



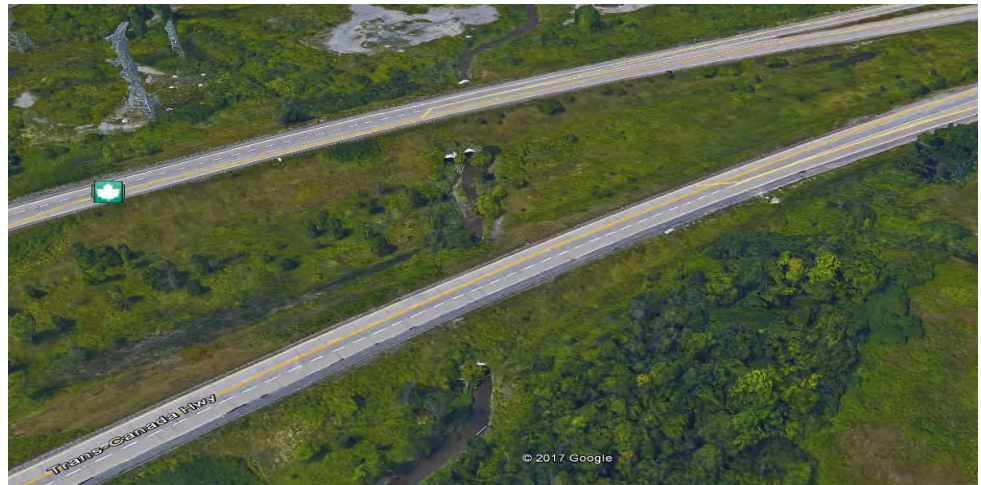
February 2018

## REPORT ON

# Foundation Investigation Green's Creek Culvert Rehabilitation - Temporary Unwatering/Dewatering Site Nos. 3-313/C1 & 3-313/C2 Highway 417 Ottawa, Ontario GWP 4145-10-00

**Submitted to:**

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REPORT



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## **FOUNDATION REPORT GREEN'S CREEK CULVERT - HIGHWAY 417**

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# **PART A**

**FOUNDATION INVESTIGATION REPORT  
GREEN'S CREEK CULVERT REHABILITATION –  
TEMPORARY UNWATERING/DEWATERING  
SITE NOS. 3-313/C1 & 3-313/C2  
HIGHWAY 417  
OTTAWA, ONTARIO  
G.W.P. 4145-10-00**



## 1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by WSP Canada Group Limited (WSP) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations associated with numerous bridge and structural culvert rehabilitations and/or replacements on Highway 417 between the Aviation Parkway and Ramsayville Road as well as the widening of Highway 417 from Ottawa Road 174 to Hunt Club Road in Ottawa, Ontario (Assignment number 4016-E-0008).

This report presents the results of the foundation investigation carried out for the temporary water diversion systems associated with the rehabilitation of the Green's Creek Culvert located beneath the Eastbound Lanes (EBL), Site 3-313/C1 and Westbound Lanes (WBL), Site 3-313/C2, of Highway 417 between the Hunt Club Road and Walkley Road interchanges in Ottawa, Ontario (G.W.P. 4145-10-00 and W.P. 4321-13-01/W.P. 4322-13-01).

The terms of reference and scope of work for the foundation investigation are outlined in the MTO's Request for Proposal (RFP), dated May 2016, and subsequent addenda. Golder's scope of work for foundation engineering services associated with the Green's Creek Culvert under Highway 417 is contained in Table 17.8.3 of WSP's Technical Proposal for this assignment. The work has been carried out in accordance with Golder's Quality Control Plan for foundation engineering services for this project dated March 13, 2017.

## 2.0 SITE DESCRIPTION

### 2.1 General

The Green's Creek culvert (Sites 3-313/C1 and 3-313/C2) is located on Highway 417, about 0.6 km south of the Walkley Road interchange in Ottawa, Ontario. The existing culvert is located at about Stations 17+766 and 17+946 at the EBL and WBL, respectively.

It is understood that the culvert was constructed in 1973 and consists of a twin cell, corrugated structural steel plate pipe arch structure. Each pipe is 5.5 m in diameter, with a 1.5 m spacing between the cells. The north and south cells of the culverts are about 74.5 to 75.1 m in length. The existing culvert inverts are at about Elevation 60.7 m. The culvert is generally in good to fair condition. The flow in the culvert is from east to west.

The existing pavement grades at the culvert location are at about Elevations 72.9 and 72.0 m at the EBL and WBL respectively, of Highway 417. In this area, Highway 417 is a divided highway with three travel lanes in each direction separated by a grass median. The existing embankment slopes at the culvert locations are about 11 to 12 m in height and are sloped at about 2 horizontal to 1 vertical (2H:1V). In addition, gabions have been installed at the inlet and outlet locations of the culvert for erosion protection. Based on visual observation, the existing embankment side slopes and gabions appear to be in fairly good condition with signs of minor erosion as well as torn gabion mesh and washout of the stone at the creek level.

Selected site photographs taken by WSP personnel showing the existing structure and surrounding area are included in Appendix D.



## **2.2 Regional Geological Conditions**

As delineated in *The Physiography of Southern Ontario*<sup>1</sup>, this section of Highway 417 lies on the border of the minor physiographic regions known as the Russell and Prescott Sand Plain and the Ottawa Valley Clay Plain, which lie within the major physiographic region of the Ottawa-St. Lawrence Lowland.

The Ottawa Valley Clay Plain region is characterized by relatively thick deposits of sensitive marine clay, silt and silty clay that were deposited within the Champlain Sea basin. These deposits, known as the Champlain Sea clay or Leda clay, overlie relatively thin, commonly reworked glacial till and glaciofluvial deposits, that in turn overlie bedrock<sup>2</sup>. The Russell and Prescott Sand Plain are generally characterized by a sand mantle about 3 to 5 m thick overlying an extensive deposit of sensitive marine clay deposited within the Champlain Sea basin, underlain by glacial till and shale bedrock.

## **3.0 INVESTIGATION PROCEDURES**

### **3.1 Current Investigation**

The subsurface investigation for the culvert site was carried out between May 30 and June 15, 2017. During that time, a total of 6 boreholes (numbered 17-1401 to 17-1406, inclusive) were advanced at the locations shown on Drawing 1. The boreholes were advanced as follows:

- Boreholes 17-1401 and 17-1402 were advanced near the western end of the culvert at the toe of the embankment for the EBL of Highway 417. The boreholes were advanced to depths of about 9.8 and 10.3 m below the existing ground surface.
- Boreholes 17-1403 and 17-1404 were advanced within the grassed median area near the culvert ends at the east and west toes of EBL and WBL of the Highway 417 embankments, respectively. The boreholes were advanced to depths of about 9.8 and 9.7 m below the existing ground surface.
- Boreholes 17-405 and 17-406 were advanced near the eastern end of the culvert at the toe of the WBL of the Highway 417 embankment. The boreholes were advanced to a depth of about 9.8 m below the existing ground surface.

The boreholes were advanced using portable drilling equipment, supplied and operated by OGS Inc. of Almonte, Ontario.

Soil samples in the boreholes were obtained at vertical intervals of about 0.61 to 1.52 m, using a 50 mm outer diameter split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures. In-situ vane testing, using a "B" -size vane was carried out to measure the undrained shear strength of the cohesive soils encountered at the site. The use of portable drilling equipment restricted the size of the casing, due to which a "B" -size vane was used instead of the "N"-size vane (MTO vane).

<sup>1</sup> Chapman, L. J. and Putnam, D. F., 1984. *The Physiography of Southern Ontario*, Ontario Geological Survey. Special Volume 2, Third Edition. Accompanied by Map P.2715, Scale 1:600,000. Ontario Ministry of Natural Resources.

<sup>2</sup> Belanger, J.R. "Urban Geology of Canada's National Capital Area", in *Urban Geology of Canadian Cities*, Geological Association of Canada Special Paper 42, Ed. P.F. Karrow and O.L. White, 1998.



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A standpipe piezometer was installed in Borehole 17-1401 to monitor the groundwater level at the site. The standpipe consists of a 32 mm diameter rigid PVC pipe with a 1.5 m long slotted screen section, installed within silica sand backfill and sealed by a section of bentonite pellet backfill. The water level in the standpipe piezometer was measured on June 15, 2017. The water levels in the open boreholes were also observed during drilling.

The boreholes were backfilled with bentonite mixed with soil cuttings except for the standpipe piezometer. The site conditions were restored following completion of the field work.

The field work was supervised by a member of Golder's technical staff, who located the boreholes, supervised 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 Golder's laboratory in Ottawa for further examination. Index and classification tests consisting of grain size distribution, Atterberg Limit testing, and water content testing were carried out on selected soil samples. The laboratory tests were carried out to MTO and/or ASTM standards as appropriate.

Three soil samples from Boreholes 17-1401, 17-1402, and 17-1406 were submitted to Eurofins Environment Testing for chemical analysis related to potential corrosion of exposed buried steel and potential sulphate attack on buried concrete elements (corrosion and sulphate attack).

The borehole locations and elevations were surveyed by Golder using a Trimble R8 GPS unit. The borehole location in MTM NAD83 (Zone 9) northing and easting coordinates, ground surface elevation referenced to geodetic datum and drilled depth are summarized in the following table and are shown on Drawing 1.

Borehole Number	MTM NAD83 (Zone 9) Northing (m)	MTM NAD83 (Zone 9) Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
17-1401	5028526.2	375777.9	65.1	9.8
17-1402	5028497.7	375775.9	65.3	10.3
17-1403	5028474.9	375849.3	64.1	9.8
17-1404	5028487.2	375893.9	65.3	9.7
17-1405	5028466.0	375959.4	65.7	9.8
17-1406	5028434.1	375964.7	65.6	9.8

### 3.2 Previous Investigation

A previous investigation was carried out in 1972 by MTO (then the Department of Transportation and Communications Ontario) for the existing culvert. The results of that investigation are contained in the report titled *"Foundation Investigation Report for Proposed Structures at the Crossings of Hwy. # 417 (E.B.L and W.B.L) and the Green's Creek Diversion, Regional Municipality of Ottawa-Carleton, District No. 9 (Ottawa) W.O. 72-11092, W.P.'s 10-69-14 (E.B.L) & 10-69-15 (W.B.L)", dated September 26, 1972 (Geocres 31G5-89).*

As part of the current assignment, previously collected subsurface information pertinent to the site was reviewed and compiled.





Four boreholes were put down at the site as part of the original investigation in 1972 along the proposed culvert alignment, the approximate locations of which 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 from the 1972 investigation are given on the Record of Borehole sheets provided in Appendix C.

## **4.0 SITE GEOLOGY AND STRATIGRAPHY**

### **4.1 Site Stratigraphy**

The subsurface soil and groundwater conditions encountered in the boreholes and the results of in-situ and laboratory testing from the current investigation are given on the Record of Borehole sheets presented in Appendix A. The results of geotechnical laboratory testing from the current investigation are also presented on Figures B1 to B5 contained in Appendix B. The Record of Borehole sheets from the previous investigation at the site (Geocres 31G5-89) are provided for reference in Appendix C. The results of chemical testing carried out on samples of soil from Boreholes 17-1401, 17-1402, and 17-1406 are included in Appendix E.

The borehole locations from the current and previous investigations are shown on Drawing 1. The interpreted stratigraphic profiles projected in the areas of the proposed temporary water diversion systems are also shown on Drawing 1. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic sections are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

In general, the subsurface conditions at the site consist of topsoil and embankment fill overlying a deposit of silty clay underlain by glacial till, followed by shale bedrock. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections. It should be noted, that the boreholes from the original 1972 investigation were advanced prior to the culvert construction and therefore the ground conditions shown on the Record of Boreholes may not be fully representative of the post-construction subsurface conditions.

### **4.2 Topsoil and Embankment Fill**

Topsoil fill exists at ground surface at the borehole locations from the current investigation and ranges in thickness from about 100 to 500 mm.

The topsoil fill is underlain by embankment fill, which was fully penetrated to depths of about 0.6 to 4.9 m below the existing ground surface (i.e., Elevations 65.1 to 60.5 m). The fill varies in thickness from about 0.4 to 4.4 m.

The embankment fill consists of interlayered cohesive and non-cohesive deposits consisting of varying compositions of gravel, sand, silt and clay. Organic matter and wood was also encountered within the embankment fill at some locations.

Standard Penetration Test (SPT) 'N' values obtained in the fill ranged from 1 to 33 blows per 0.3 m of penetration, indicating a very loose to dense compactness for non-cohesive soils and stiff consistency for cohesive soils.

The results of grain size distribution testing carried out on several samples of the embankment fill are provided on Figure B1 in Appendix B. The measured water contents of samples of the embankment fill range from approximately 4 to 37 percent.





### **4.3 Silty Clay to Clay**

The embankment fill encountered in the boreholes from the current investigation is underlain by a deposit of sensitive silty clay to clay. The clayey deposit was fully penetrated to depths between about 6.7 and 8.8 m (i.e., between Elevations 56.4 and 57.8 m) and varies in thickness from about 3.0 to 7.6 m, and is thickest at the eastern toe of the WBL of the Highway 417 embankment (i.e., at Boreholes 17-1405 and 17-1406).

At the location of previous Boreholes 1, 3, 4, and 6 from the 1972 investigation, the silty clay deposit was encountered at ground surface and fully penetrated to depths between 5.8 and 8.8 m (i.e., between Elevations 57.3 and 58.4 m).

The upper 1.8 to 2.8 m of the clayey deposit at Boreholes 17-1403 to 17-1406, inclusive, as well as previous Boreholes 1, 3, 4, and 6 has been weathered to form a grey brown crust. Standard penetration tests carried out within the weathered crust gave 'N' values generally ranging from 2 to 16 blows per 0.3 m of penetration. Exception to this was the 'N' value of 22, which was recorded at borehole 17-1406. In-situ shear vane testing carried out within the weathered deposit measured undrained shear strengths ranging from about 75 kPa to greater than 96 kPa. The results of the in-situ testing and 'N' values in the deposit, indicate a generally stiff to very stiff consistency.

The results of Atterberg limit testing carried out on four samples of the weathered silty clay to clay from the current investigation are summarized on Figure B2 in Appendix B and indicate plasticity index values generally ranging from about 31 to 35 percent and liquid limit values ranging from about 49 to 51 percent, indicating a soil of intermediate to high plasticity. The measured water content of the weathered deposit ranges from approximately 31 to 55 percent.

The clayey deposit below the depth of weathering at Boreholes 17-1403 to 17-1406, inclusive and previous Boreholes 1, 3, 4 and 6, as well as below the embankment fill at Boreholes 17-1401 and 17-1402 is grey in color. This unweathered silty clay to clay is about 3.0 to 6.6 m in thickness. Standard penetration tests carried out within the unweathered portion of the deposit gave 'N' values generally ranging from weight of hammer to 8 blows per 0.3 m of penetration. Exception to this was the 'N' value of 10, which was recorded at borehole 17-1404. In-situ shear vane testing carried out where possible within this deposit measured undrained shear strengths of 12 to 91 kPa, but more typically in the range of 29 to 54 kPa. The results of the in-situ testing indicate a soft to stiff consistency of the silty clay to clay deposit, but more typically a firm to stiff consistency based on the shear vane testing. Two lower shear strength values, 17 and 12 kPa, were measured at boreholes 17-1403 and 17-1404, respectively, which were advanced within the grassed median of Highway 417.

The results of Atterberg limit testing carried out on samples of the unweathered silty clay to clay from the current investigation are shown on Figure B3 in Appendix B and indicate plasticity index typically ranging from about 31 to 37 percent and liquid limit values ranging from 51 to 59 percent indicating a clay of typically high plasticity. However, the results of Atterberg limit testing on one sample of the deposit from Borehole 17-1402 gave a lower plasticity index value of about 15 percent and a liquid limit value of about 32 percent, indicating a silty clay of low plasticity. The measured water contents of the unweathered portion of the deposit range from about 41 to 62 percent.



#### **4.4 Sandy Clayey Silt**

The clayey deposit at Borehole 17-1404 is underlain by a layer of sandy clayey silt, with trace to some gravel. This deposit was proven to a depth of 9.7 m below the existing ground surface (i.e., Elevation 55.5 m). A standard penetration test 'N' value of 7 blows for 0.3 m of penetration was measured in this deposit, indicating a very stiff consistency.

The results of one Atterberg limit test carried out on a sample of the deposit are shown on Figure B4 in Appendix B and indicate a plasticity index value of about 7 percent and liquid limit value of about 18 percent indicating a clayey silt of low plasticity.

The results of grain size distribution testing carried out on one sample of this deposit are provided on Figure B5 in Appendix B.

#### **4.5 Sand and Silt to Silty Sand Till**

A deposit of glacial till was encountered below the silty clay and sandy clayey silt deposits (where encountered). The till consists of a heterogeneous mixture of gravel, cobbles, and boulders in a matrix of sand and silt to silty sand, with trace to some clay. The till was proven to depths of about 9.3 to 13.3 m below the existing ground surface (i.e., between Elevations 52.9 to 55.9 m).

Standard penetration test 'N' values of weight of hammer to 29 blows per 0.3 m of penetration were typically measured in the till, indicating a very loose to compact compactness. One higher 'N' value of 120 was measured in Borehole 17-1403, however this value likely reflects the presence of cobbles and boulders in the deposit, rather than the compactness of the soil matrix.

The measured water contents of samples of till from the current investigation range from about 7 to 20 percent. The results of grain size distribution testing carried out on samples of the deposit from the current investigation are provided on Figure B6 in Appendix B. These samples were retrieved using a 50 mm diameter sampler and therefore the results do not reflect the larger gravel, cobble and boulder content of the deposit.

#### **4.6 Refusal and Bedrock**

Sampler refusal was encountered at Borehole 17-1402 at a depth of about 10.3 m below the existing ground surface (i.e., Elevation 55.1 m). This refusal likely reflects the presence of cobbles and boulder in the till deposit.

Bedrock was encountered beneath the till at previous Boreholes 1, 3, 4, and 6, at depth between about 9.3 and 13.3 m below the existing ground surface (i.e., between Elevations 52.9 to 55.0 m). The bedrock was cored for depths between about where it was cored for depths between about 1.4 and 1.7 m. The following table summarizes the bedrock surface depths and elevations as encountered at the previous borehole locations.

<b>Borehole Number</b>	<b>Existing Ground Surface Elevation (m)</b>	<b>Depth to Bedrock (m)</b>	<b>Bedrock Surface Elevation (m)</b>
1	63.6	10.7	52.9
3	66.4	13.3	53.1
4	63.1	9.3	53.8
6	65.4	10.4	55.0

The bedrock encountered in the previous boreholes is described as sound grey shale bedrock.



## FOUNDATION REPORT GREEN'S CREEK CULVERT - HIGHWAY 417

### 4.7 Groundwater Conditions

The groundwater conditions observed in the open boreholes during drilling at Boreholes 17-1402 to 17-1406, inclusive, were between about Elevations 61.0 and 65.7 m.

The groundwater level in the piezometer in Borehole 17-1401 was measured on June 15, 2017, as summarized in the table below.

Borehole Number	Ground Surface Elevation (m)	Water Level Depth (m)	Water Level Elevation (m)	Date
17-1401	65.1	3.0	62.1	June 15, 2017

The groundwater levels measured within the open boreholes during the 1972 investigation indicated groundwater levels which ranged from about Elevation 61.2 to 64.8 m at the time of the investigation. In addition, the water levels in the creek were observed at about Elevations 62.6 and 62.5 m in the area of the proposed EBL and WBL culverts, respectively, on December 16, 1971, as shown on General Layout drawings from the original culvert investigation (i.e., Drawing Nos. 3-313A-1 and 3-313B-1).

It should be noted that groundwater levels in the area are subject to fluctuations both seasonally and with precipitation events. In addition, the groundwater levels from the 1972 investigation may not be representative of the current site conditions.

### 5.0 CLOSURE

This Foundation Investigation Report was prepared by Ms. Susan Trickey, P.Eng. and was reviewed by Mr. Michael Snow, P.Eng., a Principal and senior geotechnical engineer with Golder. Mr. Fin Heffernan, P.Eng., Golder's Designated MTO Foundations Contact for this project, conducted an independent quality review of the report.

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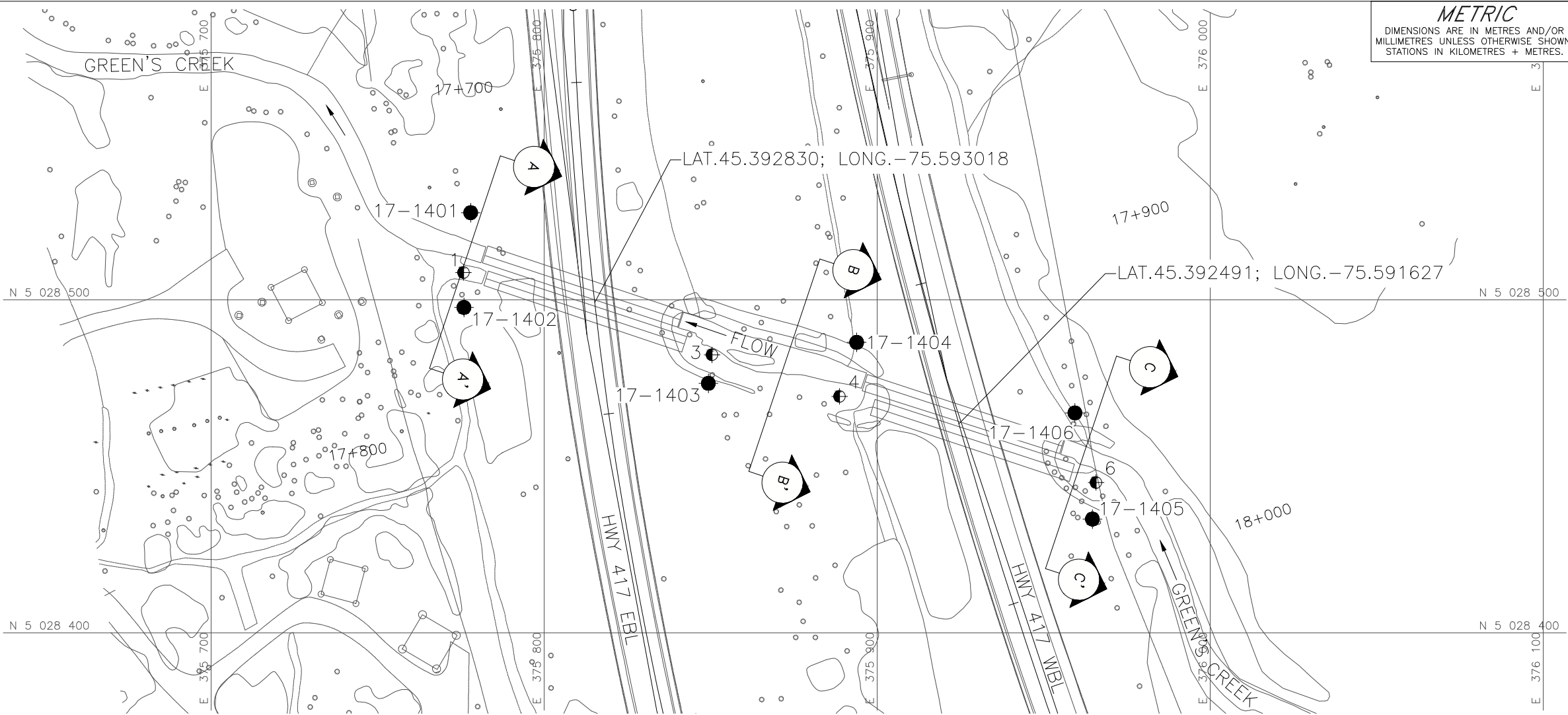


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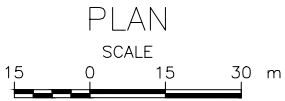


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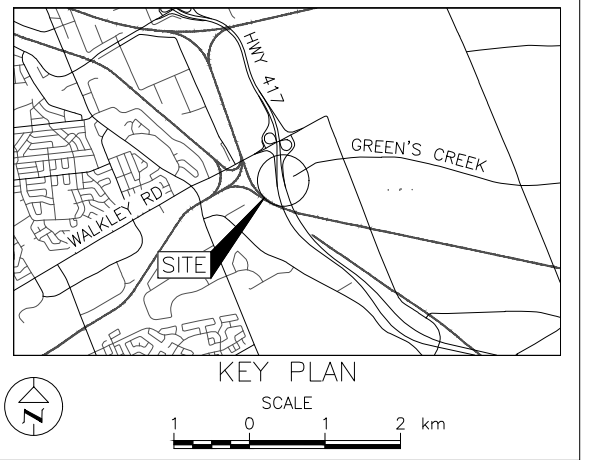
**REFERENCE**  
Base plans provided in digital format by WSP, drawing file nos. XA1-NAD 83.dwg and XB1-NAD 83 (CSRS).dwg, received APR. 19, 2017.



CONT No.  
GWP No. 4145-10-00

GREEN'S CREEK CULVERT  
SITES 3-313/C1 AND 3-313/C2  
HIGHWAY 417  
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

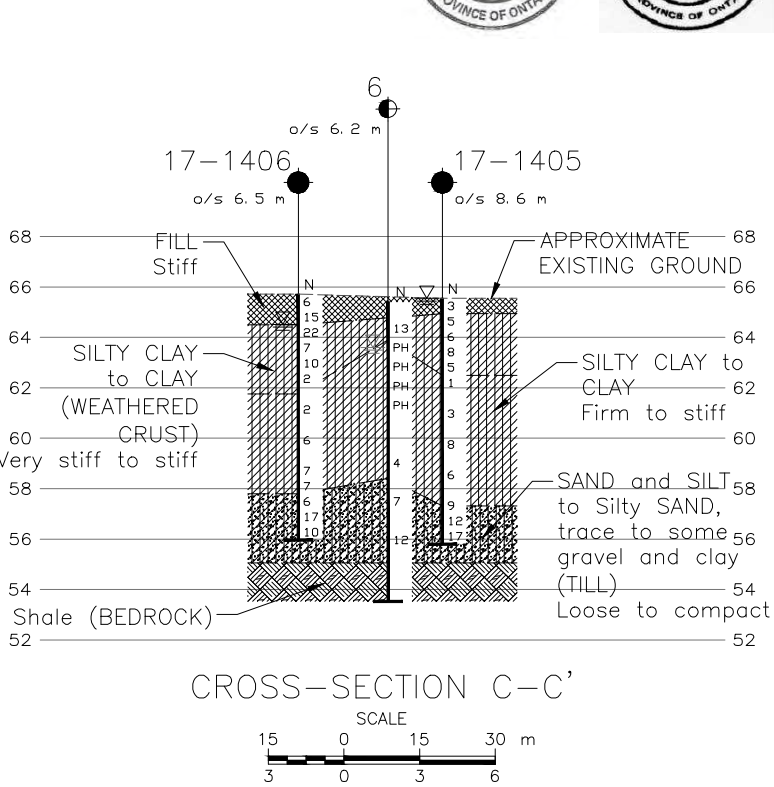
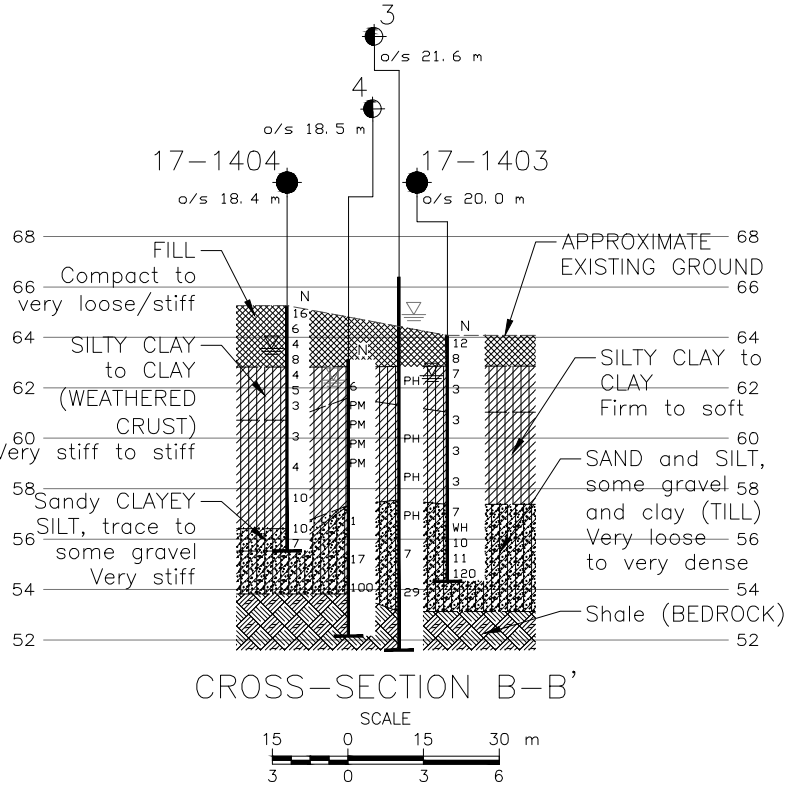
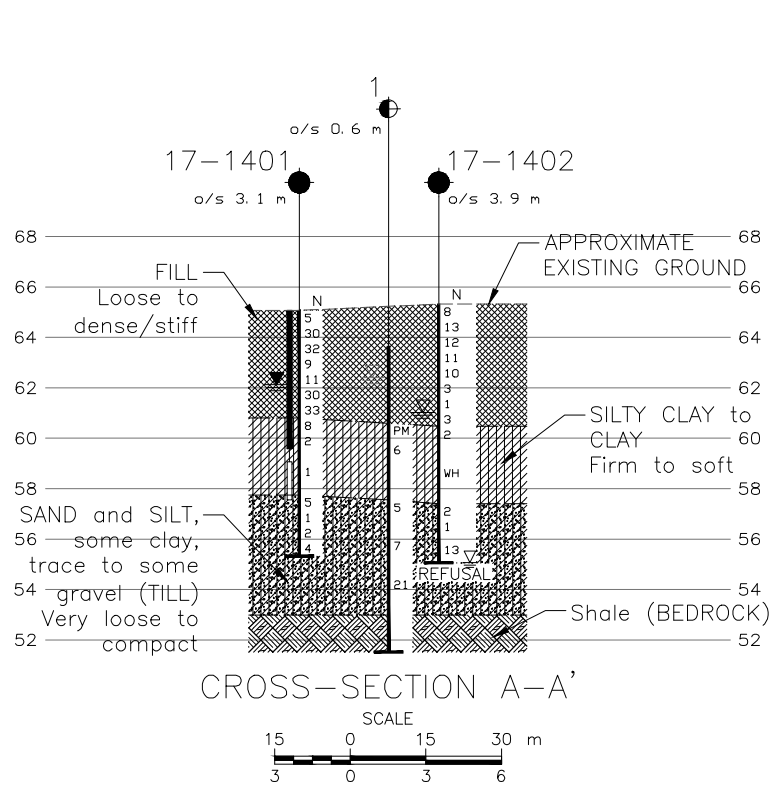


LEGEND

- Borehole — Current Investigation
- Borehole — Previous Investigation (Geocres No. 31G5-89)
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL in piezometer, measured on JUN. 22, 2017
- WL in open borehole, during drilling
- WL in open borehole, measured at time of 1972 investigation

BOREHOLE CO-ORDINATES (MTM ZONE 9)			
No.	ELEVATION	NORTHING	EASTING
17-1401	65.1	5028526.2	375777.9
17-1402	65.3	5028497.7	375775.9
17-1403	64.1	5028474.9	375849.3
17-1404	65.3	5028487.2	375893.9
17-1405	65.7	5028466.0	375959.4
17-1406	65.6	5028434.1	375964.7
1	63.6	5028508.2	375775.8
3	66.4	5028483.4	375850.4
4	63.1	5028471.0	375888.7
6	65.4	5028445.1	375965.8

**NOTES**  
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.  
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.



NO.	DATE	BY	REVISION
Geocres No. 31G5-286			
HWY. 417	PROJECT NO. 1662565		DIST. EASTERN
SUBM'D. SAT	CHKD. SAT	DATE: 2/22/2018	SITE:
DRAWN: JM	CHKD. FJH	APPD. FJH	DWG. 1



# **APPENDIX A**

## **Borehole Records, Current Investigation**

**Lists of Abbreviations and Symbols**

**Records of Boreholes 17-1401 to 17-1406**





## 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.

### III. SOIL DESCRIPTION

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

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

#### (b) Cohesive Soils Consistency

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

### IV. SOIL TESTS

w	water content
$w_p$	plastic limit
$w_l$	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test <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 <sub>4</sub>	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.

### V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand





## LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

### WEATHERINGS STATE

**Fresh:** no visible sign of weathering

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

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

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

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

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

### BEDDING THICKNESS

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

### JOINT OR FOLIATION SPACING

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

### GRAIN SIZE

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

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

### CORE CONDITION

#### Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

#### Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

#### Rock Quality Designation (RQD)

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

### DISCONTINUITY DATA

#### Fracture Index

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

#### Dip with Respect to Core Axis

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





#### Description and Notes

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

#### Abbreviations

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

<b>PROJECT</b> 1662565-1140		<b>RECORD OF BOREHOLE No 17-1401</b>		SHEET 1 OF 2		<b>METRIC</b>	
<b>G.W.P.</b> 4145-10-00		<b>LOCATION</b> N 5028526.2; E 375777.9 MTM ZONE 9 (LAT. 45.393077; LONG. -75.593490)		<b>ORIGINATED BY</b> KM			
<b>DIST</b> Eastern HWY 417		<b>BOREHOLE TYPE</b> Portable Drill, Open Hole/Wash Boring		<b>COMPILED BY</b> JM			
<b>DATUM</b> Geodetic		<b>DATE</b> June 8-13, 2017		<b>CHECKED BY</b> SAT			

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 (%)		
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × REMOULDED			$w_p$			$w$	$w_L$	
65.1	GROUND SURFACE							20	40	60	80	100	25	50	75		
-0.0	(SM) Silty sand (FILL/TOPSOIL)		1	SS	5												
0.1	Dark brown Moist (SP/GP) Sand and gravel, some silt, trace clay (FILL) Loose to dense Grey Moist		2	SS	30												44 36 15 5
			3	SS	32												
63.2	(CI/CH-ML) Silty clay to clayey silt, some sand (FILL) Stiff Brown Moist		4	SS	9												
62.6	(ML) Sandy clayey silt, some gravel (FILL) Compact to dense Brown Moist		5	SS	11												
			6	SS	30												14 24 34 28
61.4	(GP) Sandy gravel (FILL) Dense Brown Wet		7	SS	33												
60.8	(CL/CH) SILTY CLAY to CLAY Firm Grey Wet		8	SS	8												
			9	SS	2												
			10	SS	1												
57.8	(SP/ML) SAND and SILT, some clay, trace to some gravel, contains cobbles and boulders (TILL) Loose to very loose Dark grey Wet		11	SS	5												
			12	SS	1												11 34 39 16
			13	SS	2												
			14	SS	4												
55.3																	
9.8																	

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





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PROJECT <u>1662565-1140</u>		<b>RECORD OF BOREHOLE No 17-1401</b>		SHEET 2 OF 2		<b>METRIC</b>	
G.W.P. <u>4145-10-00</u>		LOCATION <u>N 5028526.2; E 375777.9 MTM ZONE 9 (LAT. 45.393077; LONG. -75.593490)</u>		ORIGINATED BY <u>KM</u>			
DIST <u>Eastern</u> HWY <u>417</u>		BOREHOLE TYPE <u>Portable Drill, Open Hole/Wash Boring</u>		COMPILED BY <u>JM</u>			
DATUM <u>Geodetic</u>		DATE <u>June 8-13, 2017</u>		CHECKED BY <u>SAT</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W <sub>p</sub>	W	W <sub>L</sub>		GR	SA	SI	CL
					○ UNCONFINED                      + FIELD VANE ● QUICK TRIAXIAL                  × REMOULDED					WATER CONTENT (%)										
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100	25	50	75					
	END OF BOREHOLE																			
	NOTES:  1. Water level in well screen at a depth of 3.0 m below ground surface (Elev. 62.1 m), measured on June 15, 2017.																			

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PROJECT 1662565-1140		<b>RECORD OF BOREHOLE No 17-1402</b>		SHEET 1 OF 2		<b>METRIC</b>	
G.W.P. 4145-10-00		LOCATION N 5028497.7; E 375775.9 MTM ZONE 9 (LAT. 45.392821; LONG. -75.593519)		ORIGINATED BY DG			
DIST Eastern HWY 417		BOREHOLE TYPE Wash Boring		COMPILED BY JM			
DATUM Geodetic		DATE June 13-15, 2017		CHECKED BY SAT			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL
								20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>					
65.3	GROUND SURFACE																			
0.0	(SM) Silty sand (FILL/TOPSOIL) Dark brown Moist		1	SS	8															
64.9	(CL/CI) Sandy silty clay (FILL) Stiff Brown Moist		2	SS	13															
0.5			3	SS	12															
			4	SS	11															
62.9	(SP/CL/ML) Sand, silty clay, and clayey silt (FILL) Compact to very loose Brown Wet		5	SS	10															
2.4			6	SS	3															
			7	SS	1															
			8	SS	3															
60.5	(CL/CH) SILTY CLAY to CLAY Firm to soft Grey with black mottling Wet		9	SS	2															
4.9																				
			10	SS	WH															
57.4	(SP/ML) SAND and SILT, some clay, trace to some gravel, contains cobbles and boulders (TILL) Very loose to compact Dark grey Wet		11	SS	2															
7.9			12	SS	1															
			13	SS	13															

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

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PROJECT 1662565-1140		<b>RECORD OF BOREHOLE No 17-1402</b>				SHEET 2 OF 2		<b>METRIC</b>								
G.W.P. 4145-10-00		LOCATION N 5028497.7; E 375775.9 MTM ZONE 9 (LAT. 45.392821; LONG. -75.593519)				ORIGINATED BY DG										
DIST Eastern HWY 417		BOREHOLE TYPE Wash Boring				COMPILED BY JM										
DATUM Geodetic		DATE June 13-15, 2017				CHECKED BY SAT										
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			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 (%)			
	--- CONTINUED FROM PREVIOUS PAGE ---															
55.1 10.3	END OF BOREHOLE SAMPLER REFUSAL  NOTES:  1. Water level in open borehole at 4.3 m (Elev. 61.0 m), measured during drilling.															

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PROJECT 1662565-1140		RECORD OF BOREHOLE No 17-1403		SHEET 1 OF 2		METRIC	
G.W.P. 4145-10-00		LOCATION N 5028474.9; E 375849.3 MTM ZONE 9 (LAT. 45.392609; LONG. -75.592585)		ORIGINATED BY		KM	
DIST Eastern HWY 417		BOREHOLE TYPE Portable Drill, Open Hole		COMPILED BY		JM	
DATUM Geodetic		DATE June 1-2, 2017		CHECKED BY		SAT	

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

PROJECT <u>1662565-1140</u>		<b>RECORD OF BOREHOLE No 17-1403</b>		SHEET 2 OF 2		<b>METRIC</b>	
G.W.P. <u>4145-10-00</u>		LOCATION <u>N 5028474.9; E 375849.3 MTM ZONE 9 (LAT. 45.392609; LONG. -75.592585)</u>		ORIGINATED BY <u>KM</u>			
DIST <u>Eastern</u> HWY <u>417</u>		BOREHOLE TYPE <u>Portable Drill, Open Hole</u>		COMPILED BY <u>JM</u>			
DATUM <u>Geodetic</u>		DATE <u>June 1-2, 2017</u>		CHECKED BY <u>SAT</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W <sub>p</sub>	W	W <sub>L</sub>		GR	SA	SI	CL	
								○ UNCONFINED	+	FIELD VANE	● QUICK TRIAXIAL	×	REMOULDED	WATER CONTENT (%)							
	--- CONTINUED FROM PREVIOUS PAGE ---						20	40	60	80	100				25	50	75				
	END OF BOREHOLE																				
	NOTES:  1. Water level in open borehole at 1.6 m (Elev. 62.5 m), measured during drilling.																				



PROJECT <u>1662565-1140</u>		<b>RECORD OF BOREHOLE No 17-1404</b>		SHEET 1 OF 2		<b>METRIC</b>	
G.W.P. <u>4145-10-00</u>		LOCATION <u>N 5028487.2; E 375893.9 MTM ZONE 9 (LAT. 45.392715; LONG. -75.592015)</u>		ORIGINATED BY <u>KM</u>			
DIST <u>Eastern</u> HWY <u>417</u>		BOREHOLE TYPE <u>Portable Drill, Open Hole</u>		COMPILED BY <u>JM</u>			
DATUM <u>Geodetic</u>		DATE <u>May 30-31, 2017</u>		CHECKED BY <u>SAT</u>			

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

PROJECT <u>1662565-1140</u>		<b>RECORD OF BOREHOLE No 17-1404</b>		SHEET 2 OF 2		<b>METRIC</b>	
G.W.P. <u>4145-10-00</u>		LOCATION <u>N 5028487.2; E 375893.9 MTM ZONE 9 (LAT. 45.392715; LONG. -75.592015)</u>		ORIGINATED BY <u>KM</u>			
DIST <u>Eastern</u> HWY <u>417</u>		BOREHOLE TYPE <u>Portable Drill, Open Hole</u>		COMPILED BY <u>JM</u>			
DATUM <u>Geodetic</u>		DATE <u>May 30-31, 2017</u>		CHECKED BY <u>SAT</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL MOISTURE   LIQUID CONTENT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W <sub>p</sub>	W	W <sub>L</sub>		GR	SA	SI	CL
								○ UNCONFINED   + FIELD VANE ● QUICK TRIAXIAL   × REMOULDED					WATER CONTENT (%)							
	--- CONTINUED FROM PREVIOUS PAGE ---  END OF BOREHOLE  NOTES:  1. Water level in open borehole at 1.7 m (Elev. 63.6 m), measured during drilling.							20	40	60	80	100		25	50	75				

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<b>PROJECT</b> 1662565-1140		<b>RECORD OF BOREHOLE No 17-1405</b>		SHEET 1 OF 2		<b>METRIC</b>	
<b>G.W.P.</b> 4145-10-00		<b>LOCATION</b> N 5028466.0; E 375959.4 MTM ZONE 9 (LAT. 45.392518; LONG. -75.591181)		<b>ORIGINATED BY</b> KM			
<b>DIST</b> Eastern HWY 417		<b>BOREHOLE TYPE</b> Portable Drill, Open Hole		<b>COMPILED BY</b> JM			
<b>DATUM</b> Geodetic		<b>DATE</b> June 4-5, 2017		<b>CHECKED BY</b> SAT			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL	
								20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>						
65.7	GROUND SURFACE																				
0.0	(ML) Sandy silt (FILL/TOPSOIL)																				
65.5	Dark brown																				
0.2	Wet		1	SS	3																
65.1	(Cl) Silty clay, some sand, trace gravel, contains wood (FILL)																				
0.6	Stiff																				
	Brown		2	SS	5																
	Wet																				
	(Cl/CH) SILTY CLAY to CLAY																				
	(WEATHERED CRUST)																				
	Very stiff to stiff																				
	Grey-brown		3	SS	6																
	Wet																				
			4	SS	8																
			5	SS	5																
62.7	(CL/CH) SILTY CLAY to CLAY																				
3.1	Firm to stiff		6	SS	1																
	Grey																				
	Wet																				
			7	SS	3																
			8	SS	8																
			9	SS	6																
			10	SS	9																
57.5	(SM) Silty SAND, some gravel, trace to some clay, contains cobbles and boulders (TILL)																				
8.2	Loose to compact																				
	Dark grey																				
	Wet		11	SS	12																
			12	SS	17																
56.0																					
9.8																					

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

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PROJECT 1662565-1140		<b>RECORD OF BOREHOLE No 17-1405</b>				SHEET 2 OF 2		<b>METRIC</b>												
G.W.P. 4145-10-00		LOCATION N 5028466.0; E 375959.4 MTM ZONE 9 (LAT. 45.392518; LONG. -75.591181)				ORIGINATED BY KM														
DIST Eastern HWY 417		BOREHOLE TYPE Portable Drill, Open Hole				COMPILED BY JM														
DATUM Geodetic		DATE June 4-5, 2017				CHECKED BY SAT														
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 $\gamma$ 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												
	--- CONTINUED FROM PREVIOUS PAGE ---						<div style="display: flex; justify-content: space-between;"> <span>20 40 60 80 100</span> <span>20 40 60 80 100</span> </div> <div style="display: flex; justify-content: space-between;"> <span>○ UNCONFINED</span> <span>+ FIELD VANE</span> </div> <div style="display: flex; justify-content: space-between;"> <span>● QUICK TRIAXIAL</span> <span>× REMOULDED</span> </div>					<div style="display: flex; justify-content: space-between;"> <span>25 50 75</span> </div>								
	END OF BOREHOLE  NOTES:  1. Water level at ground surface (Elev. 65.7 m), measured during drilling.																			

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMITOHWY417REHAB&amp;WIDENING\02\_DATA\GINT\1662565.GPJ GAL-GTA.GDT 2/22/18 ZS

PROJECT		1662565-1140		<b>RECORD OF BOREHOLE No 17-1406</b>		SHEET 1 OF 2		<b>METRIC</b>					
G.W.P.		4145-10-00		LOCATION		N 5028434.1; E 375964.7 MTM ZONE 9 (LAT. 45.392230; LONG. -75.591118)		ORIGINATED BY					
DIST		Eastern HWY 417		BOREHOLE TYPE		Portable Drill, Open Hole		COMPILED BY					
DATUM		Geodetic		DATE		June 7-8, 2017		CHECKED BY					
								SAT					
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT $\gamma$	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W <sub>p</sub> W W <sub>L</sub>	25 50 75		
65.6	GROUND SURFACE												
0.0	(ML) Sandy silt (FILL/TOPSOIL)												
65.4	Dark brown												
0.2	Moist		1	SS	6								
	(CL) Silty clay, some sand, trace gravel, contains organic matter (FILL)		2	SS	15								
64.4	Stiff Brown Moist												
1.2	(CI/CH) SILTY CLAY to CLAY (WEATHERED CRUST)		3	SS	22								
	Very stiff to stiff Grey-brown Moist to wet		4	SS	7								
			5	SS	10								
			6	SS	2								
61.6	(CL/CH) SILTY CLAY to CLAY												
4.0	Firm to stiff Grey Wet		7	SS	2								
			8	SS	6								
			9	SS	7								
			10	SS	7								
57.7	(SP/ML) SAND and SILT, some clay, trace to some gravel, contains cobbles and boulders (TILL)		11	SS	6								
7.9	Loose to compact Dark grey Wet		12	SS	17								
			13	SS	10								
55.9													
9.8													

Continued Next Page

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

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IM\MTD\HWY417\REHAB&amp;WIDENING\02\_DATA\GINT\1662565.GPJ GAL-GTA.GDT 2/22/18 ZS

PROJECT 1662565-1140		<b>RECORD OF BOREHOLE No 17-1406</b>				SHEET 2 OF 2		<b>METRIC</b>												
G.W.P. 4145-10-00		LOCATION N 5028434.1; E 375964.7 MTM ZONE 9 (LAT. 45.392230; LONG. -75.591118)				ORIGINATED BY KM														
DIST Eastern HWY 417		BOREHOLE TYPE Portable Drill, Open Hole				COMPILED BY JM														
DATUM Geodetic		DATE June 7-8, 2017				CHECKED BY SAT														
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 $\gamma$ 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												
	--- CONTINUED FROM PREVIOUS PAGE ---						<div style="display: flex; justify-content: space-between;"> <span>20 40 60 80 100</span> <span>20 40 60 80 100</span> </div> <div style="display: flex; justify-content: space-between;"> <span>○ UNCONFINED</span> <span>+ FIELD VANE</span> </div> <div style="display: flex; justify-content: space-between;"> <span>● QUICK TRIAXIAL</span> <span>× REMOULDED</span> </div>					<div style="display: flex; justify-content: space-between;"> <span>25 50 75</span> </div>								
	END OF BOREHOLE  NOTES:  1. Water level in open borehole at 1.2 m (Elev. 64.4 m), measured during drilling.																			

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMTO\HWY417\REHAB&amp;WIDENING\02\_DATA\GINT\1662565.GPJ GAL-GTA.GDT 2/22/18 ZS



## **APPENDIX B**

### **Laboratory Test Results, Current Investigation**

**Figure B1 - Grain Size Distribution – Embankment Fill**

**Figure B2 - Plasticity Chart – Weathered Silty Clay to Clay**

**Figure B3 - Plasticity Chart – Unweathered Silty Clay to Clay**

**Figure B4 - Plasticity Chart – Sandy Clayey Silt, trace to some gravel**

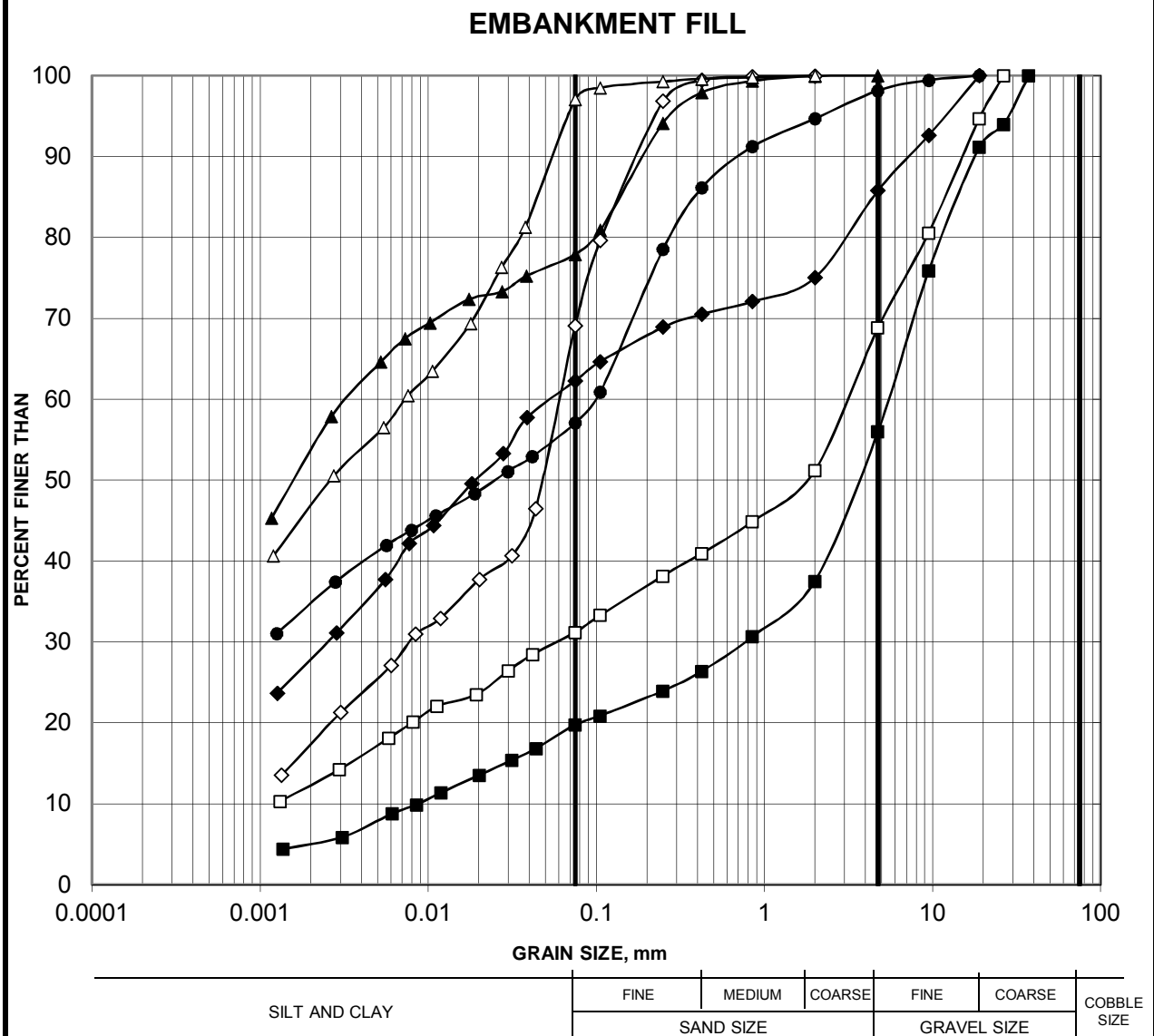
**Figure B5 - Grain Size Distribution – Sandy Clayey Silt, trace to some gravel**

**Figure B6 - Grain Size Distribution – Sand and Silt to Silty Sand Till**

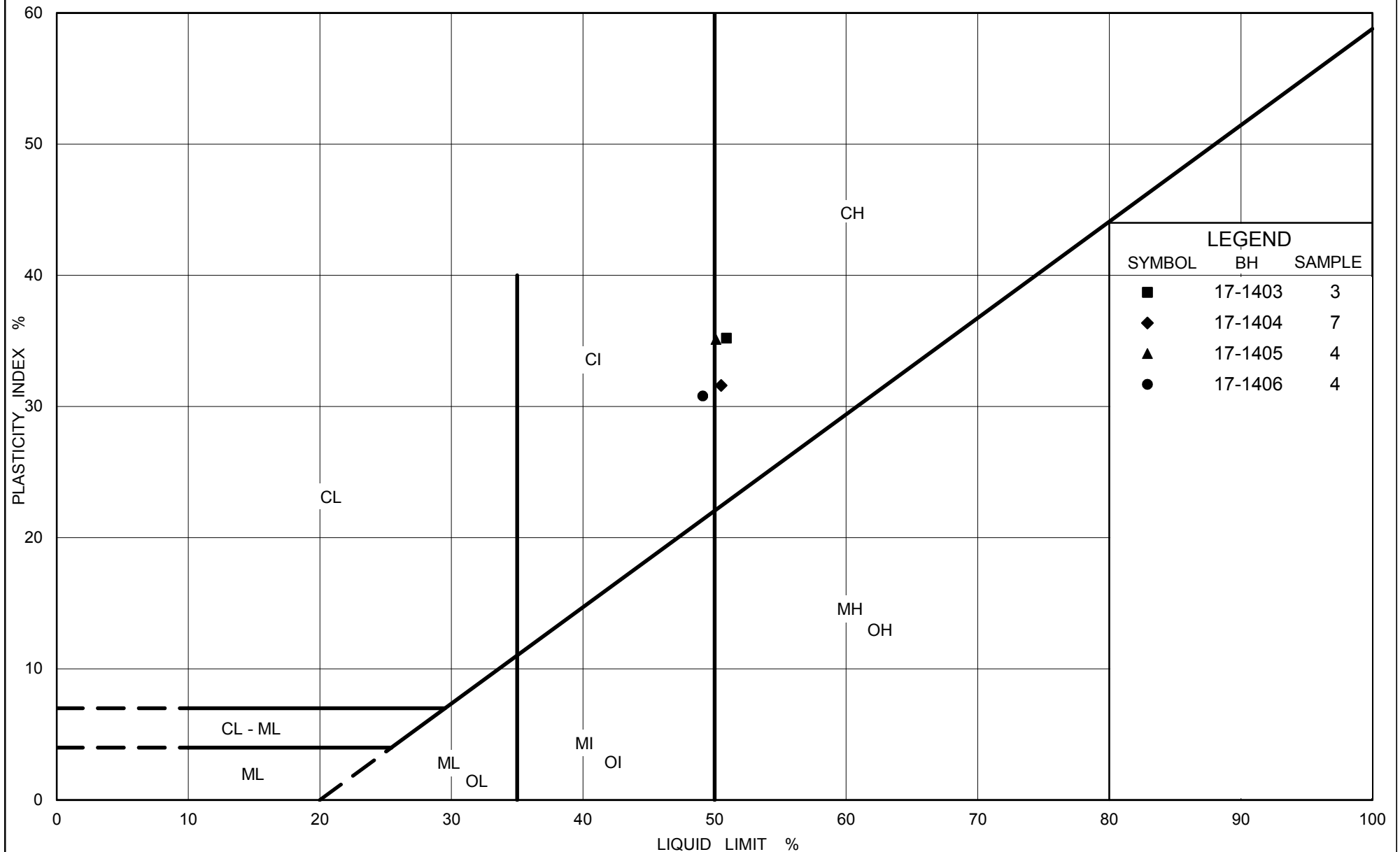


# GRAIN SIZE DISTRIBUTION

FIGURE B1



Borehole	Sample	Depth (m)
■ 17-1401	2	0.61-1.22
◆ 17-1401	6	3.05-3.66
▲ 17-1402	3	1.22-1.83
● 17-1402	5	2.44-3.05
□ 17-1403	1	0.00-0.61
◇ 17-1404	3	1.22-1.83
△ 17-1406	2	0.61-1.22



Ministry of Transportation

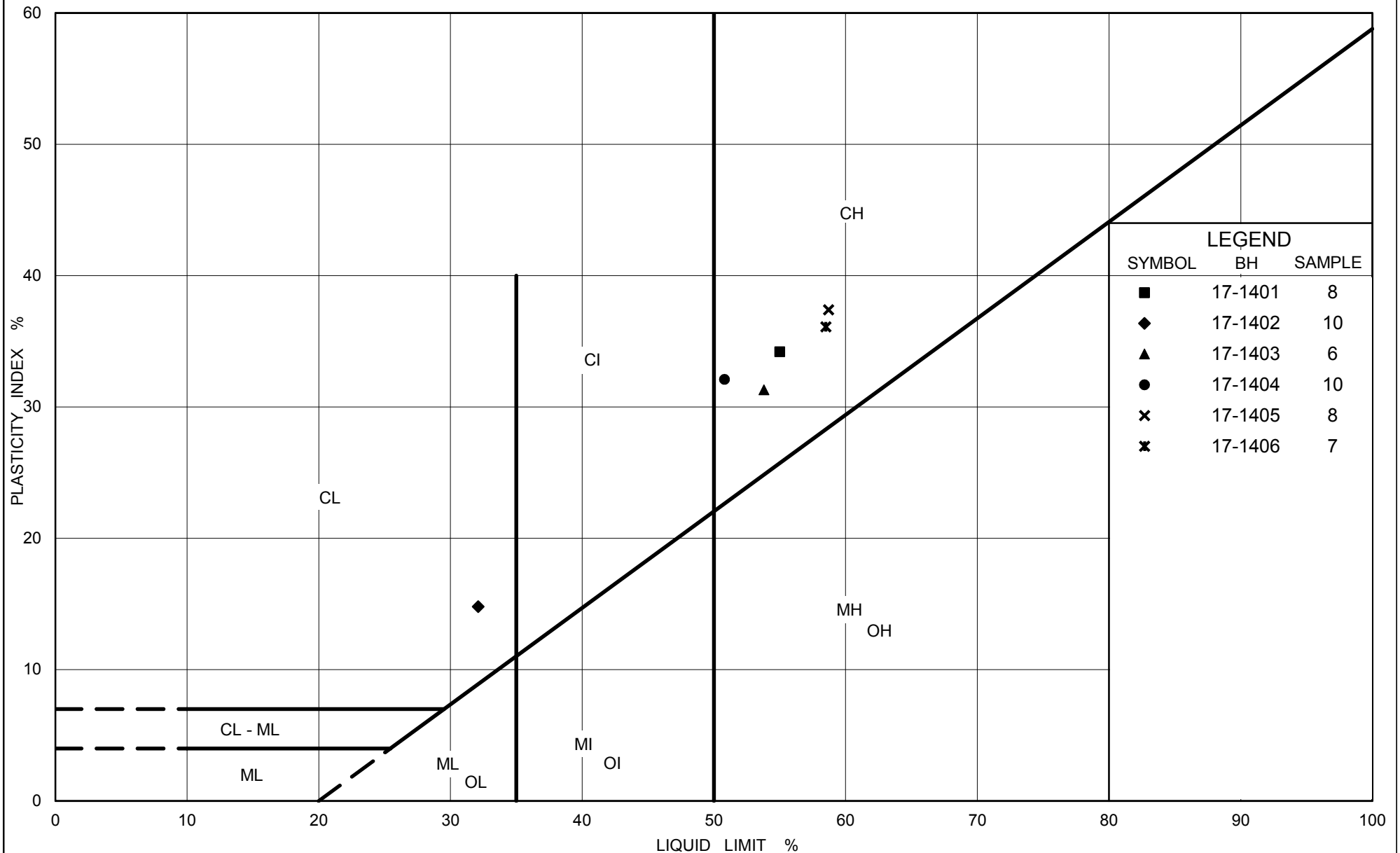
Ontario

# PLASTICITY CHART Weathered SILTY CLAY to CLAY

FIG No. B2

Project No. 1662565 /1140

Compiled By : MI      Checked By : CNM



Ontario

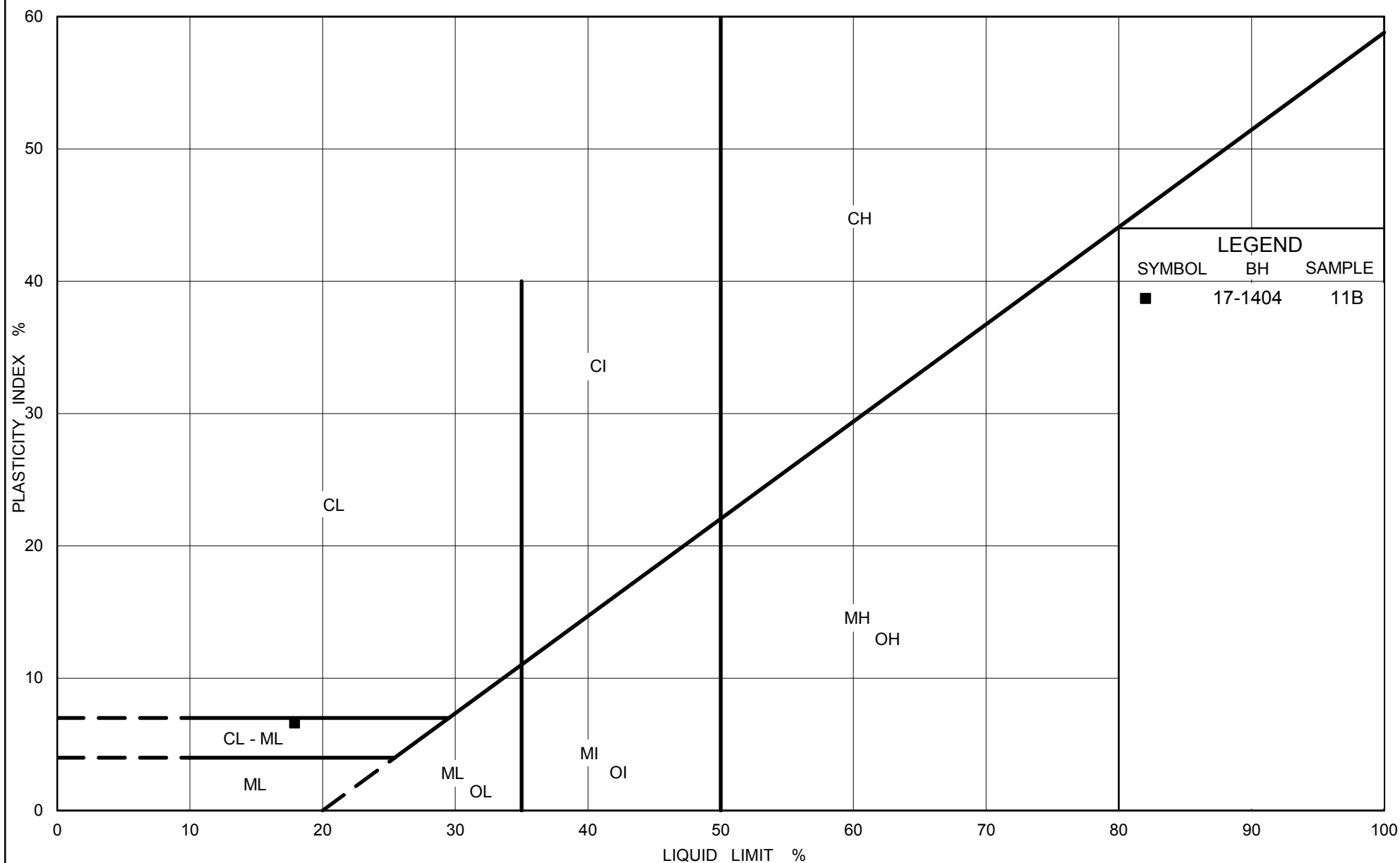
Ministry of Transportation

# PLASTICITY CHART Unweathered SILTY CLAY to CLAY

FIG No. B3

Project No. 1662565 /1140

Compiled By : MI      Checked By : CNM



Ontario

Ministry of Transportation

# PLASTICITY CHART Sandy CLAYEY SILT, trace to some gravel

FIG No. B4

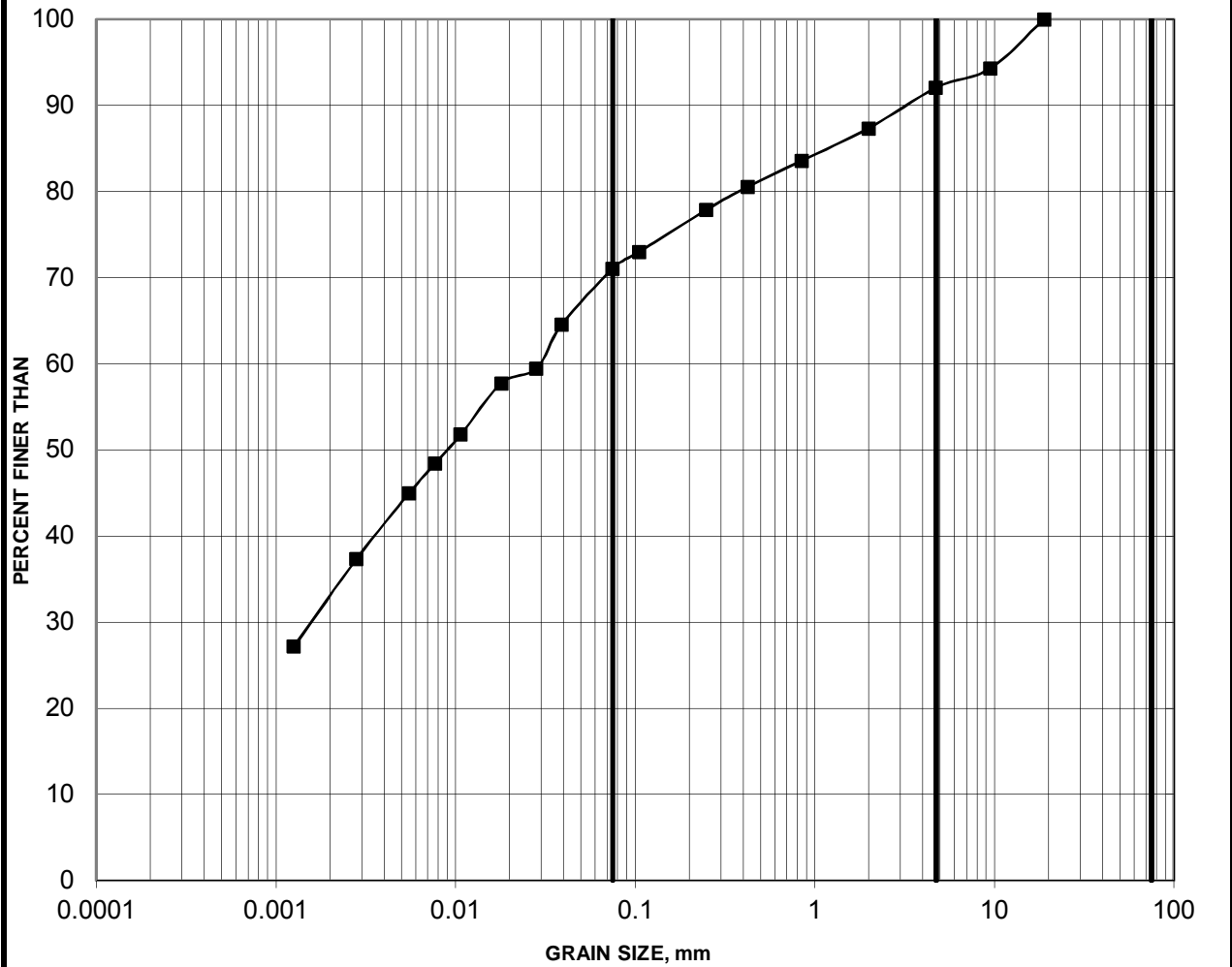
Project No. 1662565/ 1140

Compiled By : MI Checked By : CNM

# GRAIN SIZE DISTRIBUTION

FIGURE B5

## Sandy CLAYEY SILT, trace to some gravel



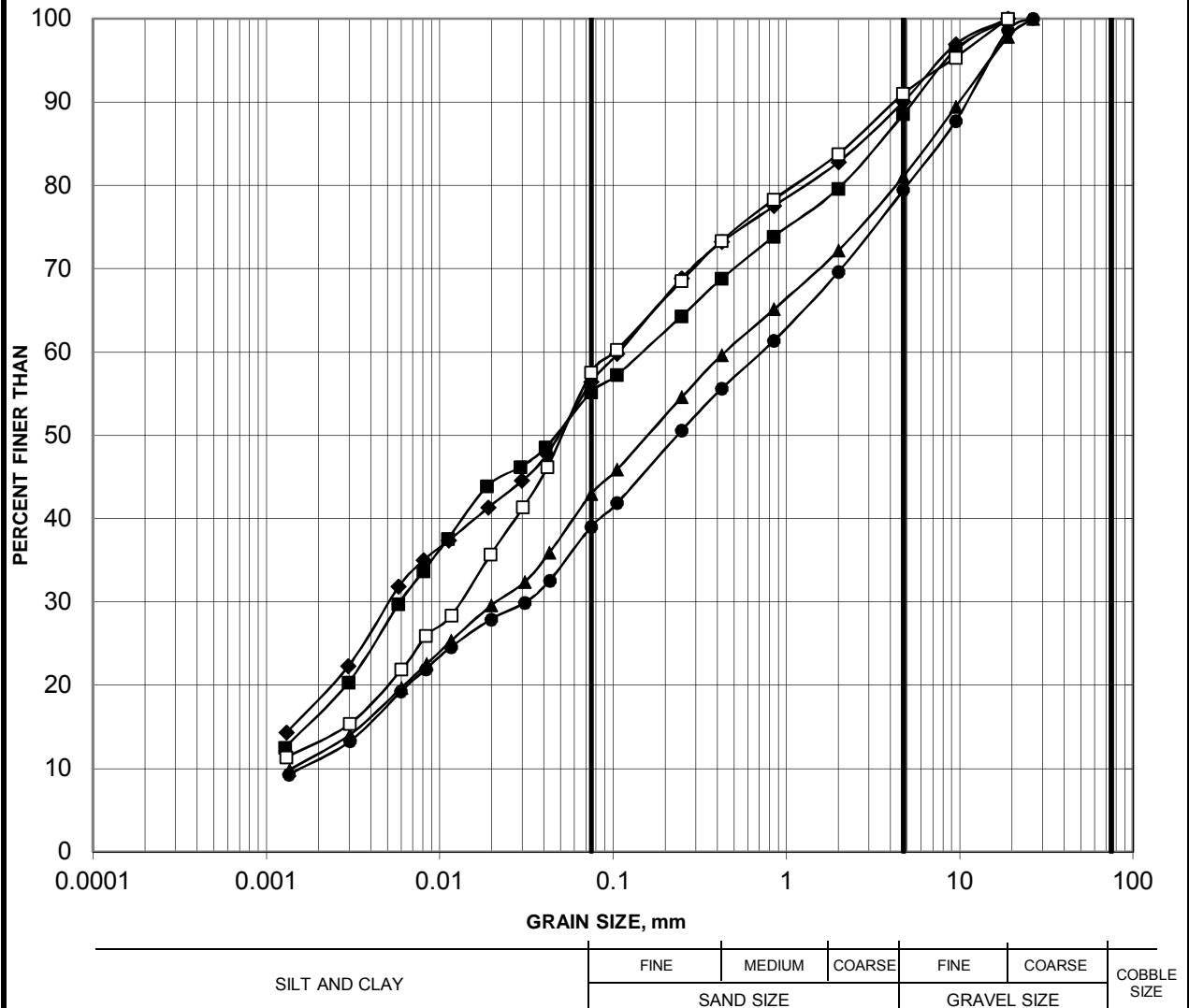
SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)
—■— 17-1404	12	9.14-9.75

# GRAIN SIZE DISTRIBUTION

FIGURE B6

## SAND and SILT to Silty SAND TILL



Borehole	Sample	Depth (m)
17-1401	12	7.92-8.53
17-1402	12	7.92-8.53
17-1403	9	7.32-7.92
17-1405	11	8.53-9.14
17-1406	13	9.14-9.75



# **APPENDIX C**

## **Previous Borehole Records Geocres No. 31G5-89** **Records of Previous Boreholes 1, 3, 4, to 6**

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

## RECORD OF BOREHOLE NO 1

JOB 72-11092

LOCATION Co-ords. 496,999 N; 232,778 E.

ORIGINATED BY SAA

W.P. 10-69-14

BORING DATE Aug. 2, 1972

COMPILED BY SAA

DATUM Geodetic

BOREHOLE TYPE Washboring, NX, RX Casing, BXL Rock Core

CHECKED BY

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT					LIQUID LIMIT $w_L$ PLASTIC LIMIT $w_p$ WATER CONTENT $w$			BULK DENSITY $\gamma$	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		20	40	60	80	100	$w_p$	$w$	$w_L$		
208.7	Ground Surface															
0.0	Silty Clay		1	SS	15											
	Brown. Very Stiff		2	TW	PM											
	Grey		3	TW	PM											
	Clay, trace of sand (silt seams up to 1/8" thick below El. 195)		4	TW	PM											
			5	SS	6											
188.7	Firm to Very Stiff															
20.0	Het. mix. of silt, sand and gravel with some clay (Glacial Till)		6	SS	5											
			7	SS	7											
			8	SS	21											
173.7	Loose to Compact															
35.0	Shale Bedrock		9	RC	100%											
168.9	Sound Grey															
39.8	End of Borehole															

OFFICE REPORT SOIL EXPLORATION



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## RECORD OF BOREHOLE NO 3

JOB 72-11092

LOCATION Co-ords. 496,919 N; 233,020 E.

ORIGINATED BY SAA

W.P. 10-69-14

BORING DATE Aug. 2, 1972

COMPILED BY SAA

DATUM Geodetic

BOREHOLE TYPE Cont. Flight Auger, BXL Rock Core, Cone Test

CHECKED BY

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT					LIQUID LIMIT $w_L$ PLASTIC LIMIT $w_p$ WATER CONTENT $w$			BULK DENSITY $\gamma$	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		20	40	60	80	100	$w_p$	$w$	$w_L$		
217.7	Ground Surface															
0.0	Silty clay (silt pockets) Desiccated Brown Very Stiff Grey		1	SS	16											
			2	TW	PH	210									118	in open BH 212.7
			3	TW	PH											
	Clay to silty clay, trace of sand (silt layers up to 1" thick below El. 194)		4	TW	PH										110	
			5	TW	PH	200									110.5	
			6	TW	PH										103	0 1 46 53
	Firm to Stiff		7	TW	PH	190									114.5	0 0 81 19 0 1 52 47
188.7																
29.0	Het. mix. of silt, sand and gravel with some clay (Glacial Till)		8	TW	PH											
			9	SS	7	180										
			10	SS	29											
174.2	Loose to Compact															
43.5	Shale Bedrock			RC												
169.2	Sound Grey		11	BXL	100%	170										
48.5	End of Borehole															

OFFICE REPORT SOIL EXPLORATION

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

## RECORD OF BOREHOLE NO 4

JOB 72-11092

LOCATION Co-ords. 496,878 N; 233,146 E.

ORIGINATED BY SAA

W.P. 10-69-15

BORING DATE August 2, 1972

COMPILED BY SAA

DATUM Geodetic

BOREHOLE TYPE Washboring, NX, BX Casing, BXL Rock Core, Cone

CHECKED BY

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT					LIQUID LIMIT $w_L$ PLASTIC LIMIT $w_p$ WATER CONTENT $w$			BULK DENSITY $\gamma$ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		SHEAR STRENGTH P.S.F.					WATER CONTENT %				
							O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE					$w_p$ — $w$ — $w_L$				
						20 40 60 80 100					20 40 60					
207.0	Ground Surface														GR.SA.SI.CL.	
0.0	Silty clay Desiccated Brown Stiff Grey		1	SS	6	200		+4	+9	x 5	105	103 107 $C_c=0.37$ $e_0=1.40$	204.2 in open BH			
2	TW		PM	190												
3	TW		PM													
4	TW		PM													
5	TW		PM													
188.0	Firm to Stiff		6	SS	1	180	10-1	100/7"	o							
19.0	Het. mix. of silt, sand and gravel, with some clay (Glacial Till) (boulders up to 6" in size below El. 180.)	7	SS	17												
176.5	Loose to Compact	8	RC	10%												
30.5	Shale Bedrock	9	SS	100/6"												
171.0	Sound Grey		10	BXL	90%	170										
36.0	End of Borehole															

OFFICE REPORT ON SOIL EXPLORATION

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

## RECORD OF BOREHOLE NO 6

JOB 72-11092

LOCATION Co-ords. 496,794 N; 233,397 E.

ORIGINATED BY SAA

W.P. 10-69-15




BORING DATE August 1, 1972

COMPILED BY SAA

DATUM Geodetic

BOREHOLE TYPE Cont. Flight Auger, BX Casing, BXL Rock Core,

CHECKED BY

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE			LIQUID LIMIT — $w_L$ PLASTIC LIMIT — $w_p$ WATER CONTENT — $w$			BULK DENSITY $\gamma$ P.C.F.	REMARKS					
ELEV. DEPTH	DESCRIPTION	STRAT. PLT	NUMBER	TYPE	BLOWS/FOOT		BLOWS / FOOT 20 40 60 80 100 +					SHEAR STRENGTH P.S.F.			WATER CONTENT % $w_p$ — $w$ — $w_L$				
							O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE 400 800 1200 1600 2000								20 40 60				
214.5	Ground Surface																		
0.0	Silty clay Desiccated Brown Very Stiff Grey		1	SS	13	210									in open BH				
			2	TW	PH										208.5				
			3	TW	PH										0 4 54 47				
	Clay to silty clay, trace of sand (occ. silt seams up to 1/2" thick throughout)		4	TW	PH	200													
			5	TW	PH														
			6	TW	4														
191.5	Firm to Stiff		7	SS	7	190													
23.0	Het. mix. of silt, sand & gravel, with some clay. (Glacial Till)		8	SS	12														
180.5	Loose to Compact					180													
34.0	Shale Bedrock		9	RC															
175.5	Sound Grey		BXL	100%															
39.0	End of Borehole																		

OFFICE REPORT ON SOIL EXPLORATION



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**FOUNDATION REPORT  
GREEN'S CREEK CULVERT - HIGHWAY 417**

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# **APPENDIX D**

## **Selected Site Photographs**





**Photograph 1:** Site 3-313/C1 (EBL), East inlet, looking west (August 24, 2017).



**Photograph 2:** Site 3-313/C1 (EBL), West outlet, looking east (August 24, 2017).

CLIENT  
WSP CANADA GROUP LIMITED

CONSULTANT



YYYY-MM-DD 2018/02/21

PREPARED SAT

DESIGN --

REVIEW MSS

APPROVED FJH

PROJECT  
GREEN'S CREEK CULVERT  
SITE NOS. 3-313/C1 & 3-313/C2  
HIGHWAY 417, OTTAWA, ONTARIO

TITLE  
**SELECTED SITE PHOTOGRAPHS**

PROJECT No.  
**1662565**

Phase  
**1140**

Rev.  
**1**

Figure  
**D1**





**Photograph 3:** Site 3-313/C2 (WBL), East inlet, looking south (August 24, 2017).



**Photograph 4:** Site 3-313/C2 (WBL), West outlet, looking east (August 24, 2017).

CLIENT  
WSP CANADA GROUP LIMITED

CONSULTANT



YYYY-MM-DD 2018/02/21

PREPARED SAT

DESIGN --

REVIEW MSS

APPROVED FJH

PROJECT  
GREEN'S CREEK CULVERT  
SITE NOS. 3-313/C1 & 3-313/C2  
HIGHWAY 417, OTTAWA, ONTARIO

TITLE  
**SELECTED SITE PHOTOGRAPHS**

PROJECT No.  
**1662565**

Phase  
**1140**

Rev.  
**1**

Figure  
**D2**



# **APPENDIX E**

## **Results of Chemical Analysis**

**Eurofins Environment Testing Report No. 1710291**





Environment Testing

## Certificate of Analysis

Client: Golder Associates Ltd. (Ottawa)  
1931 Robertson Road  
Ottawa, ON  
K2H 5B7  
Attention: Ms. Susan Trickey  
PO#:  
Invoice to: Golder Associates Ltd. (Ottawa)

Report Number: 1710291  
Date Submitted: 2017-06-23  
Date Reported: 2017-06-29  
Project: 1662565/1140  
COC #: 819388

					Lab I.D.	Sample Matrix	Sample Type	Sampling Date	Sample I.D.
Group	Analyte	MRL	Units	Guideline	1300270	1300271	1300272		
Agri. - Soil	pH	2.0			Soil	Soil	Soil	2017-06-12	2017-06-12
	SO4	0.01	%		17-1401 sa9 16-18	17-1402 sa8 14-16	17-1406 sa8 18-20		
General Chemistry	Cl	0.002	%						
	Electrical Conductivity	0.05	mS/cm						
	Resistivity	1	ohm-cm						

### Guideline = \* = Guideline Exceedence

All analysis completed in Ottawa, Ontario (unless otherwise indicated by \*\* which indicates analysis was completed in Mississauga, Ontario).  
Results relate only to the parameters tested on the samples submitted.  
Methods references and/or additional QA/QC information available on request.

146 Colonnade Rd. Unit 8, Ottawa, ON K2E 7Y1

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range



At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. 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 now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

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North America	+ 1 800 275 3281
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