April 2010

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FOUNDATION INVESTIGATION AND DESIGN REPORT

GO BRT RAMP EMP N-403W CONCRETE TOE WALL
GO TRANSIT - BUS RAPID TRANSIT WEST FROM WINSTON CHURCHILL BOULEVARD TO ERIN MILLS PARKWAY
MISSISSAUGA, ONTARIO

Submitted to:
Giffels Associates Limited/IBI Group
30 International Boulevard
Toronto, Ontario
M9W 5P3

Reference: Google Earth Pro Source: ©2010 TeleAtlas, Image©2010 DigitalGlobe, Imagery Date Plan August 31, 2009

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REPORT

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FOUNDATION INVESTIGATION REPORT
GO BRT RAMP EMP – HWY 403 N-W CONCRETE TOE WALL
MISSISSAUGA, ONTARIO

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 foundational engineering services for the detail 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 and south of the existing hydro corridor. In addition to the busway itself, the GO BRT project involves 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 foundation investigation carried out for the proposed GO BRT concrete toe wall along the south side of the Erin Mills Parkway N-W ramp. The purpose of this investigation is to determine the subsurface conditions and shallow groundwater conditions at the proposed structure site by means of putting down three (3) boreholes.

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 presented 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 site of the proposed concrete toe wall extends from approximately 100 m to 200 m west of Erin Mills Parkway along the N-W ramp within the southwest quadrant of the current Highway 403/Erin Mills Parkway interchange in the City of Mississauga, Ontario (see key plan on Drawing 1). The topography in the vicinity of the interchange is generally flat to gently sloping downward to the southeast. On the northwest and southeast quadrants of the interchange, the Highway 403 corridor is bounded by residential subdivisions. A hydro corridor parallels Highway 403 and the proposed GO BRT line along the northern boundary.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the proposed concrete toe wall was carried out on February 1, 2010, at which time three (3) boreholes (Borehole RW206, RW207 and RW208) were advanced at approximately the locations shown on Drawing 1.

The field investigation was carried out using a track-mounted drill rig supplied and operated by Walker Drilling Ltd. of Utopia, Ontario. The boreholes were advanced using 100 mm diameter solid stem augers to depths ranging from 3.1 m to 4.0 m below existing ground surface. Soil samples were obtained at 0.75 m intervals of depth using conventional 50 mm outside diameter split-spoon samplers driven by an automatic hammer in accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586).

The groundwater conditions in the open boreholes were observed throughout the drilling operations. The boreholes were 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.

The field work was supervised on a full-time basis 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 boreholes and examined and cared for the soil samples. The soil samples were identified in the field, placed in labelled containers and transported to Golder's laboratory in Mississauga for further examination and testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards as appropriate. Classification testing (water content, Atterberg limits and grain size distribution) was carried out on select soil samples.

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

Borehole	Northing (m)	Easting (m)	Ground Surface Elevation (m)
RW206	4823648.0	288726.7	164.6
RW207	4823691.8	288765.2	164.0
RW208	4823736.0	288805.3	163.5

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 variable in composition, ranging from a cohesive till comprised of clayey silt/silty clay to a cohesionless sand and silt. The study area is underlain by Ordovician shales of the Queenston Formation (Ontario Geological Society, 1991). All major rivers in this area cut through the till deposit and into the shale; the valley walls formed within the shale often are almost perpendicular. In the vicinity of the Highway 407/403 interchange and the Erin Mills Parkway interchange, the depth to bedrock is fairly shallow. However, in the vicinity of Winston Churchill Boulevard, an infilled bedrock valley exists and the depth to the bedrock surface is much greater in this area. After this glacial-time valley was formed, it was infilled with clayey silt during the retreat of the glaciers.

4.2 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are given on the borehole records following the text of this report. The results of laboratory testing are also presented on Figures 1 and 2.

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

In summary, the subsurface soil conditions encountered at the boreholes drilled at the site generally consist of fill consisting predominately of silty sand and gravel associated with the existing highway/ramp construction; the fill is underlain by residual soil/shale bedrock.

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

4.2.1 Silty Sand and Gravel Fill

Surficial silty sand and gravel fill was encountered in all three boreholes (Boreholes RW206, RW207 and RW208) drilled at the site. The silty sand and gravel fill, which is associated with the existing highway/on-ramp, extends from ground surface to a depth of 0.6 m at all three borehole locations.

The measured SPT 'N'-values in the silty sand and gravel fill ranged from 67 blows to 154 blows per 0.3 m of penetration, indicating a very dense relative density. The in situ water content of one sample of the silty sand and gravel fill was 10 percent.

4.2.2 Clayey Silt Residual Soil

Residual soil was encountered underlying the silty sand and gravel fill in Boreholes RW206 and RW207. The residual soil consists of clayey silt with a "till-like" texture and contains varying amounts of siltstone/limestone and shale fragments. Residual soil is derived from weathering of the underlying shale bedrock. The surface of the residual soil was encountered at a depth of 0.6 m in Boreholes RW206 and RW207 and the deposit was found to be 0.9 m and 0.4 m thick, respectively, in these two boreholes.

Two measured SPT 'N'-values in the clayey silt residual soil are 77 blows per 0.3 m of penetration and 100 blows per 0.15 m of penetration, indicating a hard consistency. The natural water content of two samples of the clayey silt residual soil is 5 and 15 percent. Two grain size distribution curves for the clayey silt residual soil are shown on Figure 1. Atterberg limits testing carried out one are sample of the clayey silt residual soil measured a liquid limit of 32 percent, a plastic limit of 19 percent, and a corresponding plasticity index of 13 percent. The results of the Atterberg limits testing are shown on a plasticity chart on Figure 2 and indicate that the fines are a clay of low plasticity.

4.2.3 Shale Bedrock

Shale bedrock was encountered in all the boreholes drilled as a part of this investigation. The boreholes were extended into the bedrock by augering and split spoon sampling; bedrock coring was not carried out in these boreholes. The inferred bedrock surface at the borehole locations is summarized below:

Borehole No.	Depth to Bedrock Surface	Bedrock Surface Elevation
RW 206	1.5 m	163.1 m
RW 207	1.0 m	163.0 m
RW 208	0.6 m	162.0 m

162.9m

The bedrock samples obtained consist of reddish brown shale which, based on available bedrock geology maps, is understood to be part of the Queenston Formation.

4.2.4 Groundwater Conditions

Groundwater conditions were noted within the boreholes during and on completion of the drilling operations. All three boreholes were dry on completion of drilling on February 1, 2010.

As a part of the geotechnical investigation carried out by Golder for the proposed GO BRT Erin Mills bus station, a piezometer was installed in Borehole B located approximately 80 m north of the proposed toe wall. Details of the piezometer installation are shown in the Record of Borehole sheet in Appendix A. The water level recorded in the piezometer, which was sealed within the shale bedrock, is approximately 1.3 m below the bedrock surface (corresponding to about Elevation 163.4 m) on October 8, 2009.

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 Mr. Andrew J. Hagner, P.Eng, and reviewed by Ms. Anne Poschmann, P.Eng., a Senior Geotechnical Engineer and a 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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PART B

FOUNDATION DESIGN REPORT
GO BRT RAMP EMP – HWY 403 N-W CONCRETE TOE WALL
MISSISSAUGA, ONTARIO

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides recommendations for the geotechnical engineering aspects of design for the proposed GO BRT concrete toe wall to be located along the north side of Highway 403 where the realigned Erin Mills Parkway N-W ramp embankment encroaches on the south shoulder of the highway. The recommendations are based on interpretation of the factual data obtained from the three boreholes (Boreholes RW206, RW207 and RW208) advanced during the subsurface investigation. The discussion and recommendations presented are intended to provide the designers with sufficient information to assess the feasibility of the proposed structure design. Where comments are made on construction, they are provided in order to highlight those aspects which could affect the design of the project. Those requiring information on the aspects of construction should make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

The proposed toe wall will retain a portion of the new N-W ramp embankment from Erin Mills Parkway onto the westbound Highway 403. The existing ramp will be removed as a part of the overall GO BRT construction.

Details of the proposed toe wall were initially provided on Dwg No. C-450 and subsequently on Dwg No. C-372 (prepared by Giffels/IBI Group) titled "Mississauga BRT West Concrete Toe Wall Details 2" undated, plotted April 13, 2010. Details on the embankment configuration were provided verbally by Giffels/IBI Group. The base of the toe wall will be at a depth of approximately 0.5 m below the finished road grade with the base ranging from about Elevation 163.0 m at the west end of the wall to Elevation 164.0 m at the east end of the wall. The approximately 110 m long wall will range in height above the finished grade from 0.825 m to 1.8 m. The width of the base of the toe wall will vary accordingly with the height. The embankment fill to be supported by the proposed toe wall will have slope inclination of 2 horizontal to 1 vertical (2H:1V) for the majority of the slope and 3H:1V near the top of the slope. The embankment height above the top of the wall will range from less than 1.0 m to about 4.7 m with the greatest height at the east end of the wall.

Where it has been modified for a safety barrier shape, the proposed overall toe wall design is based on OPSD-3120.100 (Wall, Retaining, Concrete Toe Wall) Type III (MOD.). For OPSD-3120.100 Type III, the following design aspects are noted for toe wall from the geotechnical perspective:

1. A minimum 300 kPa bearing capacity at Ultimate Limit States (ULS);
2. Excavation for the walls shall be backfilled with free draining granular material; and
3. The maximum height of the slope above the top of the wall is 4.0 m.

6.2 Foundation Preparation and Bearing

Based on the results of the foundation investigation, the subsurface soil conditions encountered at the boreholes drilled at the site of the proposed toe wall generally consist of very dense silty sand and gravel fill to a depth of 0.6 m below ground surface underlain by residual soil/shale bedrock. For the proposed base of the toe wall founded at a depth of 0.5 m below finished road grade, the wall would be founded on the granular fill material which is directly underlain by residual soil / shale bedrock. The base of the excavation for the toe wall should be proofrolled and subsequently inspected by a geotechnical engineer to confirm that the founding conditions are uniform and consistent with those encountered in the boreholes and free of large cobbles, boulders, ponded water and any other deleterious materials. Any loose or deleterious areas should be subexcavated and replaced with approved, compacted granular fill or mass concrete as directed by the geotechnical engineer. The founding soils are considered to be susceptible to disturbance and should be protected with a concrete working slab if the toe wall is not placed shortly following the preparation of the founding base and inspection by the geotechnical engineer. During cold weather construction, the founding soils and the concrete must be protected from freezing.

Assuming that the toe wall is founded on very dense granular fill or hard residual soil/shale bedrock at a minimum depth of 0.5 m, the factored geotechnical axial resistance at Ultimate Limit States (ULS) of 350 kPa can be assumed for the proposed toe wall with base widths ranging from 1.2 m to 1.8 m. The geotechnical resistance at Serviceability Limit States (SLS) for 25 mm will be greater than ULS; as such, ULS conditions will govern the design. The coefficient of friction (sliding) between the base of the pre-cast concrete wall and the founding silty sand and gravel fill may be taken as 0.4.

It should be noted that the native soil underlying the granular fill consists of clayey silt residual soil and / or shale bedrock which are both considered susceptible to frost desiccation/heave. In this regard, it should be recognized that the concrete toe wall will undergo heave and settlement as a consequence of the frost action.

The global stability of the wall and the embankment using the geometry which was initially provided by Giffels/IBI was assessed using the Morgenstern-Price method. The wall/embankment slope was analyzed at two locations with differing wall/slope heights. Factors of Safety greater than 1.3 were obtained using the soil parameters as shown on Figures 3 and 4, for wall heights of 0.8 m and 1.8 m above finished grade and total embankments heights of 6.3 m and 4.8 m, respectively.

It is understood that since the slope height above the top of the wall is greater than 4 m, a different wall type may be used. In this regard, shallow spread footings should be designed assuming a founding depth at 1.2 m below finished grade; the footings would therefore be placed on hard residual soil or shale bedrock. A factored geotechnical axial resistance at ULS of 500 kPa may be used for design of spread footings assuming a footing width of 1.5 m. The coefficient of friction between the cast-in-place footing and the undisturbed, properly prepared founding residual soil/shale bedrock may be taken as 0.5. The geotechnical resistance at SLS will be greater than the ULS capacity and therefore ULS conditions apply. The geotechnical resistances given above assume that the load will be applied perpendicular to the footing surface. Where the load is not applied perpendicular to the surface of the footing, inclination of the load should be taken into account in accordance with Section 6.7.4 of the Canadian Highway Bridge Design Code (CHBDC) and its Commentary.

6.3 Wall Backfill

Based on the preliminary design drawing (Dwg No. C-450 noted above) provided by IBI/Giffels plotted April 13, 2010,, the wall backfill is to consist of compacted Granular A. It is recommended that a perforated longitudinal subdrain be installed at the base behind the wall in accordance with OPSD-3120.100. The perforated subdrain should be wrapped in geotextile and surrounded on all sides by a minimum 150 mm thickness of free draining material such as concrete sand. The subdrain should discharge to a frost-free outlet. The Granular A material should be placed in lifts and uniformly compacted to 95 percent of Standard Proctor maximum dry density.

6.4 Lateral Earth Pressures

The lateral earth pressures acting on the toe wall will depend on the type and method of placement of the backfill materials, the nature of the soils behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the wall.

The following recommendations are made concerning the design and construction of the proposed wall. It should be noted that the design parameters assume backfill and ground surface behind the wall sloping upward at 2H:1V. The coefficient of lateral earth pressure must be adjusted if the embankment side slope above the wall will differ from this assumption.

- Select, free draining granular fill meeting the specifications of MTO's Special Provision 110S13 (Granulars) Granular 'A' (or Granular 'B' Type II) with less than 5 percent passing the 200 sieve should be used as backfill behind the wall.

- The following parameters (unfactored) may be used assuming the use of granular earth fill such as Select Subgrade Material (SSM) for embankment construction:

	Earth Fill
Soil unit weight:	20 kN/m^3
Coefficients of static lateral earth pressure:	
Active, K_a	0.5
At rest, K_o	0.7

If the wall is allowed lateral yielding, active earth pressures may be used in the geotechnical design of the structure. If the lateral yielding is not allowed, at-rest earth pressures should be assumed for geotechnical design.

7.0 CLOSURE

This Foundation Design Report was prepared by Mr. Andrew J. Hagner, P.Eng, and reviewed by Ms. Anne S. Poschman, P.Eng., a Senior Geotechnical Engineer and a 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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Chapman, L.J., and Putnam, D.F. 1984. The Physiography of Southern, 3rd Edition. Ontario Geological Survey, Special Volume 2. Ontario Ministry of Natural Resources.

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 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

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan\delta$
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

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

LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
SS	Split-spoon
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:
The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d:
The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 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.

Golder Associates

RECORD OF BOREHOLE No RW206

 METRIC

PROJECT 09-1181-1045
G.W.P.
DIST ____ HWY 403
DATUM Geodetic

LOCATION N 4823648.0 ;E 288727.7
BOREHOLE TYPE 100 mm Outside Diameter Solid Stem Augers
DATE February 1, 2010

ORIGINATED BY MWK
COMPILED BY SMM
CHECKED BY SMM

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
164.6	GROUND SURFACE											
0.0	Silty sand and gravel (FILL) Very dense Brown Moist	1	SS	67								
164.0 0.6	CLAYEY SILT, some sand, containing shale and limestone fragments (RESIDUAL SOIL) Hard Reddish brown Moist	2	SS	100/.15		164	o	np	15	13	56	16
163.1 1.5	SHALE (BEDROCK) Reddish brown	3	SS	30/.1*		163						
		4	SS	100/.08		162						
	Augers grinding between 2.7 m and 3.1 m depth	5	SS	100/.02		161						
160.6		6	SS	100/.08								
4.0	END OF BOREHOLE											

* Spoon bouncing on shale

NOTE:
1. Open 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: 10 20 30
REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

Golder Associates

RECORD OF BOREHOLE No RW207

 METRIC

PROJECT 09-1181-1045
G.W.P.
LOCATION N 4823691.8 ;E 288765.2
ORIGINATED BY MWK
DIST HWY 403
BOREHOLE TYPE 100 mm Outside Diameter Solid Stem Augers
COMPILED BY SMM
DATUM Geodetic
DATE February 1, 2010
CHECKED BY SMM

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
164.0	GROUND SURFACE								
0.0	Silty sand and gravel (FILL) Very dense Brown Mosit	1	SS	76					
163.4 / 163.0 / 1.0	CLAYEY SILT, some sand, containing shale and siltstone fragments (RESIDUAL SOIL) Hard Reddish brown Moist	2A / 2	SS	77		163			0 5 61 34
	SHALE (BEDROCK) Reddish brown	3	SS	100/.13					
						162			
		4	SS	100/.15					
160.8		5	SS	100/.13		161			
3.2	END OF BOREHOLE								

NOTE:

1. Open borehole dry upon completion of drilling.

Plot headings: 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.

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

Golder Associates

RECORD OF BOREHOLE No RW208

 METRIC

PROJECT 09-1181-1045
G.W.P.
DIST HWY 403
DATUM Geodetic

LOCATION N 4823736.0 ;E 288805.3
BOREHOLE TYPE 100 mm Outside Diameter Solid Stem Augers
DATE February 1, 2010

ORIGINATED BY MWK
COMPILED BY SMM
CHECKED BY SMM

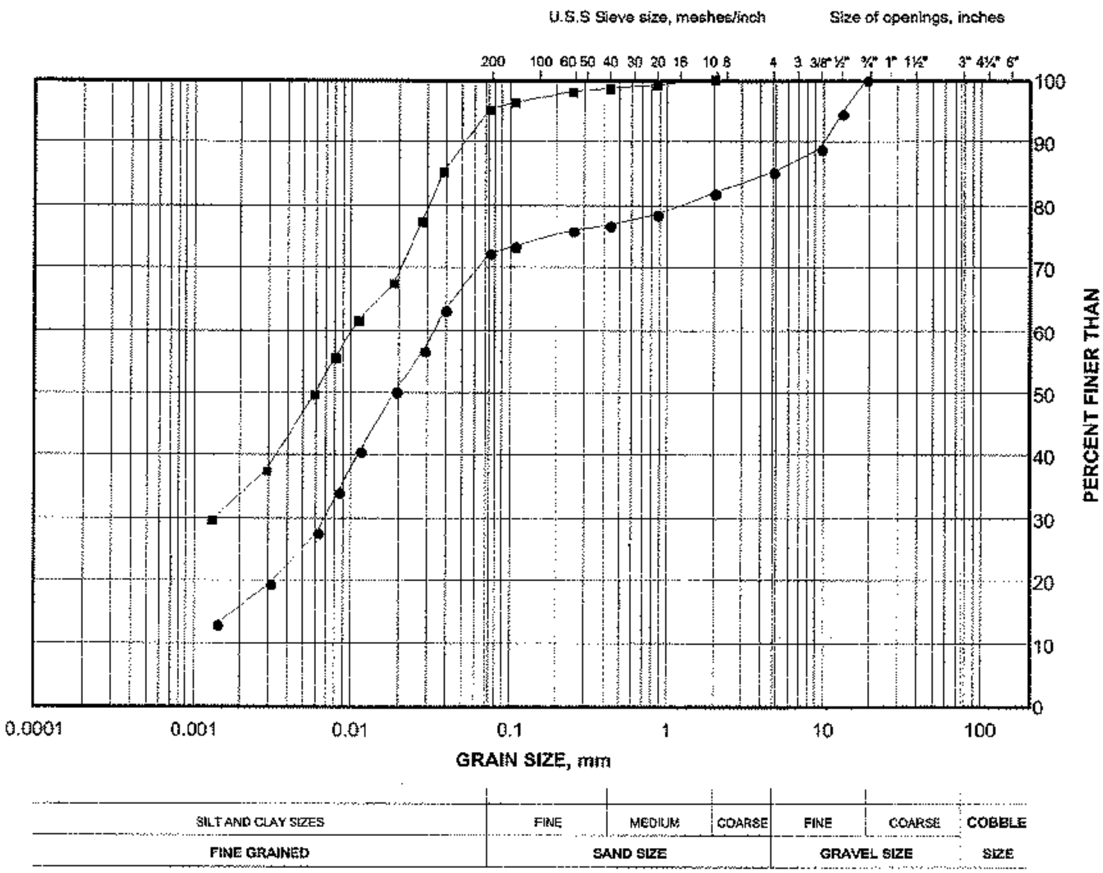
ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
163.5	GROUND SURFACE										
0.0	Silty sand and gravel (FILL) Very dense Brown Moist		1	SS	154						
							163				
162.9 0.6	SHALE (BEDROCK) Reddish brown		2	SS	147						
			3	SS	100/ 1		162				
			4	SS	100/ 13		161				
160.4			5	SS	100/ 1						
3.1	END OF BOREHOLE										

NOTE:

1. Open borehole dry upon completion of drilling.

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

GRAIN SIZE DISTRIBUTION Clayey Silt (Residual Soil)	FIGURE 1



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	RW206	2	163.7
■	RW207	2A	163.1

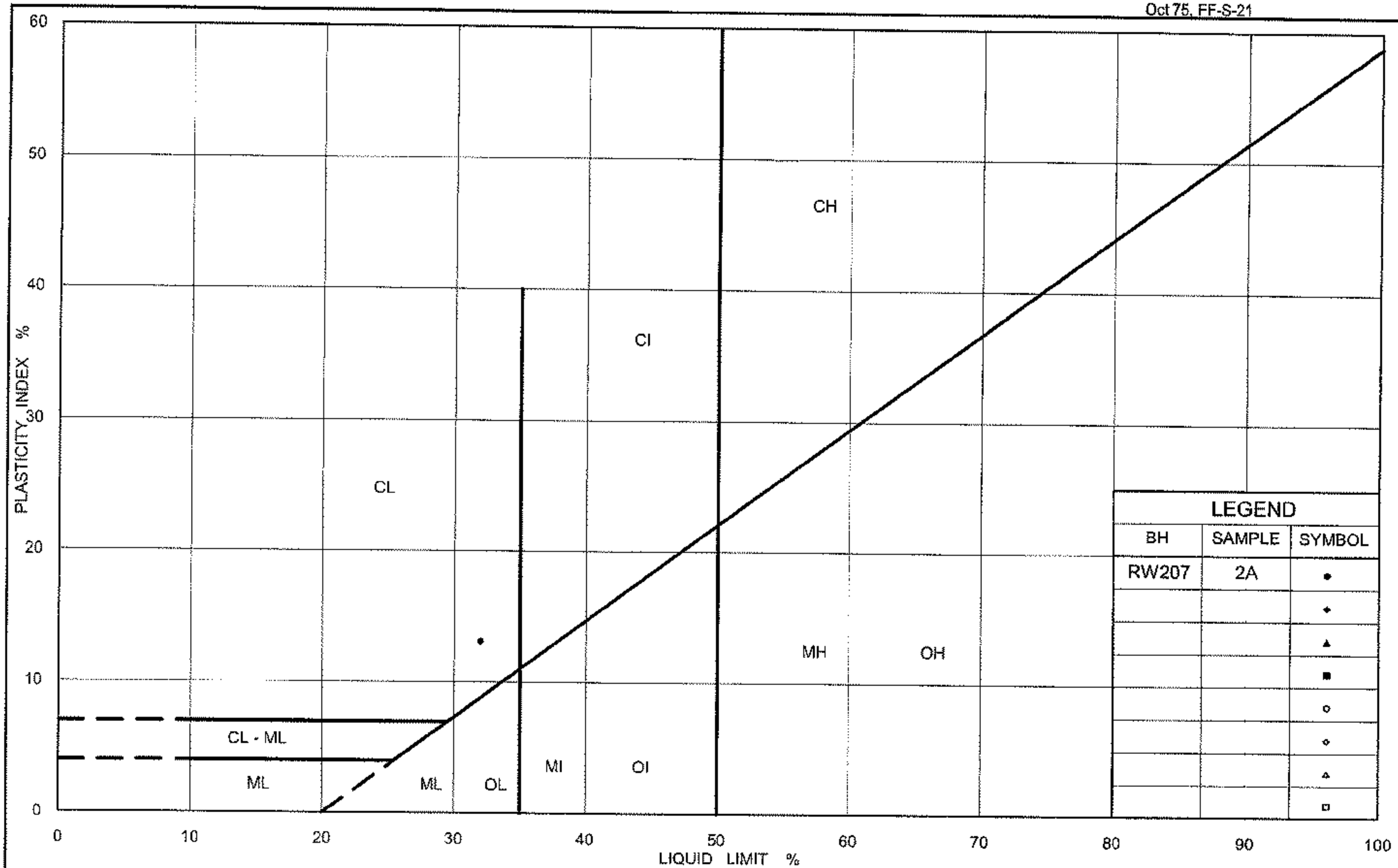
Project Number: 09-1181-1045-2

Checked By: ASP

Golder Associates

Date: 13-Apr-10

Oct 75, FF-S-21



Ministry of Transportation

Ontario

PLASTICITY CHART
Clayey Silt (Residual Soil)

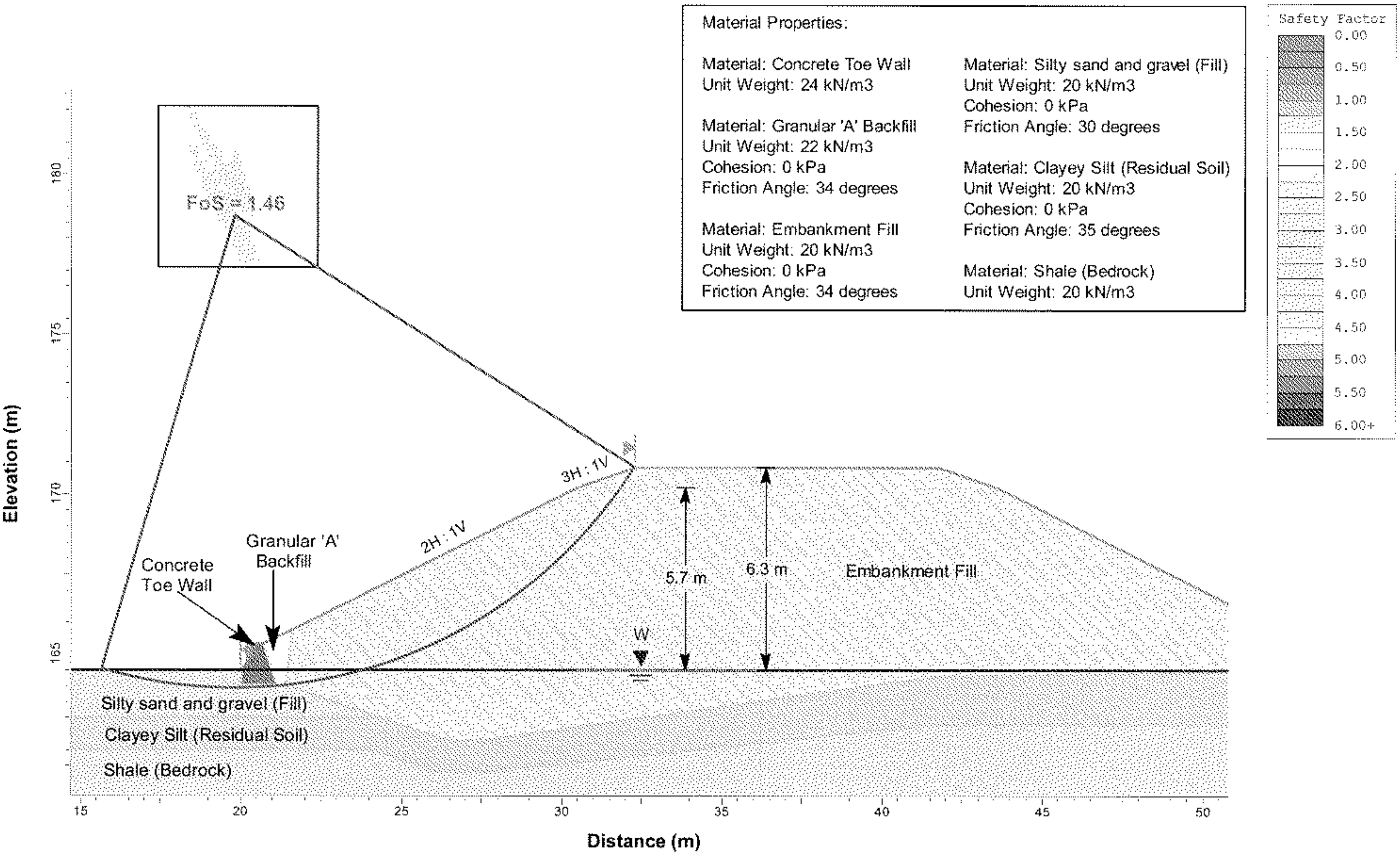
Figure No. 2

Project No. 09-1181-1045-2

Checked By: A.G.

Erin Mills Parkway/Hwy 403 N-W Ramp – Concrete Toe Wall Static Global Stability – STA 10+735

Figure 3



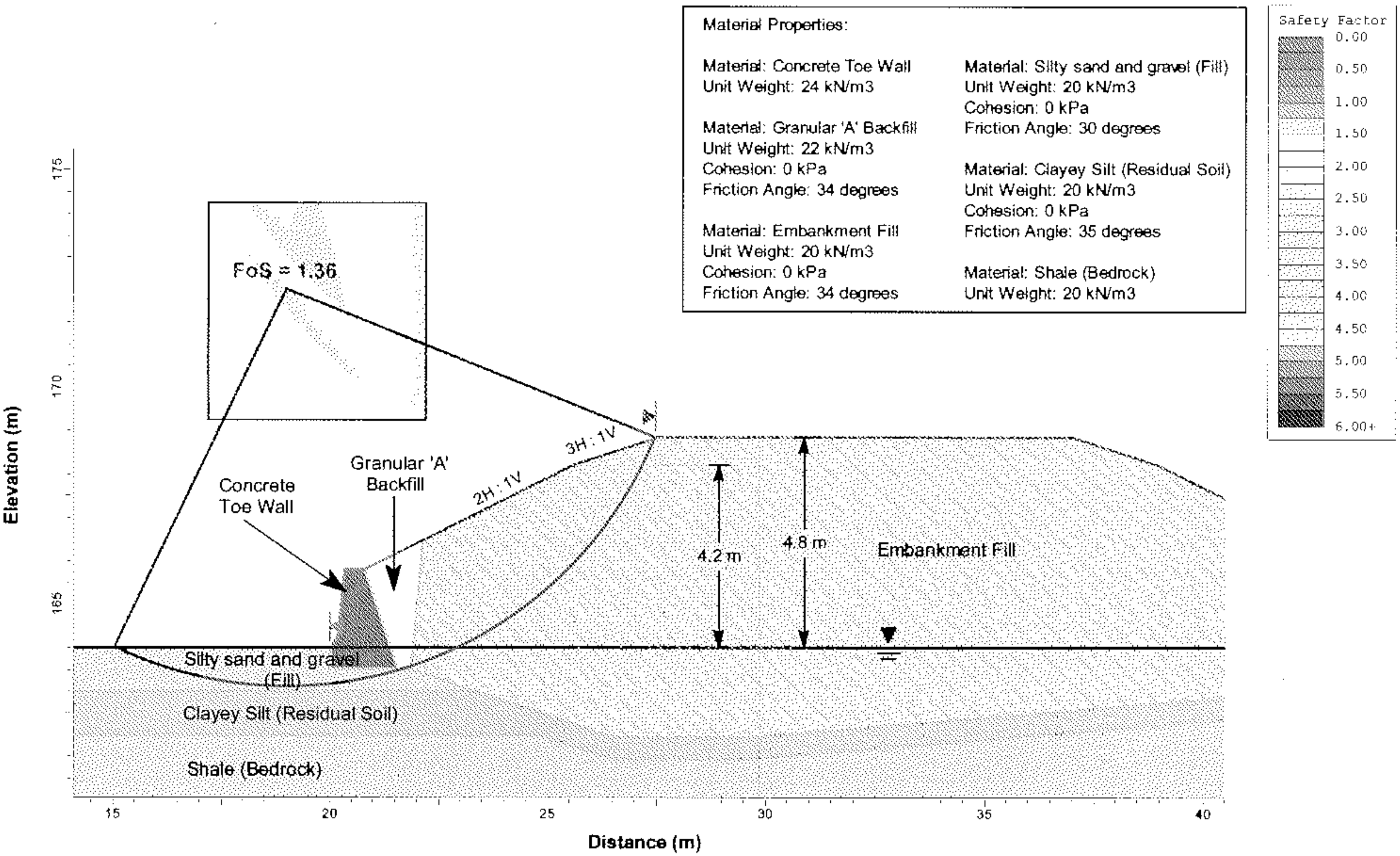
Date: April 2010
Project No: 09-1181-1045 -2

Analysis By: TZ **Reviewed By:** ASP

Golder Associates

Erin Mills Parkway/Hwy 403 N-W Ramp – Concrete Toe Wall Static Global Stability – STA 10+775

Figure 4



Date: April 2010

Project No: 09-1181-1045 -2

Analysis By: TZ **Reviewed By:** ASP

Golder Associates

MINISTRY OF TRANSPORTATION, ONTARIO

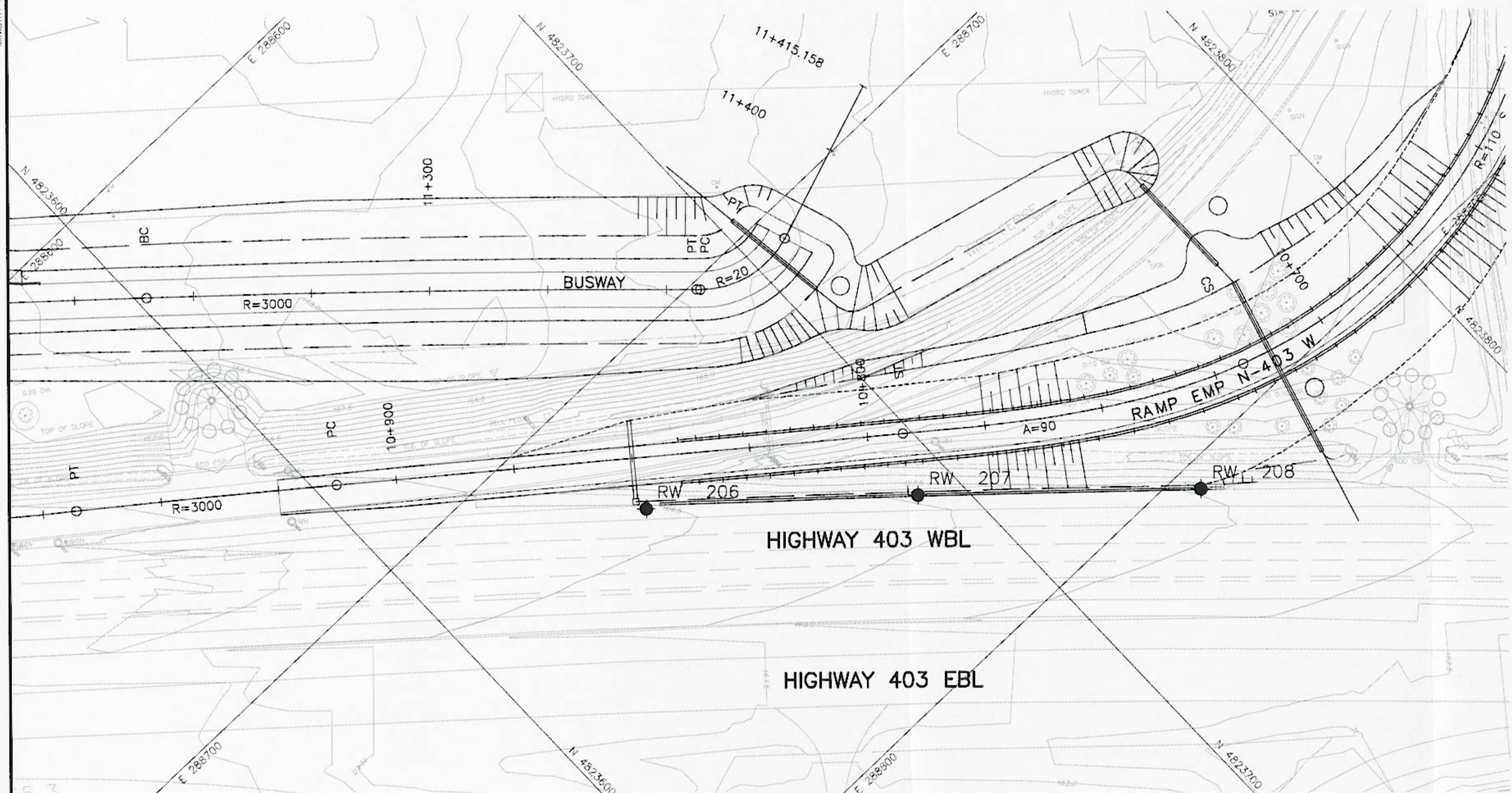
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No.

SHEET

GO TRANSIT BUS RAPID TRANSIT W.
CONCRETE TOE WALL – RAMP EMP N-403 W
ERIN MILLS PARKWAY
BOREHOLE LOCATIONS

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN
SCALE
10 0 10 20 m

KEY PLAN
SCALE
2 0 2 4 km

LEGEND

● Borehole – Current Investigation

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
RW 206	164.6	4823648.0	288727.7
RW 207	164.0	4823691.8	288765.2
RW 208	163.5	4823736.0	288805.3

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.

J.M.A. COSTA
April 14, 2010
LICENSED PROFESSIONAL ENGINEER
PROVINCE OF ONTARIO

A.S. POSCHMANN
April 14, 2010
REGISTERED PROFESSIONAL ENGINEER
PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No.

HWY.		PROJECT NO. 09-1181-1045-2	DIST.
SUBM'D. AH	CHKD. SMM	DATE: April 2010	SITE:
DRAWN: JFC	CHKD. SMM	APPD. JMAC	DWG. 1