April 2010

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FOUNDATION INVESTIGATION AND DESIGN REPORT

OVERHEAD SIGN AT ERIN MILLS PARKWAY E-N/S RAMP GO TRANSIT - BUS RAPID TRANSIT WEST FROM WINSTON CHURCHILL BOULEVARD TO ERIN MILLS PARKWAY, MISSISSAUGA, ONTARIO

Submitted to:
Giffels Associates Limited/IBI Group
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Reference: Google Earth Pro Source: ©2010 TeleAtlas, Image©2010 DigitalGlobe, Imagery Date Plan August 31, 2009

REPORT

Report Number: 09-1811-1045-3

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MISSISSAUGA, ONTARIO

Golder Associates

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Giffels Associates Limited/IBI Group (Giffels/IBI) on behalf of GO Transit (GO) to provide geotechnical engineering services for the detailed design of the GO Bus Rapid Transit West (GO BRT) between Winston Churchill Boulevard and Erin Mills Parkway, in the City of Mississauga, Ontario. The proposed GO BRT alignment will run parallel to and on the north side of the existing Highway 403 alignment, and south of the existing hydro corridor. In addition to the GO BRT, the overall scope of this project involves the bus stations at Winston Churchill Boulevard and at Erin Mills Parkway, ramps, five bridges, associated retaining walls, high mast lights and overhead signs.

This report addresses the geotechnical investigation carried out for the proposed GO BRT overhead steel monotube sign to be located on the Erin Mills Parkway E-N/S ramp.

This report addresses only the geotechnical (physical) aspects of the subsurface conditions at this site. The geo-environmental (chemical) aspects, including consequences of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources, are outside the terms of reference for this report.

The factual data, interpretations and recommendations contained in this report pertain to a specific project as described in the report and are not applicable to any other project or site location. If the project is modified in concept, location or elevation, or if the project is not initiated within twelve months of the date of the report, Golder should be given an opportunity to confirm that the recommendations are still valid.

This report should be read in conjunction with "Important Information and Limitations of This Report", following the text of this report. The reader's attention is specifically drawn to this information, as it is essential for the proper use and interpretation of this report.

The terms of reference for the foundation investigation and design services are outlined in GO Transit's Request for Proposal dated June 15, 2009. The scope of work for this component of the project is outlined in Golder's proposal P9-1181-1045, dated June 25, 2009.

2.0 SITE AND PROJECT DESCRIPTION

The proposed overhead sign structure is located on the proposed new alignment of the E-N/S Ramp approximately 100 m northeast of the Erin Mills Parkway centreline, within the northeast quadrant of the current Highway 403-Erin Mills Parkway interchange in the City of Mississauga, Ontario (see key plan on Drawing 1). The ground surface in the vicinity of the interchange is generally flat to gently sloping toward the southeast. In the northwest and southeast quadrants of the Erin Mills Parkway interchange, the Highway 403 corridor is bounded by residential subdivisions. A hydro corridor parallels Highway 403 and the proposed GO BRT roadway along the northwest boundary of the highway right-of-way.

3.0 INVESTIGATION PROCEDURES

The field work for the proposed sign structure was carried out on February 24 and 25, 2010, at which time one borehole (Borehole OS-3) was advanced on the north shoulder of the existing E-N/S Ramp at the location shown on Drawing 1, following the text of this report.

The field investigation was carried out using a track-mounted drill rig supplied and operated by DBW Drilling Limited of Toronto, Ontario. The borehole was advanced using 150 mm diameter solid stem augers to a depth of 7.8 m below the existing ground surface. Soil samples were obtained at regular intervals of depth using a conventional 50 mm outside diameter split-spoon sampler driven by an automatic hammer in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586). Rock was cored from a depth of 7.8 m to 10.8 m using diamond coring techniques with an NQ-size core barrel.

The groundwater conditions in the open borehole were observed throughout the drilling operations. The borehole was backfilled with bentonite upon completion of drilling in accordance with Ontario Regulation (O. Reg.) 903 as amended by O.Reg. 372/07 of the Ontario Water Resources Act. Cold patch asphalt was placed at the ground surface.

The field work was supervised full-time by a member of Golder's technical staff who arranged for service clearances and road occupancy permits, observed the drilling, sampling and in situ testing operations, logged the borehole, and examined and cared for the soil and rock samples. The soil and rock samples were identified in the field, placed in labelled containers and transported to Golder's laboratory in Mississauga for further examination and testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards as appropriate. Soil classification tests (water content, Atterberg limits and grain size distribution) were carried out on selected soil samples.

The borehole location was surveyed in the field by SCS Consulting Group Ltd. prior to drilling operations. The as-drilled borehole location (referenced to the MTM NAD83 co-ordinate system) and ground surface elevation (referenced to geodetic datum) is summarized below.

Borehole	Northing (m)	Easting (m)	Ground Surface Elevation (m)
OS-3	4,823,992.4	288,809.2	165.4

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

The study area for this investigation lies within the Trafalgar Moraine portion of the South Slope, as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984). A surficial till sheet, which generally follows the surface topography, is present throughout much of this area. The till is typically comprised of clayey silt to silty clay and sand and silt.

The till in this area is underlain by Ordovician shales of the Queenston Formation (Ontario Geological Society, 1991). In the vicinity of the Highway 407/403 interchange and Erin Mills Parkway, the depth to the bedrock is fairly shallow; however, in the vicinity of Winston Churchill Boulevard, a bedrock valley exists and the bedrock surface is much deeper. After the bedrock valley was formed, it was infilled during the retreat of the glaciers with a deposit of clayey silt.

4.2 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the borehole and the results of in situ and laboratory testing are given on the Record of Borehole OS-3 following the text of this report. The results of laboratory testing are also presented on Figures 1 to 5.

The stratigraphic boundaries shown on the borehole record are inferred from non-continuous sampling, observations of drilling progress and the results of Standard Penetration Tests (SPTs). These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Subsoil conditions will vary between and beyond the borehole locations.

In summary, the subsoil conditions encountered in the borehole consist of the highway shoulder pavement structure (asphalt underlain by granular base fill), constructed on a low embankment of clayey silt fill, which is underlain by clayey silt till, clayey silt residual soil, and shale bedrock. A more detailed description of the subsurface conditions encountered in the borehole is provided in the following sections.

4.2.1 Pavement Structure

A 76 mm thick layer of asphalt was encountered immediately below the ground surface, underlain by 0.6 m of silty sand and gravel fill. The water content measured on one sample of the silty sand and gravel is approximately 4 percent.

4.2.2 Clayey Silt Fill

An approximately 1.9 m thick layer of clayey silt fill was encountered below the asphalt and granular fill, extending from a depth of 0.7 m (Elevation 164.7 m) below ground surface.

The measured SPT 'N' values in the clayey silt fill are 5 and 8 blows per 0.3 m of penetration, suggesting a firm to stiff consistency.

The clayey silt fill contains trace sand and trace gravel. The results of a grain size distribution test completed on one sample of the clayey silt fill are shown on Figure 1. An Atterberg limits test carried out on one sample of the fill indicates a plastic and liquid limit of 19 and 30 percent, respectively, and a corresponding plasticity index of 11 percent. The results of the Atterberg limits testing are shown on the borehole record and on a plasticity chart on Figure 2, and confirm that this material is a clayey silt of low plasticity. The natural water content measured on three samples of the clayey silt fill range from 15 to 17 percent, slightly below the plastic limit of the material.

4.2.3 Clayey Silt Till

A 0.7 m thick deposit of clayey silt till was encountered below the fill, extending from a depth of about 2.6 m (Elevation 162.8 m) below the pavement surface.

One measured SPT 'N' value in the clayey silt till is 62 blows per 0.3 m of penetration, suggesting that this deposit has a hard consistency.

The clayey silt till contains some sand and gravel; the results of a grain size distribution test on one sample of the till are shown on Figure 3. Atterberg limits testing carried out on one sample of the till measured plastic and liquid limits of 19 and 33 percent, respectively, and a corresponding plasticity index of 14 percent. The results of this testing are shown on the borehole record and on a plasticity chart on Figure 4, and confirm that the till material is a clayey silt of low plasticity. The natural water content measured on two samples of the clayey silt till is 8 and 12 percent.

4.2.4 Clayey Silt Residual Soil

Residual soil was encountered below the clayey silt till, extending from a depth of about 3.3 m to 3.8 m below the pavement grade (Elevations 162.1 m and 161.6 m).

One SPT 'N' value of 65 blows per 0.3 m of penetration was measured in the residual soil, indicating a hard consistency.

The residual soil, which is derived from weathering of the underlying shale bedrock, consists of clayey silt containing varying amounts of limestone and shale fragments. A grain size distribution test was conducted on the recovered sample of the residual soil, and the results are shown on Figure 5. The natural water content of one sample of the clayey silt residual soil is 11 percent.

4.2.5 Shale Bedrock

Shale bedrock was encountered in the borehole at a depth of 3.8 m (Elevation 161.6 m) below the top of pavement. The borehole was extended into the bedrock by augering and split-spoon sampling to a depth of 7.8 m (Elevation 157.6 m) and then was cored from a depth of 7.8 m to 10.8 m (to Elevation 154.2 m).

The bedrock is described as reddish-brown shale, which is mapped in this area as the Queenston Formation. The measured rock quality designation (RQD) values range from 17 to 58 percent within the cored interval.

4.2.6 Groundwater Conditions

The groundwater conditions were noted within the borehole during and on completion the drilling operations. The borehole was dry on completion of augering and split-spoon sampling on February 25, 2010.

A piezometer was installed in Borehole B, drilled for the proposed GO BRT Erin Mills Bus Station, located approximately 200 m southwest of the proposed overhead sign location. The piezometer installed in Borehole B was sealed within the upper portion of the shale bedrock. Details of the well installations are shown on the Record of Borehole sheet contained in Appendix A. The water level measured in the piezometers was at Elevation 163.4 m on October 8, 2009, at a depth of approximately 2.7 m below ground surface, corresponding to a depth of 1.3 m below the bedrock surface at that location.

The groundwater level is expected to fluctuate seasonally and is expected to rise during wet periods of the year.

5.0 CLOSURE

This Foundation Investigation Report was prepared by Mr. Andrew J. Hagner, P.Eng, and reviewed by Ms. Lisa Coyne, P.Eng., a geotechnical engineer and Principal with Golder. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and a Principal with Golder, conducted an independent quality control review of the report.

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PART B

FOUNDATION DESIGN REPORT
SIGN AT ERIN MILLS PARKWAY E-N/S RAMP
GO TRANSIT - BUS RAPID TRANSIT WEST FROM WINSTON CHURCHILL BOULEVARD TO ERIN MILLS PARKWAY
MISSISSAUGA, ONTARIO

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides foundation design recommendations for the proposed overhead steel monotube sign structure to be located on the Erin Mills Parkway E-N/S Ramp, approximately 100 m northeast of the Erin Mills Parkway centreline. The recommendations are based on interpretation of the factual data obtained during a subsurface investigation at the site.

The interpretation and recommendations provided in this section are intended for use by the design engineer. Where comments are made on construction, they are provided only to highlight those aspects that 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 method and scheduling.

6.2 Design of Sign Foundations

Caisson foundations for sign supports should be designed in accordance with the requirements in MTO's *Sign Support Manual* (MTO, 2004). The *Sign Support Manual* includes standard caisson foundation designs for various sign types, including steel monotube signs in Section 7 (Overhead Monotube Sign Supports) – Standard Drawings SS118-40, SS118-41 and SS118-42.

The standard sign foundation designs presented in the MTO's *Sign Support Manual* have been developed based on the minimum soil conditions given below. Where weaker soils or rock fill are encountered, a site-specific design is required.

- **Case 1 (Cohesionless Soils):** Sand with a friction angle of 28 degrees surrounding the upper two-thirds of the caisson foundation below the frost depth, and sand with a friction angle of 30 degrees surrounding the lower third of the portion of the caisson below the design frost depth.
- **Case 2 (Cohesive Soils):** Soft clay with an undrained shear strength of 25 kPa surrounding the upper two-thirds of the portion of the caisson foundation below the frost depth, and "soft" clay with an undrained shear strength of 50 kPa surrounding the lower third of the portion of the caisson below the design frost depth.

In the standard foundation design for overhead steel monotube signs, the caissons are to be extended for a total depth of 3 m below the surrounding grade.

Based on the results of Borehole OS-3, the top of bedrock was encountered at Elevation 161.6 m, which is about 2.4 m and 0.7 m below the current ground surface at the north and south ends, respectively, of the proposed sign overhead sign. Where the depth to bedrock is shallow (i.e. less than the proposed foundation length of 3 m) following the final earthworks and grading at the site, the sign support foundations could consist of a caisson embedded into the bedrock, or a spread footing or caisson anchored/dowelled to the surface of the bedrock to avoid coring into bedrock. However, it is noted that the bedrock has experienced some degree of weathering and was able to be augered to a depth of 7.8 m (Elevation 157.6 m) in Borehole OS-3; stronger, "fresh" rock is interpreted to occur below approximately Elevation 156.7 m in Borehole OS-3, based on the measured RQD values of 70 and 100 percent below this depth. Based on these results, it is recommended that the proposed overhead steel monotube sign supports be founded on caissons that are embedded into the bedrock.

For the proposed overhead steel monotube sign on this project, the depth to bedrock is less than 3 m below the current ground surface at the proposed foundation locations. A 3 m deep caisson could be constructed or, alternatively, the depth of the rock socket required for the caisson foundations could be assessed and likely reduced with a site-specific design using the following equations to calculate the unfactored passive lateral earth pressure, Pp (kPa), distributed along the depth of the caisson foundation:

$$Pp = Kp\,\gamma\,dw \qquad \text{above the groundwater table, and}$$

$$Pp = Kp\,\gamma\,dw + Kp\,\gamma'\,(d - dw) \qquad \text{below the groundwater table,}$$

where Kp is the passive earth pressure coefficient;
γ is the bulk unit weight of the soil (kN/m3);
γ' is the effective unit weight of the soil below the groundwater level (kN/m3);
d is the depth below the ground surface (m); and
dw is the depth to the groundwater level (m).

The simplified stratigraphy and design parameters for the subsurface conditions encountered in the borehole for this sign site are given in Table 1 following the text of this report.

In the site-specific design of caisson foundations, the passive resistance within the upper 1.2 m below ground surface should be neglected to account for frost action. The unfactored lateral resistance should be calculated assuming an equivalent width equal to three times the caisson diameter. A resistance factor of 0.5 should be applied to the unfactored lateral resistance to obtain the factored lateral geotechnical resistance at Ultimate Limit States (ULS).

Where an undrained shear strength, c_u, is provided for a cohesive soil layer in Table 1, the capacity of the caisson should be checked to determine whether the drained (effective stress) or undrained case will govern. For the undrained case, the lateral resistance for the length of the caisson within the cohesive soil should be calculated assuming an unfactored passive lateral pressure distribution varying from 2 c_u at the surface to 9 c_u at and below a depth equivalent to three caisson diameters, acting over the actual width of the caisson. A resistance factor of 0.5 should be applied to this calculated lateral resistance in order to obtain the factored lateral geotechnical resistance at ULS.

6.3 Contract Documents and Construction Considerations

If caisson foundations are adopted for support of the sign support structure, Ontario Provincial Standard Specification (OPSS) 903 (Deep Foundations) should be included in the Contract Documents. In addition, it is recommended that a Non-Standard Special Provision (NSSP) be included in the Contract Documents to warn the Contractor that the shale bedrock is weak to medium strong and contains medium strong interlayers of limestone, as this may impact the installation method for the caisson foundations; appropriate equipment and procedures will be required to penetrate the shale bedrock and limestone layers.

7.0 CLOSURE

This Foundation Design Report was prepared by Mr. Andrew J. Hagner, P.Eng, and reviewed by Ms. Lisa C. Coyne, P.Eng., a geotechnical engineer and Principal with Golder. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and Principal with Golder, conducted an independent quality control review of the report.

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TABLE 1: DESIGN PARAMETERS FOR SIGN FOUNDATIONS

Borehole No.	Borehole Location	Stratum	Depth[1] (m)	Elevation[1] (m)	Design Parameters [2,3]					Groundwater Elevation [4]
					c_u	φ'	γ	γ'	K_p	
OS-3	N 4,823,992.4 E 288,809.2	Clayey silt fill	0.7 – 2.6	164.7 – 162.8	30	27	17	-	2.7	160.5 m (Assumed)
		Clayey silt till	2.6 – 3.3	162.8 – 162.1	-	35	21	-	3.7	
		Clayey silt residual soil	3.3 – 3.8	162.1 – 161.6	-	32	21	11	3.3	
		Shale bedrock	Below 3.8	Below 161.6	-	38	23	13	4.2	

Reviewed by: L.C. Coyne

NOTES:

1. Depth to bedrock is given for the borehole location; the ground surface elevation at the borehole location should be compared to the ground surface elevation at the actual overhead steel monotube sign support location, and the depths and/or elevations adjusted accordingly.
2. Design parameters: c_u = undrained shear strength (kPa);
   φ' = effective friction angle (degrees);
   γ = bulk unit weight (kN/m^3);
   γ' = effective unit weight below the groundwater level (kN/m^3); and,
   K_p = passive earth pressure coefficient.
3. Although the passive resistance in the upper 1.2 m is to be neglected to account for frost action, φ' and K_p parameters are given in the event that the ground surface elevation varies significantly between the borehole and sign support locations.
4. Assumed groundwater level based on the site stratigraphy, soil samples and nearby Borehole B.

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IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

Standard of Care: Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder can not be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the report was prepared to be included for a specific permit application process, then upon the reasonable request of the client, Golder may authorize in writing the use of this report by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process. Any other use of this report by others is prohibited and is without responsibility to Golder. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client can not rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder can not be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Groundwater Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report. The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

Sample Disposal: Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

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	c_u, s_u 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.

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
υ	poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - \mu$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
μ	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

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

(a) Index Properties (continued)

w	water content
w_l	liquid limit
w_p	plastic limit
I_p	plasticity index $= (w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index $= (w - w_p) / I_p$
I_C	consistency index $= (w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index $= (e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_a	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation pressure
OCR	over-consolidation ratio $= \sigma'_p / \sigma'_{vo}$

(d) Shear Strength

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

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

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

LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERINGS STATE

Fresh: no visible sign of weathering

Faintly weathered: weathering limited to the surface of major discontinuities.

Slightly weathered: penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

Moderately weathered: weathering extends throughout the rock mass but the rock material is not friable.

Highly weathered: weathering extends throughout rock mass and the rock material is partly friable.

Completely weathered: rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

BEDDING THICKNESS

Description	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 m to 2 m
Medium bedded	0.2 m to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	Less than 6 mm

JOINT OR FOLIATION SPACING

Description	Spacing
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

GRAIN SIZE

Term	Size*
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: * Grains greater than 60 microns diameter are visible to the naked eye.

CORE CONDITION

Total Core Recovery (TCR)
The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

Solid Core Recovery (SCR)
The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

Rock Quality Designation (RQD)
The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varied from 0% for completely broken core to 100% for core in solid sticks.

DISCONTINUITY DATA

Fracture Index
A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

Dip with Respect to Core Axis
The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90° angle is horizontal.

Description and Notes
An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

Abbreviations

JN	Joint	PL	Planar
FLT	Fault	CU	Curved
SH	Shear	UN	Undulating
VN	Vein	IR	Irregular
FR	Fracture	K	Slickensided
SY	Stylolite	PO	Polished
BD	Bedding	SM	Smooth
FO	Foliation	SR	Slightly Rough
CO	Contact	RO	Rough
AXJ	Axial Joint	VR	Very Rough
KV	Karstic Void		
MB	Mechanical Break		

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RECORD OF BOREHOLE No OS-3

 METRIC

PROJECT 09-1181-1045			
G.W.P.	LOCATION N 4823992.4 ;E 288809.2		ORIGINATED BY RS
DIST	HWY 403	BOREHOLE TYPE 150 mm Outside Diameter Solid Stem Augers	COMPILED BY AH
DATUM Geodetic	DATE February 24 and 25, 2010		CHECKED BY AH/MC

Column headings: SOIL PROFILE (ELEV / DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; 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; REMARKS & GRAIN SIZE DISTRIBUTION (%) (GR SA SI CL)

ELEV / DEPTH	DESCRIPTION
165.4	GROUND SURFACE
0.0	ASPHALT
0.2	Silty sand and gravel (FILL) Brown Moist
164.7 / 0.7	Clayey silt, trace to some sand and gravel (FILL) Firm to stiff Brown Moist
162.8 / 2.6	CLAYEY SILT, some sand, some gravel, containing limestone fragments (TILL) Hard Reddish brown Moist
162.1 / 3.3	
161.6 / 3.8	CLAYEY SILT, trace sand, containing shale and limestone fragments (RESIDUAL SOIL) Hard Reddish brown Moist
	SHALE (BEDROCK) Reddish brown
	Bedrock cored from 7.8 m to 10.8 m depth. For bedrock coring details, refer to Record of Drillhole OS-3.
154.6 / 10.8	END OF BOREHOLE

NOTE:
1. Open borehole dry upon completion of augering and split-spoon sampling.

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	AS	—	
2	SS	8	
3	SS	5	7 9 62 22
4A / 4B	SS	62	14 15 48 23
5A / 5B	SS	65	0 2 72 26
6	SS	62/.15	
7	SS	55/.1	
8	SS	50/.13	
9	SS	61/.15	
1	RC	REC 47%	RQD = 17%
2	RC	REC 70%	RQD = 0%
3	RC	REC 100%	RQD = 17%

Elevation scale: 165, 164, 163, 162, 161, 160, 159, 158, 157, 156, 155

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

RECORD OF DRILLHOLE: OS-3

PROJECT: 09-1181-1045

SHEET 1 OF 1

LOCATION: N 4823992.4 ;E 288809.2

DRILLING DATE: February 24 and 25, 2010

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: D-120 TRACK MOUNT

DRILLING CONTRACTOR: WALKER DRILLING

JN - Joint, FLT - Fault, SHR - Shear, VN - Vein, CJ - Conjugate, BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Cleavage, PL - Planar, CU - Curved, UN - Undulating, ST - Stepped, IR - Irregular, PO - Polished, K - Slickensided, SM - Smooth, Ro - Rough, MB - Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	RUN No.	COLOUR % RETURN (FLUSH)	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	NOTES WATER LEVELS INSTRUMENTATION
		CONTINUED FROM RECORD OF BOREHOLE OS-3		157.6				
8–10.8	NQ RC; NW CASING	SHALE (BEDROCK) containing interbeds of grey, slightly to moderately weathered, medium strong limestone 10 mm to 50 mm thick interlayers (QUEENSTON FORMATION) Slightly to completely weathered Reddish brown Extremely weak to medium Thinly laminated		7.8	1	Reddish brown 100%	" " BD,UN,SM BD,PL,SM JN,CU,Ro	
					2	Reddish brown 100%	CO,CU,SM BD,UN,SM BD,CU,SM BD,CU,SM BD,UN,Ro BD,UN,SM BD,CU,Ro BD,UN,SM BD,UN,Ro BD,UN,SM BD,UN,Ro JN,IR,Ro	
				154.6	3	Reddish brown 100%	BD,UN,Ro BD,UN,SM BD,UN,SM BD,UN,Ro BD,UN,SM JN,IR,Ro BD,UN,SM JN,CU,Ro BD,CU,SM BD,UN,SM BD,CU,SM BD,UN,SM BD,CU,SM BD,UN,SM BD,UN,Ro	
		END OF DRILLHOLE		10.8				

Depth scale: 8, 9, 10, 11, 12, 13, 14, 15, 16, 17

MIS-RCK 023 0911811045.GPJ GAL-MISS.GDT 13/4/10 JFC

DEPTH SCALE 1 : 50

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LOGGED: RS

CHECKED: MC

PLOT DATE: April 16, 2010
FILENAME: T:\Projects\2009\09-1181-1045 (GIFFELS, Mississauga)\-CA- (OVERHEAD SIGN_OS-3)\0911811104CA01.dwg

MINISTRY OF TRANSPORTATION, ONTARIO

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

CONT No.
WP No.

SHEET

GO TRANSIT BUS RAPID TRANSIT W.
SIGN AT ERIN MILLS PARKWAY E-N/S RAMP
BORESHOLE LOCATION

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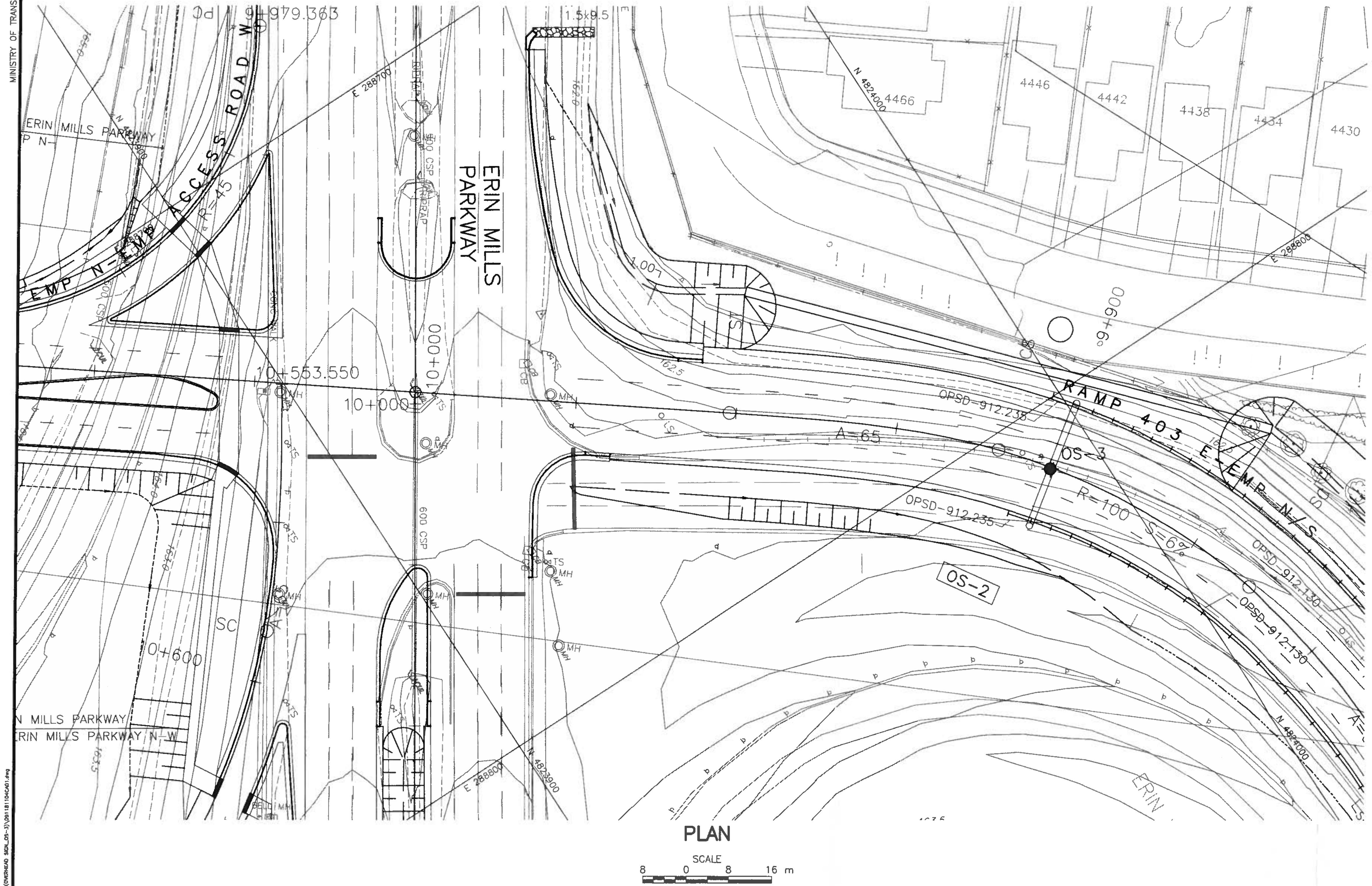
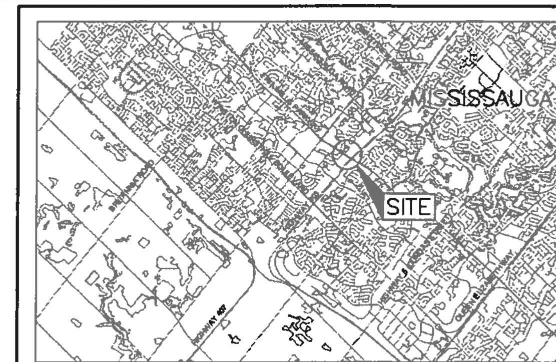
MISSISSAUGA, ONTARIO, CANADA





KEY PLAN
SCALE
2 0 2 4 km

LEGEND

● Borehole – Current Investigation

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
OS-3	165.4	4823992.4	288809.2

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.

REFERENCE

Base plan provided in digital format by Giffels/IBI Group, (Drawing File No.'s 069770-C_Base.dwg and 069770-c_mnc.dwg, saved dated March 3, 2010).

LICENSED PROFESSIONAL ENGINEER J.M.A. COSTA April 13, 2010 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER L.C. COYNE April 13, 2010 PROVINCE OF ONTARIO

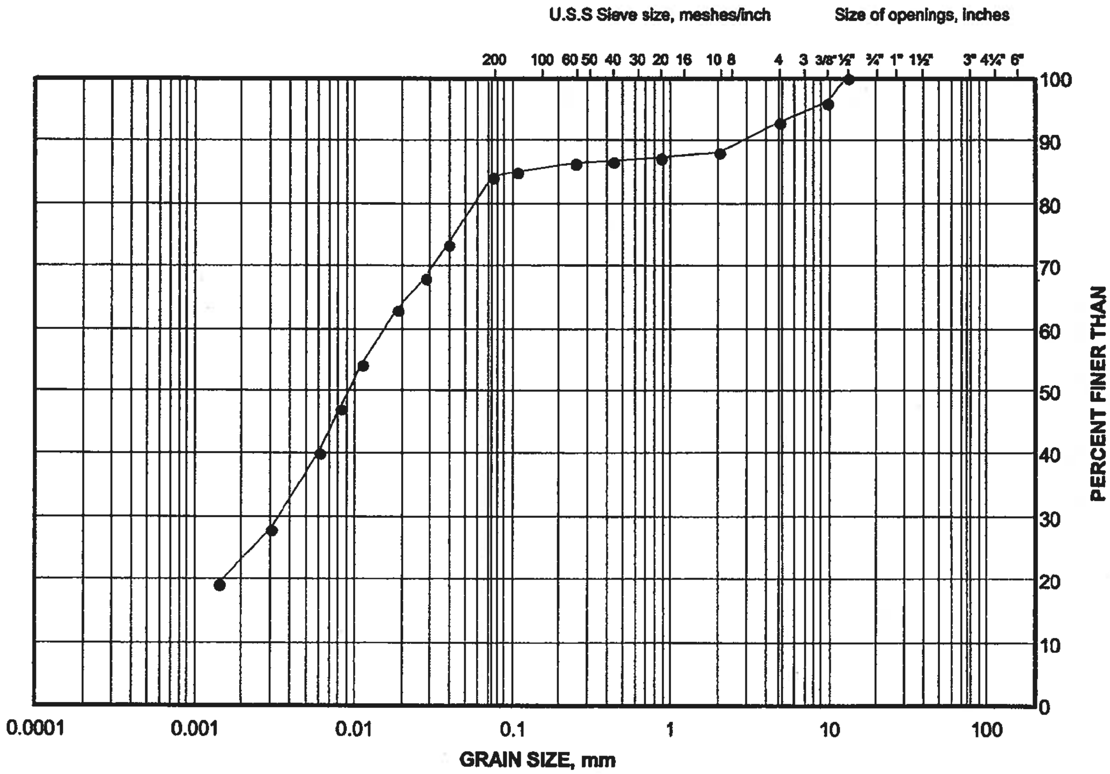
NO.	DATE	BY	REVISION

Geocres No.

HWY.		PROJECT NO. 09-1181-1045-3	DIST.
SUBM'D. AH	CHKD. LCC	DATE: April 2010	SITE:
DRAWN: JFC	CHKD. LCC	APPD. JMAC	DWG. 1

GRAIN SIZE DISTRIBUTION
CLAYEY SILT FILL

FIGURE 1



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

LEGEND

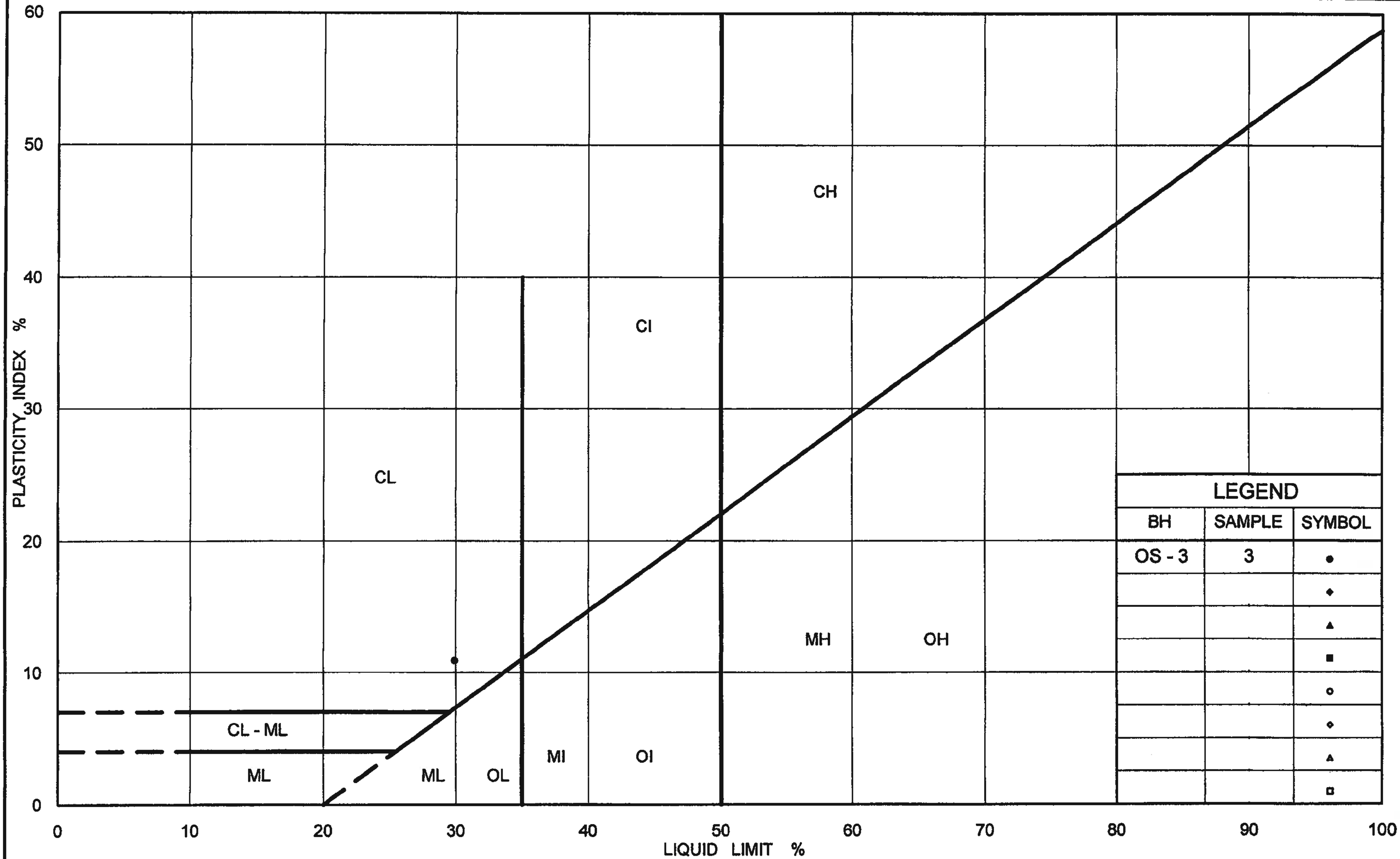
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	OS-3	3	163.7

Project Number: 09-1181-1045-3

Checked By: [signature]

Golder Associates

Date: 13-Apr-10



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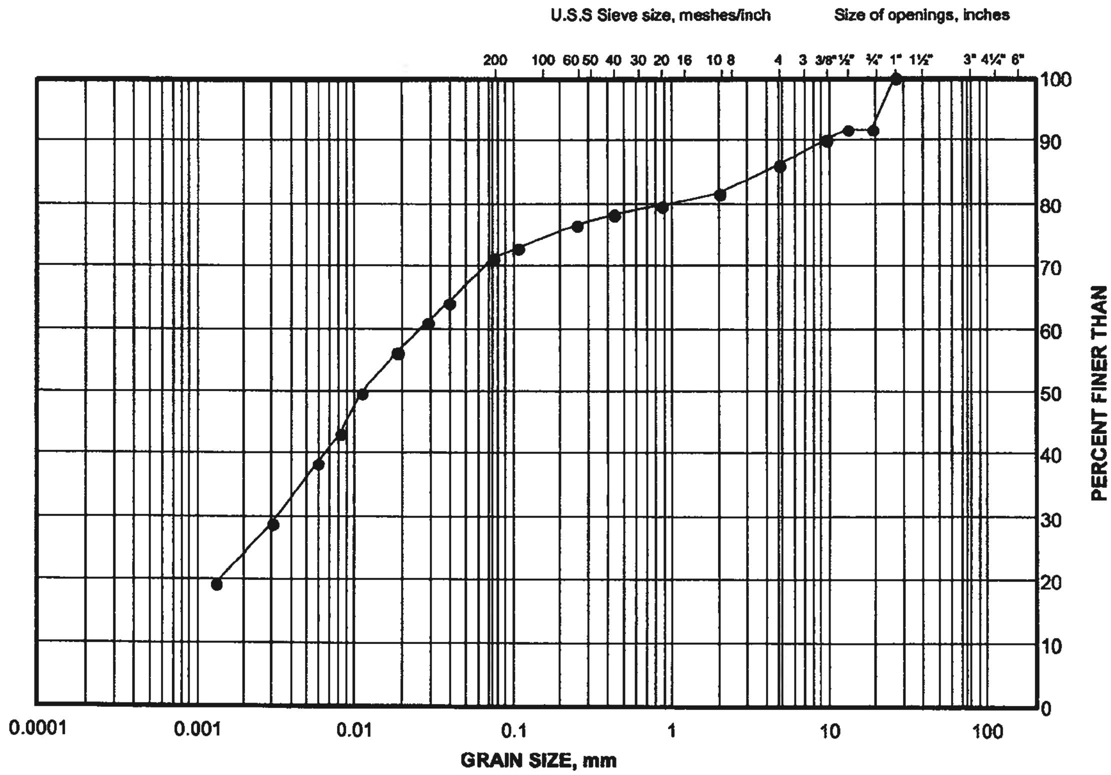
PLASTICITY CHART
Clayey Silt Fill

Figure No.	2
Project No.	09-1181-1045
Checked By:	

GRAIN SIZE DISTRIBUTION

CLAYEY 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)
●	OS-3	4B	162.8

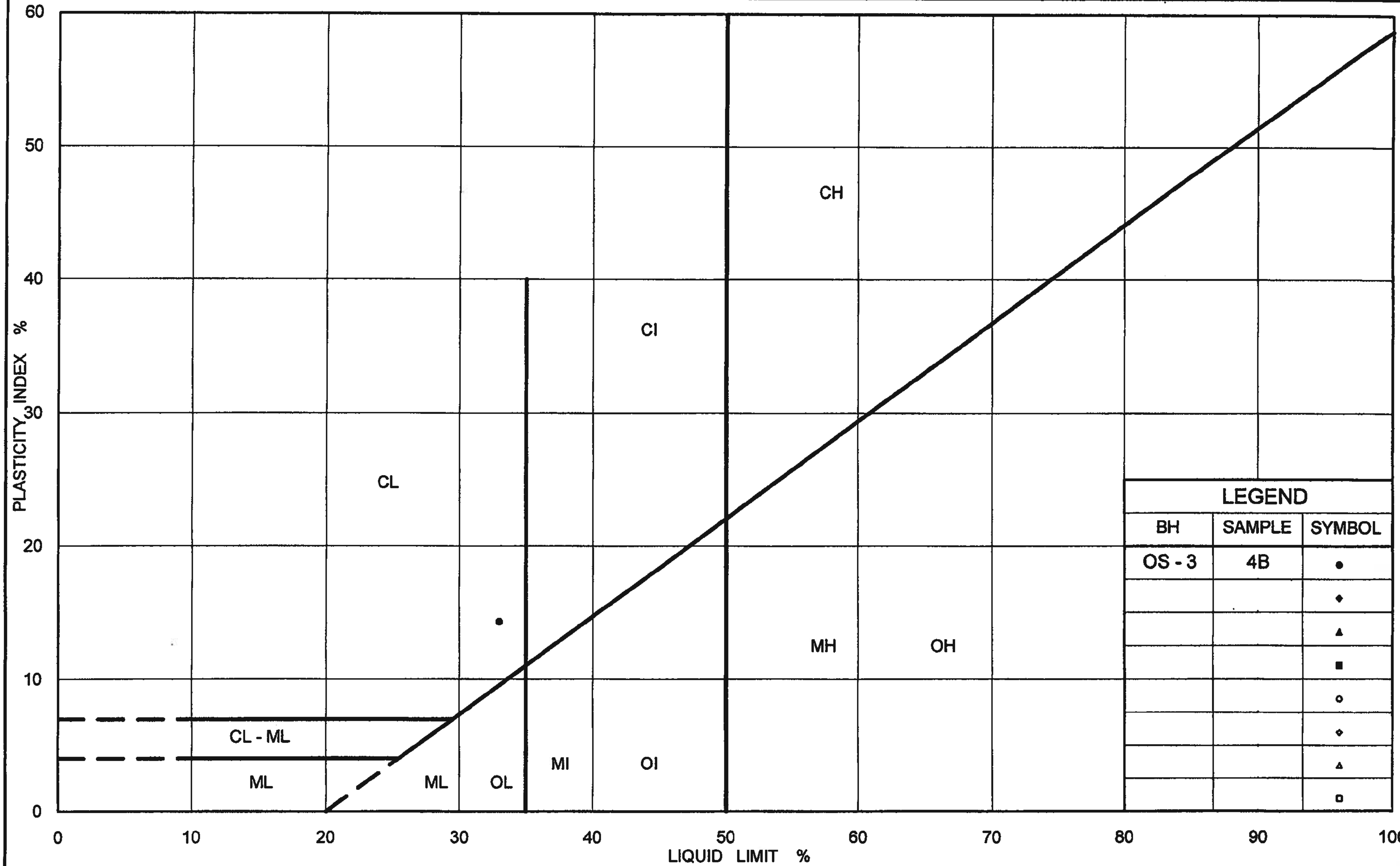
Project Number: 09-1181-1045-3

Checked By: SM

Golder Associates

Date: 13-Apr-10

Oct 75, FF-S-21



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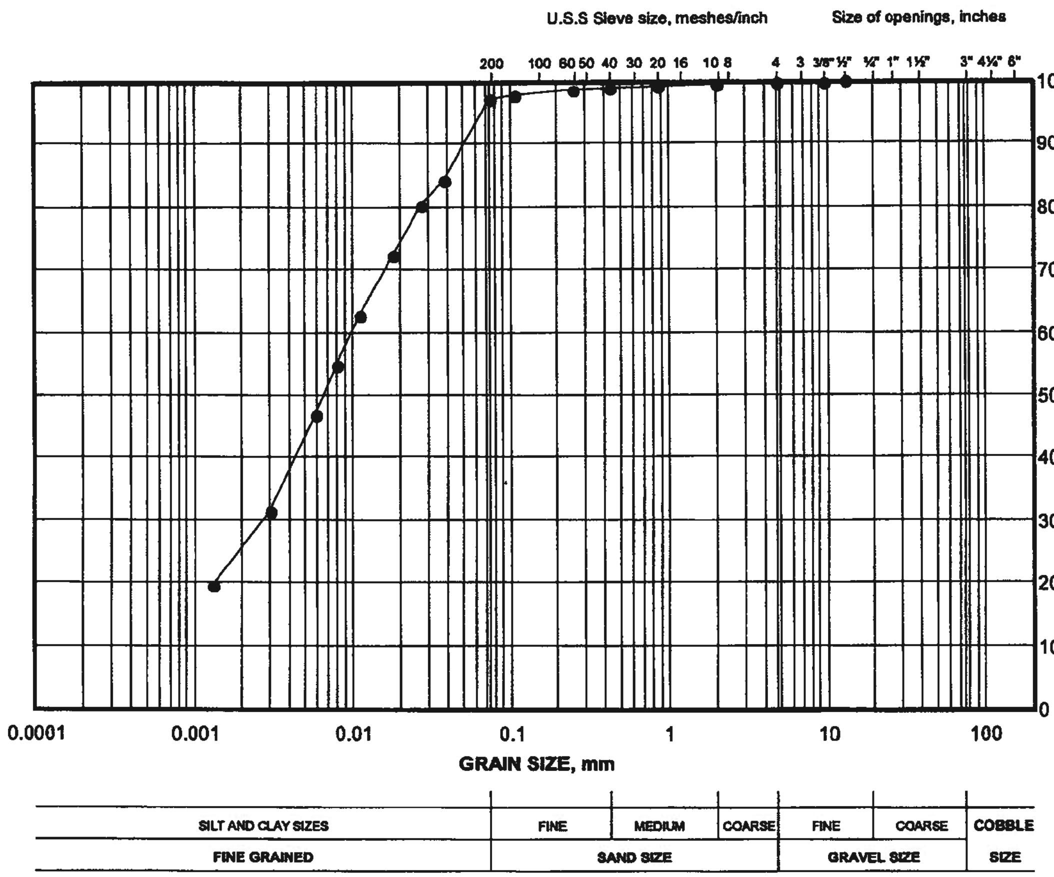
PLASTICITY CHART
Clayey Silt Till

Figure No. 4

Project No. 09-1181-1045

Checked By: [signature]

GRAIN SIZE DISTRIBUTION CLAYEY SILT (RESIDUAL SOIL)	FIGURE 5



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	OS-3	5B	162.0

Project Number: 09-1181-1045-3

Checked By: [signature]

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Date: 13-Apr-10

APPENDIX A

Record of Boreholes

PROJECT: 09-1181-1045

RECORD OF BOREHOLE BH B

LOCATION: SEE FIGURE 2

BORING DATE: September 30, 2009

DATUM: GEODETIC

SAMPLER HAMMER, 63.5kg; DROP, 760mm

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm

Column headings: DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE (DESCRIPTION, STRATA PLOT, ELEV. DEPTH (m)) | SAMPLES (NUMBER, TYPE, BLOWS/0.3m) | ELEVATION | DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20, 40, 60, 80); SHEAR STRENGTH Cu, kPa (25, 50, 75, 100) nat V. + Q - ● rem V. ⊕ U - ○ | HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6}, 10^{-5}, 10^{-4}, 10^{-3}); WATER CONTENT PERCENT Wp —○W— Wl (10, 20, 30, 40) | ADDITIONAL LAB. TESTING | INSTALLATION AND GROUNDWATER OBSERVATIONS

BORING METHOD: TRACK MOUNTED POWER AUGER, 115 mm Dia. Solid Stem Augers

DESCRIPTION	ELEV. / DEPTH (m)
GROUND SURFACE	166.08
TOPSOIL	0.00
Very stiff to hard CLAYEY SILT to SILTY CLAY, trace to some sand	0.20
Hard reddish brown SHALE	164.71 / 1.37
END OF BOREHOLE PRACTICAL REFUSAL TO FURTHER AUGERING.	161.41 / 4.67

NUMBER	TYPE	BLOWS/0.3m
1A		.
1B	50 DO	23
2	50 DO	68
3	50 DO	75
4	50 DO	50/.15
5	50 DO	50/.10
6	50 DO	50/.10

ELEVATION: 166, 165, 164, 163, 162

DEPTH SCALE METRES: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

INSTALLATION AND GROUNDWATER OBSERVATIONS:

25 mm Dia. Standpipe

Bentonite Seal

Silica Sand Filter

Borehole open and dry upon completion of drilling, Sept. 30/09

Groundwater level in piezometer at a depth of 2.71 m or elevation of 163.37 m on Oct. 8/09

DEPTH SCALE

1 : 50

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LOGGED: VZ

CHECKED: AOB

LDN_BHS 09-1181-1045.GPJ GLDR_LDN.GDT 12/18/09 DATA INPUT: PJV Nov. 2009

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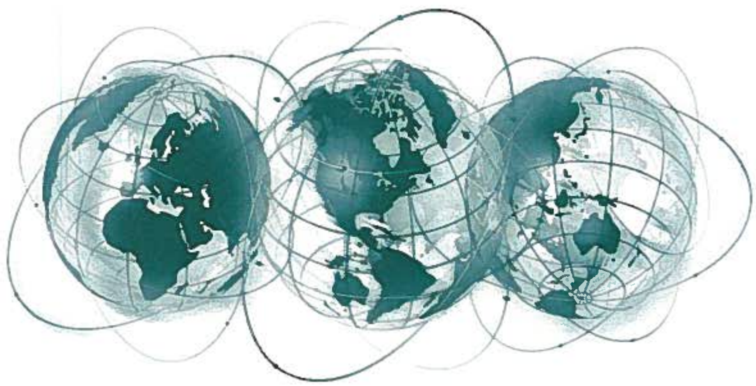

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