



April 2014

## FOUNDATION INVESTIGATION REPORT

### Overhead Sign Supports Highway 401/Holt Road Interchange Reconfiguration Clarington, Ontario G.W.P. 2101-08-00

**Submitted to:**  
URS Canada Inc.  
30 Leek Crescent, 4th Floor  
Richmond Hill, Ontario  
L4B 4N4

**GEOCRES No. 30M15-184**



**Report Number:** 09-1111-0019

**Distribution:**

5 Copies - MTO – Eastern Region  
1 Copy - MTO – Foundations Section  
2 Copies - URS Canada Inc.  
2 Copies - Golder Associates Ltd.

REPORT





## Table of Contents

<b>1.0 INTRODUCTION.....</b>	<b>1</b>
<b>2.0 SITE DESCRIPTION.....</b>	<b>1</b>
<b>3.0 INVESTIGATION PROCEDURES .....</b>	<b>1</b>
<b>4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS .....</b>	<b>3</b>
4.1 Regional Geology .....	3
4.2 Subsurface Conditions.....	3
4.2.1 OHS No. 1.....	4
4.2.2 OHS No. 2.....	5
4.3 Groundwater Conditions .....	6
<b>5.0 CLOSURE.....</b>	<b>7</b>

### **DRAWINGS**

Drawing 1 Borehole Locations

### **APPENDIX A Borehole Records**

Lists of Abbreviations and Symbols  
Records of Boreholes  
HR-1, HR-2, 13-45, 13-46, 13-47, 13-48, 13-49, 13-50,

### **APPENDIX B Laboratory Test Results**



### 1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by URS Canada Inc. (URS) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the Highway 401/Holt Road Interchange reconfiguration in the Town of Clarington, Regional Municipality of Durham, Ontario.

This report addresses the results of the detail subsurface investigation carried out for the Overhead Sign (OHS) support foundations.

The Terms of Reference for the foundation engineering services are outlined in MTO's Request for Proposal (RFP) for Assignment No. 2008-E-0059 dated March 2009 and associated clarifications, and in Section 6.8 of the URS *Technical Proposal* for this assignment. The Scope of Work for the OHS foundation investigation is summarised in Golder's Scope Change dated March 19, 2014.

### 2.0 SITE DESCRIPTION

Based on the drawings of the proposed Highway 401/Holt Road Interchange provided by URS (Drawing No. 2013-10-24-Hwy401-HoltRd\_profile and 2013-10-24-Hwy401-HoltRd\_plan), the existing Holt Road will be realigned and a new bridge structure with associated interchange ramps will be constructed about 30 m to the east of the existing underpass bridge. Further, it is understood that the South Service Road will be realigned to the south as part of the interchange reconfiguration, to accommodate the future Highway 407 East Durham Link that connects to Highway 401 immediately to the west of the site.

In general, the terrain in the area of the proposed new interchange is relatively flat to gently rolling, with the natural ground surface within the limits of the project ranging between about Elevations 111 m and 116 m.

The proposed OHS supports are located within the approach embankments immediately north and south of the proposed Holt Road bridge structure, at the intersection of Holt Road/Highway 401 overpass as shown on Drawing 1, and summarised below.

- OHS No. 1 – Holt Road northbound, north of Highway 401 at about Station 9+950, and
- OHS No. 2 – Holt Road southbound, south of Highway 401 at about Station 10+050.

### 3.0 INVESTIGATION PROCEDURES

As part of the foundation investigation for the interchange reconfiguration (Golder 2014 (a) and (b)), fifty one (51) boreholes (Boreholes HR-1, HR-2, 13-1 to 13-21 and 13-23 to 13-50) were advanced on November 22, 2012 and between May 27 and August 22, 2013 to investigate the subsurface conditions at the proposed bridge structure, high fill embankments and deep cut areas. The boreholes from this investigation located in the area of the proposed OHS supports have been used in this report, namely Boreholes HR-1, HR-2 and 13-45 to 13-50 and specifically the boreholes which are closest to the proposed OHS supports, that is, Boreholes HR-1 and 13-46 at OHS No. 1 and Boreholes HR-2 and 13-50 at OHS No. 2.

The boreholes for the bridge structure investigation were drilled by conventional track and truck mounted drill rigs supplied and operated by KC Drilling Ltd. of Innisfil, Ontario and Strong Soil Search Inc. of Claremont,



## FOUNDATION REPORT OVERHEAD SIGN SUPPORTS

Ontario. The boreholes were advanced through the overburden using 108 mm, 120 mm and 150 mm solid stem augers. In general, samples of the overburden soils were obtained at intervals of depth ranging from 0.75 m to 1.5 m using a 50 mm outer diameter (O.D.) split-spoon sampler operated by an automatic hammer on the drill rigs, performed in accordance with Standard Penetration Testing (SPT) procedures, as specified in ASTM Method D1586.

The groundwater conditions were observed in the open boreholes during and immediately following the drilling operations, and monitored in piezometers installed in two of the boreholes (in the area of OHS No. 1), and are described on the Record of Borehole sheets in Appendix A. It should be noted that groundwater elevations as encountered in the boreholes may not be representative of static groundwater levels since the groundwater levels in the boreholes may not have stabilized on completion of drilling. Furthermore, groundwater elevations will vary depending on seasonal fluctuations in precipitation and on local soil permeability. All boreholes were abandoned by backfilling to the ground surface with bentonite upon completion in accordance with Ontario Regulation 903 (as amended).

The four boreholes specific to the OHS support locations (Boreholes HR-1, 13-46, HR-2 and 13-50) were advanced to depths between 6.3 m and 9.2 m below existing ground surface, generally penetrating below ground surface to a depth equivalent the proposed height of the embankment fill and a minimum of 3 m into "refusal" material (SPT N-values > 100 blows per 0.3 m of penetration).

The proposed centreline of each roadway and ramp alignment was staked at 50 m intervals in the field by URS prior to drilling. The as-drilled borehole locations, in stations and offsets, were measured in reference to the centreline alignment and were subsequently converted into MTM NAD 83 coordinates using the base drawing provided by URS in AutoCAD format. Borehole elevations were surveyed by a member of our technical staff in reference to the surveyed ground surface elevations at the centreline median. The locations of the closest borehole(s) to the proposed OHS supports shown on Drawing 1 are positioned relative to MTM NAD 83 northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The as-drilled borehole locations, ground surface elevations and drilled depths are as follows:

**Summary of Borehole Locations and Elevations**

OHS Designation	Borehole Number	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
OHS No. 1	HR-1	4860786.9	367290.0	111.7	7.8
	13-46	4860802.0	367275.0	114.1	9.2
OHS No. 2	HR-2	4860707.2	367300.7	111.7	6.3
	13-50	4860695.0	367316.0	111.0	9.2

The field work was observed by members of our engineering and technical staff who located the boreholes, arranged for the clearance of underground services, observed the drilling, sampling and in situ testing operations, logged the boreholes, and examined and cared for the soil samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Mississauga geotechnical laboratory where the samples underwent further detailed visual examination and laboratory 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 selected samples. The results of the laboratory classification testing are summarized on the Record of Borehole sheets and are included in Appendix B for the four specific boreholes drilled closest to the OHS support locations.

## 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

### 4.1 Regional Geology

This section of Highway 401 is located within the Iroquois Plain physiographic region, as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984)<sup>1</sup> and *Urban Geology of Canadian Cities* (Karrow and White, 1998)<sup>2</sup>. The Iroquois Plain extends around the western shores of Lake Ontario. The Plain is comprised of the flat to undulating lakebed and beaches of the former glacial Lake Iroquois, which occupied this area during the last glacial recession.

The surficial soils in this area of the Iroquois Plain are typically comprised of glaciolacustrine clays, silts and sands to gravelly sands, which are underlain by an extensive till deposit that is mapped in this area as the Bowmanville Till. Within the area approximately bounded by Holt Road and Morgan's Road, the surficial glaciolacustrine deposits are absent or of limited thickness and the Bowmanville Till unit is frequently present immediately below the ground surface. Between these limits, an extensive surficial deposit of clayey silt to silty clay is present over the Bowmanville Till (Karrow and White, 1998). More recent alluvial deposits of gravel, sand, silt and/or clay are present in the valleys associated with Bowmanville Creek, Soper Creek, Wilmot Creek and Graham Creek.

The overburden soils are underlain by limestone bedrock of the Lindsay Formation, Simcoe Group (Geological Survey of Canada, 1997).<sup>3</sup>

### 4.2 Subsurface Conditions

The borehole locations and ground surface elevations are shown on Drawing 1. 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 contained in Appendix A. The results of geotechnical laboratory testing on samples from pertinent boreholes are also presented on Figures B1 to B7 contained in Appendix B.

The stratigraphic boundaries shown on the borehole records are inferred from observations of drilling progress and from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsurface conditions will vary between and beyond the borehole locations.

The description of the subsurface conditions encountered at the site in the following sections is based on the four (4) boreholes advanced as part of the bridge structure investigation that are closest in proximity to the OHS support locations (Boreholes HR-1, HR-2, 13-46 and 13-50). The subsurface conditions encountered in these boreholes are generally consistent with the subsurface conditions encountered in other boreholes advanced in

<sup>1</sup> Chapman, L.J., and Putnam, D.F., 1984. *The Physiography of Southern Ontario*, 3rd Edition. Ontario Geological Survey, Special Volume 2. Ontario Ministry of Natural Resources.

<sup>2</sup> Karrow, P. F., and White, O. L., 1998. *Urban Geology of Canadian Cities*. Geological Association of Canada Special Paper No. 42. St. John's, Nfld.

<sup>3</sup> Ontario Geological Society, 1991. *Geology of Ontario*. Special Volume 4, Part 1. Eds. P.C. Thurston, H.R. Williams, R.H. Sutcliffe and G.M. Stott. Ministry of Northern Development and Mines, Ontario.



the general vicinity of the OHS support locations shown on Drawing 1, the results of which are presented on the Record of Borehole sheets included in Appendix A.

In summary, the subsurface conditions encountered at the site consist of a surficial layer of topsoil underlain by a fill deposit comprised of sand and silt to sandy silt to clayey silt, underlain by a very dense/hard silt and sand to silt to clayey silt till deposit.

A more detailed description of the subsurface conditions encountered in the four boreholes is provided in the following sections. The subsurface conditions for each specific OHS support location can be inferred from the closest boreholes.

### 4.2.1 OHS No. 1

#### Topsoil

A 0.6 m thick deposit of topsoil was encountered immediately below ground surface in Borehole 13-46.

One Standard Penetration Test (SPT) "N"-value measured within the topsoil deposit is 19 blows per 0.3 m of penetration, suggesting a compact relative density.

#### Sand (Fill)

A fill deposit comprised of sandy silt to sand and silt to silty sand, trace gravel, trace clay was encountered immediately below ground surface in Borehole HR-1 and below the topsoil in Borehole 13-46 and. The surface of the granular fill deposit was encountered at Elevations 111.7 m and 113.5 m and the deposit is 2.3 m and 3.8 m thick in the respective boreholes.

The measured SPT "N"-values within this deposit range from 7 to 87 blows per 0.13 m of penetration, indicating a loose to very dense relative density.

The result of a grain size distribution test completed on one selected sample of the sand and silt fill from Borehole 13-46 is shown on Figure B1 in Appendix B.

The natural water content measured on samples of the sand fill deposit ranges from about 5 per cent to 16 per cent.

#### Clayey Silt (Till)

A deposit of clayey silt till was encountered below the fill in Boreholes HR-1 and 13-46. The surface of the clayey silt till was encountered at depths of 2.3 m and 4.4 m below ground surface, corresponding to Elevations 109.4 m and 109.7 m in the respective boreholes. The thickness of this till deposit is about 1.5 m and 3.9 m in the respective boreholes.

The measured SPT "N"-values within the clayey silt till deposit range from 30 blows per 0.3 m of penetration to 50 blows per 0.03 m of penetration, suggesting a hard consistency.

The till deposit consists of clayey silt with sand, trace to some gravel. The presence of cobbles and boulders within this deposit was inferred from grinding of the augers as noted on the Record of Borehole sheets. The results of grain size distribution tests completed on two selected samples of the clayey silt till are shown on Figure B3 in Appendix B.



Atterberg limits testing was conducted on two selected samples of the clayey silt till and measured plastic limits of 15 per cent, liquid limits of about 10 per cent and plasticity indices of about 5 per cent. The results of the Atterberg limits tests are shown on the plasticity chart on Figure B3 in Appendix B and indicate that the material is a clayey silt of low plasticity.

The natural water content measured on samples of the clayey silt till deposit ranges from about 5 per cent to 10 per cent.

### **Sand and Silt (Till)**

A deposit of sand and silt to sandy silt till was encountered underlying the clayey silt till deposit in Boreholes HR-1 and 13-46. The surface of the sand and silt to sandy silt till was encountered at depths of 3.8 m and 8.3 m below ground surface, corresponding to Elevations 107.9 m and 105.8 m in the respective boreholes. The thickness of this till deposit is about 4.0 m and 0.9 m in the respective boreholes, and the deposit was not fully penetrated.

The measured SPT “N”-values within this deposit are 100 blows per 0.13 m of penetration to 50 blows per 0.05 m of penetration, indicating a very dense relative density.

The glacial till deposit consists of sand and silt to sandy silt, trace to some clay, trace to some gravel. The presence of cobbles and boulders within this deposit was inferred from grinding of the augers in other boreholes in this area of the site. The results of grain size distribution tests completed on two selected samples of the sand and silt till are shown on Figure B4 in Appendix B.

The natural water content measured on two samples of the sand and silt to sandy silt till deposit are about 6 per cent and 8 per cent.

### **4.2.2 OHS No. 2**

#### **Topsoil**

A 0.4 m thick deposit of topsoil was encountered immediately below ground surface in Borehole 13-50.

One Standard Penetration Test (SPT) “N” value measured within the topsoil deposit is 8 blows per 0.3 m of penetration, suggesting a loose relative density.

#### **Sandy Silt (Fill)**

A fill deposit comprised of sandy silt, trace gravel, trace clay containing rootlets and organics was encountered immediately below ground surface in Borehole HR-2.

The measured SPT “N”-values within this deposit are 9 blows and 12 blows per 0.3 m of penetration, indicating a loose to compact relative density.

The natural water content measured on one sample of the granular fill is 12 per cent.

#### **Clayey Silt (Fill)**

A deposit of clayey silt fill was encountered below the topsoil in Borehole 13-50. The surface of the cohesive fill deposit was encountered at 110.6 m and the thickness of the deposit is 0.4 m.



### Clayey Silt (Till)

A deposit of clayey silt till was encountered below the fill in Borehole 13-50, and as an interlayer within the upper portion of the sandy silt to sand and silt till deposit in Borehole HR-2. The surface of the clayey silt till was encountered at depths of 0.8 m and 2.3 m below ground surface, corresponding to Elevations 110.2 m to 109.4 m in the respective boreholes. The thickness of this till deposit ranges from about 0.6 m in Borehole HR-2 to 8.4 m in Borehole 13-50 where it was not fully penetrated.

The measured SPT “N” values within this deposit range from 28 blows per 0.3 m of penetration to 50 blows per 0.03 m of penetration, suggesting a very stiff to hard consistency.

The till deposit consists of clayey silt with sand to some sand, trace to some gravel and contains occasional silt seams at some locations. The presence of cobbles and boulders was inferred from grinding of the augers within this deposit as noted on the Record of Borehole sheets. The results of grain size distribution tests completed on four selected samples of the clayey silt till are shown on Figure B5.

Atterberg limits testing was conducted on three selected samples of the clayey silt till and measured plastic limits ranging from 10 per cent to 15 per cent, liquid limits ranging from 13 per cent to 33 per cent and plasticity indices ranging from 2 per cent to 18 per cent. The results of the Atterberg limits tests are shown on the plasticity chart on Figure B6 and indicate that the material is a clayey silt of low plasticity with zones that may be classified as silt of slight plasticity.

The natural water content measured on samples of the clayey silt till deposit ranges from about 5 per cent to 15 per cent.

### Sand and Silt to Sandy Silt (Till)

A deposit of sandy silt to sand and silt till was encountered underlying the fill deposit in Borehole HR-2. The surface of the sandy silt to sand and silt till deposit was encountered at a depth of 1.8 m below ground surface, at Elevation 109.9 m. The borehole was terminated within this till deposit.

The measured SPT “N” values within this deposit range from 100 blows per 0.13 m of penetration to 100 blows per 0.07 m of penetration, indicating a very dense relative density.

The glacial till deposit consists of sandy silt to sand and silt, trace to some clay, trace to some gravel, interlayered as noted above with clayey silt till in places. The presence of cobbles and boulders was inferred from grinding of the augers within this deposit in other boreholes in the area(s) of the proposed overhead signs. The results of a grain size distribution test completed on one selected sample of the sand and silt till are shown on Figure B7 in Appendix B.

The natural water content measured on two samples of the sand and silt till deposit are about 6 per cent and 7 per cent.

## 4.3 Groundwater Conditions

Details of the water levels observed in the open boreholes at the time of drilling are summarized on the Record of Borehole sheets in Appendix A of this report. The water level in the open boreholes was measured at between 4.7 m and 6.2 m below ground surface corresponding to between Elevations 107.9 m and 105.5 m.



## FOUNDATION REPORT OVERHEAD SIGN SUPPORTS

A standpipe piezometer was installed in Borehole 13-46 to permit monitoring of the groundwater level at that location. Details of the piezometer installation are shown on the Record of Borehole sheet in Appendix A. Groundwater levels measured in the piezometer are summarized below.

Borehole No.	Ground Surface Elevation	Depth to Groundwater Level	Groundwater Elevation	Date of Measurement
13-46	114.1 m	3.9 m	110.2 m	September 10, 2013

The water level at the site is expected to fluctuate seasonally in response to changes in precipitation and snow melt, and is expected to be higher during the spring season and periods of precipitation. Given the presence of a deposit of granular fill soils overlying very stiff to hard/very dense till, perched groundwater conditions can be expected to be present directly above the till deposits.

### 5.0 CLOSURE

This Foundation Investigation Report was prepared by Mr. Matthew Kelly, P.Eng. and reviewed by Mr. Jorge Costa, P.Eng., a Principal with and Designated MTO Foundations Contact for Golder.

GOLDER ASSOCIATES LTD.



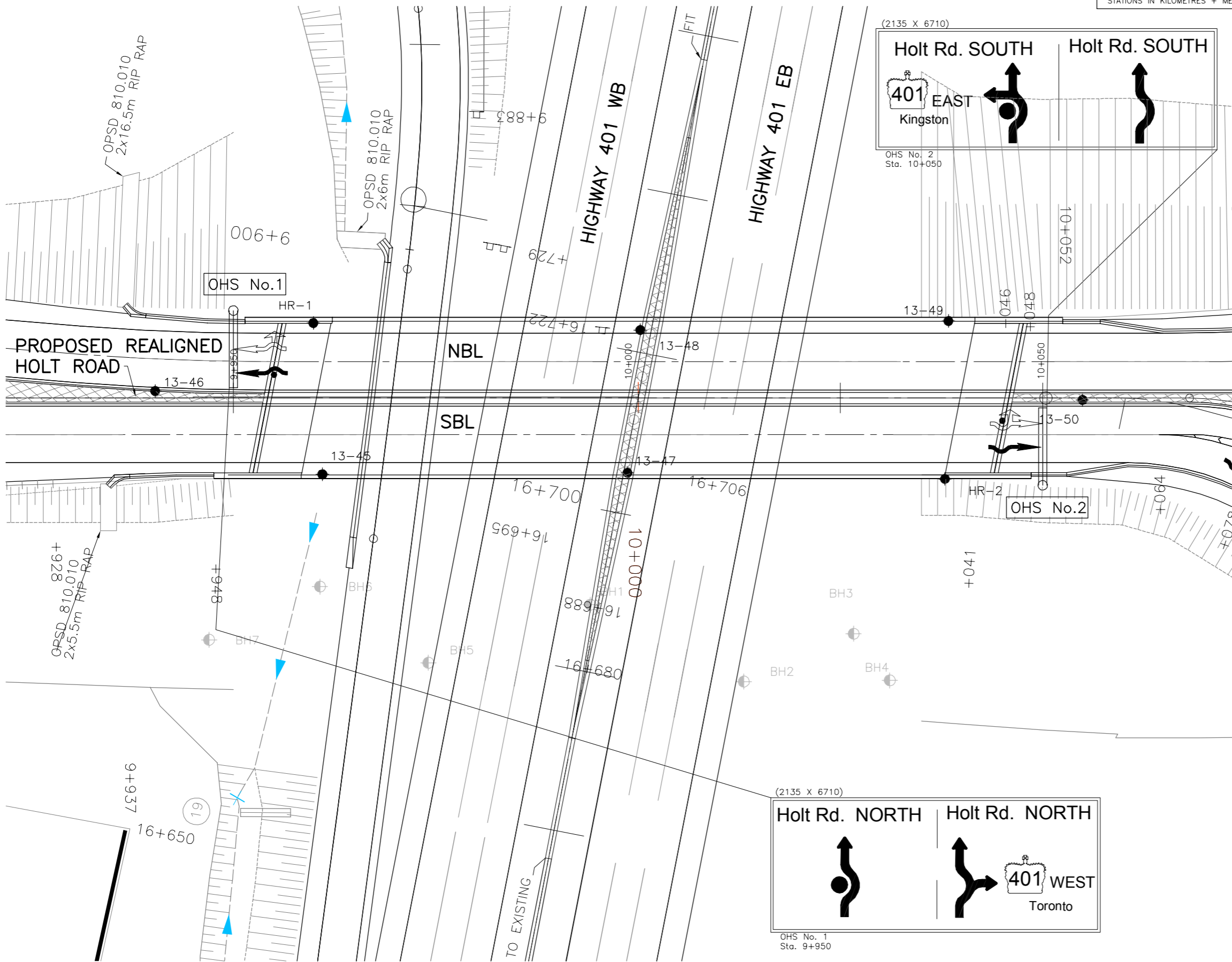
Matthew Kelly, P.Eng.  
Geotechnical Engineer



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

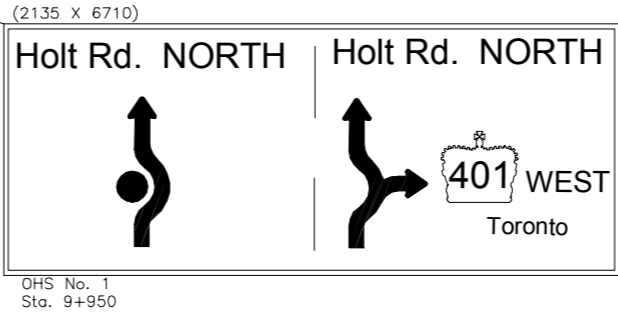
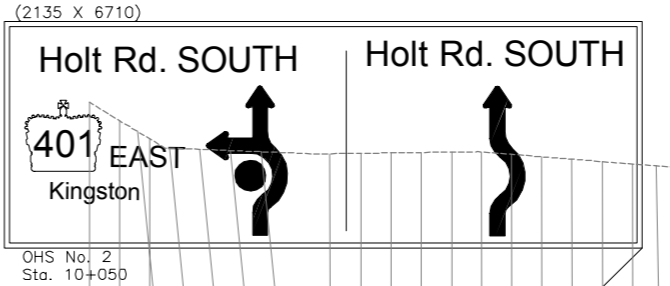
MWK/JMAC/jl

n:\active\2009\1111\09-1111-0019 urs - hwy 401 holt rd - clarington\reporting\detail design\ohs\final\09-1111-0019 rpt 2014apr04 ohs.docx



PLAN  
SCALE  
5 0 5 10 m

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



CONT No.  
GWP No. 2101-08-00

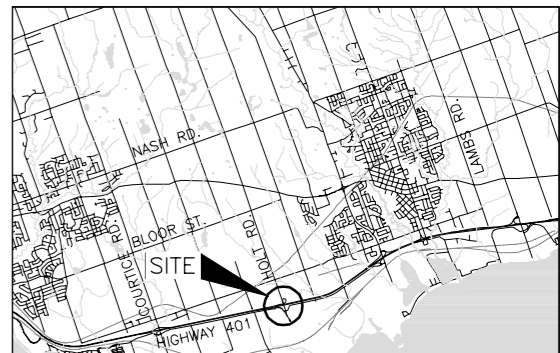


HIGHWAY 401/HOLT ROAD  
INTERCHANGE OVERHEAD SIGNS  
BOREHOLE LOCATIONS

SHEET



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



KEY PLAN

SCALE

2 0 2 4 km

LEGEND

- Borehole - Current Investigation (Holt Road Bridge)
- Borehole - Previous Investigation (1961)

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
13-45	113.8	4860779.0	367273.0
13-46	114.1	4860802.0	367275.0
13-47	112.3	4860744.0	367287.0
13-48	111.8	4860749.0	367304.0
13-49	111.0	4860714.0	367319.0
13-50	111.0	4860695.0	367316.0
HR-1	111.7	4860786.9	367290.0
HR-2	111.7	4860707.2	367300.7

NOTES

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

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

REFERENCE

Base plan provided in digital format by URS, drawing file no. Hwy401-HoltRd\_PavementMarkings&Signs.dwg, received March 20, 2014.

NO.	DATE	BY	REVISION
Geocres No. <b>30M15-184</b>			
HWY. 401		PROJECT NO. 09-1111-0019	DIST.
SUBM'D. MWK	CHKD. MWK	DATE: Mar. 2014	SITE: 21-159
DRAWN: JFC	CHKD.	APPD. JMAC	DWG. 1



# **APPENDIX A**

## **Borehole Records**



## 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
FoS	factor of safety

### II. STRESS AND STRAIN

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta \sigma$
$\varepsilon$	linear strain
$\varepsilon_v$	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 stress (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

<b>(a)</b>	<b>Index Properties</b>
$\rho(\gamma)$	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

### (a) Index Properties (continued)

w	water content
$w_l$ or LL	liquid limit
$w_p$ or PL	plastic limit
$I_p$ or PI	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
$C_\alpha$	secondary compression index
$m_v$	coefficient of volume change
$C_v$	coefficient of consolidation (vertical direction)
$C_h$	coefficient of consolidation (horizontal direction)
$T_v$	time factor (vertical direction)
U	degree of consolidation
$\sigma'_p$	pre-consolidation stress
OCR	over-consolidation ratio = $\sigma'_p / \sigma'_{vo}$

### (d) 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

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

Notes: 1  
2

$$\tau = c' + \sigma' \tan \phi'$$
$$\text{shear strength} = (\text{compressive strength})/2$$



## 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
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
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<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.

### V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier
0 to 5	Trace
5 to 12	Trace to Some (or Little)
12 to 20	Some
20 to 30	(ey) or (y)
over 30	And (non-cohesive (cohesionless)) or With (cohesive)

### III. SOIL DESCRIPTION

#### (a) Non-Cohesive (Cohesionless) Soils

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

#### (b) Cohesive Soils Consistency

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

### IV. SOIL TESTS

w	water content
$w_p$	plastic limit
$w_l$	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
$D_R$	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)
$\gamma$	unit weight

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

#### Example

Trace sand  
Trace to some sand  
Some sand  
Sandy  
Sand and Gravel  
Silty Clay with sand / Clayey Silt with sand

PROJECT		RECORD OF BOREHOLE		No HR-1		SHEET 1 OF 1		METRIC									
W.P.		LOCATION		ORIGINATED BY		DIST		BOREHOLE TYPE									
2101-08-00		N 4860786.9 ; E 367290.0		BM		HWY 401		108 mm O.D. Continuous Flight Solid Stem Power Augering									
DATUM		DATE		CHECKED BY		COMPILED BY		MS									
Geodetic		November 22, 2012		MWK													
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			SHEAR STRENGTH kPa									WATER CONTENT (%)
111.7	GROUND SURFACE							20	40	60	80	100					
0.0	Sandy silt to silty sand, trace clay, trace to some gravel, containing rootlets and organics (FILL) Loose to compact Brown to grey Moist		1	SS	14												
			2	SS	15												
			3	SS	7												
109.4																	
2.3	CLAYEY SILT with sand, some gravel (TILL) Hard Grey Moist		4	SS	30												
			5	SS	33												
107.9																	
3.8	SAND and SILT, some clay, trace to some gravel (TILL) Very dense Grey Moist		6	SS	100/0.13												
			7	SS	100/0.13												
			8	SS	100/0.13												
104.7																	
7.0	Sandy SILT, trace clay, trace to some gravel (TILL) Very dense Grey Moist																
103.9			9	SS	100/0.13												
7.8	END OF BOREHOLE																
NOTES:																	
1. Water level in open borehole measured at a depth of 4.9 m below ground surface (Elev. 106.8 m) on completion of drilling.																	

PROJECT		RECORD OF BOREHOLE		No HR-2		SHEET 1 OF 1		METRIC								
W.P. 09-1111-0019		LOCATION		N 4860707.2 ; E 367300.7		ORIGINATED BY		BM								
DIST		HWY 401		BOREHOLE TYPE		108 mm O.D. Continuous Flight Solid Stem Power Augering		COMPILED BY								
DATUM Geodetic		DATE		November 22, 2012		CHECKED BY		MWK								
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			SHEAR STRENGTH kPa								
111.7	GROUND SURFACE															
0.0	Sandy silt, trace clay, trace gravel, containing rootlets and organics (FILL) Loose to compact Brown to grey Moist		1	SS	9											
			2	SS	12											
109.9																
1.8	Sandy SILT, trace clay, trace gravel (TILL) Compact Grey Moist		3	SS	14											
109.4																
2.3			4	SS	28											
108.8	CLAYEY SILT, some sand, trace gravel (TILL) Very stiff Grey Moist		5	SS	100/0.07											1 12 52 35
2.9			6	SS	100/0.07											5 47 34 14
	SAND and SILT, some clay, trace to some gravel (TILL) Very dense Grey Moist		7	SS	100/0.07											
105.4	END OF BOREHOLE		8	SS	100/0.07											
6.3	NOTES:  1. Water level in open borehole measured at a depth of 4.7 m below ground surface (Elev. 107.0 m) on completion of drilling.															

PROJECT		RECORD OF BOREHOLE No 13-45		SHEET 1 OF 1		METRIC											
G.W.P. 09-1111-0019		LOCATION N 4860779.0 ; E 367273.0		ORIGINATED BY JLC													
DIST HWY 401		BOREHOLE TYPE 120 mm O.D. Continuous Flight Solid Stem Power Auger		COMPILED BY BM													
DATUM Geodetic		DATE May 28, 2013		CHECKED BY MWK													
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ	GR SA SI CL
							20 40 60 80 100	20 40 60 80 100	W <sub>p</sub>	W	W <sub>L</sub>	10 20 30					
113.8	GROUND SURFACE																
0.0	TOPSOIL		1	SS	17		113										
113.4			2	SS	29												
0.4	Sand and silt, trace to some gravel, some clay, trace organics (FILL) Compact Grey to dark brown Moist		3	SS	28		112										8 42 37 13
	Pockets of organics below a depth of 1.8 m (Elev. 112.0 m)		4	SS	41												15 37 33 15
110.9							111										
2.9	CLAYEY SILT with SAND, trace gravel (TILL) Hard Brown to grey Moist		5	SS	100/0.23												
	Auger grinding on possible cobbles and boulders below 3.0 m depth		6	SS	100/0.13		110										
			7	SS	100/0.13		109										3 40 42 15
							108										
107.6			8	SS	100/0.13												
6.2	END OF BOREHOLE																
NOTES:																	
1. Borehole caved at a depth of 5.8 m below ground surface (Elev. 108.0 m) upon completion of drilling.																	
2. Water level at 3.0 m below ground surface (Elev. 110.8 m) upon completion of drilling.																	
3. Water level measurements in Piezometer:																	
Date    Depth (m)    Elev. (m)																	
05/29/13    3.0    110.8																	
09/10/13    2.1    111.7																	

PROJECT 09-1111-0019		<b>RECORD OF BOREHOLE No 13-46</b>		SHEET 1 OF 1		<b>METRIC</b>	
G.W.P. 2101-08-00		LOCATION N 4860802.0 ; E 367275.0		ORIGINATED BY JLC			
DIST _____ HWY 401		BOREHOLE TYPE 120 mm O.D. Continuous Flight Solid Stem Power Auger		COMPILED BY BM			
DATUM Geodetic		DATE June 11, 2013		CHECKED BY MWK			

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			SHEAR STRENGTH kPa					WATER CONTENT (%)							
								20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>					
114.1	GROUND SURFACE																			
0.0	TOPSOIL Compact Dark brown Moist		1	SS	19															
113.5	Sand and silt, some gravel, some clay, trace organics (FILL) Compact to very dense Grey to black Moist  Pockets of wood fibres/rootlets below Elev. 111.0 m		2	SS	87															
0.6																				
				3	SS	29														
				4	SS	24														
				5	SS	37														
				6	SS	36														
109.7	CLAYEY SILT with SAND, trace to some gravel (TILL) Hard Brown to grey Moist  ----- Auger grinding on possible cobbles and boulders below 5.1 m depth		7	SS	97															
4.4																				
				8	SS	50/0.03														
				9	SS	50/0.03														
105.8	SAND and SILT, trace to some gravel, some clay (TILL) Very dense Grey Moist																			
8.3																				
104.9																				
9.2	END OF BOREHOLE		10	SS	50/0.03															
	NOTES:  1. Borehole caved at a depth of 8.7 m below ground surface (Elev. 105.4 m) upon completion of drilling.  2. Water level in caved borehole at a depth of 6.2 m below ground surface (Elev. 107.9 m) upon completion of drilling.  3. Water level measurements in Piezometer:  Date    Depth (m)    Elev. (m)  09/10/13    3.9        110.2																			

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

PROJECT		RECORD OF BOREHOLE No 13-47		SHEET 1 OF 1		METRIC											
G.W.P. 09-1111-0019		LOCATION N 4860744.0 ; E 367287.0		ORIGINATED BY JLC													
DIST _____ HWY 401		BOREHOLE TYPE 120 mm O.D. Continuous Flight Solid Stem Power Auger		COMPILED BY BM													
DATUM Geodetic		DATE June 9, 2013		CHECKED BY MWK													
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ	GR SA SI CL
								20 40 60 80 100	20 40 60 80 100	W <sub>p</sub>	W	W <sub>L</sub>	10 20 30				
112.3	GROUND SURFACE																
0.0	ASPHALT																
111.5	Sand and gravel, some silt (FILL) Compact Brown Moist		1	SS	25		112										
0.8	Clayey silt, with sand, trace to some gravel, trace organics (FILL) Very stiff Brown Moist		2	SS	16		111										9 43 32 16
110.9	SAND and SILT, some gravel, some clay (TILL) Dense to very dense Grey Moist		3	SS	42		110										
1.5			4	SS	43		109										
			5	SS	43		108										
			6	SS	100/0.10		107										
			7	SS	100/0.13		106										15 38 31 16
			8	SS	100/0.08		105										
			9	SS	100/0.13												
104.2	END OF BOREHOLE																
8.1	NOTE:  1. Water level in open borehole at a depth of 7.3 m below ground surface (Elev. 105.0 m) upon completion of drilling.																

PROJECT		RECORD OF BOREHOLE No 13-48		SHEET 1 OF 1		METRIC							
G.W.P. 09-1111-0019		LOCATION N 4860749.0 ; E 367304.0		ORIGINATED BY JLC									
DIST _____ HWY 401		BOREHOLE TYPE 120 mm O.D. Continuous Flight Solid Stem Power Auger		COMPILED BY BM									
DATUM Geodetic		DATE June 9, 2013		CHECKED BY MWK									
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC NATURAL LIQUID UNIT REMARKS				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	20 40 60 80 100	W <sub>p</sub> W W <sub>L</sub>	WATER CONTENT (%)	γ	GR SA SI CL
111.8	GROUND SURFACE												
0.9	ASPHALT												
	Sand and gravel, trace silt (FILL)		1	SS	20		111						
	Compact		2	SS	22								
	Brown												
	Moist												
110.4	Sandy silt, some gravel, trace clay, trace organics (FILL)		3	SS	35		110						
1.5	Dense												
109.6	Brown to grey												
2.2	Moist		4	SS	71		109						22 35 30 13
	SAND and SILT, trace to some gravel, some clay (TILL)		5	SS	140/0.15								
	Very dense		6	SS	120/0.15		108						5 44 36 15
	Grey		7	SS	125/0.15		107						
	Moist												
							106						
105.4	END OF BOREHOLE		8	SS	111/0.15								
6.4	NOTE:												
	1. Open borehole dry on completion of drilling.												

PROJECT		RECORD OF BOREHOLE		No 13-49		SHEET 1 OF 1		METRIC						
G.W.P. 09-1111-0019		LOCATION		N 4860714.0 ; E 367319.0		ORIGINATED BY		JLC						
DIST		HWY 401		BOREHOLE TYPE		120 mm O.D. Continuous Flight Solid Stem Power Auger		COMPILED BY						
DATUM		Geodetic		DATE		May 27, 2013		CHECKED BY						
								MWK						
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			SHEAR STRENGTH kPa						
111.0	GROUND SURFACE													
0.0	TOPSOIL													
110.6	Loose Dark brown Moist		1	SS	8									
110.2	Clayey silt, some sand, trace gravel, trace organics (FILL) Firm Dark brown Moist		2	SS	29									
0.8	CLAYEY SILT with SAND, trace to some gravel (TILL) Very stiff to hard Brown to grey Moist		3	SS	50/0.13									
			4	SS	100/0.08									
			5	SS	100/0.08									
107.4	SAND and SILT, trace to some gravel, trace to some clay (TILL) Very dense Grey Moist		6	SS	100/0.13									
3.6			7	SS	100/0.13									
	Auger grinding on probable cobbles or boulders at 4.9 m (Elev. 106.0 m)													
104.8	END OF BOREHOLE		8	SS	100/0.13									
6.2	NOTE: 1. Open borehole dry on completion of drilling.													

PROJECT		RECORD OF BOREHOLE		No 13-50		SHEET 1 OF 1		METRIC						
G.W.P. 09-1111-0019		LOCATION		N 4860695.0 ; E 367316.0		ORIGINATED BY		JLC						
DIST _____ HWY 401		BOREHOLE TYPE		120 mm O.D. Continuous Flight Solid Stem Power Auger		COMPILED BY		BM						
DATUM Geodetic		DATE		May 27, 2013		CHECKED BY		MWK						
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			SHEAR STRENGTH kPa						
111.0	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100	10 20 30				
0.0	TOPSOIL		1	SS	8									
110.6	Loose Brown Moist													
110.2	Clayey silt, some sand, trace gravel, trace organics (FILL) Dark brown Moist		2	SS	47									5 37 41 17
0.8	CLAYEY SILT with SAND, trace to some gravel, occasional silt seams (TILL) Hard Brown to grey Moist		3	SS	50/0.13									2 39 44 15
			4	SS	50/0.10									
			5	SS	50/0.08									10 42 35 13
			6	SS	50/0.06									
			7	SS	50/0.03									
			8	SS	50/0.05									
			9	SS	50/0.08									
			10	SS	50/0.08									
101.8	END OF BOREHOLE													
9.2	NOTES: 1. Water level at a depth of 5.5 m below ground surface (Elev. 105.5 m) during drilling. 2. Borehole caved to a depth of 6.1 m below ground surface (Elev. 104.9 m) upon completion of drilling.													



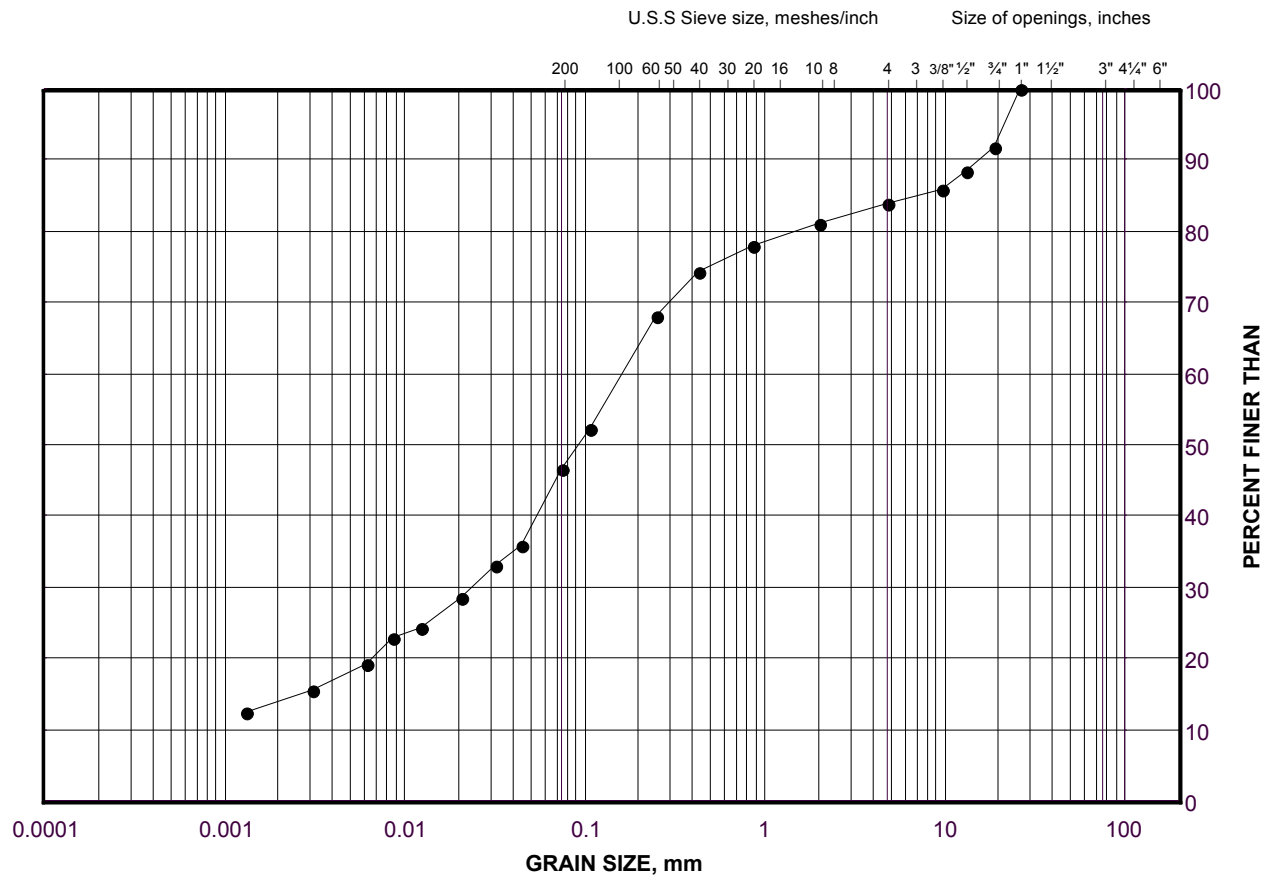
# **APPENDIX B**

## **Laboratory Test Results**

# GRAIN SIZE DISTRIBUTION

Sand and Silt (Fill) - OHS No. 1

FIGURE B1



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

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	13-46	5	110.8

Project Number: 09-1111-0019

Checked By: MWK

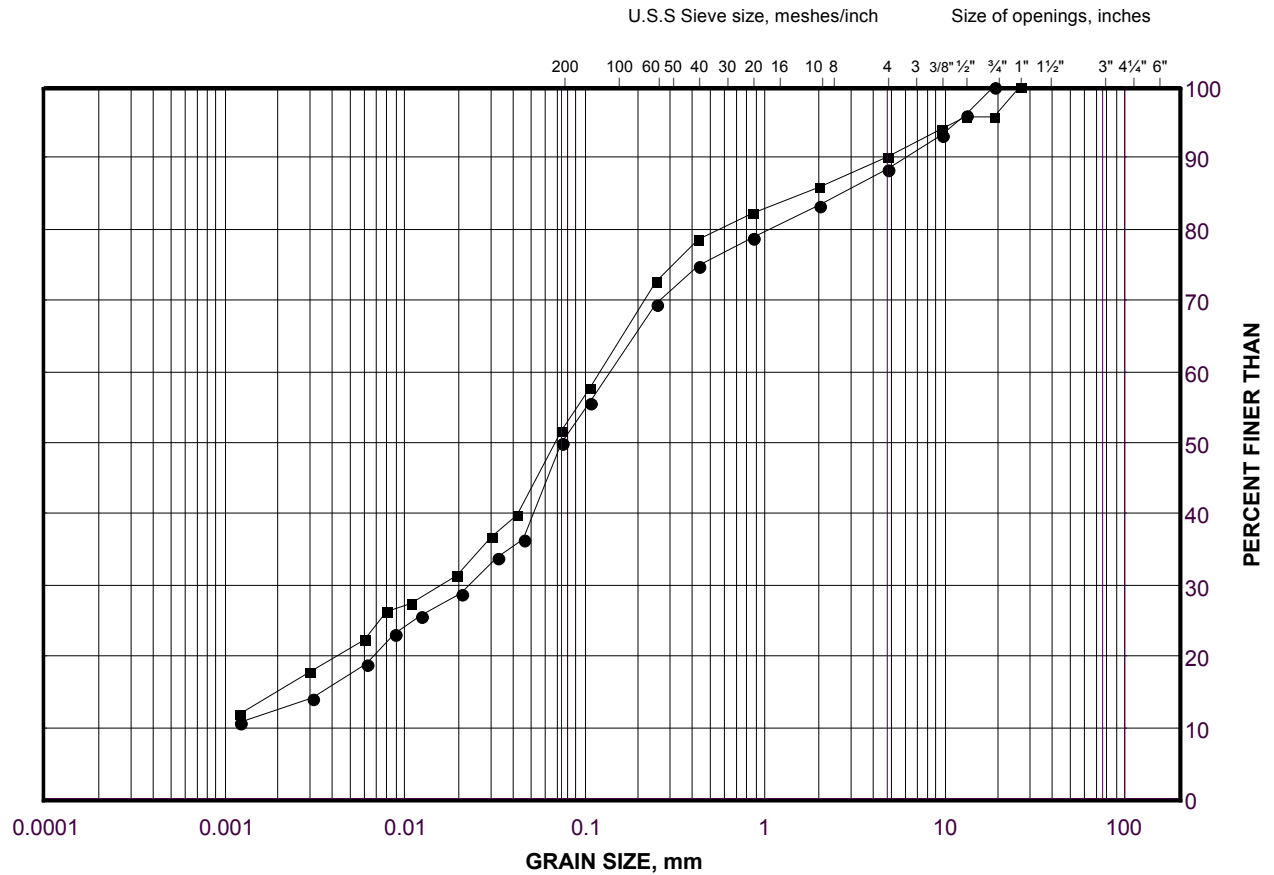
**Golder Associates**

Date: 27-Mar-14

# GRAIN SIZE DISTRIBUTION

Clayey Silt (Till) - OHS No.1

FIGURE B2



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

## LEGEND

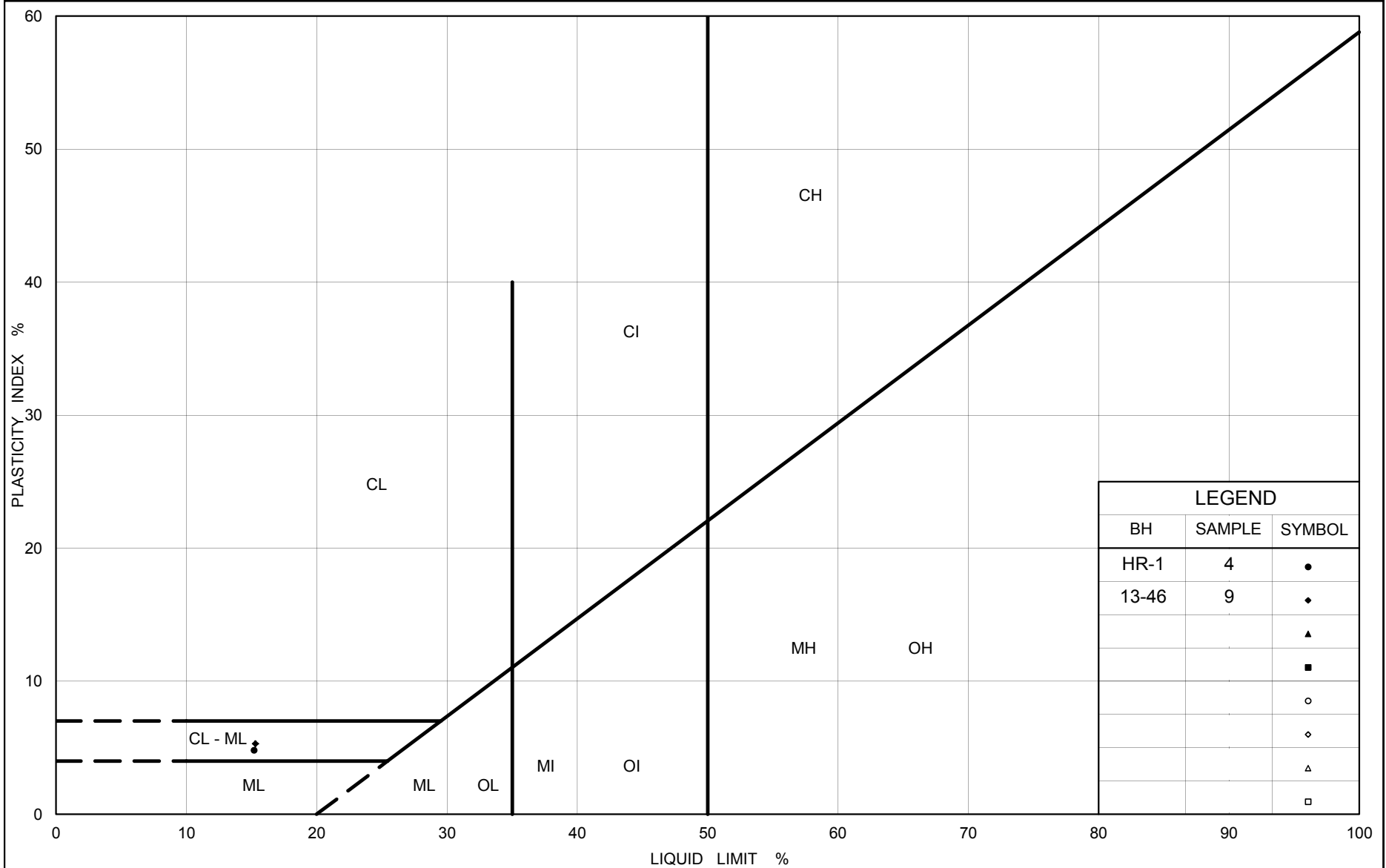
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	HR-1	4	109.1
■	13-46	7	109.3

Project Number: 09-1111-0019

Checked By: MWK

**Golder Associates**

Date: 27-Mar-14



Ministry of Transportation

Ontario

# PLASTICITY CHART Clayey Silt (Till) - OHS No.1

Figure No. B3

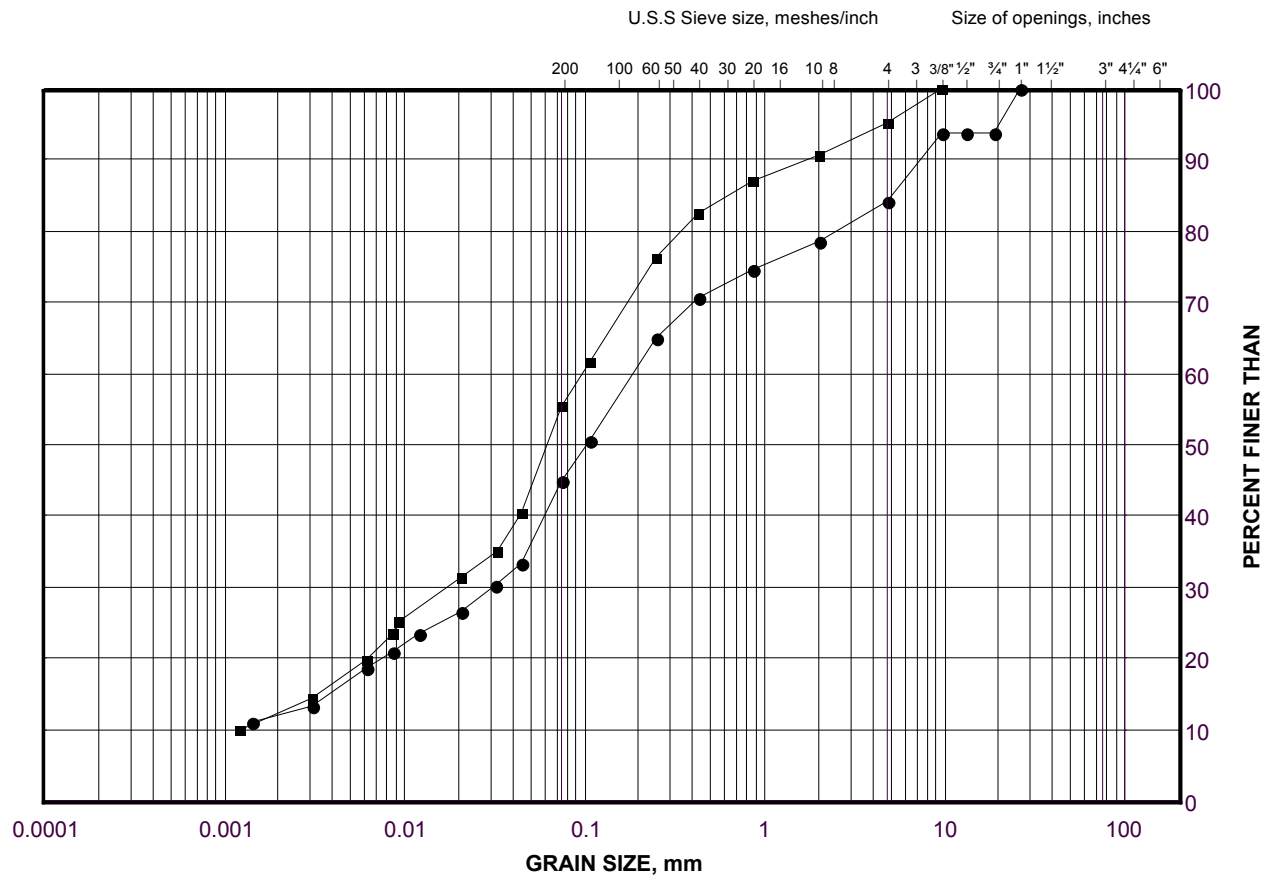
Project No. 09-1111-0019

Checked By: MWK

# GRAIN SIZE DISTRIBUTION

Sand and Silt (Till) - OHS No.1

FIGURE B4



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

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	HR-1	6	107.8
■	HR-1	8	105.5

Project Number: 09-1111-0019

Checked By: MWK

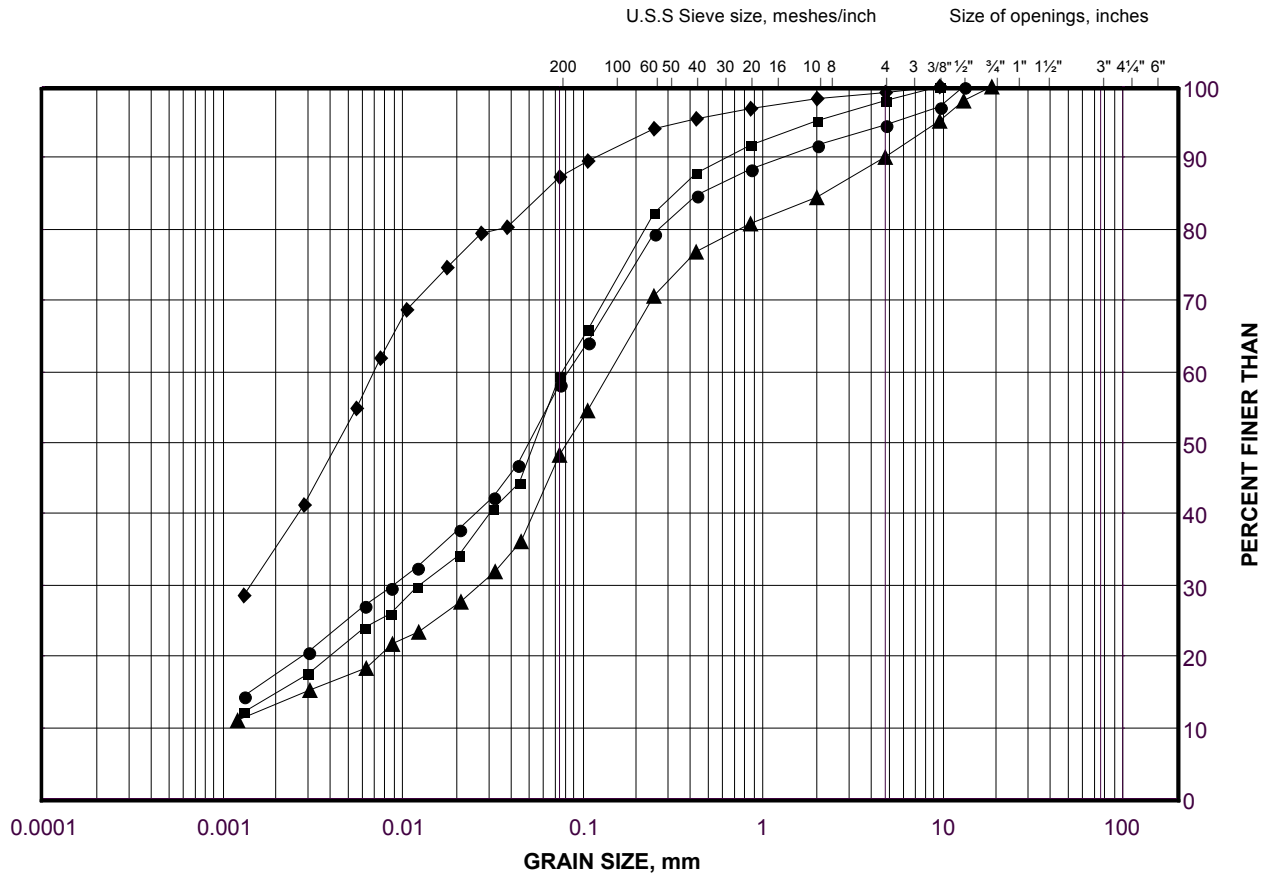
**Golder Associates**

Date: 27-Mar-14

# GRAIN SIZE DISTRIBUTION

Clayey Silt (Till) OHS No.2

FIGURE B5



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

## LEGEND

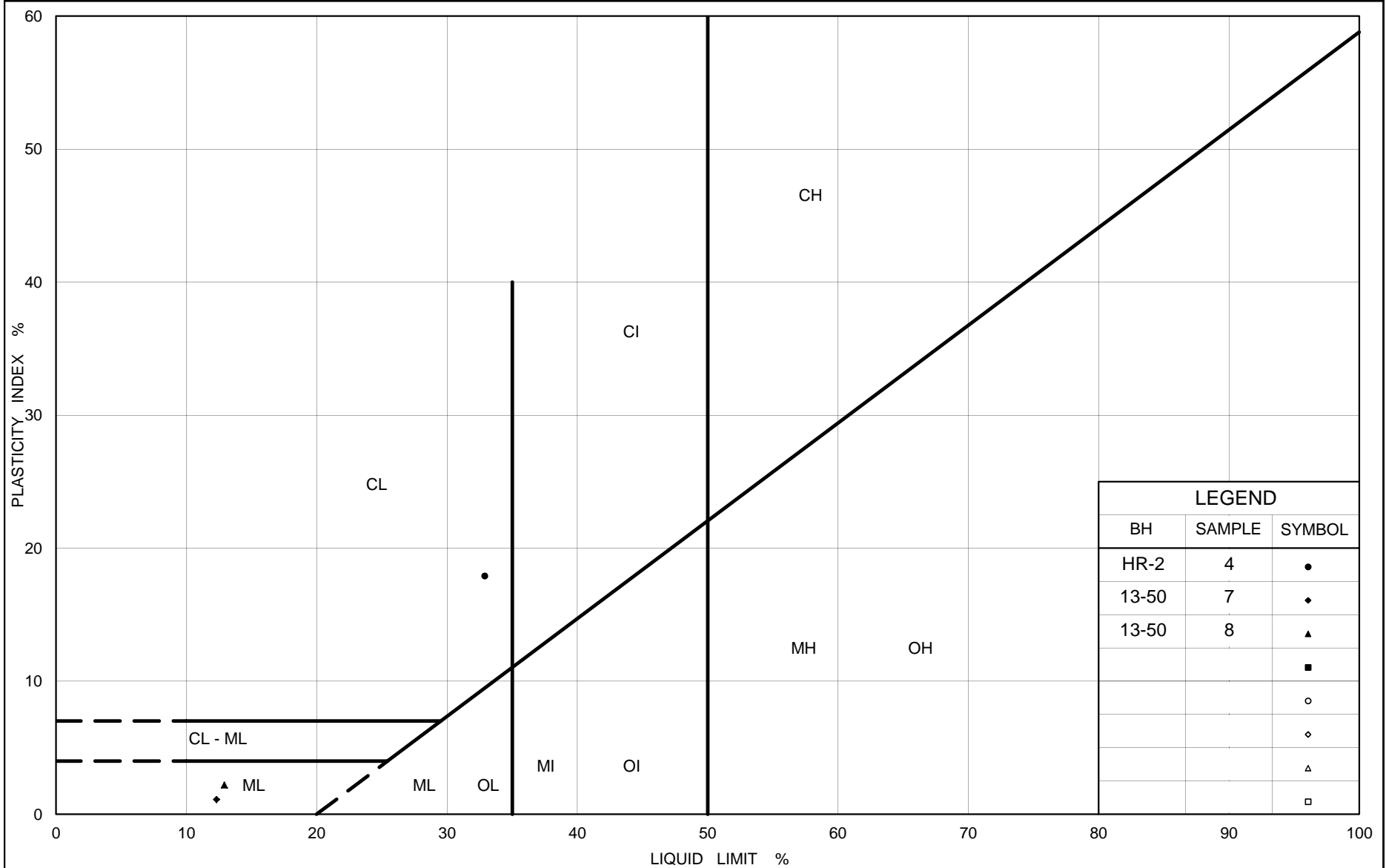
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	13-50	2	110.0
■	13-50	3	109.4
◆	HR-2	4	109.1
▲	13-50	5	107.9

Project Number: 09-1111-0019

Checked By: MWK

**Golder Associates**

Date: 27-Mar-14



Ministry of Transportation

Ontario

## PLASTICITY CHART

### Clayey Silt (Till) - OHS No.2

Figure No. B6

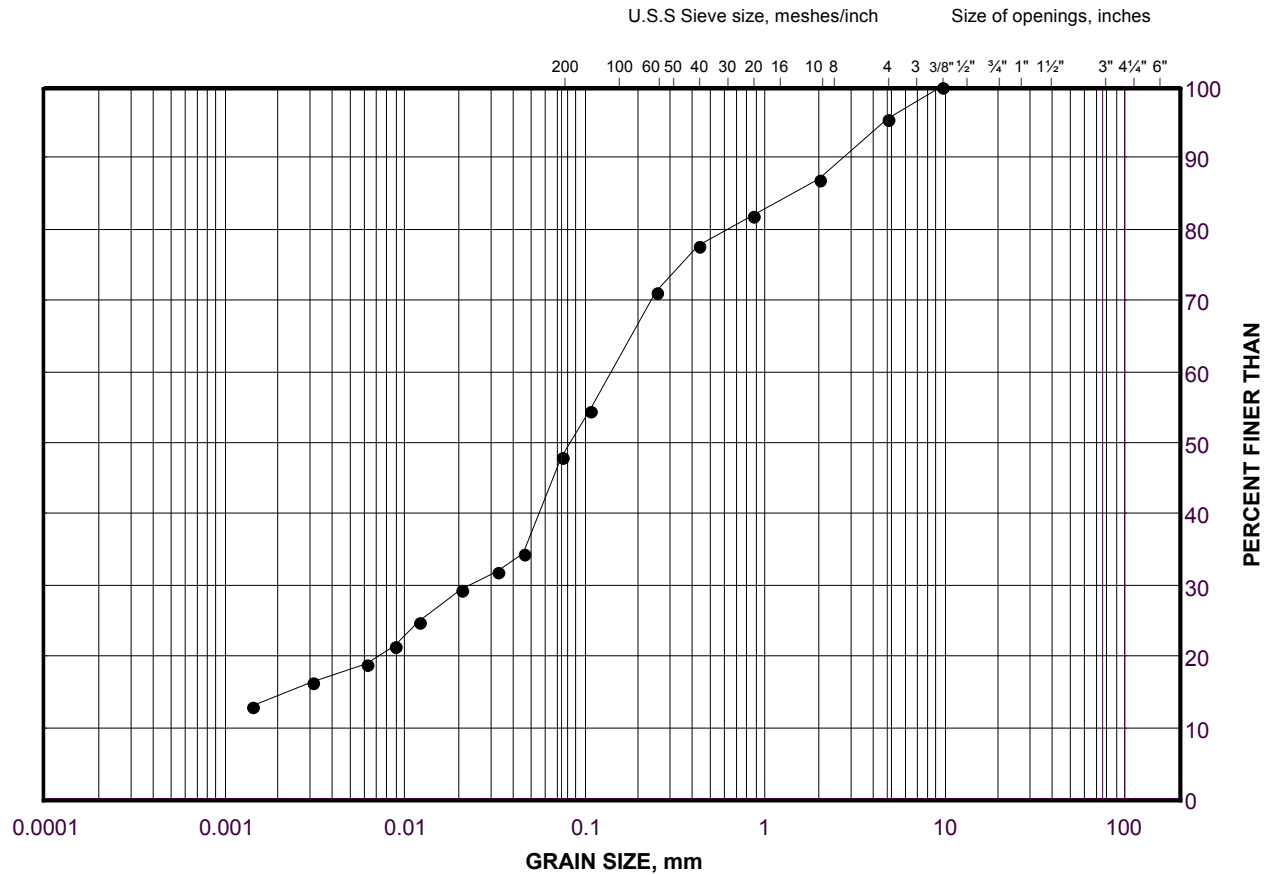
Project No. 09-1111-0019

Checked By: MWK

# GRAIN SIZE DISTRIBUTION

Sand and Silt (Till) - OHS No.2

FIGURE B7



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

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	HR-2	5	108.6

Project Number: 09-1111-0019

Checked By: MWK

**Golder Associates**

Date: 27-Mar-14

At Golder Associates we strive to be the most respected global company providing consulting, design, and construction services in earth, environment, and related areas of energy. Employee owned since our formation in 1960, our focus, unique culture and operating environment offer opportunities and the freedom to excel, which attracts the leading specialists in our fields. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees who operate from offices located throughout Africa, Asia, Australasia, Europe, North America, and South America.

Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

[solutions@golder.com](mailto:solutions@golder.com)  
[www.golder.com](http://www.golder.com)

**Golder Associates Ltd.**  
**6925 Century Avenue, Suite #100**  
**Mississauga, Ontario, L5N 7K2**  
**Canada**  
**T: +1 (905) 567 4444**

