

Golder Associates Libraries



1110 - 0001211

532

FOUNDATION INVESTIGATION AND DESIGN  
HIGH MAST LIGHTS  
NORTH HALF OF QUEEN ELIZABETH WAY  
AND GUELPH LINE INTERCHANGE  
REGIONAL MUNICIPALITY OF HALTON  
GWP: 47-88-00

Submitted to:





**Golder Associates Ltd.**

2180 Meadowvale Boulevard  
Mississauga, Ontario, Canada L5N 5S3  
Telephone (905) 567-4444  
Fax (905) 567-6561



REPORT ON

FOUNDATION INVESTIGATION AND DESIGN  
HIGH MAST LIGHTS  
NORTH HALF OF QUEEN ELIZABETH WAY  
AND GUELPH LINE INTERCHANGE  
REGIONAL MUNICIPALITY OF HALTON  
GWP: 47-88-00

Submitted to:

McCormick Rankin Corporation  
2655 North Sheridan Way  
Mississauga, Ontario  
L5K 2P8

DISTRIBUTION:

- 10 Copies - The Ministry of Transportation, Ontario,  
Downsview, Ontario
- 3 Copies - McCormick Rankin Corporation,  
Mississauga, Ontario
- 2 Copies - Golder Associates Ltd.,  
Mississauga, Ontario

January 2001

991-1105E

## TABLE OF CONTENTS

<u>SECTION</u>	<u>PAGE</u>
<b>PART A - FOUNDATION INVESTIGATION REPORT</b>	
1.0 INTRODUCTION .....	1
2.0 SITE DESCRIPTION .....	2
3.0 INVESTIGATION PROCEDURES .....	3
4.0 GENERAL SITE GEOLOGY AND STRATIGRAPHY .....	4
4.1 Site Geology .....	4
4.2 Site Stratigraphy .....	4
4.2.1 Topsoil .....	4
4.2.2 Road Base Fill .....	5
4.2.3 Fill .....	5
4.2.4 Silty Clay Till .....	5
4.2.5 Silty Sand Till .....	6
4.2.6 Bedrock .....	6
4.3 Groundwater Conditions .....	7
<b>PART B - FOUNDATION DESIGN REPORT</b>	
5.0 ENGINEERING RECOMMENDATIONS .....	8
5.1 General .....	8
5.2 High Mast Light Foundations .....	8

In Order  
Following  
Page No. 10

List of Abbreviations and Symbols  
Record of Borehole Sheets (Boreholes 19, 20, 21 and 24)  
Drawing 1  
Figures 1 and 2

## LIST OF DRAWINGS

Drawing 1      Borehole Location Plan – High Mast Light Poles

## LIST OF FIGURES

Figure 1      Grain Size Distribution Curve – Silty Clay (Glacial Till)  
Figure 2      Plasticity Chart – Silty Clay (Glacial Till)

PART A

FOUNDATION INVESTIGATION REPORT  
HIGH MAST LIGHTS  
NORTH HALF OF QUEEN ELIZABETH WAY  
AND GUELPH LINE INTERCHANGE  
REGIONAL MUNICIPALITY OF HALTON  
GWP: 47-88-00

## TABLE OF CONTENTS

<u>SECTION</u>	<u>PAGE</u>
<b>PART A - FOUNDATION INVESTIGATION REPORT</b>	
1.0 INTRODUCTION .....	1
2.0 SITE DESCRIPTION .....	2
3.0 INVESTIGATION PROCEDURES .....	3
4.0 GENERAL SITE GEOLOGY AND STRATIGRAPHY .....	4
4.1 Site Geology .....	4
4.2 Site Stratigraphy .....	4
4.2.1 Topsoil .....	4
4.2.2 Road Base Fill .....	5
4.2.3 Silty Clay Fill .....	5
4.2.4 Silty Clay Till .....	5
4.2.5 Silty Sand Till .....	6
4.2.6 Bedrock .....	6
4.3 Groundwater Conditions .....	7

In Order  
Following  
Page No. 10

List of Abbreviations and Symbols  
Record of Borehole Sheets (Boreholes 19, 20, 21 and 24)  
Drawing 1  
Figures 1 and 2

## LIST OF DRAWINGS

Drawing 1      Borehole Location Plan – High Mast Light Poles

## LIST OF FIGURES

Figure 1      Grain Size Distribution Curve – Silty Clay (Glacial Till)  
Figure 2      Plasticity Chart – Silty Clay (Glacial Till)



## 1.0 INTRODUCTION

Golder Associates Ltd. has been retained by McCormick Rankin Corporation (McCormick Rankin) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out a foundation investigation at the site of the proposed Guelph Line underpass at Queen Elizabeth Way (QEW) in the Region of Halton, Ontario. The project consists of the north half of the QEW and Guelph Line interchange and includes the replacement of the existing Guelph Line underpass, a new bridge at the North Service Road and as well as culvert extensions. This report addresses the High Mast Light Pole foundations.

The purpose of the foundation investigation is to determine the subsurface conditions at the site by drilling a limited number of boreholes, and carrying out in-situ tests and laboratory tests on selected samples. The terms of reference for the scope of work are outlined in our Total Project Management proposal P81-1394-1, dated September 1998. The work was carried out in accordance with our Quality Control Plan for Foundation Design Services, Agreement No. 9820-7411-2715, dated January 1999. The digital plan for the Interchange was presented on profiles provided to us by McCormick Rankin on August 31, 2000.

## **2.0 SITE DESCRIPTION**

The site is located at the existing QEW and Guelph Line interchange, and is within the MTO District 4 in the City of Burlington.

The topography of the site area is generally level and gradually slopes downwards towards the south. The site is occupied by the existing QEW and associated ramps and North Service Road which are constructed on embankments. Drainage ditches and Roseland Creek are located in the north-east quadrant of the interchange. A private business and its associated parking lot are located between the QEW and the existing North Service Road in the north-east quadrant of the interchange. The vegetation cover generally consists of grass, bushes and trees. The median of the QEW has been paved.

### 3.0 INVESTIGATION PROCEDURES

The field work for this investigation was carried out between July 21 and August 15, 2000. At this time four (4) boreholes were put down at the site. Boreholes 19, 20, 21 and 24 were put down near the proposed locations of three of the high mast light poles. Borehole 19 was put down north of the north shoulder of the QEW close to the culvert extension. Borehole 20 and 21 were put down at through the north shoulder of the QEW near two of the high mast light locations and in the general vicinity of the other two high mast light locations along the QEW. Borehole 24 was put down close to the HML location within the SW Ramp loop.

The investigation was carried out using both a bombardier-mounted and a truck-mounted CME-55 drill rig supplied and operated by Master Soil Investigations of Toronto, Ontario. In the boreholes, samples of the overburden were obtained at regular intervals of depth using 50 mm outside diameter split-spoon samplers in accordance with the Standard Penetration Test (SPT) procedures. The boreholes were extended to depths between 6.1 m and 7.6 m below the existing ground surface. Groundwater conditions in the open boreholes were observed throughout the drilling operations. Piezometers were installed in two boreholes to permit monitoring of the groundwater levels at the site. The piezometers consisted of a 200 mm long slotted tip threaded into 12 mm diameter PVC rigid tubing or a slotted 12 mm diameter tube.

The field work was supervised on a full-time basis by a member of our engineering staff who located the boreholes in the field, directed the drilling, sampling and in-situ testing operations, and logged the boreholes. The soil samples were identified in the field, placed in labeled containers and transported to our laboratory in Mississauga for further examination. Index and classification tests were carried out on selected samples. The results of the testing are shown on the attached Record of Borehole sheets and on Figures 1 and 2.

A plan of the proposed Guelph Line Interchange was provided to us in digital format by McCormick Rankin. The borehole locations were surveyed and staked in the field by Bennet Young Limited, professional land surveyors. Based on the information provided, the northing and easting co-ordinates of the borehole locations are given in UTM, and the borehole elevations are referenced to Geodetic Datum. The co-ordinates of the boreholes are indicated on the Record of Borehole sheets and the locations of the boreholes are shown on Drawing 1.



## **4.0 GENERAL SITE GEOLOGY AND STRATIGRAPHY**

### **4.1 Site Geology**

The site is located in the physiographic region known as the Iroquois Plain. The Iroquois Plain is generally composed of a shallow cover of sand and till covering portions between Hamilton and Toronto (Chapman and Putnam, "The Physiography of Southern Ontario", 3<sup>rd</sup> Edition, 1984). The surface topography slopes gradually and fairly uniformly towards Lake Ontario. The native overburden at the site area is a silty clay till which is underlain by bedrock comprised of red shale and limestone interbeds of the Queenston Formation. The depth to bedrock at this site is shallow, varying typically between 2 m to 4 m below original ground surface.

### **4.2 Site Stratigraphy**

The detailed subsurface soil and groundwater conditions 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 stratigraphic boundaries shown on the borehole sheets are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. Subsoil conditions will vary between and beyond the borehole locations. The subsurface conditions at specific HML locations can be inferred from the nearest borehole.

In summary, the subsoils at the site generally consist of a surficial layer of topsoil or road base fill underlain by a layer of silty clay fill material. A 0.6 m to 1.7 m thick layer of hard silty clay till is present below the fill and a 0.8 m to 1.2 m layer of very dense silty sand till is encountered below the silty clay till at two borehole locations. The till is underlain by shale bedrock of the Queenston Formation.

The location of the borings are shown on the attached Drawing 1. A detailed description of the subsurface conditions encountered in the boreholes for this investigation is provided in the following sections.

#### **4.2.1 Topsoil**

A surficial layer of topsoil (about 0.05 m to 0.1 m thick) was encountered in Boreholes 19 and 24.

#### 4.2.2 Road Base Fill

A 0.8 m to 1.5 m thick layer of brown, moist sand and gravel to silty sand containing trace organics was encountered below the ground surface in Boreholes 20 and 21 which are located close to the shoulder of the QEW. The Standard Penetration Test 'N' values measured within this fill were between 11 and 78 blows per 0.3 m of penetration indicating that the fill is in a compact to very dense state of packing. Measured water contents on selected samples of the road base fill were between 4 percent and 6 percent.

#### 4.2.3 Fill

In Boreholes 21 and 24, a 1.4 m to 2.0 m thick layer of brown to red-brown, silty clay fill containing trace to with sand and gravel and trace organics was encountered below the topsoil or road base fill. The measured SPT 'N' values ranged from 9 blows to 21 blows per 0.3 m of penetration indicating a stiff to very stiff consistency. The measured water contents of selected samples of the fill were between 6 percent and 11 percent.

In Borehole 19, a 1.3 m thick layer of red-brown sandy silt till containing trace to some clay and trace gravel and organics was encountered below the topsoil. The measured SPT 'N' values ranged from 14 blows to 73 blows per 0.3 m of penetration indicating a compact to very dense state of packing. The measured water contents of selected samples of the sandy silt till were between 9 percent and 11 percent.

#### 4.2.4 Silty Clay Till

A 0.6 m to 2.3 m thick deposit of red-brown clayey silt to silty clay till containing trace sand and gravel was encountered in all boreholes below the fill. In Borehole 19, the till is classified as clayey silt with sand containing trace gravel and root fibres. A grain size distribution curve for a selected sample of the silty clay till is shown on Figure 1. The SPT 'N' values measured within the till deposit range from 25 blows to greater than 100 blows per 0.3 m of penetration, indicating a very stiff to hard consistency.

Atterberg limits testing carried out on a selected sample of the silty clay till gave a liquid limit of about 27 percent and a plasticity index of about 10 percent. This classifies the till as inorganic and of low plasticity. The results of the Atterberg limits testing are shown on Figure 2. The natural

water content for selected samples of the till ranged from about 7 percent to 12 percent. The water contents were less than the plastic limit.

Although not encountered in the boreholes, cobbles and boulders should be expected within this glacially derived deposit.

#### **4.2.5 Silty Sand Till**

A 1.2 m to 1.3 m thick deposit of red-brown silty sand till containing trace to with gravel and occasional cobbles was encountered in Boreholes 20 and 21 below the silty clay till. The SPT 'N' values within the till deposit are greater than 100 blows per 0.3 m of penetration, indicating a very dense state of packing. Measured water contents on selected samples of the silty sand till range from 6 percent to 13 percent.

The silty sand till where encountered at this site is generally found to be water bearing. Sloughing of the sand till is expected to occur in an uncased hole. Cobbles were noted in the boreholes and the deposit is also expected to contain boulders.

#### **4.2.6 Bedrock**

The till deposits are underlain by shale bedrock in all of the boreholes. The surface of the bedrock was encountered at about Elevation 105.1 m and 105.2 m in Boreholes 19 and 24, respectively, and about Elevation 106.9 m and 107.3 m in Boreholes 20 and 21, respectively.

Limestone layers up to 200 mm in thickness were encountered throughout the shale in boreholes where bedrock coring was carried out for other aspects of this project. Frequent limestone layers were noted in the three boreholes put down for the high mast light poles. These layers were inferred based on auger resistance while drilling through the bedrock. A minimum of 2.3 m of the bedrock was augered in each borehole and no significant resistance was encountered. Limestone layers should be expected throughout the shale and layers greater than 200 mm could be encountered.



### 4.3 Groundwater Conditions


All boreholes were dry upon completion of drilling. Piezometers were installed in two boreholes and the water levels are summarized in the table below.


Borehole	On Completion of Drilling		Water Levels in Piezometers					
			July 25, 2000		August 16, 2000		September 6, 2000	
	Depth (m)	Elevation (m)	Depth (m)	Elevation (m)	Depth (m)	Elevation (m)	Depth (m)	Elevation (m)
21	Dry	N/A					1.6	110.0
24	Dry	N/A	2.7	106.4	2.7	106.4		

These measurements, together with other groundwater level information in the north-east quadrant of the interchange, indicate that the groundwater table generally slopes downward toward the south and the west. The groundwater table is generally found to be above the bedrock surface but tends to follow the bedrock surface topography.

Groundwater levels may be higher where drainage channels are in close proximity to the HML locations. It should be noted that groundwater levels are expected to fluctuate seasonally and are expected to be higher during wet periods of the year.

#### GOLDER ASSOCIATES LTD.

  
Sarah E.M. Poot, P.Eng.

  
Anne S. Poschmann, P.Eng.  
Principal

  
Fintan J. Heffernan, P.Eng.  
Designated MTO Contact

SEMP/ASP/FJH/clg

S:\FINAL\DAT\PROJECTS\1999\991-1105\2001\991105E\RTA01.DOC



PART B

FOUNDATION DESIGN REPORT  
HIGH MAST LIGHTS  
NORTH HALF OF QUEEN ELIZABETH WAY  
AND GUELPH LINE INTERCHANGE  
REGIONAL MUNICIPALITY OF HALTON  
GWP: 47-88-00

## 5.0 ENGINEERING RECOMMENDATIONS

### 5.1 General

This section of the report provides our recommendations on the geotechnical aspects of design of the High Mast Light foundations based on our interpretation of the factual information obtained during the investigation. It should be noted that the interpretation and recommendations are intended for use only by the design engineer. Where comments are made on construction they are provided only in order to highlight those aspects which could affect the design of the project. 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.

It is understood that as part of the QEW and Guelph Line Interchange (north half), High Mast Lights (HML) will be installed at four locations in the centre median of the QEW and at one location within the loop of the SW Ramp.

### 5.2 High Mast Light Foundations

631501

Reference should be made to Special Provision No. 631F02ERS – Construction Specification for Concrete Footings for High Mast Light Poles.

The subsurface conditions at specific HML locations can be inferred from the nearest borehole. Simplified soil stratigraphy and design parameters for the soils as encountered in the four boreholes drilled are given in the table below:

Approximate HML Station	Relevant Borehole Numbers	Strata	Elevation (m)	Groundwater Level	Design Parameters				
					$c_u$	$c'$	$\phi'$	$\gamma$	$K_p$
10+025 SW Ramp	24	Silty Clay Fill	Ground surface to 107.0	2.7 m depth	-	-	28	19	2.8
		Silty Clay Till	107.0 to 105.2	Elevation 106.4 m	100	-	32	21	3.2
		Shale Bedrock	Below 105.2			10	36	23	4.5
13+950 QEW	19	Sandy Silt Fill	Ground surface to 107.0	Elevation 106.0 m	-	-	28	19	2.8
		Clayey Silt Till	107.0 to 106.0		100	-	32	21	3.2
		Shale Bedrock	Below 106.0		-	10	36	23	4.5



Approximate HML Station	Relevant Borehole Numbers	Strata	Elevation (m)	Groundwater Level	Design Parameters				
					$c_u$	$c'$	$\phi'$	$\gamma$	$K_p$
14+100 QEW and 14+250 QEW	20	Sand and Gravel Fill	Ground surface to 108.5	Elevation 108.0 m	-	-	28	21	2.8
		Silty Clay Till	108.5 to 108.0		100	-	32	21	3.2
		Silty Sand Till	108.0 to 107.0		-	-	34	21	3.5
		Weathered Shale Bedrock	Below 107.0		-	-	36	23	4.5
14+400 QEW	21	Silty Sand to Silty Clay Fill	Ground surface to 109.4	1.6 m depth	-	-	28	29	2.8
		Silty Clay Till	109.4 to 108.6		100	-	32	21	3.2
		Silty Sand Till	108.6 to 107.3	Elevation 110.0 m	-	-	34	21	3.5
		Shale Bedrock	Below 107.3		-	10	36	23	4.5

Where

- $c_u$  is the undrained shear strength, in kPa  
 $c'$  is the effective cohesion, in kPa  
 $\phi$  is the effective angle of friction, degrees  
 $\gamma$  is the bulk unit weight, in kN/m<sup>3</sup>  
 $K_p$  is the passive earth pressure coefficient

The unfactored passive lateral earth pressure,  $P_p$ , distributed along the caisson acting over depth,  $d$  in m, may be calculated using the following expression and the parameters given above:

$$P_p = K_p \gamma d + 2 c' \sqrt{K_p}$$

The groundwater level as encountered in the boreholes is generally within the overburden some 1 m to 3 m above the surface of the bedrock. As such, the effective unit weight of the glacial till and the shale bedrock should be used and should be taken as 11 kN/m<sup>3</sup> and 13 kN/m<sup>3</sup>, respectively.

Where an undrained shear strength,  $c_u$  is provided, the undrained capacity of the caisson should be checked to establish whether the drained or the undrained case will govern. The capacity for the length of the caisson within the silty clay till may be calculated assuming  $\phi'$  of zero and an unfactored passive lateral pressure distribution equivalent to 2 times the undrained shear strength.

The unfactored lateral resistance should be calculated assuming an equivalent pile width equal to 3 times the caisson diameter. A resistance factor of 0.5 should be applied to the lateral resistance as calculated to obtain the factored lateral geotechnical resistance.

The groundwater level should be assumed at 2 m depth below ground surface for the three High Mast Light poles between Station 13+900 and 14+300. The passive resistance in front of the caisson within the upper 1.2 m below ground surface should be neglected in the design of the foundations to account for frost action.

The design frost protection depth for this site should be 1.2 m.

Sockets for the HML foundations will primarily be formed in the till deposits and the shale bedrock. Limestone layers were encountered in the shale at all borehole locations; however, the bedrock was augered for depths of 2.3 m to 3.6 m without significant resistance. Based on our experience with the shale in this area, there is potential for encountering harder, thicker limestone layers than were found in the boreholes completed. All of the boreholes were dry upon completion of drilling; the groundwater level is within the overburden above the bedrock. The sandy till deposit may be unstable below the groundwater level if the caissons are drilled without a liner or fluid support.

**GOLDER ASSOCIATES LTD.**



Sarah E.M. Poot, P.Eng.



Anne S. Poschmann, P.Eng.  
Principal



Fintan J. Heffernan, P.Eng.  
Designated MTO Contact



SEMP/ASP/FJH/clg

S:\FINAL\DAT\PROJECTS\1999\991-1105\2001\991105RPTA01.DOC

## 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

### 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

### 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.)

#### (b) Cohesive Soils

Consistency	$c_u, s_u$	$c_u, s_u$
	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

#### 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<sup>2</sup> 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.

### IV. SOIL TESTS

w	water content
w <sub>p</sub>	plastic limit
w <sub>l</sub>	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
D <sub>R</sub>	relative density (specific gravity, G <sub>s</sub> )
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 <sub>4</sub>	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

$\pi$	= 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

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta \sigma$
$\epsilon$	linear strain
$\epsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	Poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stresses (major, intermediate, minor)
$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	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
$\gamma'$	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 $\rho$ . Unit weight symbol is $\gamma$ where $\gamma = \rho g$ (i.e. mass density $\times$ acceleration due to gravity)	

#### (a) Index Properties (con't.)

$w$	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)

#### (c) 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

#### (d) Consolidation (one-dimensional)

$C_c$	compression index (normally consolidated range)
$C_r$	recompression index (overconsolidated range)
$C_s$	swelling index
$C_\alpha$	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
$\sigma'_p$	pre-consolidation pressure
OCR	Overconsolidation ratio $= \sigma'_p / \sigma'_{vo}$

#### (e) Shear Strength

$\tau_p, \tau_r$	peak and residual shear strength
$\phi'$	effective angle of internal friction
$\delta$	angle of interface friction
$\mu$	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  $= (\text{Compressive strength})/2$

PROJECT		RECORD OF BOREHOLE No 19		1 OF 1		METRIC						
W.P. 47-88-00		LOCATION N 4801473.3, E 280339.9		ORIGINATED BY SEP								
DIST 4 HWY QEW		BOREHOLE TYPE 114mm SOLID STEM AUGERS		COMPILED BY SEP								
DATUM Geodetic		DATE August 15, 2000		CHECKED BY ASP								
SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER			TYPE	"N" VALUES					
107.40	GROUND SURFACE											
107.00	Topsoil Sandy Silt, trace to some clay, trace gravel, trace organics Compact to very dense Red-brown Dry (Fill)		1	SS	14							
106.03			2	SS	73							
105.11	Clayey Silt with sand, trace gravel, trace root fibres Very Stiff Red-brown Dry to Moist (Glacial Till)		3	SS	25							
105.11			4	SS	75/12							
101.30	Red-brown SHALE bedrock (Queenston Formation), with 0.05 m to 0.2 m thick hard limestone layers inferred from auger resistance during drilling at 3.2 m, 4.0 m, 4.6 m and 5.0 m depth.											
101.30	END OF BOREHOLE											
6.10	Note: 1 Open Borehole dry upon completion of drilling											

ON MOT 991-1105 GPJ ON MOT GDT 14/12/00





PROJECT 991-1105 (3000)			RECORD OF BOREHOLE No 21			1 OF 1			METRIC		
W.P. 47-88-00			LOCATION N 4801908 7, E 280719 0			ORIGINATED BY SEP					
DIST 4 HWY QEW			BOREHOLE TYPE 114mm SOLID STEM AUGERS			COMPILED BY SEP					
DATUM Geodetic			DATE July 28, 2000			CHECKED BY ASP					
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC NATURAL LIQUID		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	W <sub>p</sub> W <sub>n</sub> W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
111.57	GROUND SURFACE										
0.00	Silty Sand, trace organics Compact Brown Moist (Fill)		1	SS	11						
110.77											
0.80	Silty Clay, trace sand and gravel and organics Stiff to very stiff Brown Moist (Fill)		2	SS	9						
109.37											
2.20	Silty Clay, some sand, some gravel, occasional cobbles Hard Red-brown Moist (Glacial Till)		3	SS	20						
108.57											
3.00	Silty Sand with gravel, trace clay Very dense Red-brown Moist to wet (Glacial Till)		4	SS	60						
107.27											
4.30	Red-brown SHALE bedrock (Queenston Formation), with hard limestone layers inferred from auger resistance during drilling		5	SS	60						
103.97											
7.60	END OF BOREHOLE										
	Note: 1. Open Borehole dry upon completion of drilling. 2. Water level measured in piezometer at 1.6 m depth (Elev. 110.0 m) on September 6, 2000.										

ON MOT 991-1105.GPJ ON MOT GOT 14/12/00

PROJECT 991-1105 (3000)		<b>RECORD OF BOREHOLE No 24</b>		1 OF 1	<b>METRIC</b>
W.P. 47-88-00	LOCATION N 4801283.0 E 280085.9	ORIGINATED BY SEP			
DIST 4 HWY QEW	BOREHOLE TYPE 114mm SOLID STEM AUGERS	COMPILED BY SEP			
DATUM Geodetic	DATE July 21, 2000	CHECKED BY ASP			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40					
109.03	GROUND SURFACE													
0.00	Topsoil													
0.10	Silty Clay, some to with sand, trace gravel, trace organics Very stiff Red-brown Moist (Fill)		1	SS	21									
			2	SS	21									
106.93														
2.10	Silty Clay, trace to some sand, trace gravel Hard Red-brown Moist (Glacial Till)		3	SS	33									
	Limestone gravel in tip of spoon at 3.3 m depth.		4	SS	62/15									
105.23														
3.80	Red-brown SHALE bedrock (Queenston Formation), with 0.03 m to 0.15 m thick hard limestone layers inferred from auger resistance during drilling at 3.9 m, 4.9 m, 5.2 m and 5.8 m depth.		5	SS	100/100									
102.93														
6.10	END OF BOREHOLE													
	Note: 1. Open Borehole dry upon completion of drilling. 2. Water level measured in piezometer at 2.68 m depth (Elev. 106.35 m) on July 25, 2000 and August 16, 2000.													



DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

WP No. 47-88-00

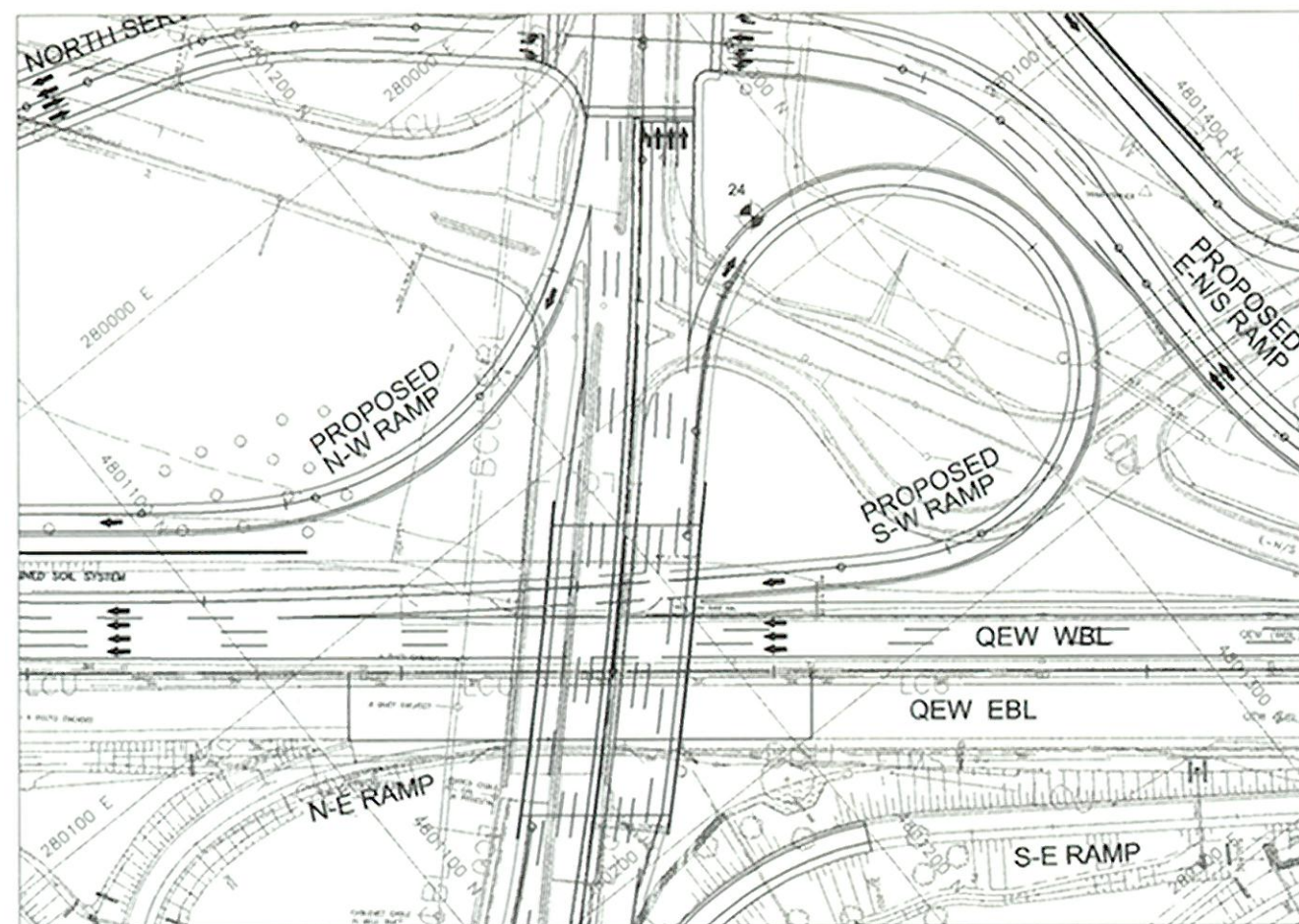


SHEET

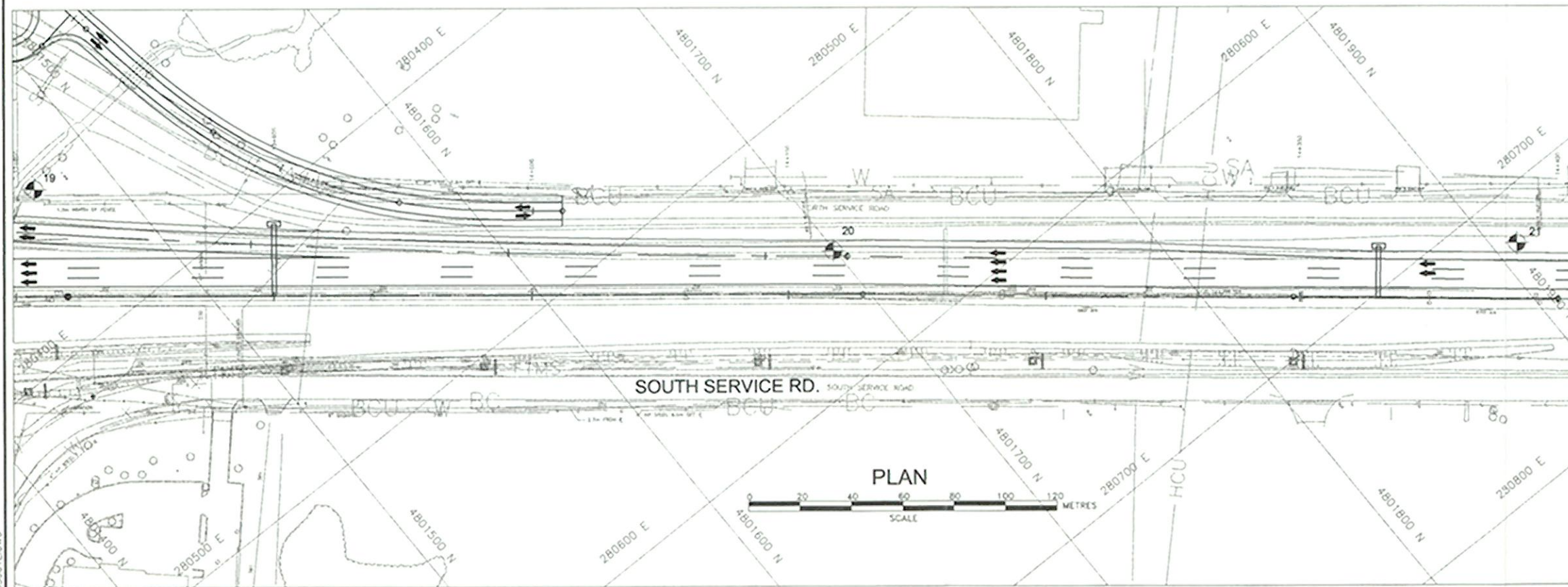
Q.E.W./GUELPH LINE  
HIGH MAST LIGHTING  
BOREHOLE LOCATION PLAN



**Golder Associates Ltd.**  
MISSISSAUGA, ONTARIO, CANADA



## PLAN



## PLAN



LEGEND



Borehole

No.	ELEVATION	LOCATION	
		NORTHING	EASTING
19	107.40	4801473.3	280339.1
20	110.23	4801699.5	280553.1
21	111.57	4801908.7	280719.1
24	109.03	4801283.0	280085.1

## NOTES

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

## REFERENCE

This drawing was created from digital file "53899-01.dwg"  
Titled "Q.E.W. UNDERPASS AT GUELPH LINE" provided by  
McCormick Rankin Corp. on August 31, 2000

NO.	DATE	BY	REVISION	

Geocres No.

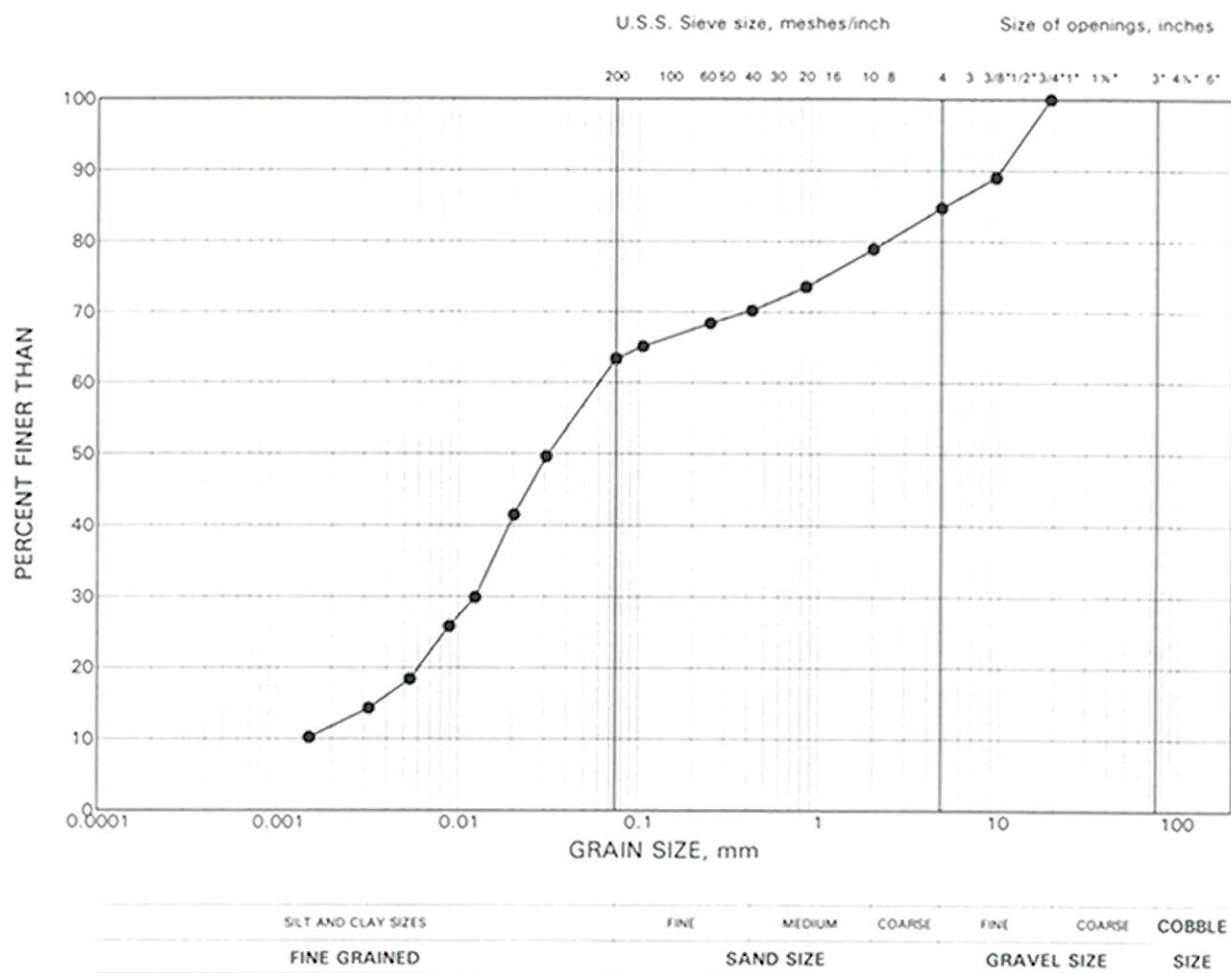
Q.E.W.		PROJECT NO.:		991-1105	DIST.	4
SUBM'D.	SEP	CHKD:	ASP	DATE: 2000 12 07	SITE	
DRAWN:	JFC	CHKD:	SEP	APPO.	DWG. 1	

1" = 1" imp. (1:100000)



# GRAIN SIZE DISTRIBUTION SILTY CLAY (GLACIAL TILL)

FIGURE 1



## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
•	21	4	108.7

**LEGEND**

BH	SAMPLE	SYMBOL
21	4	●

### PLASTICITY CHART SILTY CLAY (GLACIAL TILL)

FIG No

2

GWP	47-88-00
-----	----------