REPORT ON

FOUNDATION INVESTIGATION AND DESIGN
CULVERT REPLACEMENT AT STATION 16+255
HIGHWAY 89 PAVEMENT REHABILIZATION FROM ROSEMONT
TO 0.9 KM EAST OF COUNTY ROAD 13
SIMCOE COUNTY, ONTARIO
G.W.P. 2479-04-00

Submitted to:

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by McCormick Rankin Corporation (MRC) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services associated with the rehabilitation of Highway 89 from Rosemont to 0.9 km east of County Road 13, in Simcoe County. Foundation engineering services are required for the widening of the Nottawasaga River Bridge (MTO Structure Site No.30-250), construction of a new retaining wall to the northwest of the widened bridge structure, and replacement of an existing concrete culvert structure at Station 16+255 between Rosemont and Alliston (Culvert 30-545C).

This report addresses the foundation investigation carried out for the proposed culvert replacement at Station 16+255 (Culvert 30-545C) as part of the Highway 89 rehabilitation project.

The terms of reference and scope of work for the foundation investigation are outlined in MTO's Request for Proposal for Agreement No. 2004-E-0032, issued in April 2005, and in Section 6.8 of MRC's *Technical Proposal* for G.W.P. 2479-04-00 as well as Golder's proposal letter dated January 22, 2007 for additional foundation engineering services relating to the proposed retaining wall and culvert replacement.

2.0 SITE DESCRIPTION

The site of the proposed culvert replacement on Highway 89, is located approximately 0.8 km east of Simcoe County Road 13, Ontario. Highway 89 in this area is approximately 7.5 m wide consisting of two lanes with 3 m wide fully paved shoulders on both sides of the highway.

The site generally consists of the raised highway embankment with gently sloping, grass covered side-slopes. Based on the general arrangement drawing provided by MRC entitled "Hwy. 89 Culvert at Sta. 16+255.000-General Arrangement", dated January 2007, the existing Highway 89 grade is between Elevation 245 m and Elevation 245.3 m and the approximate streambed is between Elevation 243.6 m (at the culvert inlet) and Elevation 243.2 m (at the culvert outlet). The existing culvert is an open footing concrete structure, 3.67 m wide and 21 m long. The opening height (creek bottom to soffit) is approximately 0.8 m.

Vegetation in the vicinity of the existing culvert consists primarily of grasses with some small shrubs.

3.0 INVESTIGATION PROCEDURES

3.1 Foundation Investigation

The subsurface investigation at the site of the proposed culvert replacement was completed on September 26, 2007. Two boreholes were advanced at the south shoulder and embankment toe of the highway, adjacent to the existing culvert; however due to access constraints in the immediate vicinity of the toe/culvert end at the north side of the embankment, one borehole was advanced 9 m north of the end of the culvert (i.e. culvert inlet) and one borehole was advanced through the north shoulder of the highway, about 6 m south of the culvert inlet. The borehole locations are shown on Drawing 1.

The field investigation was carried out using a track-mounted drill rig, supplied and operated by Walker Drilling Ltd. of Barrie, Ontario. The boreholes were advanced using 108 mm outside diameter (O.D.) solid stem augers to depths ranging from about 3.5 m to 7.8 m below the existing ground surface. Soil samples were obtained at intervals ranging from 0.75 m to 1.5 m intervals of depth, using a 50 mm outer diameter (O.D.) split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures. The groundwater conditions in the open boreholes were observed throughout the drilling operations, and a standpipe piezometer was installed in Boreholes 07-4 to permit monitoring of the groundwater level at this location. The piezometer consist of a 50 mm diameter PVC pipe with a 1.5 m long slotted screen installed within a 3 m long sand filter pack. Upon completion of drilling, the boreholes and annulus surrounding the piezometer pipe above the sand filter pack were backfilled to the surface with bentonite pellets in accordance with Ontario Regulation (O.Reg.) 903.

The field work was monitored on a full-time basis by a member of Golder's technical staff who located the boreholes in the field, cleared the site of buried utility services, directed the sampling, 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 geotechnical laboratory testing. Index and classification tests (water content determinations, Atterberg limits and grain size distribution) as well as organic content tests were carried out on selected soil samples.

The borehole elevations were measured in the field by members of Golder's technical staff, relative to a geodetic bench mark, located at the northwest corner of the existing culvert structure (BM 621-W0427107B) and the borehole locations were measured by Golder relative to site features. The borehole locations (including MTM NAD83 northing and easting coordinates) and ground surface elevations (referenced to geodetic datum) are summarized below and are shown on Drawing 1.

Borehole Number	*MTM NAD83*		*Ground Surface Elevation (m)*
	Northing (m)	*Easting (m)*	
07-1	4888984.1	271368.2	245.1
07-2	4888976.6	271365.2	243.6
07-3	4889006.6	271355.7	243.7
07-4	4888994.0	271361.1	244.9

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

The area of Highway 89 at the location of Culvert 30-545C lies within the Simcoe Lowlands physiographic region, as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984[1]).

The Simcoe Lowlands comprise the lowlands bordering Georgian Bay to the west and Lake Simcoe to the east (Chapman and Putnam, 1984[1]). To the west are the plains lying between Elevation 176 m and Elevation 228 m, draining into Nottawasaga Bay by way of the Nottawasaga River and are referred to as the Nottawasaga Basin. To the east are the lowlands surrounding Lake Simcoe lying between Elevation 219 m and Elevation 259 m which are referred to as the Lake Simcoe Basin.

Within the southern portion of the Nottawasaga Basin in the Alliston area lies Adjala Township where the proposed culvert replacement site is located. The surficial soils in the Alliston area are typically comprised of sandy loam and silt loam. Most of the Nottawasaga Basin was at one time part of the floor of Lake Algonquin and its surface beds are of deltaic and lacustrine origin.

4.2 Subsoil Conditions

Four boreholes (Boreholes 07-1 to 07-4) were drilled at the site of the culvert replacement as shown on Drawing 1. Two boreholes were advanced through the existing Highway 89 north and south embankments and two borehole were drilled at the embankment toes, adjacent to the existing culvert structure.

The detailed subsurface soil and groundwater conditions as encountered in the boreholes, together with the results of the laboratory tests carried out on selected soil samples, are given on the attached Record of Borehole sheets following the text of this report. The laboratory test results are also presented on Figures 1 to 5.

[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 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 and the subsurface conditions will vary between and beyond the borehole locations. The inferred soil stratigraphy based on the results of the boreholes at the site of the culvert replacement is shown on Drawing 1.

In summary, the subsoil conditions encountered in the boreholes generally consist of surficial silty sand and clayey silt fill materials underlain by a very stiff to hard clayey silt with sand till deposit, which grades into a silt and sand till at the location of Borehole 07-3. A detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Fill

Fill materials were encountered in all of the boreholes immediately below the ground surface. In Boreholes 07-1, 07-2, and 07-4, the fill consists of an upper layer of silty sand, between 500 mm and 800 mm thick, overlying clayey silt containing variable amounts of sand, trace gravel, and trace quantities of organic matter. In Borehole 07-3, drilled some 9 m north of the existing culvert inlet at the north embankment toe, the fill consists of silty clay with trace sand and organic matter. The thickness of the fill ranges from about 1.8 m in Borehole 07-3 to about 3.5 m in Borehole 07-1.

The measured SPT “N” values within the fill materials typically range from 3 to 11 blows per 0.3 m of penetration, indicating a very loose to compact relative density /soft to stiff consistency . One SPT “N” value of 35 blows per 0.3 m of penetration was measured in the upper silty sand fill at the location of Borehole 07-1, which was advanced through the embankment on the south shoulder of the highway.

The clayey silt and silty clay fill materials contain variable amounts of organic matter; organic content tests carried out on samples of these materials, selected on the basis of visual and olfactory indication of organics, yielded organic contents varying from 5.2 percent to 7.2 percent for the soil samples collected between about Elevation 241.5 m and Elevation 243.5 m.

The results of one grain size distribution test carried out on a sample of the clayey silt fill is shown on Figure 1 and indicates that the sample tested is a clayey silt with sand. Atterberg limits tests carried out on two samples of the clayey fill materials encountered in Boreholes 07-2 and 07-3 yielded plastic limits of 16 percent and 24 percent, liquid limits of 26 percent and 41 percent, and corresponding plasticity indices of 10 percent and 17 percent, respectively. These results indicate that the samples tested are comprised of clayey silt of low plasticity to silty clay of intermediate plasticity as illustrated on Figure 2.

The measured water contents on samples of the fill materials vary between about 6 percent and 37 per cent.

4.2.2 Clayey Silt with Sand to Silt and Sand Till

A till deposit consisting of clayey silt with sand was encountered below the fill materials between approximately Elevation 241.4 m and Elevation 242.2 m in the boreholes located on the shoulders of the roadway and the south end of the culvert. The till at the location of the Borehole 07-3 beyond the north end of the culvert is granular, comprised of silt and sand and was encountered at Elevation 241.9 m. The clayey silt with sand till extends to the termination depths of boreholes 07-1, 07-2, and 07-4 between about Elevation 237.1 m and Elevation 240.2 m.

The results of three grain size distribution tests carried out on selected samples of the clayey silt till and silt and sand till materials are shown on Figures 3 and 4, respectively. Atterberg limits tests carried out on two selected samples of the clayey silt with sand yielded plastic limits of about 9 and 10 percent, liquid limits of about 14 and 18, and corresponding plasticity indices of 5 percent and 8 percent for the clayey silt portion of this deposit, whereas a non-plastic result was obtained for the silt and sand till encountered in Borehole 07- 3. The results, plotted on Figure 5, confirm that the cohesive till deposit is a clayey silt of low plasticity. The measured water contents on samples of the clayey silt with sand till range between approximately 6 percent and 20 per cent.

The measured SPT “N” values in the clayey silt with sand till range from 26 blows per 0.3 m of penetration to 109 blows for 0.15 m of penetration, indicating a very stiff to hard consistency; while the SPT “N” values measured in the silt and sand till encountered in Borehole 07-3, range from 75 blows to 94 blows per 0.3 m of penetration, indicating a very dense relative density.

4.2.3 Groundwater Conditions

All of the open boreholes were dry upon completion of drilling. The water levels measured in the piezometer installed in Borehole 07-4 are summarized below:

Borehole Number	*Ground Surface Elevation (m)*	*Measured Groundwater Elevation (m)*	
		September 26, 2007	*October 15, 2007*
07-4	244.9	240.1	242.8

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

5.0 CLOSURE

This Foundation Investigation Report was prepared by Ms. Veronica Olatunji, and reviewed by Ms. Houda Jadi, P.Eng., a Geotechnical Engineer with Golder. Mr. Jorge M. A. Costa, P.Eng., a Designated MTO Contact and Principal with Golder conducted an independent technical review and quality control of the report.

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PART B

FOUNDATION DESIGN REPORT
CULVERT REPLACEMENT AT STATION 16+255
HIGHWAY 89 PAVEMENT REHABILITATION FROM ROSEMONT
TO 0.9 KM EAST OF COUNTY ROAD 13
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6.0 ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the design of the proposed culvert replacement associated with the Highway 89 improvement works in Simcoe County, Ontario. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the subsurface investigation at this site. The interpretation and recommendations provided are intended to provide the designers with sufficient information to assess the feasible foundation alternatives for the design of the proposed culvert. Where comments are made on construction, they are provided in order 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.

6.1 General

The existing culvert consists of an open footing concrete structure, 3.67 m wide and 21 m long. The opening height (creek bottom to soffit) is approximately 0.8 m. Based on the general arrangement drawing provided by MRC entitled “Hwy. 89 Culvert at Sta. 16+255.000-General Arrangement”, dated January 2007, the replacement culvert will consist of a pre-cast concrete box structure with wing walls on the four quadrants. The wing walls will be 5.5 m long and approximately 1.8 m high; it is understood that the currently preferred option for the wing walls is a mechanically-reinforced soil retaining system (retained soils system or RSS walls).

The existing Highway 89 grade at the site of the proposed culvert replacement is between Elevation 245 m and Elevation 245.3 m. The invert elevation of the proposed culvert is between Elevation 242.7 m and Elevation 243 m while the approximate stream bed is between Elevation 243.6 m and elevation 243.2 m.

The surface of the hard/very dense till deposit was encountered between approximately Elevation 241.5 m and Elevation 242 m in the boreholes.

6.2 Foundation and Subgrade Preparation

Based on the subsurface conditions encountered at the site and proposed invert elevation of the new culvert, it is recommended that the existing soft to stiff clayey silt and silty clay fill materials containing organic matter be removed from under the footprint of the proposed replacement culvert and RSS walls (i.e. below the facing footings and RSS mass) to be founded on the hard clayey silt with sand till or silt and sand till deposit at or below Elevation 241.5 m (on the south side of Highway 89) and Elevation 242 m (on the north side of Highway 89). As such, subexcavation of approximately 0.8 m to 1.2 m of the clayey silt to silty clay fill materials will be required below the proposed base of the culvert and between about 1.5 m to 2 m of excavation/subexcavation within the RSS walls footprints will be required, to expose the till foundation stratum.

The approximate invert elevations, recommended level of subexcavation, and founding soil type for the proposed pre-cast concrete box culvert and associated wing walls/headwalls are presented below.

Founding Elevations				
Approximate Culvert Location	***Relevant Boreholes***	***Approximate Invert Elevation (m)***	***Recommended Subexcavation Level / Founding Level (m)***	***Founding Soil Type***
Sta. 16+255	07-3 07-4	243.0	242	clayey silt till to silt and sand till
	07-1 07-2	242.7	241.5	clayey silt till

The subgrade should be inspected following subexcavation to ensure that all soft clayey materials have been removed. The subexcavated areas beneath the base of the culvert should be replaced with Ontario Provincial Standard Specification (OPSS) 1010 Granular "A" or Granular "B" Type II backfill, placed and compacted in accordance with the requirements of MTO's Special Provision SP105S10. If Granular "B" Type II is used, the upper 300 mm of the backfill immediately under the culvert should consist of Granular "A" material (i.e. bedding layer).

For the RSS walls, the facing footings and RSS mass may be founded directly on the till deposit at the founding elevations provided above or on a compacted granular pad placed over the till deposit, consisting of Ontario Provincial Standard Specification (OPSS) 1010 Granular "A" or Granular "B" Type II backfill.

Excavation for and construction of the box culvert structure should be in accordance with Special Provision 902S01.

6.2.1 Geotechnical Resistance

A factored geotechnical resistance at Ultimate Limit States (ULS) of 400 kPa and a geotechnical resistance at Serviceability Limit States (SLS) of 275 kPa may be used for the design of the box culvert, placed on the properly prepared subgrade at or below the founding elevations given in Section 6.2. The SLS resistance value is based on 25 mm of settlement. The geotechnical resistance values assume that the culvert will be founded on granular bedding soils / granular engineered fill over undisturbed native clayey silt with sand till or silt and sand till. These geotechnical resistances are given under the assumption that the loads will be applied perpendicular to the surface of the culvert base. Where the load is not applied perpendicular to the surface of the culvert base, inclination of the load should be taken into account in accordance with the *Canadian Highway Bridge Design Code (CHBDC).*

Assuming that the RSS walls act as a unit and utilize the full width of the reinforced soil mass, which has been taken as two-thirds of the height of the wall (i.e. assumed a reinforced width equal to 1.5 m), a factored geotechnical resistance at ULS of 175 kPa may be used for assessment of the reinforced mass founded on the properly prepared engineered fill materials or undisturbed native till. RSS walls are semi-flexible structures, typically tolerating larger settlements than rigid structures. The total and differential settlements of the RSS walls at this site are estimated to be less than 25 mm under the load of the wall and reinforced soil mass, founded on the native till subgrade. It is noted that the estimated total and differential settlements will occur during and immediately after completion of the reinforced soil mass construction. A geotechnical resistance at Serviceability Limit States (SLS) of 120 kPa for 25 mm settlement may be used for assessment of the RSS walls founded on the properly prepared engineered fill materials or undisturbed native till as described above.

6.2.2 Settlement

Provided that the existing Highway 89 embankment is not raised, and that the culvert replacement structure and associated retaining walls are founded as described in Section 6.2, the settlement of these structures is expected to be less than 25 mm.

6.2.3 Resistance to Lateral Loads

The pre-cast concrete box culvert will be constructed on a compacted granular pad/granular bedding on top of the hard clayey silt with sand to silt and sand till. RSS wing walls will also be constructed on compacted granular fill. In this case, the coefficient of friction, tan δ, between the concrete and the granular bedding or between the compacted granular fills of the RSS walls and the properly prepared subgrade can be taken as 0.5. This value is unfactored; in accordance with the *CHBDC,* a factor of 0.8 is to be applied in calculating the horizontal resistance.

6.3 Bedding / Backfill and Erosion Protection

The replacement box culvert should be provided with a minimum of 300 mm of OPSS 1010 Granular “A” bedding; a greater thickness of bedding material is required following subexcavation of the existing fill materials as discussed in Section 6.2. The bedding should be placed and compacted in accordance with MTO’s Special Provision SP105S10.

Backfill to the culvert walls should consist of granular fill meeting the requirements of OPSS 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 to at least 98 per cent of the material’s standard Proctor maximum dry density (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 culverts should also consist of OPSS 1010 Granular “A” or Granular “B” Type II fill, to minimize differential settlements along Highway 89. The culvert 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 above and surrounding the culvert.

Compaction equipment should be used in accordance with Special Provision No. 105S10. Inspection and field density testing should be carried out by qualified geotechnical personnel during all engineered fill placement operations to ensure that appropriate materials are used, and that adequate levels of compaction have been achieved.

If the water course flow velocities are sufficiently high, provision should be made for scour and erosion protection (suitable non-woven geotextiles and/or rip-rap) for the new culvert. In order to prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring) or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a clay seal or concrete cut-off wall should be provided at the upstream ends of the culvert. If a clay seal is adopted, the clay material should meet the requirements of OPSS 1205, and the seal 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 culvert inlet opening, and a minimum vertical height equivalent to the high water level.

The requirements for and design of erosion protection measures for the inlet and outlet of the new culvert should be assessed by the hydraulics design engineer. As a minimum, rip-rap treatment for the outlet of the culvert should be consistent with the standard presented in OPSD 810.010 Rip-Rap Treatment Type A. Erosion protection for the inlet of the culvert 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 cut-off measures noted above.

Similarly, rip-rap should be provided over the full extent of the clay blanket, including the creek side slopes and fill slope over the culvert.

6.4 Lateral Earth Pressures for Design

The lateral earth pressures acting on the culvert walls and retaining walls or headwalls 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. For this site location, the geotechnical seismic considerations do not affect the design since it is within a very low seismic zone as given in the *CHBDC* (2006); the calculated seismic active earth pressure coefficient (K_{AE}) derived based on a design zonal acceleration ratio of A =0.05 (for Alliston) in accordance with Sections 4.6.4 and C.4.6.4 of the *CHBDC* and its *Commentary*, is equal to or less than the corresponding static earth pressure coefficient; this is due to the incorporation of the effect of the wall friction in the calculation of the seismic active earth pressure coefficient.

The design recommendations and parameters that are provided below assume the use of Granular "A" or "B" Type II backfill and an even backfilling process on both sides of the culvert walls. It is also assumed that the ground surface behind the walls is level. Where there is sloping ground behind the walls (as, for example, with embankment side s lopes behind headwalls or retaining walls), the coefficient of lateral earth pressure must be adjusted to account for the slope. Adjusted earth pressure coefficients are provided below for conventional embankment side slopes of 2 horizontal to 1 vertical (2H:1V).

- Longitudinal drains and weep holes should be installed through the headwalls to provide positive drainage of the granular backfill. Other aspects of the granular backfill requirements with respect to sub-drains and frost taper should be in accordance with OPSD 3101.150 and 3121.150.

- 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. Compaction equipment should be used in accordance with MTO's Special Provision SP105S10. 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 1.2 m behind the back of the wall stem (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 (Case II on Figure C6.20(b) of the *Commentary to the 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'**
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)	

- If the wall support and superstructure allow lateral yielding of the stem, active earth pressures should 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 the geotechnical design.

6.5 Considerations for Culvert Construction

6.5.1 Groundwater and Surface Water Control

The water level measured in the piezometer installed in Boreholes 07-4 was at Elevation 242.8 m which is just above the recommended subexcavation depths; however, the soils at the culvert replacement site are predominantly fine-grained and cohesive, thus, any groundwater seepage into the excavations for the culvert replacement is expected to be minor and can be handled with the use of properly filtered sumps within the excavation, if needed.

Control of the creek water will be necessary at the culvert site in order for foundation construction to be carried out in dry conditions. Depending on the creek flow at the time of construction, the flow could be passed through the culvert areas by means of a temporary pipe, or diverted by pumping from behind a temporary cofferdam. Assuming that the cofferdam and/or temporary bypass are effective, any seepage into the excavation during normal creek flow conditions should be adequately controlled by pumping from properly filtered sumps.

Surface water should be directed away from the excavation area, to prevent ponding of water that could result in disturbance and weakening of the foundation subgrade; further discussion on this aspect is provided in Section 6.5.3.

6.5.2 Excavations and Temporary Roadway Protection

Temporary excavations for the culvert construction will extend through the existing fill and into the clayey silt till to sand and silt till deposit. Excavation works must be carried out in accordance with the guidelines outlined in the latest edition of the Occupational Health and Safety Act and Regulations for Construction Projects. The existing fill materials and any softened surficial portions of the till are classified as Type 3 soil according to the OHSA. Where space permits, temporary open-cut excavations through these materials should be made with side slopes not steeper than 1 horizontal to 1 vertical (1H:1V).

Depending on the construction staging sequence and schedule, temporary roadway protection will be required along Highway 89 to facilitate the culvert construction works. 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 are present along Highway 89 can tolerate 25 mm of deformation.

6.5.3 Subgrade Protection

The clayey silt till to sand and silt till that is exposed at the founding/subgrade level is susceptible to disturbance from construction traffic and ponded water, leading to degradation of the founding soils. A Non-Standard Special Provision (NSSP) should be included in the Contract Documents to warn the contractor of this effect. In order to limit this detrimental conditions, a working mat of lean concrete should be placed on the subgrade as soon as possible after excavation; but must be placed within four hours after preparation, inspection and approval of the footing subgrade. An example NSSP that addresses this requirement has been included in Appendix A.

6.6 CLOSURE

This report was prepared by Ms. Veronica Olatunji, and reviewed by Ms. Houda Jadi, P.Eng., a Geotechnical Engineer with Golder. Mr. Jorge M. A. Costa, P.Eng., a Designated MTO Contact and Principal with Golder conducted an independent review and provided quality control of the report.

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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.

S:\FINALDAT\ABBREV\2000\LOFA-D00.DOC

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 ($\sigma' = \sigma''$-u)
σ'_{vo}	initial effective overburden stress
$\sigma_1\sigma_2\sigma_3$	principal stresses (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 ($D_R= p_s/p_w$) formerly (G_s)
e	void ratio
n	porosity
S	degree of saturation

* Density symbol is p. Unit weight symbol is γ where γ=pg(i.e. mass density x acceleration due to gravity)

(a) Index Properties (cont'd.)

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 (overconsolidated 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	Overconsolidation ratio=σ'_p/σ'_{vo}

(d) Shear Strength

$\tau_p\tau_r$	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. τ=c'σ' tan |'

2. Shear strength=(Compressive strength)/2

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RECORD OF BOREHOLE No BH07-1

 METRIC

PROJECT 05-1111-034			
W.P. 2479-04-00	LOCATION N 4888984.1 ;E 271368.2		ORIGINATED BY SB
DIST Central HWY	BOREHOLE TYPE Power Auger, 108 mm O.D. Solid Stem Augers		COMPILED BY DD
DATUM Geodetic	DATE September 26, 2007		CHECKED BY SMM

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
245.1	GROUND SURFACE						245			
0.0	Silty sand, trace gravel (FILL) Dense Brown Moist		1	SS	35			o		
244.6 / 0.5	Clayey silt, some sand, trace gravel, containing organics (FILL) Soft to stiff Brown and grey Moist		2	SS	9		244			
			3	SS	4		243			OC 5.2%
			4	SS	5		242			
			5	SS	6			o		
241.6 / 3.5	CLAYEY SILT with sand, some gravel, containing cobbles (TILL) Hard Brown Dry		6	SS	68		241			
	Becoming grey at 4.5 m depth		7	SS	109/.15		240	o (with plastic/liquid limit range)		12 37 36 15
238.8			8	SS	100/.05		239	o		
6.3	END OF BOREHOLE									

Note:

1. Borehole dry upon completion of drilling.

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

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

RECORD OF BOREHOLE No BH07-2

 METRIC

PROJECT 05-1111-034
W.P. 2479-04-00
LOCATION N 4888976.6 ;E 271365.2
ORIGINATED BY SB
DIST Central HWY
BOREHOLE TYPE Power Auger, 108 mm O.D. Solid Stem Augers
COMPILED BY DD
DATUM Geodetic
DATE September 26, 2007
CHECKED BY SMM

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
243.6	GROUND SURFACE							
0.0	Silty sand, trace gravel (FILL) Loose Brown Moist	1	SS	5		243	○	
243.0 / 0.6	Clayey Silt with sand, trace gravel, containing organics (FILL) Soft to stiff Grey Moist	2	SS	3				
		3	SS	9		242	⊢○⊣	5 40 39 16
241.4 / 2.2	CLAYEY SILT with sand, some gravel (TILL) Hard Grey Dry	4	SS	83		241		
		5	SS	62/.15			○	
		6	SS	105		240		
		7	SS	76		239	○	
						238		
237.2		8	SS	85/.15				
6.4	END OF BOREHOLE							

Note:

1. Borehole dry upon completion of drilling.

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

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

RECORD OF BOREHOLE No BH07-3

 METRIC

PROJECT 05-1111-034
W.P. 2479-04-00
LOCATION N 4889006.7 ;E 271355.7
ORIGINATED BY SB
DIST Central HWY
BOREHOLE TYPE Power Auger, 108 mm O.D. Solid Stem Augers
COMPILED BY DD
DATUM Geodetic
DATE September 26, 2007
CHECKED BY SMM

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
243.7	GROUND SURFACE							
0.0	Silty clay, trace sand, containing organics and rootlets (FILL) Soft to firm Dark brown Moist	1	SS	6	243			
		2	SS	3		41		OC 7.2
241.9		3	SS	11	242			
1.8	SILT and SAND, some gravel, trace clay, containing cobbles below 2.2 m depth (TILL) Compact to very dense Brown and grey Moist	4	SS	75	241		NP	12 48 35 5
240.2		5	SS	94				
3.5	END OF BOREHOLE							

Note:

1. Borehole dry upon completion of drilling.

Column headings: SOIL PROFILE; SAMPLES; STRAT PLOT; GROUND WATER CONDITIONS; 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

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

Golder Associates

RECORD OF BOREHOLE No BH07-4

 METRIC

PROJECT 05-1111-034
W.P. 2479-04-00
LOCATION N 4888994.0 ;E 271361.1
ORIGINATED BY SB
DIST Central HWY
BOREHOLE TYPE Power Auger, 108 mm O.D. Solid Stem Augers
COMPILED BY DD
DATUM Geodetic
DATE September 26, 2007
CHECKED BY SMM

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
244.9	GROUND SURFACE						
0.0	Silty sand, trace gravel (FILL) Brown Moist						
244.1 0.8	Clayey silt, trace to some sand, trace gravel, containing rootlets (FILL) Firm Brown Moist	1	SS	8	244	o	
		2	SS	6	243	o	
	Becoming dark grey to black, containing organics and decayed wood fibres at 2.2 m depth	3	SS	6		o	OC 6.7
242.2 2.7	CLAYEY SILT with sand, trace gravel (TILL) Very stiff to hard Grey Dry	4	SS	26	242		
		5	SS	83	241	o	
		6	SS	97/.15	240	o	
		7	SS	85/.15	239	o (with plastic/liquid limits)	3 44 41 12
					238		
237.1		8	SS	107/.15		o	
7.8	END OF BOREHOLE						

Notes:

1. Borehole dry upon completion of drilling.

2. Water level in piezometer at a depth of 4.8 m (Elev. 240.1 m) upon completion of piezometer installation on September 26, 2007.

3. Water level in piezometer at a depth of 2.1 m (Elev. 242.8 m) below ground surface on October 15, 2007.

Column headings: SOIL PROFILE; SAMPLES; STRAT PLOT; GROUND WATER CONDITIONS; 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

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

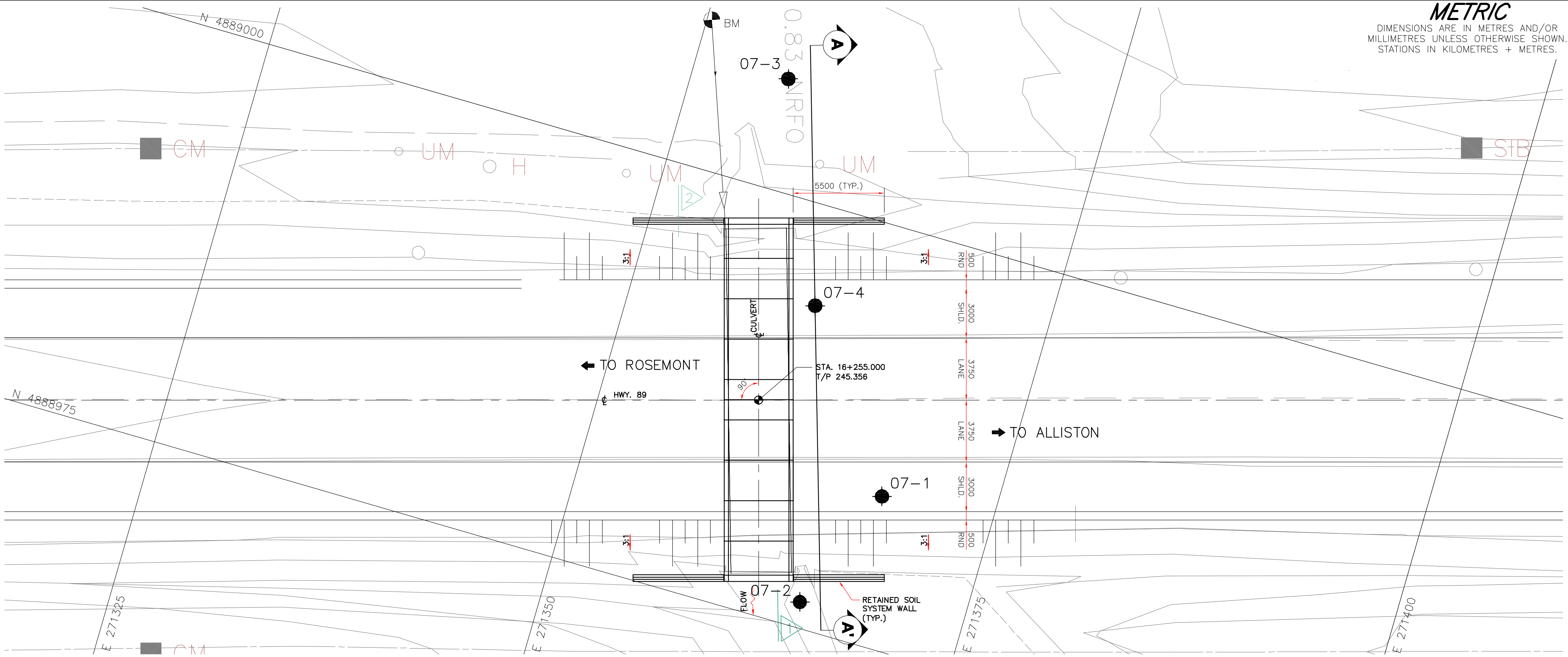
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 2479-04-00

SHEET

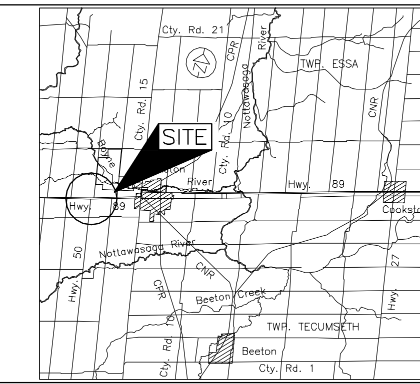
HWY 89
CULVERT REPLACEMENT AT STATION 16+255
BOREHOLE LOCATION AND SOIL STRATA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN

SCALE 3 0 3 6 m

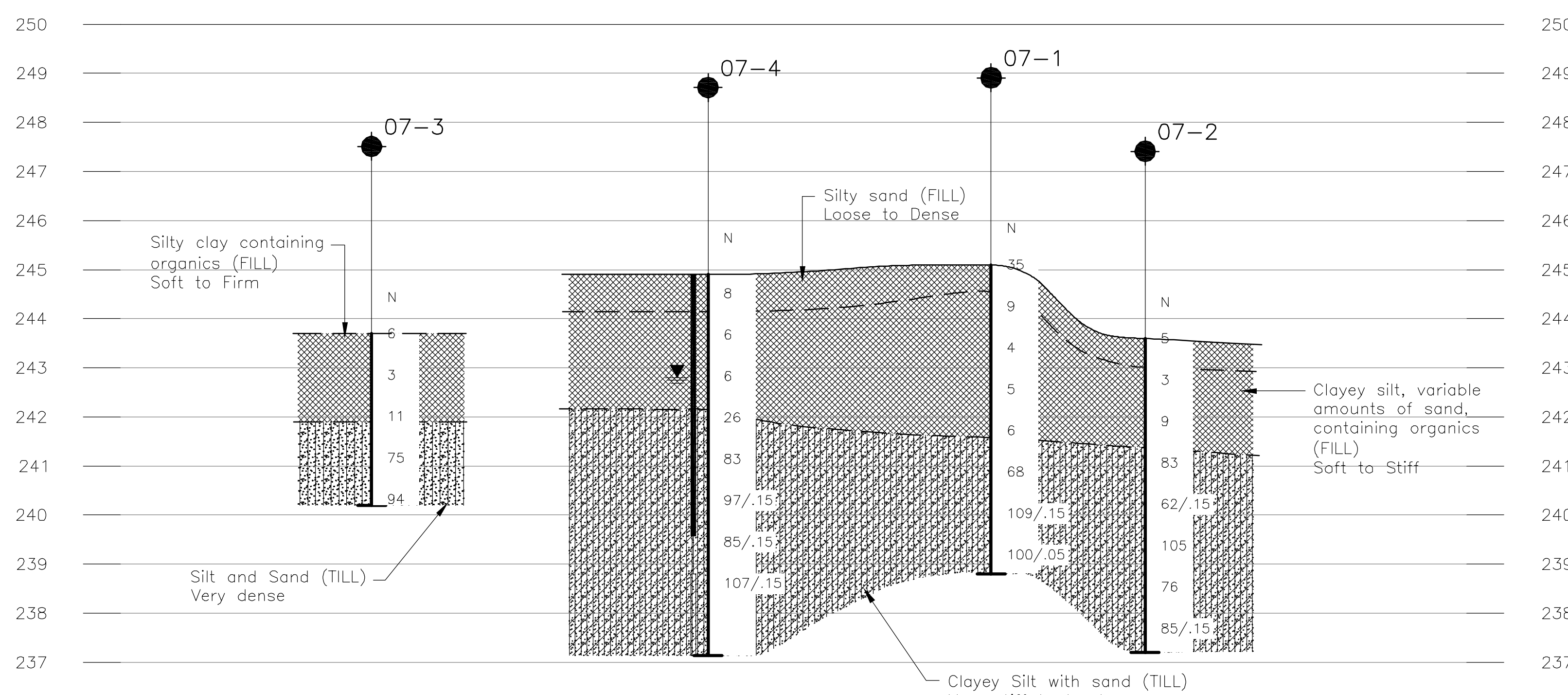


KEY PLAN
NOT TO SCALE

LEGEND

- Borehole – Current Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- WL in piezometer, measured on October 15, 2007

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
07-1	245.1	4888984.1	271368.2
07-2	243.6	4888976.6	271365.2
07-3	243.7	4889006.6	271355.7
07-4	244.9	4888994.0	271361.1



PROFILE A–A'

SCALE
HOR. 3 0 3 6 m

SCALE
VERT. 1.5 0 1.5 3 m

NOTES

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

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

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

REFERENCE

Base plans provided in digital format by MRC, drawing file no. 1 entitled "HWY 89 Culvert at sta. 16+255 general arrangement", dated Jan. 2007, received Nov. 23, 2007.

NO.	DATE	BY	REVISION

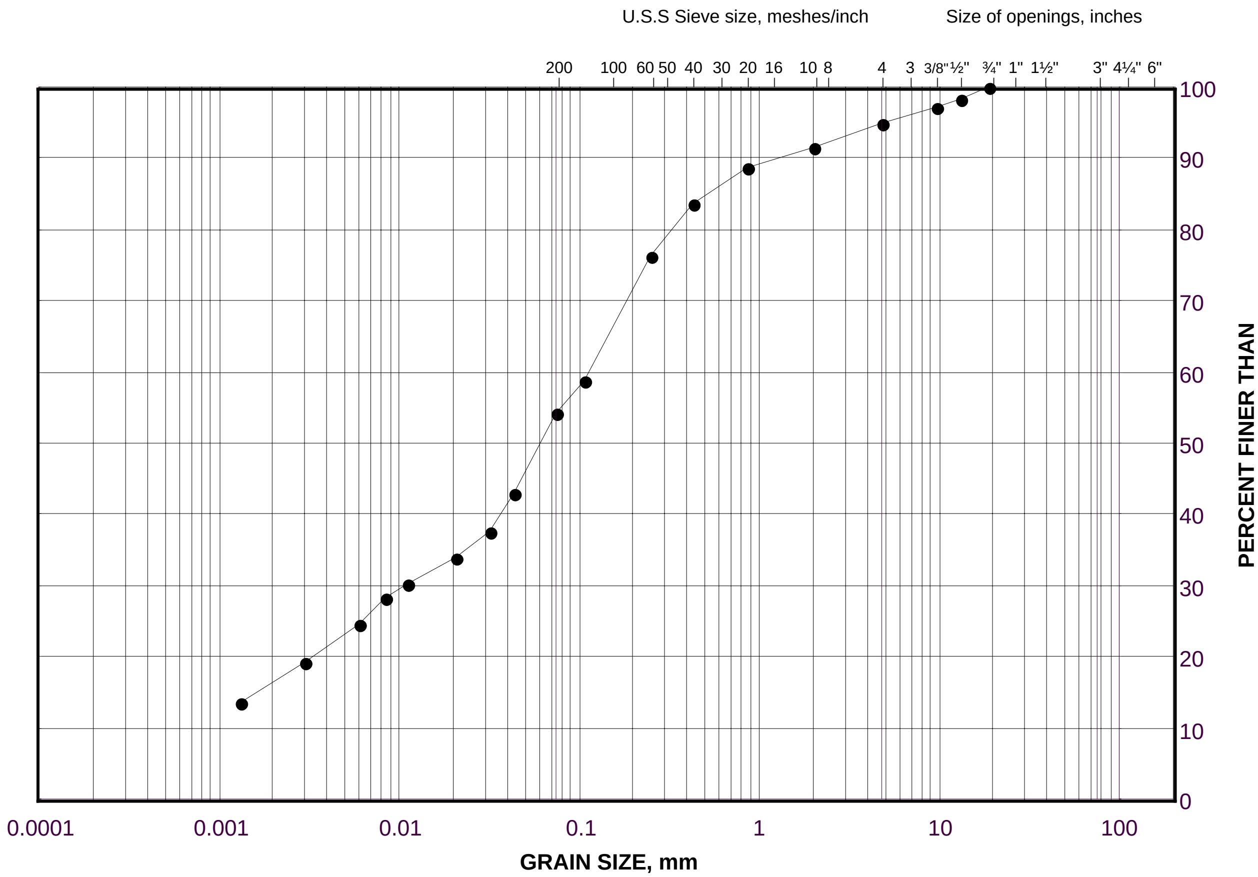
Geocres No. 31D-451

HWY.	PROJECT NO. 05-1111-034		DIST.
SUBM'D.	CHKD.	DATE: 20-Jan-2009	SITE: 30-545C
DRAWN: DD	CHKD. HJ	APPD. JMAC	DWG. 1

GRAIN SIZE DISTRIBUTION

Clayey Silt with Sand (Fill)

FIGURE 1



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

LEGEND

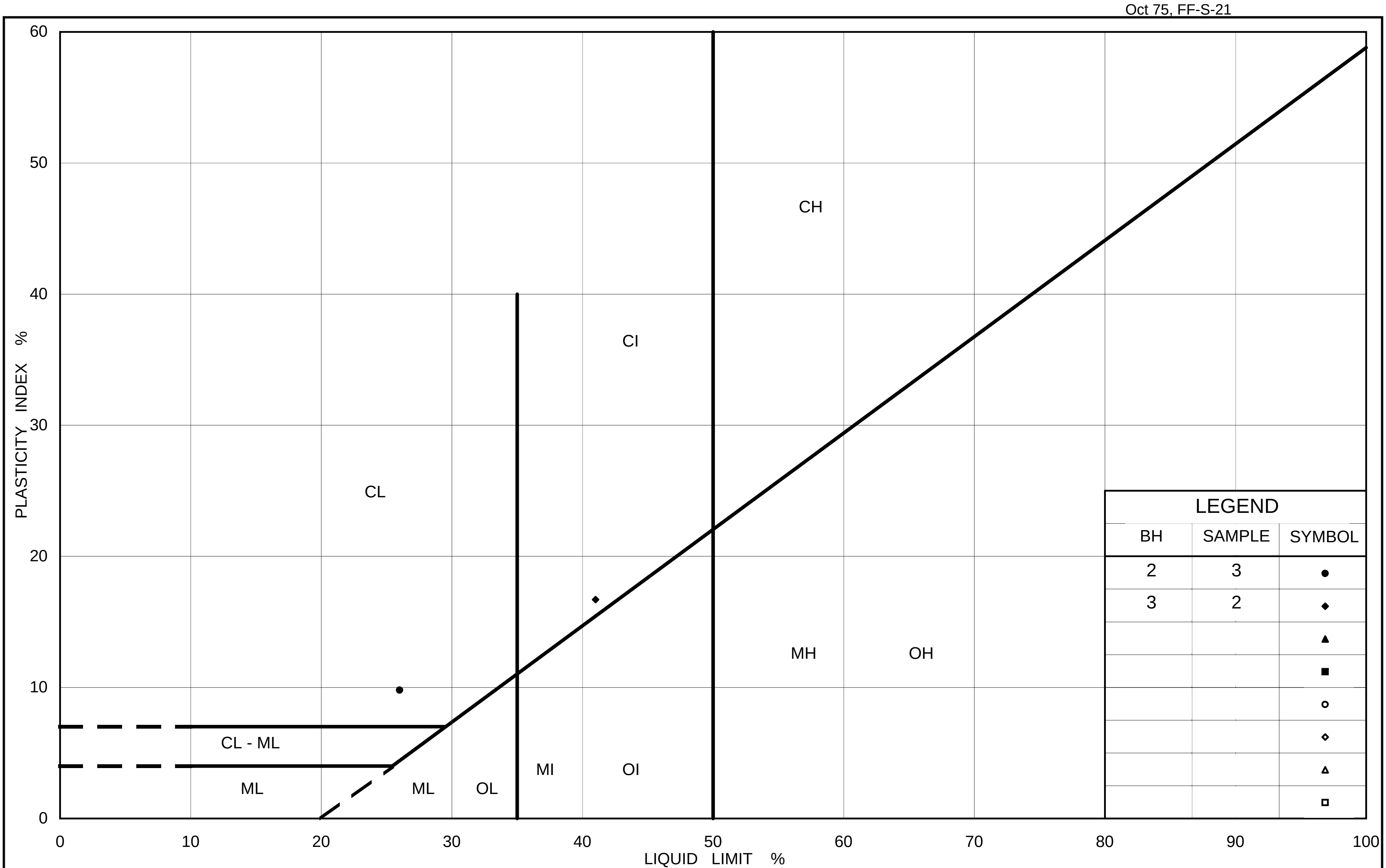
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	07-2	3	241.8

Project Number: 05-1111-034

Checked By: HJ

Golder Associates

Date: 17-Dec-07



Ministry of Transportation

Ontario

PLASTICITY CHART
Clayey Silt to Silty Clay Fill

Figure No. 2

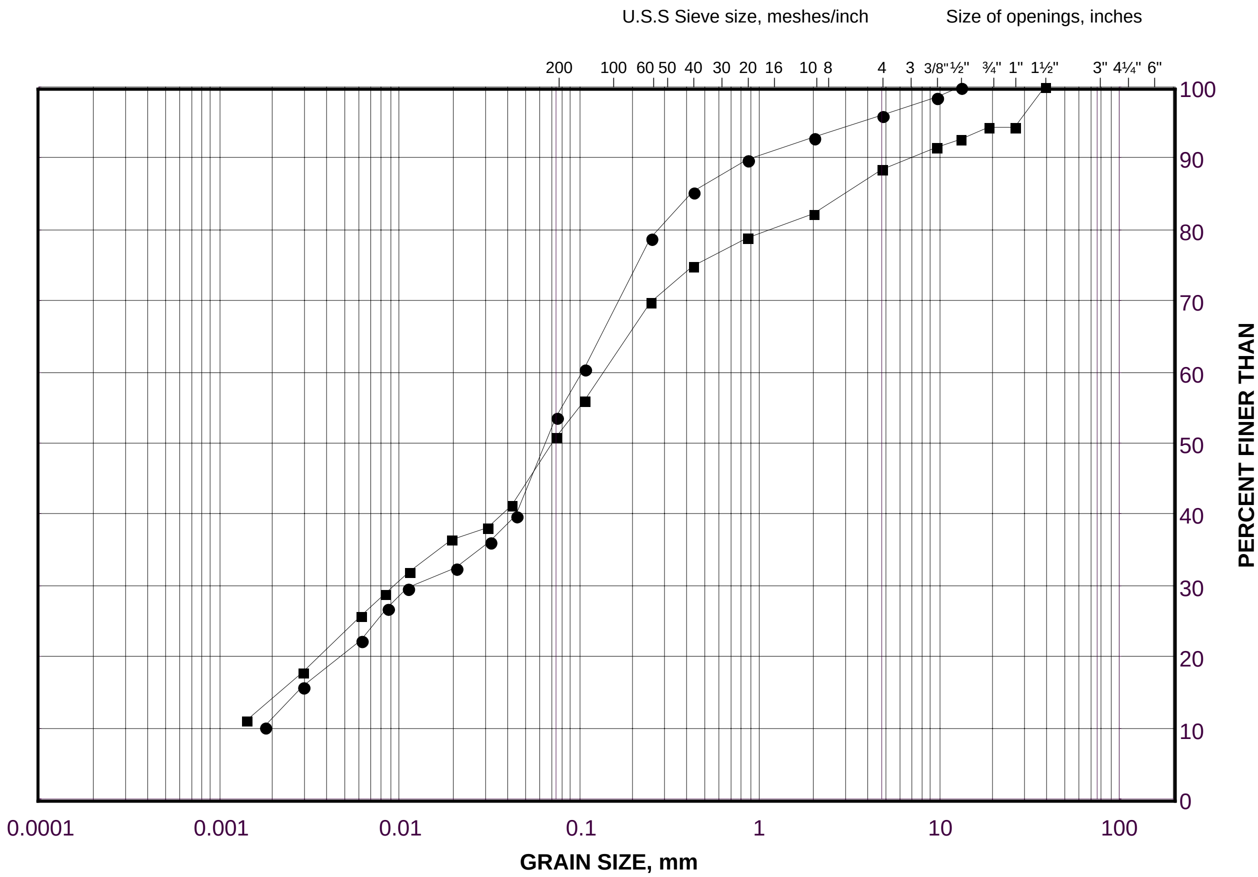
Project No. 05-1111-034

Checked By: HJ

GRAIN SIZE DISTRIBUTION

Clayey Silt with Sand (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)
●	07-4	7	238.8
■	07-1	7	240.5

Project Number: 05-1111-034

Checked By: HJ

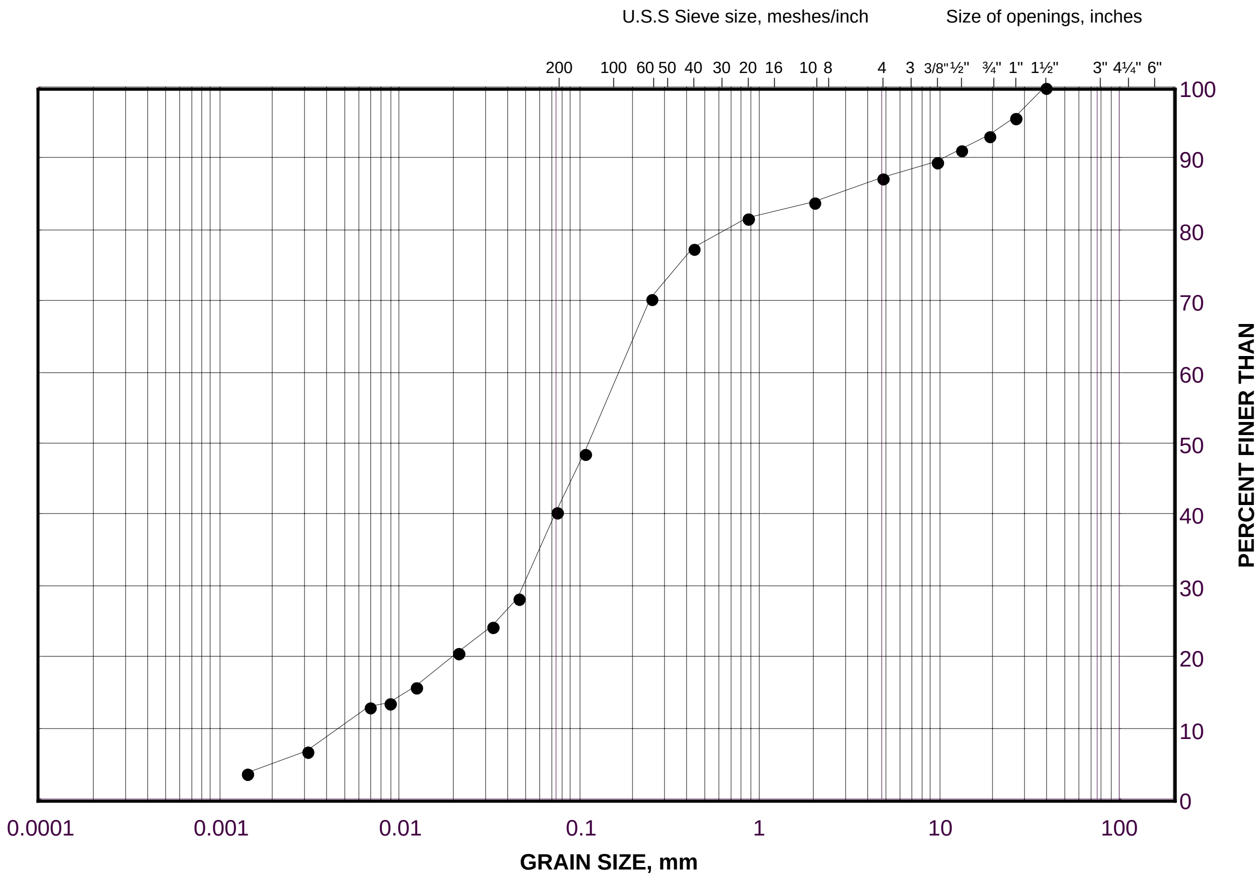
Golder Associates

Date: 17-Dec-07

GRAIN SIZE DISTRIBUTION

Silt and Sand (Till)

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)
●	07-3	4	241.2

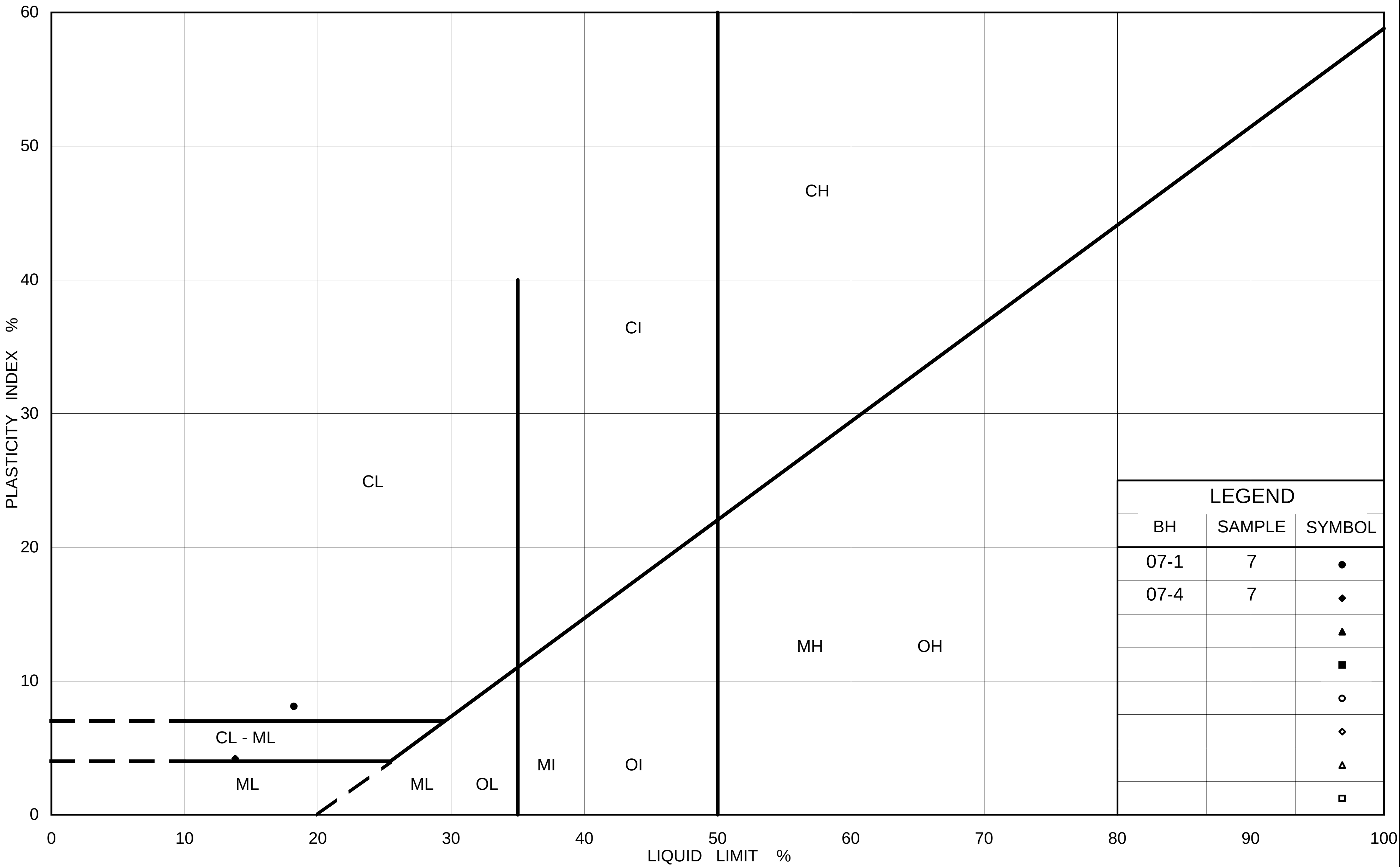
Project Number: 05-1111-034

Checked By: HJ

Golder Associates

Date: 17-Dec-07

Oct 75, FF-S-21



Ministry of Transportation

Ontario

PLASTICITY CHART
Clayey Silt Till

Figure No. 5

Project No. 05-1111-034

Checked By: HJ

APPENDIX A

NON-STANDARD SPECIAL PROVISION

SUBGRADE PROTECTION - ITEM NO.

Special Provision **January 2009**

1.0 Scope

The work under this item shall include the supply and placement of lean mix concrete, with a minimum thickness of 150 mm, on the founding level for the footings within four (4) hours of subgrade preparation and inspection.

Lean concrete should have a compressive strength of at least 5 MPa and be placed in accordance with OPSS904

2.0 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