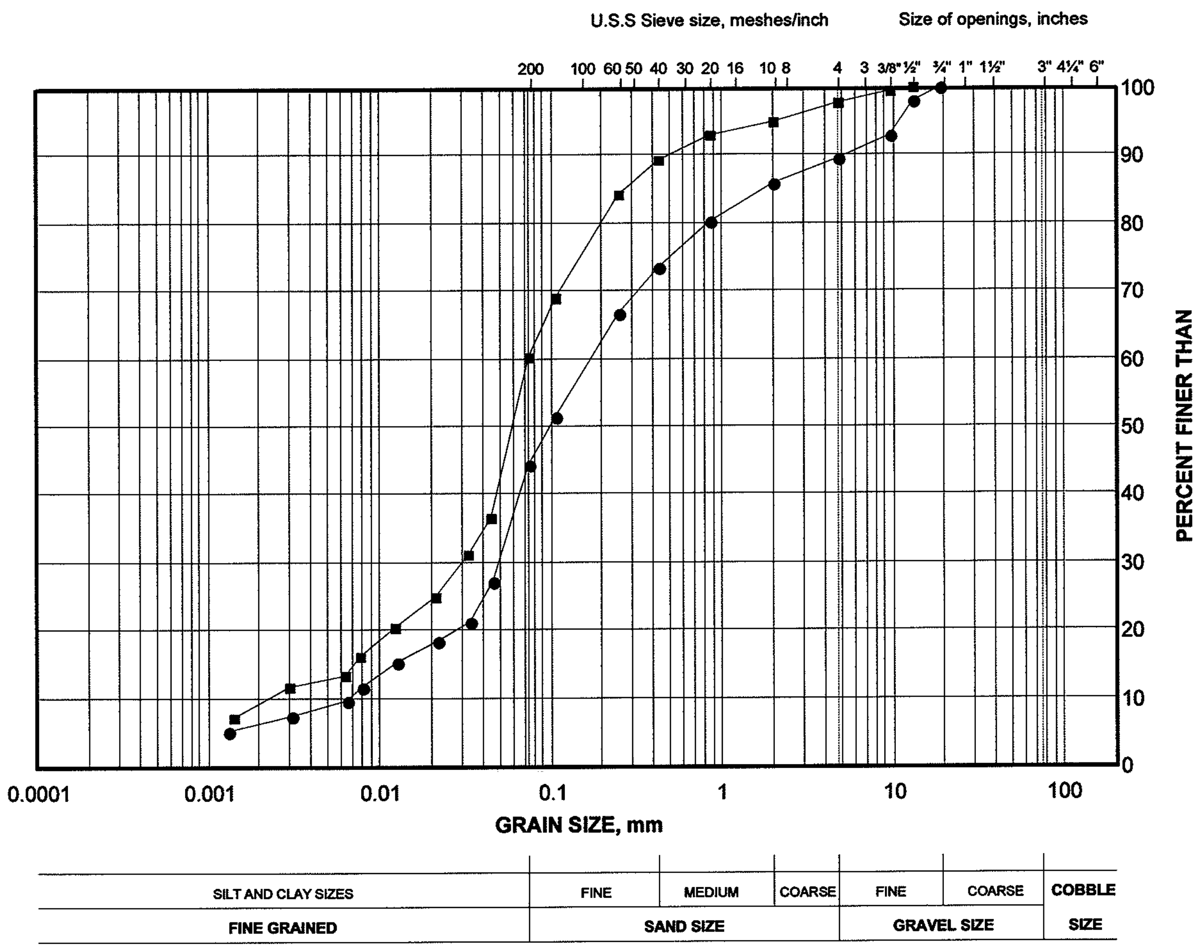
Geocres No.

HWY. HIGHWAY 401	PROJECT NO. 06–1111–057		DIST.
SUBM'D. MWK	CHKD. LCC	DATE: 29–May–09	SITE:
DRAWN: JFC/RJ	CHKD. MWK/LCC	APPD. LCC/JMAC	DWG. 1

PLOT DATE: May 29, 2009

GRAIN SIZE DISTRIBUTION TEST RESULTS
Sand and Silt Fill

FIGURE 1



LEGEND

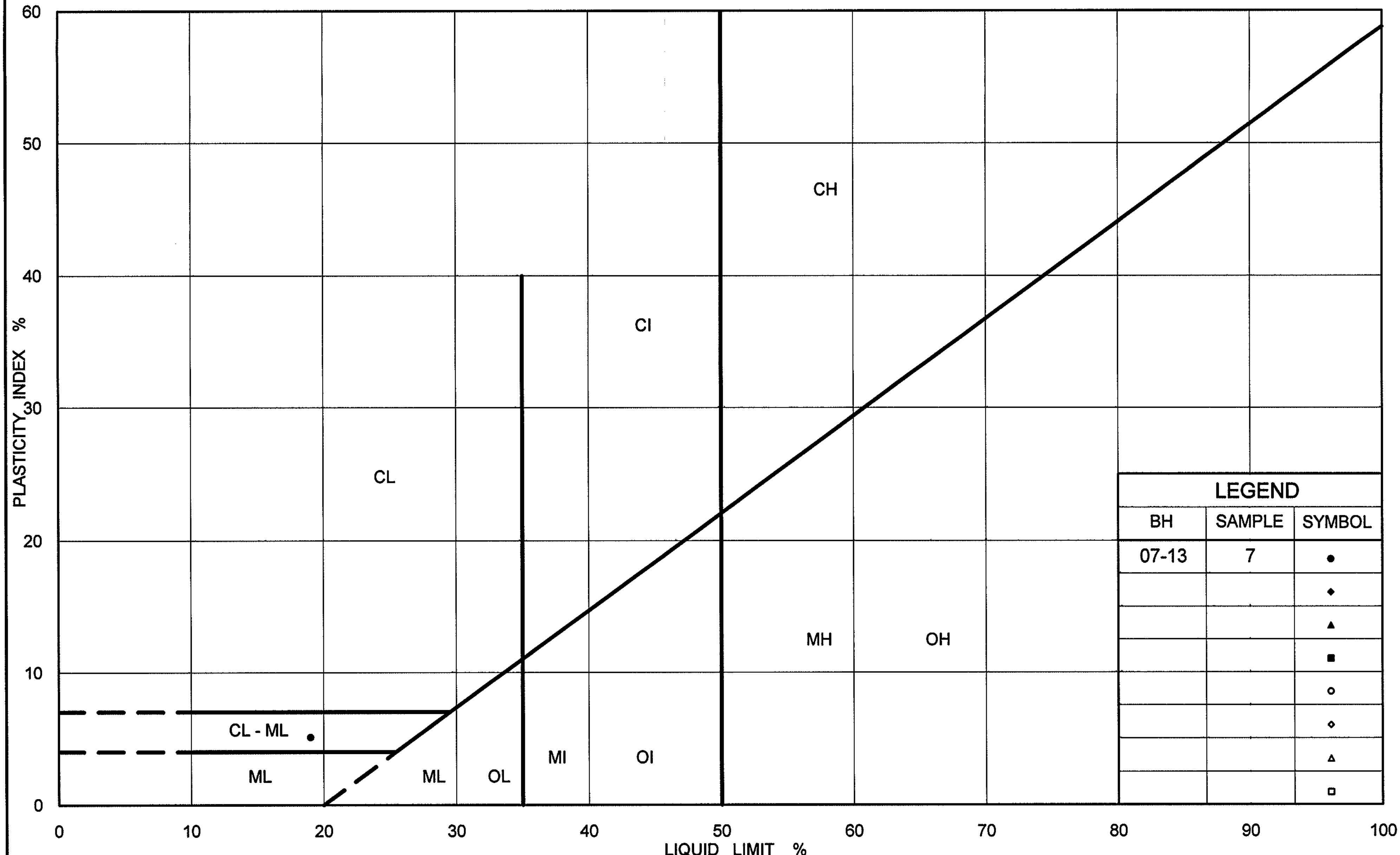
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	07-12	3	193.3
■	07-13	4	196.1

Project Number: 06-1111-057-3

Checked By: [signature]

Golder Associates

Date: 01-Jun-09



Ministry of Transportation Ontario	**PLASTICITY CHART** Sand and Silt and Clayey Silt Fill

Figure No. 2

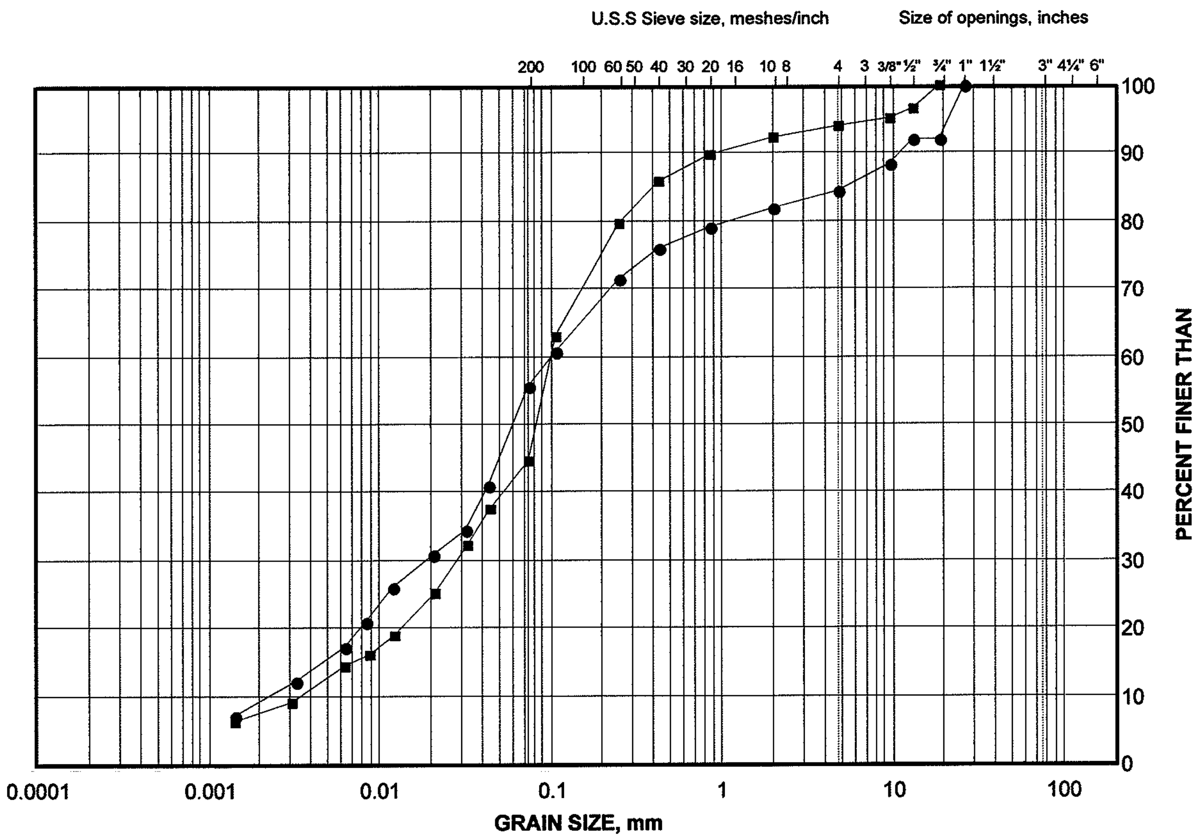
Project No. 06-1111-057-3

Checked By: [signature]

GRAIN SIZE DISTRIBUTION TEST RESULTS

Sand and Silt to Sandy Silt Till

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)
●	07-12	5	191.7
■	07-12B	6	191.4

Project Number: 06-1111-057-3

Checked By: [signature]

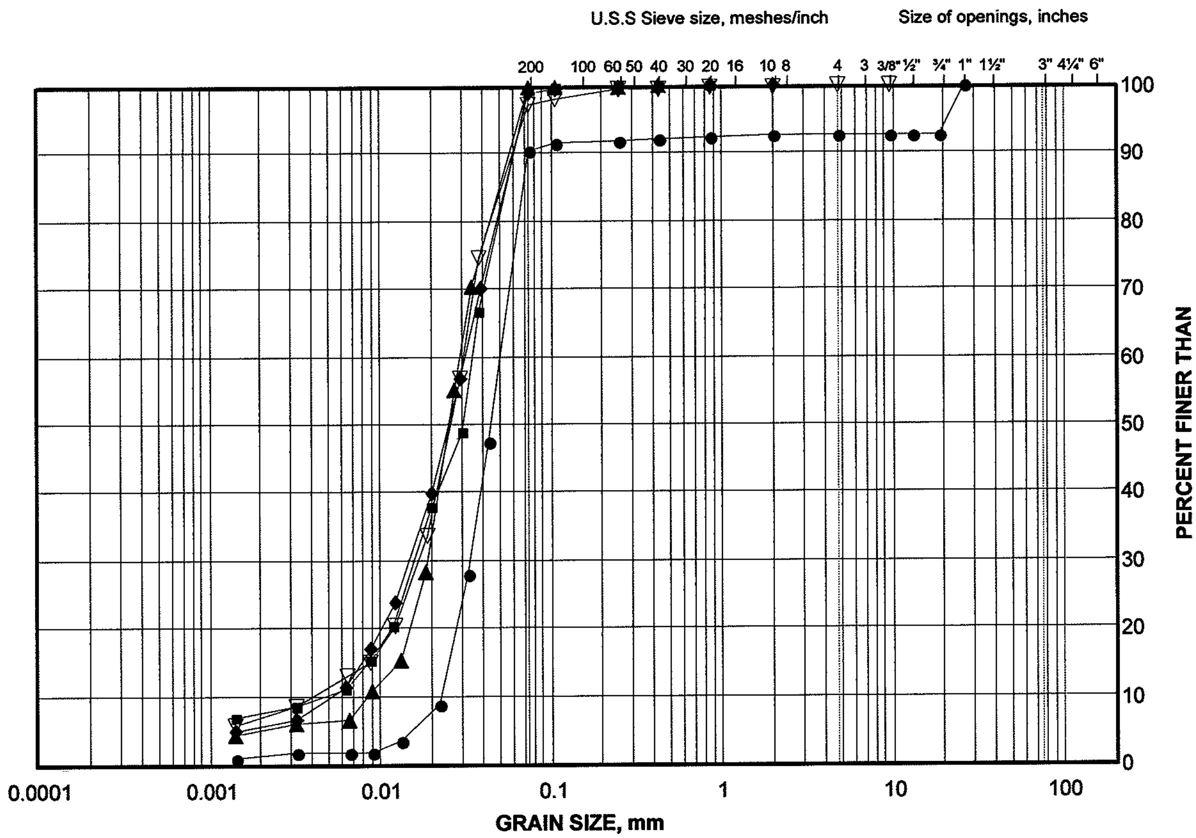
Golder Associates

Date: 01-Jun-09

GRAIN SIZE DISTRIBUTION TEST RESULTS

Silt

FIGURE 4



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	07-12B	10	186.1
■	07-13	10	186.9
◆	07-12B	11	184.5
▲	07-13	13	182.3
▽	07-13	8	189.9

Project Number: 06-1111-057-3

Checked By: [signature]

Golder Associates

Date: 01-Jun-09

APPENDIX A

BOREHOLE RECORDS AND
GRAIN SIZE DISTRIBUTION TEST DATA
FROM PERMIT TO TAKE WATER (PTTW) INVESTIGATION

RECORD OF MONITORING WELL MW 1-08

PROJECT: 07-1182-0059 (6000)

LOCATION: SEE FIGURE 2

BORING DATE: November 28, 2008

SHEET 1 OF 1

SAMPLER HAMMER, 63.5kg; DROP, 760mm

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm

Soil Profile Description	Elev. Depth (m)	Sample Number	Type	Blows/0.3m	Additional Lab. Testing	Installation and Groundwater Observations
GROUND SURFACE						
TOPSOIL	0.00	1A				
Loose to compact, brown to grey, moist to wet SILTY SAND, trace to some gravle, trace clay, trace organics	0.20	1B	50 DO	18		
		2A	50 DO	13		
		2B				
		3A	50 DO	6		Bentonite Seal
		3B				
Compact, greenish-brown, wet SILTY GRAVEL, some sand	2.10	4A	50 DO	16		
Compact, grey, wet SILTY SAND, trace to some gravel, trace clay	2.56	4B				
		5A	50 DO	18		
Compact, brown to grey, moist to wet SAND, trace gravel, trace silt	3.51	5B				
		6A			MH	
Compact to dense, grey, moist SILTY SAND, some gravel, trace clay	4.11	6B	50 DO	18		Silica Sand Filter
Dense, brown, moist SAND, trace silt	4.50	7A			MH	
Dense, brown to grey, moist to wet SILTY SAND, trace to some gravel	4.78	7B	50 DO	33		
Dense, grey, moist to wet SILT, some very fine sand, trace clay, trace gravel	5.05	7C				
		8	50 DO	36		Bentonite Seal
		9	50 DO	27		
END OF BOREHOLE	6.71					Groundwater level measured in monitoring well at a depth of 1.76 m below ground surface on Jan. 16/09

Column headings: DEPTH SCALE METRES; BORING METHOD; SOIL PROFILE (DESCRIPTION, STRATA PLOT, ELEV. DEPTH (m)); SAMPLES (NUMBER, TYPE); ELEVATION; DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa (nat V. + Q - ●, rem V. ⊕ U - O) (20, 40, 60, 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT (Wp —O W— Wl) (10, 20, 30, 40); ADDITIONAL LAB. TESTING; INSTALLATION AND GROUNDWATER OBSERVATIONS

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

DRAFT

DEPTH SCALE

1 : 50

Golder Associates

LOGGED:

CHECKED:

PROJECT: 07-1182-0059 (6000)

RECORD OF MONITORING WELL MW 2-09

SHEET 1 OF 1

LOCATION: SEE FIGURE 2

BORING DATE: January 12, 2009

SAMPLER HAMMER, 63.5kg; DROP, 760mm

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm

DESCRIPTION (SOIL PROFILE)	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	INSTALLATION AND GROUNDWATER OBSERVATIONS
GROUND SURFACE						
TOPSOIL		1A				Concrete and Casing
Light brown to dark brown, moist, loose to compact SANDY SILT, trace to some gravel, trace organics	0.10	1B	50 DO	12		
		2A, 2B, 2C	50 DO	7		Bentonite Seal
Brown, moist to wet, compact SILTY SAND, some gravel, sand seams	1.27	3A				
Brown, moist, compact SAND AND GRAVEL, some silt	1.93	3B	50 DO	24	MH	
Brown to grey, moist, dense SILTY FINE SAND, trace gravel	2.29	4A	50 DO	34		
Brown to grey, moist, dense SILT, some sand; trace gravel, some clay	2.69	4B			MH	Silica Sand Filter
Grey moist hard CLAYEY SILT, some sand, some gravel (TILL)	2.97	5	50 DO	176		
		6	50 DO	139 .25		
END OF BOREHOLE	4.11					Groundwater level measured in monitoring well at a depth of 1.29 m below ground surface on Jan. 16/09

Column headings: DEPTH SCALE METRES (0–10); BORING METHOD; SOIL PROFILE; STRATA PLOT; SAMPLES; ELEVATION; DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa (nat V. + Q - ● rem V. ⊕ U - O) (20, 40, 60, 80); HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT Wp —O W— Wl (10, 20, 30, 40); ADDITIONAL LAB. TESTING; INSTALLATION AND GROUNDWATER OBSERVATIONS

LDN_BHS 07-1182-0059 (6000).GPJ GLDR_LDN.GDT 2/3/09 DATA INPUT: ph 02/2009

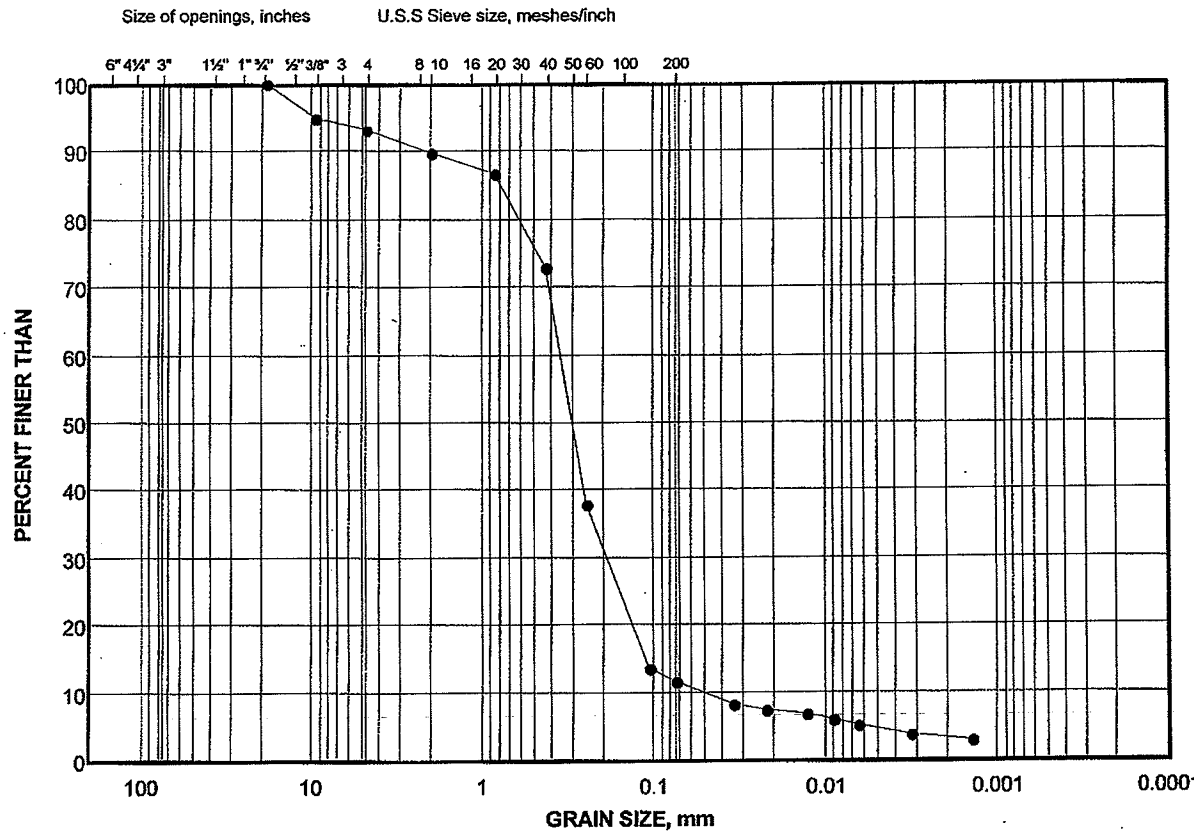
DEPTH SCALE 1 : 50

Golder Associates

LOGGED:

CHECKED:

GRAIN SIZE DISTRIBUTION SAND, trace gravel, trace silt, trace clay	FIGURE



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	1-08	6A	3.81 - 4.11

Project Number: 07-1182 0059

Checked By: ______________

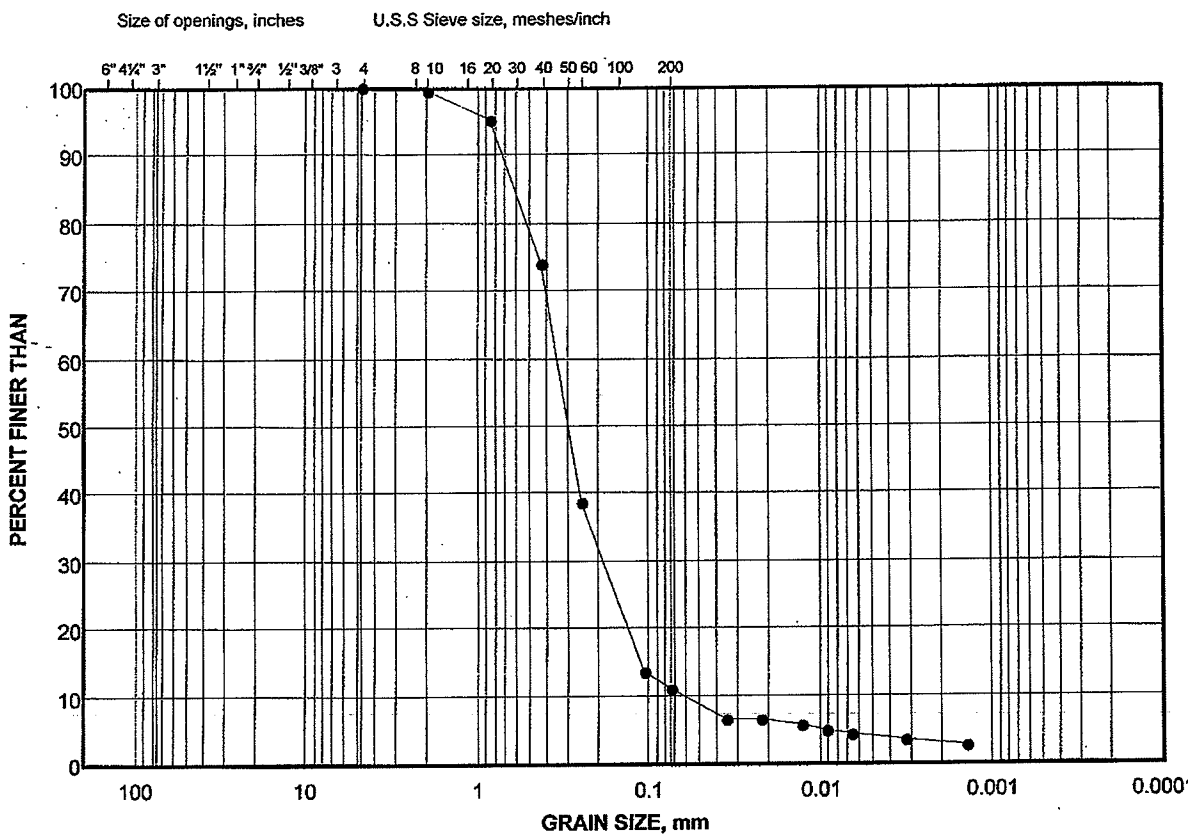
Golder Associates

Date: 03-Feb-09

GRAIN SIZE DISTRIBUTION

SAND, trace silt, trace clay

FIGURE



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	1-08	7A	4.57 - 4.78

Project Number: 07-1182 0059

Checked By: ____________

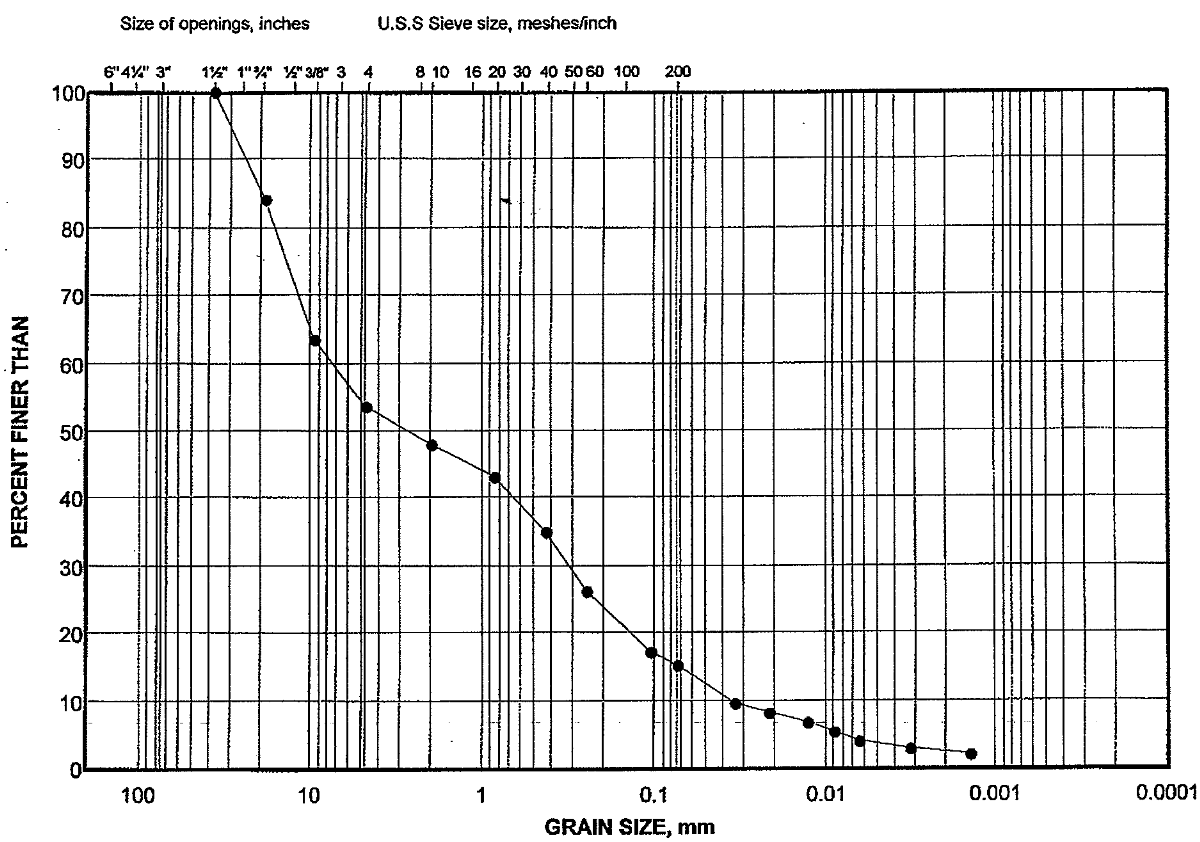
Golder Associates

Date: 03-Feb-09

GRAIN SIZE DISTRIBUTION

SAND and GRAVEL, some silt, trace clay

FIGURE



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	2-09	3B	1.93 - 2.29

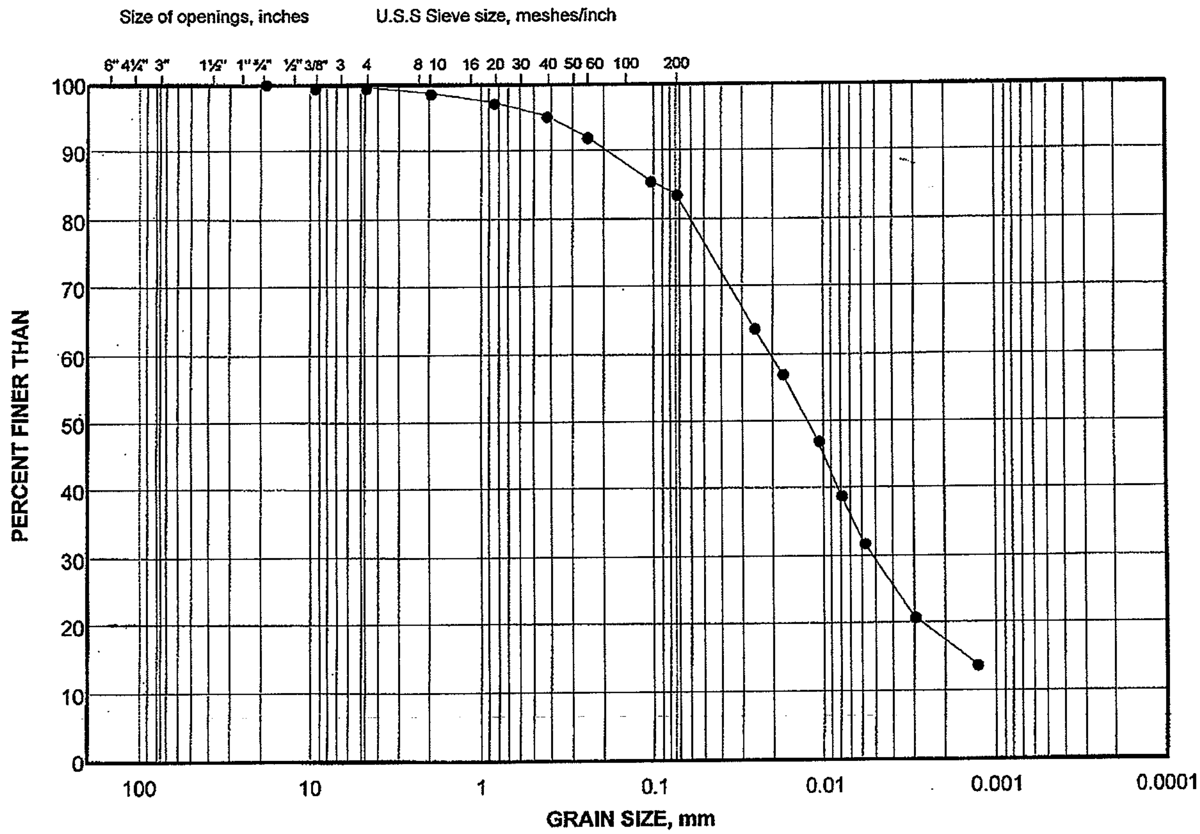
Project Number: 07-1182 0059

Checked By: ____________

Golder Associates

Date: 03-Feb-09

GRAIN SIZE DISTRIBUTION SILT, some sand, some clay	FIGURE



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	2-09	4B	2.69 - 2.90

Project Number: 07-1182 0059

Checked By: ____________

Golder Associates

Date: 03-Feb-09

APPENDIX B

NON-STANDARD SPECIAL PROVISIONS

GROUNDWATER CONTROL – Item No.

Non-Standard Special Provision

Foundations for the culvert extension/replacement will require excavation into the compact to very dense sand and silt till below the groundwater level at the site. The cohesionless soils below the groundwater table will be subjected to conditions of unbalanced hydrostatic head and can slough, boil and cave in. Appropriate groundwater control systems shall be designed and installed to draw the groundwater level down to a minimum of 0.3 m below the footing founding level, to allow excavation, foundation subgrade preparation and foundation construction in dry conditions.

Basis of Payment

Payment at the contract price for the above tender item shall include full compensation for all labour and materials to complete the work.

END OF SECTION

MASS CONCRETE – Item No.

Non-Standard Special Provision

The subgrade for the culvert foundations will be comprised of compact to very dense sand and silt till; these soils will be susceptible to disturbance and loosening from construction traffic and ponded water. Following inspection and approval of the prepared subgrade, a working mat of mass concrete with a minimum thickness of 100 mm shall be placed on the foundation subgrade.

The concrete shall have a compressive strength of at least 20 MPa, and be placed in accordance with OPSS 904.

Basis of Payment

Payment at the contract price for the above tender item shall include full compensation for all labour and materials to complete the work.

END OF SECTION