



**REPORT**

**Foundation Investigation  
Cyrville Road Underpass Rehabilitation  
Site No. 3-314 - Highway 417  
Ottawa, Ontario**

*G.W.P. 4074-11-00*

*W.P. 4043-11-01*

Submitted to:

**WSP Canada Group Limited**

300-2611 Queensview Drive  
Ottawa, Ontario  
K2B 8K2

Submitted by:

**Golder Associates Ltd.**

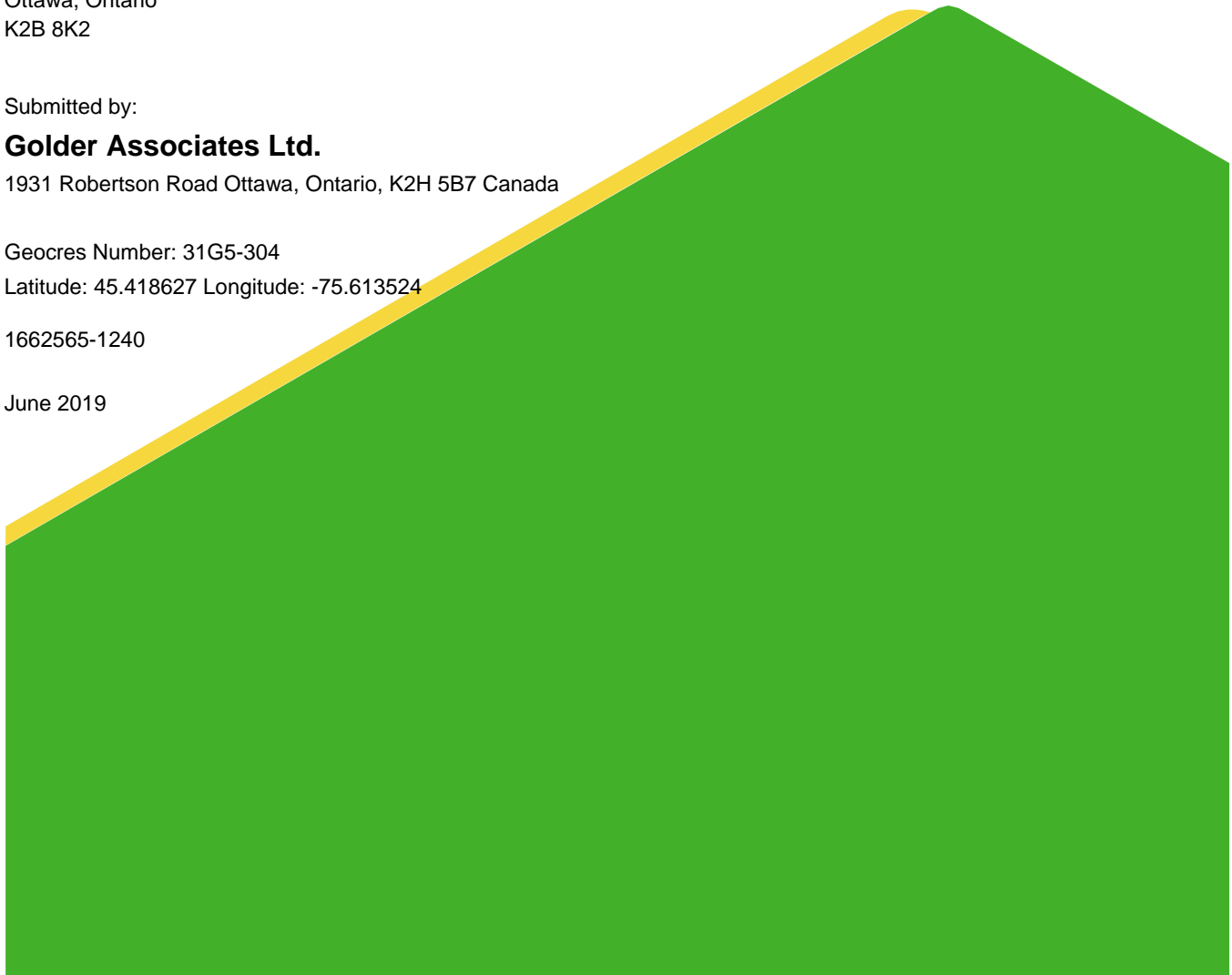
1931 Robertson Road Ottawa, Ontario, K2H 5B7 Canada

Geocres Number: 31G5-304

Latitude: 45.418627 Longitude: -75.613524

1662565-1240

June 2019



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**PART A**

Foundation Investigation Report  
Cyrville Road Underpass Rehabilitation  
Site No. 3-314 - Highway 417  
Ottawa, Ontario  
G.W.P. 4074-11-00  
W.P. 4043-11-01

## 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 (OR) 174 to Hunt Club Road in Ottawa, Ontario (Assignment number 4016-E-0008).

This report presents the results of the foundation investigation carried out to collect subsurface information required for the static and seismic assessment of the bridge foundations as input to the rehabilitation of the Cyrville Road Underpass, Site No. 3-314 located on Highway 417 in Ottawa, Ontario (G.W.P. 4074-11-00 and W.P. 4043-11-01). The rehabilitation of the existing structure is to be carried out in accordance with the current version of the Canadian Highway Bridge Design Code (CHBDC, S6-14).

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 Highway 417 Cyrville Road Underpass 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 AND GEOLOGY

### 2.1 General

The Cyrville Road Underpass is located approximately 600 m north west of Innes Road in Ottawa, Ontario. At this location, Highway 417 is a divided highway with two travel lanes in each direction separated by a median.

The existing bridge was constructed in 1974 and is a two-span structure, about 102 m long with span lengths of about 51.2 m. It is a concrete post-tensioned rectangular voided structure with four rectangular voids. The overall structure width is about 13 m including barrier walls, and sidewalks. The centre pier consists of a single circular column supported by a spread footing founded on bedrock. The bridge abutments sit on "perched" pile caps supported on battered steel HP12x74 (HP310x110) piles bearing on bedrock. The existing approach embankments are about 7 m to 8 m high relative to the highway profile. The embankment side slopes were constructed at about 2H:1V (horizontal:vertical). Based on visual observation at the time of the site investigation and subsequent discussion with WSP, no signs of foundation settlement or significant embankment erosion were observed, and the existing embankment slopes appear to be performing satisfactorily.

### 2.2 Regional Geology

As delineated in *The Physiography of Southern Ontario*<sup>1</sup>, this section of Highway 417 lies on the boundary of the minor physiographic regions known as the Ottawa Valley Clay Plain and the Russell and Prescott Sand plain, which lies 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

<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.

bedrock<sup>2</sup>. The Russell and Prescott Sand Plains 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.

This region is underlain by a series of sedimentary rocks, consisting of sandstones, dolostones, limestones and shales that are, in turn, underlain at depth by bedrock of Carlsbad Formation.

The site falls within the Western Québec (WQ) seismic zone according to the Geological Survey of Canada. The WQ zone constitutes a large area which encompasses the urban areas of Montreal, Ottawa-Hull and Cornwall. Within the WQ zone recent seismic activity has been concentrated in two subzones; one along the Ottawa River and another more active subzone along the Montreal-Maniwaki axis. The two major earthquakes in the WQ zone includes the 1935 Témiscaming event which had a magnitude (i.e., a measure of the intensity of the earthquake) of 6.2, and the 1944 Cornwall-Massena event which had a magnitude of 5.6.

## 3.0 INVESTIGATION PROCEDURES

### 3.1 Current Investigation (2018)

The subsurface investigation for the bridge rehabilitation was carried out on June 7, 2018. During that time, one borehole (18-2401) was advanced at the Highway 417 level near the existing pier. The borehole location is shown on Drawing 1.

The borehole was advanced using 108 mm inside diameter (200 mm outside diameter) continuous flight hollow stem augers on a track mounted drill rig, supplied and operated by George Downing Estate Drilling of Grenville-sur-la-routge, Québec. The borehole was advanced to a depth of about 8.8 m below the existing ground surface.

Samples of the overburden were obtained at 0.8 m intervals of depth using 50 mm outside diameter split-spoon samplers in general accordance with the Standard Penetration Test (SPT) procedure (ASTM D1586, latest edition).

Upon reaching refusal to auger advancement in Borehole 18-2401, the borehole was advanced about 6.1 m into the bedrock surface using rotary diamond drilling techniques while retrieving NQ sized core. A water truck was on site to supply the drill rig with water for coring the bedrock. Traffic control required to allow the water truck and support vehicles to park on the site was supplied by Beacon Lite Ltd. of Ottawa, Ontario.

A monitoring well was installed in Borehole 18-2401 to monitor the groundwater level at the site. The monitoring wells consisted of 30 mm outside diameter PVC tubing with a 3.0 m long screen. The groundwater level was measured in the monitoring well on July 26, 2018. The monitoring wells were decommissioned after taking the final water level measurement by removal of the piping and reinstatement by grouting in accordance with O. Reg. 903.

The remainder of the borehole was backfilled with bentonite mixed with soil cuttings. The site conditions were restored following completion of the field work.

The field work was supervised on a full time basis by members of Golder's staff who located the borehole in the field, directed the drilling, sampling, and in situ testing operations, and logged the borehole. The soil and bedrock samples were identified in the field, placed in labelled containers, and transported to Golder's laboratory in Ottawa for further examination and to Golder's laboratories in Ottawa for testing. Index and classification tests consisting of water content determinations and grain size distribution analyses were carried out on selected soil specimens

<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.

at the Golder Ottawa laboratory. Unconfined compressive strength tests were carried out on selected rock core samples in the Golder Ottawa laboratory. The laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate.

One soil sample from Borehole 18-2401 was 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).

In addition to the borehole investigation, shear wave velocity profiling at the site was completed using the Multichannel Analysis of Surface Waves (MASW) technique and was conducted on June 26, 2018, by personnel from the Golder Associates' Mississauga and Ottawa offices. A series of 24 low frequency (4.5 Hz) geophones were laid out at 3 m intervals. A 9.9 kg sledge hammer and 45 kg weight drop were used as the seismic source. The source locations were offset at distances of 5, 10, and 15 m off the end and collinear with the geophone array.

The borehole elevation was surveyed by Golder using a Trimble R8 GPS unit. The borehole location, including MTM NAD83 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.

**Table 1: Summary of Borehole Location**

Borehole Number	Borehole Location	MTM NAD83 Zone 9 Northing (m)	MTM NAD83 Zone 9 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
18-2401	Pier	5031331.6	374189.2	66.4	8.8

### 3.2 Previous Investigation (1972)

A previous investigation was carried out in 1972 by the MTO (then the Ministry of Transportation and Communications, Ontario) for the design of the existing bridge. The results of that investigation are contained in the report titled "*Foundation Investigation Report for The Proposed Underpass Structure at the Crossing of Hwy. #417, (E.B. and W.B. Lanes) and Realigned Cyrville Rd., Twp. Of Gloucester, Reg. Mun. of Ottawa-Carleton, District No. 9 (Ottawa), W.O. 72-11109 – W.P. 13-68-04*" dated November 7, 1972 (GEOCREC No. 31G05-114).

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

Twelve boreholes, were put down at the site as part of the original investigation along the then-proposed bridge alignment. The approximate borehole and ground surface elevations are shown on the Record of Borehole sheets included in Appendix B and are also shown on Drawing 1. The locations and ground surface elevation of the previous boreholes should be considered approximate since the locations were referenced to an imperial borehole location plan rather than metric MTM coordinates. The detailed subsurface soils and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are given on the borehole records from the 1972 investigation.

## 4.0 DESCRIPTION OF SUBSURFACE CONDITIONS

### 4.1 Site Stratigraphy

The Record of Borehole sheets from the current investigation are presented in Appendix A. The results of the laboratory testing carried out during the current investigation are presented on the Record of Borehole sheets and on Figure B1 and Figure B2 in Appendix B. The Record of Borehole sheets and laboratory test results from the previous investigation are presented in Appendix C. The results of basic chemical analysis completed on select soil samples are provided in Appendix D. The borehole locations and the interpreted stratigraphic profile projected along the Cyrville Road Underpass are shown on Drawings 1. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile are inferred from observations of drilling progress and 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.

The MASW test results and report are presented in Appendix E and include the calculated shear wave velocity profile measured from the field testing and a graphical representation of the shear wave velocity profile with depth.

In general, the subsurface conditions at the site consist of a layer of fill overlying shale bedrock.

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

### 4.2 Current Investigation

In general, the subsurface conditions at Borehole 18-2401 for the current investigation consists of asphaltic concrete overlying granular fill overlying shale bedrock.

#### 4.2.1 Pavement Structure and Fill

At the location of borehole 18-2401, the pavement structure consists of about 0.2 m of asphaltic concrete overlying a layer of sandy gravel fill. The fill extends to a depth of about 2.3 m.

Standard Penetration Tests carried out within the granular fill gave SPT “N” values of greater than 50 blows per 0.3 m of penetration, indicating a very dense state of compactness.

The results of grain size distribution testing carried out on one sample of the granular fill are provided on Figure B1 in Appendix B. The results of natural water content testing carried out on one sample of the granular fill was about 2 percent.

### 4.3 Previous Investigation

In general, the subsurface conditions in the boreholes for the previous investigation consist of fill overlying silty sand to sandy silt overlying glacial till overlying shale bedrock. It should be noted that these boreholes were advanced prior to the construction of the Cyrville Road underpass, and the subsurface conditions would likely have changed since the previous investigation.

#### 4.3.1 Fill and Topsoil

A layer of fill was encountered at the ground surface in Borehole 12 and generally consists of sand and gravel. This layer extends to about 1.2 m below the existing ground surface.

A 300 mm thick layer of topsoil was encountered at the ground surface in Boreholes 10 and 11.

### 4.3.2 Silty Sand to Sand to Silty Sand to Sandy Silt

A discontinuous deposit of silty sand to sand, trace to no gravel and clay and silty sand to sandy silt, trace to some clay was encountered in Boreholes 1 to 11. This layer extends to depths ranging from about 1.5 to 2.6 m below the existing ground surface (Elevations ranging from about 66.0 m to 65.0 m).

Standard Penetration Tests carried out within the silty sand, sand, and sandy silt deposits gave SPT “N” values ranging from 5 to 66 blows per 0.3 m of penetration, indicating a loose to very dense state of compactness.

The results of grain size distribution testing carried out as part of the previous investigation are provided in Appendix C.

### 4.3.3 Clayey Silt (Till)

A deposit of glacial till was encountered below the silty sand, sand, and sandy silt deposits in Boreholes 1 through 12. The glacial till generally consists of a clayey silt matrix with sand and gravel, and shale fragments. The glacial till extends to depths ranging from about 2.3 to 3.8 m below the existing ground surface (Elevation ranging from about 65.0 m to 63.7).

Standard Penetration Tests carried out within the glacial till gave SPT “N” values ranging from 24 to greater than 100 blows per 0.3 m of penetration, indicating a compact to very dense state of compactness.

The results of grain size distribution testing carried out as part of the previous investigation are provided in Appendix C.

The results of Atterberg limit testing on four samples of the clayey silt from the previous investigation gave a plasticity index value ranging from about 4 to 8 percent and a liquid limit value ranging from about 18 to 22 percent. The measured natural water content of four samples of the clayey silt were about 8 and 11 percent.

## 4.4 Bedrock

Bedrock was encountered beneath the fill in Borehole 18-2401 from the current investigation, and beneath the glacial till in Boreholes 1, 4, 5, 11, and 12 from the previous investigation at depths ranging from about 2.3 to 3.8 m below the existing ground surface (Elevations ranging from about 64.8 m to 63.7 m). In borehole 18-2401, the bedrock was cored about 6.1 m using NQ-sized coring equipment.

Refusal to sampler advancement was encountered in Boreholes 6, 7, 8, 9, and 10 at depths ranging from about 2.6 to 3.4 m below the existing ground surface (Elevations ranging from about 64.8 to 64.1 m).

The following table summarizes the bedrock surface or refusal depths and elevations as encountered at the borehole locations.

**Table 2: Summary of Bedrock Surface and Auger Refusal Depths and Elevations**

Borehole Number	Existing Ground Surface Elevation (m)	Depth to Bedrock/Refusal (m)	Bedrock Surface/Refusal Elevation (m)
18-2401	66.4	2.3	64.1
1	67.7	3.4	64.4
4	67.8	3.4	64.5
5	67.9	3.4	64.6

Borehole Number	Existing Ground Surface Elevation (m)	Depth to Bedrock/Refusal (m)	Bedrock Surface/Refusal Elevation (m)
6	67.2	3.1 <sup>1</sup>	64.1 <sup>1</sup>
7	67.9	2.9 <sup>1</sup>	65.0 <sup>1</sup>
8	67.6	2.8 <sup>1</sup>	64.8 <sup>1</sup>
9	67.4	2.6 <sup>1</sup>	64.8 <sup>1</sup>
10	67.7	3.4 <sup>1</sup>	64.3 <sup>1</sup>
11	67.5	3.8	63.7
12	67.1	2.3	64.8

**Note 1:** Refusal to sampler advancement.

The bedrock encountered in these boreholes consist of highly weathered to fresh, thinly laminated, grey to black shale of the Carlsbad Formation. The Rock Quality Designation (RQD) values measured on recovered bedrock core samples ranged from about 0 to 52 percent, indicating a poor to fair quality rock.

Results of unconfined compressive strength testing carried out on one bedrock core sample are presented in Figure B2. The results gave a value of about 20 MPa indicating a weak bedrock.

## 4.5 Groundwater Conditions

A monitoring well was installed in Borehole 18-2401 to monitor the groundwater level at the site. The water level was measured in the monitoring well July 26, 2018 and the results are summarized in the following table.

**Table 3: Summary of Measured Groundwater Levels**

Borehole	Ground Surface Elevation (m)	Screened Interval Material	Water Level Depth (m)	Water Level Elevation (m)	Date of Reading
18-2401	66.4	Bedrock	1.2	65.2	July 26, 2018

It is expected that this water level will be subject to fluctuations both seasonally and as a result of precipitation events.

## 4.6 Corrosion and Cement Type

One soil sample from Borehole 18-2401 was 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 results of the testing are attached in Appendix D and are summarized in the table below.

**Table 4: Summary of Corrosivity of Sample**

Borehole / Sample No.	Sample Depth (m)	Sample Type	Chloride (%)	pH	Electrical Conductivity (mS/cm)	Resistivity (ohm-cm)	Sulphate (%)
18-2401 / 3	1.52 – 1.65	Soil	0.030	8.1	0.78	1280	0.07

## 5.0 CLOSURE

This report was prepared by Ms. Sarah Ghadbane, P.Eng., and reviewed by Mr. Michael Snow P.Eng., a senior geotechnical engineer and Principal with Golder. Mr. Fintan Heffernan, P.Eng., a Senior Consultant with Golder and the Designated MTO Foundations Contact, conducted an independent quality control review of this report.


### Golder Associates Ltd.



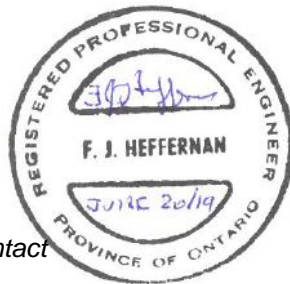
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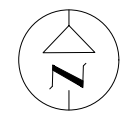
WAM/SG/MSS/mvrd

[https://golderassociates.sharepoint.com/sites/11263g/shared documents/01\\_foundations/6 - reports/1240 cyrville/03\\_final/1662565-1240-001-r-rev0-cyrville\\_road-fir-2006\\_19.docx](https://golderassociates.sharepoint.com/sites/11263g/shared%20documents/01_foundations/6_reports/1240_cyrville/03_final/1662565-1240-001-r-rev0-cyrville_road-fir-2006_19.docx)

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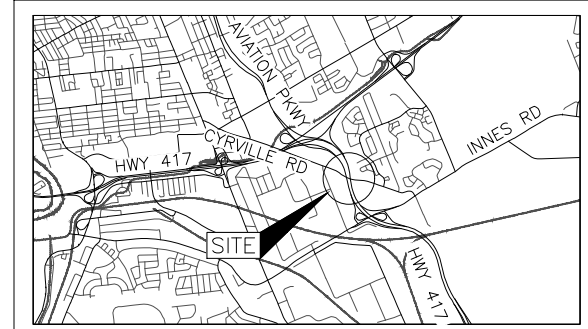
**METRIC**  
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CONT No. GWP No. 4074-11-00

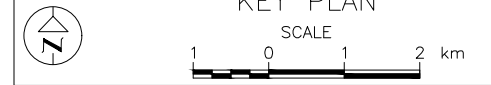


**CYRVILLE ROAD OVERPASS**  
HIGHWAY 417  
BOREHOLE LOCATIONS AND SOIL STRATA  
LAT. 45.418672 LONG. -75.613657

SHEET

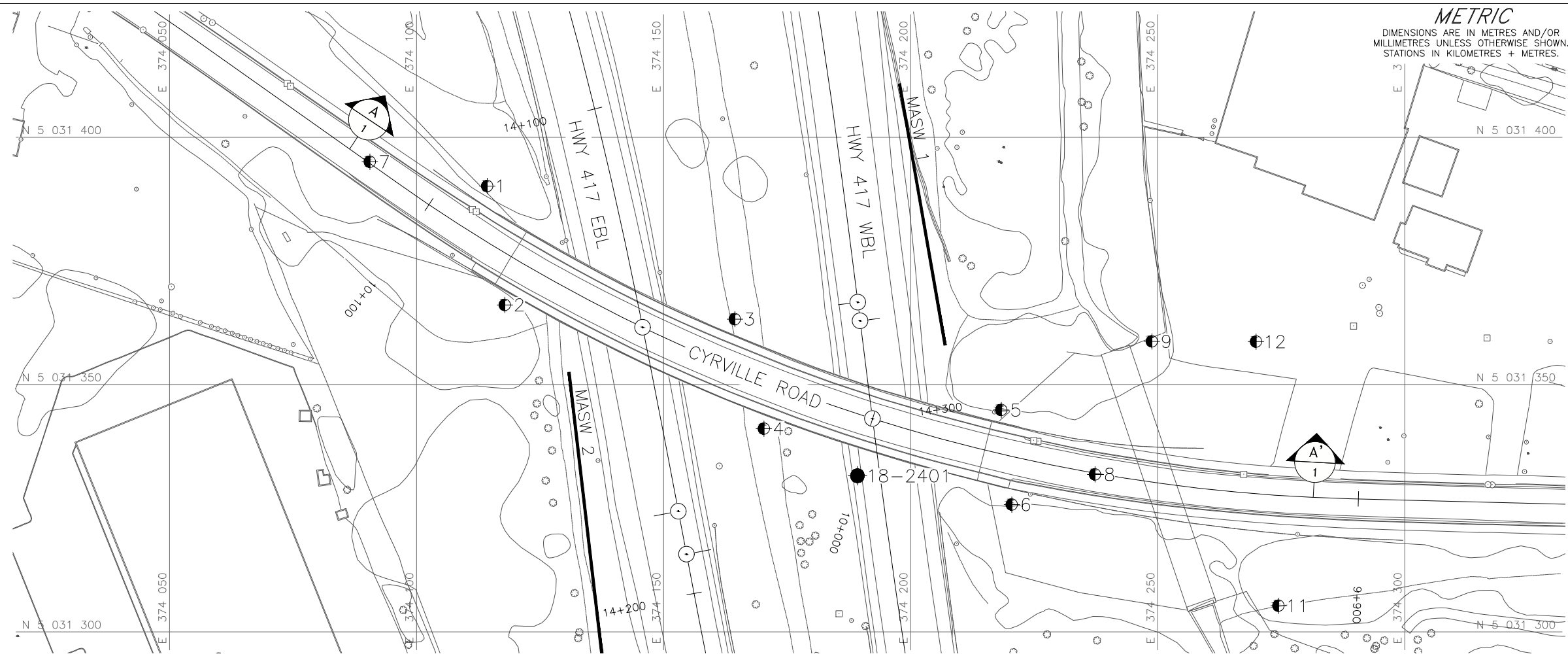


KEY PLAN

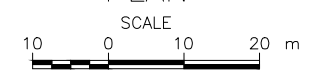


LEGEND

- Borehole - Current Investigation
- ⊙ Borehole - Previous Investigation (Geocres No. 31G05-114)
- ⊥ Seal
- ⊥ Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)
- ≡ WL in piezometer, measured on XXX XX, XXXX



PLAN



BOREHOLE CO-ORDINATES (MTM ZONE 9)

No.	ELEVATION	NORTHING	EASTING
1	67.7	5031390.1	374114.3
2	67.8	5031366.1	374117.9
3	67.8	5031363.2	374164.4
4	67.8	5031341.1	374170.3
5	67.9	5031344.9	374218.4
6	67.2	5031325.7	374220.5
7	67.9	5031395.0	374090.6
8	67.6	5031331.8	374237.3
9	67.4	5031358.7	374248.8
11	67.5	5031305.3	374274.5
12	67.1	5031358.7	374269.9
18-2401	66.4	5031331.6	374189.2

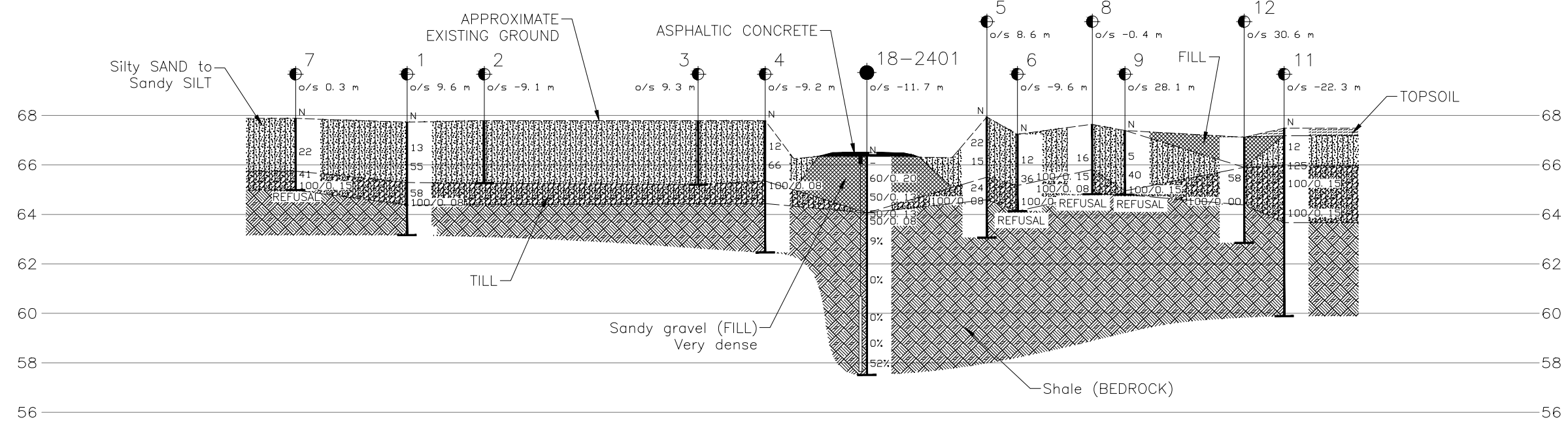
NOTES

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

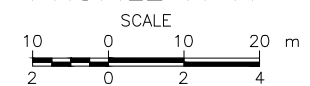
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

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.



PROFILE A-A'



NO.	DATE	BY	REVISION

Geocres No. 31G5-304

HWY. 417	PROJECT NO. 1662565	DIST. EASTERN
SUBM'D. SG	CHKD. SG	DATE: 6/21/2019
DRAWN: JM	CHKD. MSS	APPD. FJH
		SITE: 3-314
		DWG. 1

PLOT FILE: ...  
 FILENAME: ...

**APPENDIX A**

# Borehole and Drillhole Records, Current Investigation

Lists of Abbreviations and Symbols

Lithological and Geotechnical Rock Description Terminology

Records of Borehole 18-2401

Figure A1 – Borehole Core Photograph

## LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

<b>I.</b>	<b>GENERAL</b>	<b>(a)</b>	<b>Index Properties (continued)</b>
$\pi$	3.1416	w	water content
$\ln x$ ,	natural logarithm of x	$w_l$ or LL	liquid limit
$\log_{10}$	x or log x, logarithm of x to base 10	$w_p$ or PL	plastic limit
g	acceleration due to gravity	$I_p$ or PI	plasticity index = $(w_l - w_p)$
t	time	$w_s$	shrinkage limit
FoS	factor of safety	$I_L$	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>II.</b>	<b>STRESS AND STRAIN</b>	<b>(b)</b>	<b>Hydraulic Properties</b>
$\gamma$	shear strain	h	hydraulic head or potential
$\Delta$	change in, e.g. in stress: $\Delta \sigma$	q	rate of flow
$\varepsilon$	linear strain	v	velocity of flow
$\varepsilon_v$	volumetric strain	i	hydraulic gradient
$\eta$	coefficient of viscosity	k	hydraulic conductivity (coefficient of permeability)
$\nu$	Poisson's ratio	j	seepage force per unit volume
	total stress	<b>(c)</b>	<b>Consolidation (one-dimensional)</b>
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )	C	compression index (normally consolidated range)
$\sigma'_{vo}$	initial effective overburden stress	$C_r$	recompression index (over-consolidated range)
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, minor)	$C_s$	swelling index
$\sigma_{oct}$	mean stress or octahedral stress = $(\sigma_1 + \sigma_2 + \sigma_3) / 3$	$C_\alpha$	secondary compression index
$\tau$	shear stress	$m_v$	coefficient of volume change
u	porewater pressure	$c_v$	coefficient of consolidation (vertical direction)
E	modulus of deformation	$C_h$	coefficient of consolidation (horizontal direction)
G	shear modulus of deformation	$T_v$	time factor (vertical direction)
K	bulk modulus of compressibility	U	degree of consolidation
<b>III.</b>	<b>SOIL PROPERTIES</b>	$\sigma'_p$	pre-consolidation stress
<b>(a)</b>	<b>Index Properties</b>	OCR	over-consolidation ratio = $\sigma'_p / \sigma'_{vo}$
$\rho(\gamma)$	bulk density (bulk unit weight)*	<b>(d)</b>	<b>Shear Strength</b>
$\rho_d(\gamma_d)$	dry density (dry unit weight)	$\tau_p, \tau_r$	peak and residual shear strength
$\rho_w(\gamma_w)$	density (unit weight) of water	$\phi'$	effective angle of internal friction
$\rho_s(\gamma_s)$	density (unit weight) of solid particles	$\delta$	angle of interface friction
$\gamma'$	unit weight of submerged soil ( $\gamma' = \gamma - \gamma_w$ )	$\mu$	coefficient of friction = $\tan \delta$
$D_R$	relative density (specific gravity) of solid particles ( $D_R = \rho_s / \rho_w$ ) (formerly $G_s$ )	$c'$	effective cohesion
e	void ratio	$C_u, S_u$	undrained shear strength ( $\phi = 0$ analysis)
n	porosity	p	mean total stress $(\sigma_1 + \sigma_3) / 2$
S	degree of saturation	$p'$	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)		<b>Notes:</b> 1	$\tau = c' + \sigma' \tan \phi'$
		2	shear strength = (compressive strength)/2

## LIST OF ABBREVIATIONS

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

### I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
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	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

### III. SOIL DESCRIPTION

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

Compactness	N
Condition	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 <sub>p</sub>	plastic limit
w <sub>l</sub>	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
D <sub>R</sub>	relative density (specific gravity, G <sub>s</sub> )
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO <sub>4</sub>	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

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

# 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

<u>Description</u>	<u>Bedding Plane Spacing</u>
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

<u>Description</u>	<u>Spacing</u>
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

<u>Term</u>	<u>Size*</u>
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	

PROJECT <u>1662565-1240</u>	<b>RECORD OF BOREHOLE No 18-2401</b>	SHEET 1 OF 1	<b>METRIC</b>
G.W.P. <u>4074-11-00</u>	LOCATION <u>N 5031331.6; E 374189.2 NAD 83 MTM ZONE 9 (LAT. 45.418480; LONG. -75.613380)</u>	ORIGINATED BY <u>DG</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)/Rotary Drill, NW Casing</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>June 7-8, 2018</u>	CHECKED BY <u>SG</u>	

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	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 kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
			NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
								20	40	60	80	100						
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × REMOULDED					WATER CONTENT (%)					
								20	40	60	80	100	25	50	75			
66.4	GROUND SURFACE																	
0.0	ASPHALTIC CONCRETE																	
0.2	(SW) Sandy gravel (FILL) Very dense Grey Moist		1	GRAB	-		66										72 23 3 2	
			2	SS	60/0.20													
			3	SS	50/0.13													
64.1	Weathered Shale (BEDROCK)		4	SS	50/0.13		64											
63.7	Shale (BEDROCK)		5	SS	50/0.08													
2.7	Bedrock cored from depths of 2.7 m to 8.8 m  For bedrock coring details refer to Record of Drillhole 18-2401		1	RC	REC 100%		63										RQD = 9%	
			2	RC	REC 81%		62											RQD = 0%
			3	RC	REC 67%		61											RQD = 0%
			4	RC	REC 100%		60											RQD = 0%
58.5	Shale (BEDROCK)		5	RC	REC 100%		59											RQD = 52%
7.9							58											
57.6	END OF BOREHOLE																	
8.8	NOTES:  1. Water level in well screen at a depth of 1.2 metres below ground surface (Elev. 65.2 m), measured on July 26, 2018																	

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMTO\HWY417\REHAB&amp;WIDENING\02\_DATA\GINT\1662565.GPJ GAL-GTA.GDT 19-5-27 ZS

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



PROJECT <u>1662565-1240</u>	<b>RECORD OF BOREHOLE No 18-2401</b>	SHEET 1 OF 1	<b>METRIC</b>
G.W.P. <u>4074-11-00</u>	LOCATION <u>N 5031331.6; E 374189.2 NAD 83 MTM ZONE 9 (LAT. 45.418480; LONG. -75.613380)</u>	ORIGINATED BY <u>DG</u>	
DIST <u>Eastern</u> HWY <u>417</u>	BOREHOLE TYPE <u>Power Auger, 200 mm Diam. (Hollow Stem)/Rotary Drill, NW Casing</u>	COMPILED BY <u>ZS</u>	
DATUM <u>Geodetic</u>	DATE <u>June 7-8, 2018</u>	CHECKED BY <u>SG</u>	

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	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 kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
			NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
							20 40 60 80 100	○ UNCONFINED	+ FIELD VANE								
							20 40 60 80 100	● QUICK TRIAXIAL	× REMOULDED								
								WATER CONTENT (%)									
								25	50	75							
66.4	GROUND SURFACE																
0.0	ASPHALTIC CONCRETE																
0.2	(SW) Sandy gravel (FILL) Very dense Grey Moist		1	GRAB	-		66									72 23 3 2	
			2	SS	60/0.20												
			3	SS	50/0.13												
64.1	Weathered Shale (BEDROCK)		4	SS	50/0.13		64										
63.7	Shale (BEDROCK)		5	SS	50/0.08												
2.7	Bedrock cored from depths of 2.7 m to 8.8 m  For bedrock coring details refer to Record of Drillhole 18-2401		1	RC	REC 100%		63									RQD = 9%	
			2	RC	REC 81%		62									RQD = 0%	
			3	RC	REC 67%		60									RQD = 0%	
			4	RC	REC 100%		59									RQD = 0%	
58.5	Shale (BEDROCK)		5	RC	REC 100%		58									RQD = 52%	
57.6	END OF BOREHOLE																
	NOTES:  1. Water level in well screen at a depth of 1.2 metres below ground surface (Elev. 65.2 m), measured on July 26, 2018																

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMTO\HWY417\REHAB&amp;WIDENING\02\_DATA\GINT\1662565.GPJ GAL-GTA.GDT 6/21/19 ZS

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



**BH 18-2401 (Wet)**  
**Cored Length of 2.67 to 8.84 metres**  
**Core Box 1 to 3 of 3**

2.67 m Top of Bedrock



8.84 m End of Borehole



**Geotechnical Investigation**  
**Cyrville Road Underpass**  
**Ottawa, Ontario**

Project No.	1662565
Drawn:	WAM
Date:	8/27/2018
Checked:	SG
Review:	MSS

**Figure A1**

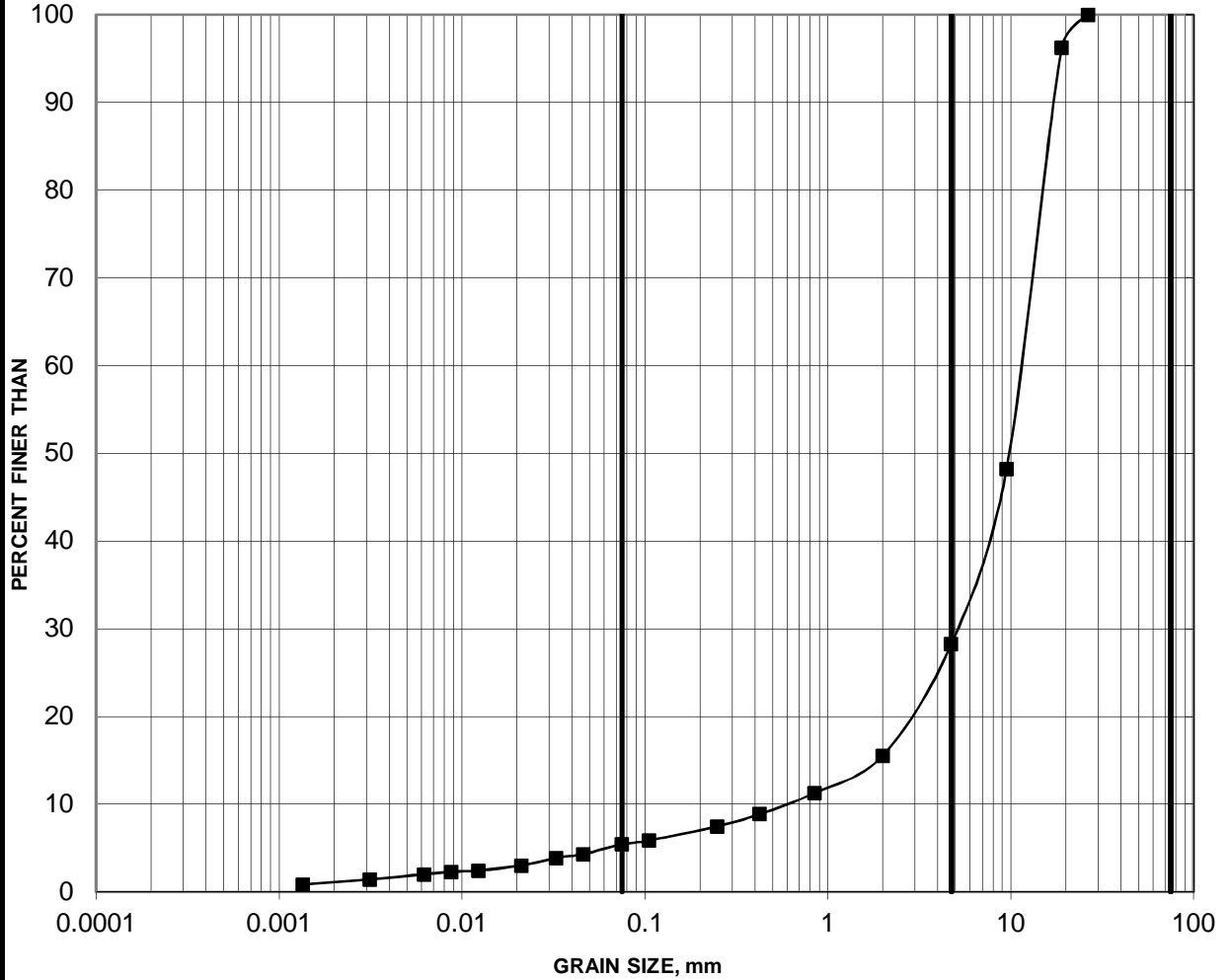
**APPENDIX B**

**Laboratory Testing, Current Investigation**

Figure B1 – Grain Size Distribution Test Results – Sandy Gravel (FILL)

Figure B2 – Results of Unconfined Compressive Strength Testing

SANDY GRAVEL (FILL)

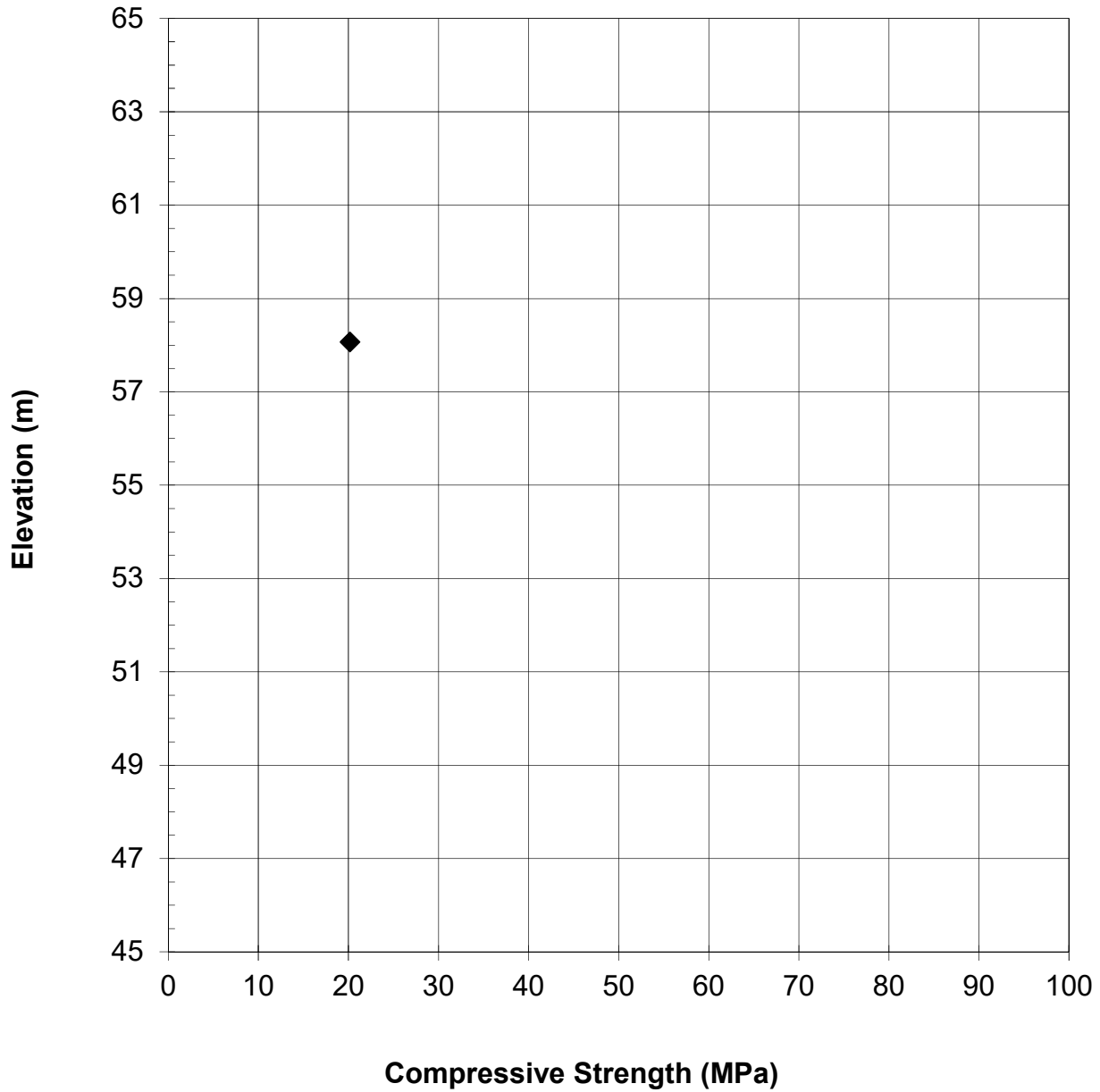


SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)
■ 18-2401	1	0.15-0.46

**SUMMARY OF LABORATORY COMPRESSIVE STRENGTH  
UNCONFINED COMPRESSION TESTS**

**FIGURE B2**



◆ 18-2401

**APPENDIX C**

**Borehole and Drillhole Records and Laboratory Test Results  
(Previous Investigation, GEOCREG 31G5-114)**

Record of Previous Boreholes BH 1 to BH 12

Laboratory Test Results

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FOUNDATIONS OFFICE

RECORD OF BOREHOLE NO 1

JOB 72-11109

LOCATION Co-ords. 16,506,449 N; 1,227 332 E.

ORIGINATED BY SAA

W.P. 13-58-04

BORING DATE Sept. 21, 1972

COMPILED BY SAA

DATUM Geodetic

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

CHECKED BY *[Signature]*

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	$w_p$		
222.2	Ground Level													
0.0	Silty sand with trace of clay & gravel. Grey		1	SS	13									
214.2	Compact to Very Dense		2	SS	55									
8.0	Glacial Till, fragments of shale. Hard		3	SS	58									
211.2			4	SS	100									
11.0	Bedrock - Shale		5	BXL	80									
207.2	Sound Grey		6	BXL	100									
15.0	End of Borehole													

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RECORD OF BOREHOLE NO 2

JOB 72-11109

LOCATION Co-ords. 16,506,372 N; 1,227,342 E.

ORIGINATED BY SAA

W.P. 13-68-04

BORING DATE Sept. 21, 1972

COMPILED BY SAA

DATUM Geodetic

BOREHOLE TYPE Dynamic Cone Test

CHECKED BY *[Signature]*

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT					LIQUID LIMIT $W_L$			BULK DENSITY $\gamma$	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		20	40	60	80	100	PLASTIC LIMIT $W_P$	WATER CONTENT $W$			
							SHEAR STRENGTH P.S.F.					$W_P$	$W$	$W_L$		
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE					WATER CONTENT %				
222.4	Ground Surface															
0.0	Probably Silty Sand					220										
214.1																
8.3	End of Cone Test					210				100/4"						

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RECORD OF BOREHOLE NO 3

JOB 72-11109 LOCATION Co-ords. 16,506,363 N; 1,227,495 E. ORIGINATED BY SAA  
 W.P. 13-63-04 BORING DATE Sept. 21, 1972 COMPILED BY SAA  
 DATUM Geodetic BOREHOLE TYPE Dynamic Cone Test CHECKED BY *[Signature]*

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	$w_p$	$w$	$w_L$		
222.4	Ground Level															
0.0	Probably Silty Sand					220										
213.9																
8.5	End of Cone Test					210				100/5"						

OFFICE REPORT SOIL EXPLORATION

DESIGN SERVICES BRANCH

FOUNDATION OFFICE

RECORD OF BOREHOLE NO 4

JOB 72-11109

LOCATION Co-ords. 16,506,291 N; 1,227,514 E.

ORIGINATED BY SAA

W.P. 13-68-04

BORING DATE Sept. 21, 1972

COMPILED BY SAA

DATUM Geodetic

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

CHECKED BY *[Signature]*

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE Blows / Foot 20 40 60 80 100	LIQUID LIMIT $w_L$ PLASTIC LIMIT $w_p$ WATER CONTENT $w$ $w_p$ — $w$ — $w_L$	BULK DENSITY $\gamma$ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT					
222.4	Ground Surface									
0.0	Silty sand to sandy silt, trace to some clay. Grey	[Dotted Pattern]	1	SS	12	220				0 30 57 13 217.9
214.4	Compact to Very Dense	[Dotted Pattern]	2	SS	66					
8.0	Glacial till with shale fragments	[Diagonal Lines]	3	SS	100	100/2"				29 49 17 5
211.4	shale fragments	[Diagonal Lines]	4	BXL	50%					
11.0	weathers	[Diagonal Lines]	5	BXL	80%					
12.0	Bedrock Shale	[Diagonal Lines]	6	BXL	90%					
204.9	Sound Grey	[Diagonal Lines]								
17.5	End of Borehole									

OFFICE REPORT SOIL EXPLORATION

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RECORD OF BOREHOLE NO 5

JOB 72-11109

LOCATION Co-ords. 16,506,303 N; 1,227,670 E.

ORIGINATED BY SAA

W.P. 13-68-04

BORING DATE Sept. 21, 1972

COMPILED BY SAA

DATUM Geodetic

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

CHECKED BY

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE					LIQUID LIMIT $W_L$			BULK DENSITY	REMARKS		
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		BLOWS / FOOT					WATER CONTENT $W$						
						20	40	60	80	100	SHEAR STRENGTH P.S.F.			$W_p$	$W$	$W_t$		
											○ UNCONFINED + FIELD VANE		WATER CONTENT %					
											● QUICK TRIAXIAL x LAB VANE		10	20	30	P.C.F.	GR. SA. SI. CL.	
222.9	Ground Surface																	
0.0	Silty sand to sandy silt, trace of clay.		1	SS	22												220.9	
214.9	Compact		2	SS	15												22 68 10	
8.0	Glacial Till, fragments of shale. Very Stiff		3	SS	24												21 47 23 9	
211.9	weathered		4	SS	70													
11.0	Shale Bedrock		5	BXL	60%													
13.0	Scand Grey		6	BXL	90%													
206.9	End of Borehole																	
16.0																		

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RECORD OF BOREHOLE NO 6

JOB 72-11109  
 W.P. 13-68-04  
 DATUM Geodetic

LOCATION Co-ords. 16,506,241 N; 1,227,676 E.  
 BORING DATE Sept. 22, 1972  
 BOREHOLE TYPE Cont. Flight Auger; Cone Test

ORIGINATED BY SAA  
 COMPILED BY SAA  
 CHECKED BY *[Signature]*

SOIL PROFILE		SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE					LIQUID LIMIT $w_L$			BULK DENSITY $\gamma$	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE		BLOWS/FOOT	SLOWS / FOOT					WATER CONTENT $w$			
						20	40	60	80	100	$w_p$ — $w$ — $w_L$ 10 20 30				
						SHEAR STRENGTH P.S.F.									
						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE									
220.6	Ground Level														
0.0	Silty sand with trace of clay		1	SS	12										0 75 15 10
213.8	Compact to loose		2	SS	56				145						215.6
6.8 210.4	Glacial Till, shale fragments. Hard		3	SS	100	3"									
10.2	End of Borehole Probably Bedrock														

OFFICE REPORT SOIL EXPLORATION



DESIGN SERVICES BRANCH

RECORD OF BOREHOLE NO 3

FOUNDATION OFFICE

JOB 72-11109 LOCATION Co-ords. 16,506,261 N; 1,227,731 E. ORIGINATED BY SAA  
 W.P. 13-68-04 BORING DATE Sept. 22, 1972 COMPILED BY SAA  
 DATUM Geodetic BOREHOLE TYPE Cont. Flight Auger CHECKED BY [Signature]

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					
221.9	Ground Level									
0.0	Silty sand, trace of clay.		1	SS	16					0 57 35 8
215.9	Compact									$\gamma$ 215.9
6.0	Glacial Till, fragments of shale. Hard		2	SS	100	6"				
212.3			3	SS	100	3"				
9.3	End of Borehole Probable Bedrock									

OFFICE REPORT ON SOIL EXPLORATION

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

RECORD OF BOREHOLE NO 9

JOB 72-11109  
 W.P. 13-58-01  
 DATUM Geodetic

LOCATION Co-ords. 16,506,346 N; 1,227 774 E.  
 BORING DATE September 22, 1972  
 BOREHOLE TYPE Cont. Flight Auger

ORIGINATED BY SAA  
 COMPILED BY SAA  
 CHECKED BY 2

SOIL PROFILE		SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT	LIQUID LIMIT $w_L$ PLASTIC LIMIT $w_p$ WATER CONTENT $w$ $w_p$ — $w$ — $w_L$ WATER CONTENT %	BULK DENSITY $\gamma$	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE					
221.1	Ground Level								
0.0	Silty sand, trace of gravel. Brown		1	SS	5				
213.1	Loose to Dense		2	SS	10				
212.7	Gravel fill. Hard		3	SS	10				
8.5	End of Borehole Probable Bedrock								

P.C.F. GR. SA. SI. CL  
 216.0  
 WL in open RH

OFFICE REPORT ON SOIL EXPLORATION

DESIGN SERVICES BRANCH

RECORD OF BOREHOLE NO 10

FOUNDATIONS OFFICE

JOB 72-11109 LOCATION Co-ords. 16,506,686 N; 1,227,754 E.  
 W.P. 13-68-04 BORING DATE Nov. 1, 1972  
 DATUM Geodetic BOREHOLE TYPE Flight Auger and Cone Test

ORIGINATED BY JC  
 COMPILED BY JC  
 CHECKED BY

SOIL PROFILE		SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100	LIQUID LIMIT — $w_L$ PLASTIC LIMIT — $w_p$ WATER CONTENT — $w$	BULK DENSITY $\gamma$	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE					
222.0	Ground Level								
1.0	Silty sand to sand with a trace of gravel.		1	SS	11				
213.8	Compact to Dense		2	SS	12				
8.2	Glacial Till Hard		3	SS	15				
211.0	End of Borehole Probably Bedrock					65			
11.0						0"			

OFFICE REPORT SOIL EXPLORATION

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

RECORD OF BOREHOLE NO 11

JOB 72-11109

LOCATION Co-ords. 16,506,172 N; 1,227,855 E.

ORIGINATED BY JC

W.P. 13-68-04

BORING DATE Nov. 1, 1972

COMPILED BY JC

DATUM Geodetic

BOREHOLE TYPE Flight Auger, EXL Rock Core and Cone Test

CHECKED BY *[Signature]*

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100	LIQUID LIMIT $w_L$ PLASTIC LIMIT $w_p$ WATER CONTENT $w$	WATER CONTENT % $w_p$ — $w$ — $w_L$	BULK DENSITY $\gamma$	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLT	NUMBER	TYPE	BLOWS/FOOT						
221.1	Ground Level										
1.0	Silty sand to sand with a trace of gravel. Compact		1	SS	12	220					
216.1			2	SS	125						
5.0	Clayey silt with sand & gravel (Glac. Till) (shale fragments throughout)		3	SS	100						
203.9	Hard		4	SS	100	210					
12.5	Shale Bedrock (Fractured and weathered)		5	EXL RC	20%						
198.1			6	EXL RC	60%	200					
196.5	Sound		7	EXL	95%						
24.9	End of Borehole					190					

OFFICE REPORT SOIL EXPLORATION

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

RECORD OF BOREHOLE NO 12

JOB 72-11109

LOCATION Co-ords. 16,506,345 N; 1,227,842 E.

ORIGINATED BY JC

W.P. 13-68-04

BORING DATE Oct. 31, 1972

COMPILED BY JC

DATUM Geodetic

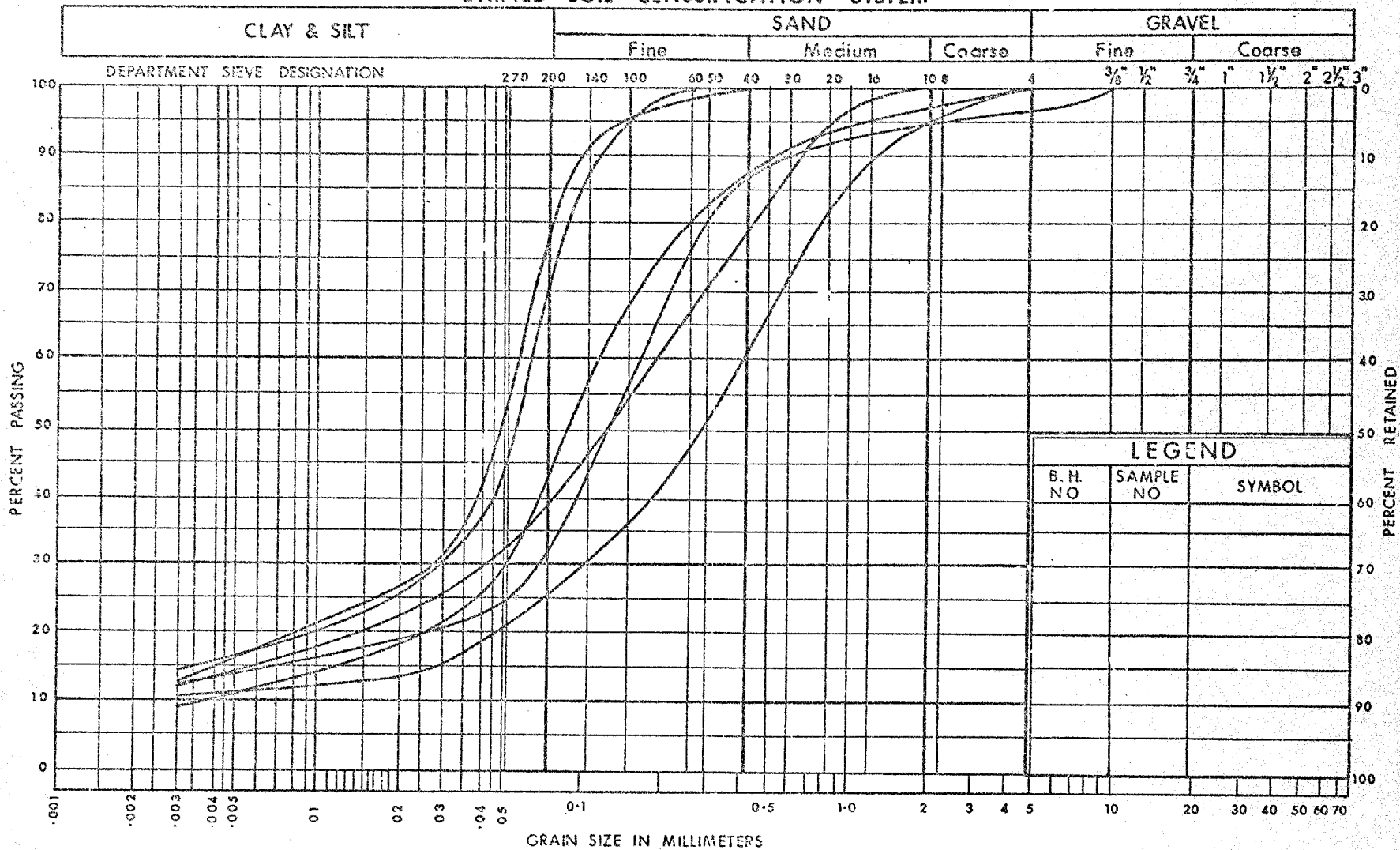
BOREHOLE TYPE Flight Auger and BXL Rock Core

CHECKED BY                     

ELEV. DEPTH	SOIL PROFILE DESCRIPTION	STRAT. PLOT	SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT		LIQUID LIMIT — W <sub>L</sub> PLASTIC LIMIT — W <sub>P</sub> WATER CONTENT — W		BULK DENSITY γ	REMARKS
			NUMBER	TYPE	BLOWS/FOOT		SHEAR STRENGTH P.S.F. ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB. VANE		W <sub>p</sub> — W — W <sub>L</sub> WATER CONTENT %			
220.2	Ground Level											
0.0	Granular Road Fill (sand and gravel)	⊗				220						
216.2	Compact											
4.0	Clayey silt with sand & gravel (Glac. Till)	⊗	1	SS	58							216.0
212.7	Hard											WL in open BH
211.2	Weathered	⊗	2	SS	100	210						
9.0	Shale Bedrock		3	RC								
	Numerous fissures throughout.			BXL	88%							
206.2	Sound		4	RC								
				BXL	81%							
14.0	End of Borehole					200						

OFFICE REPORT ON SOIL EXPLORATION

### UNIFIED SOIL CLASSIFICATION SYSTEM

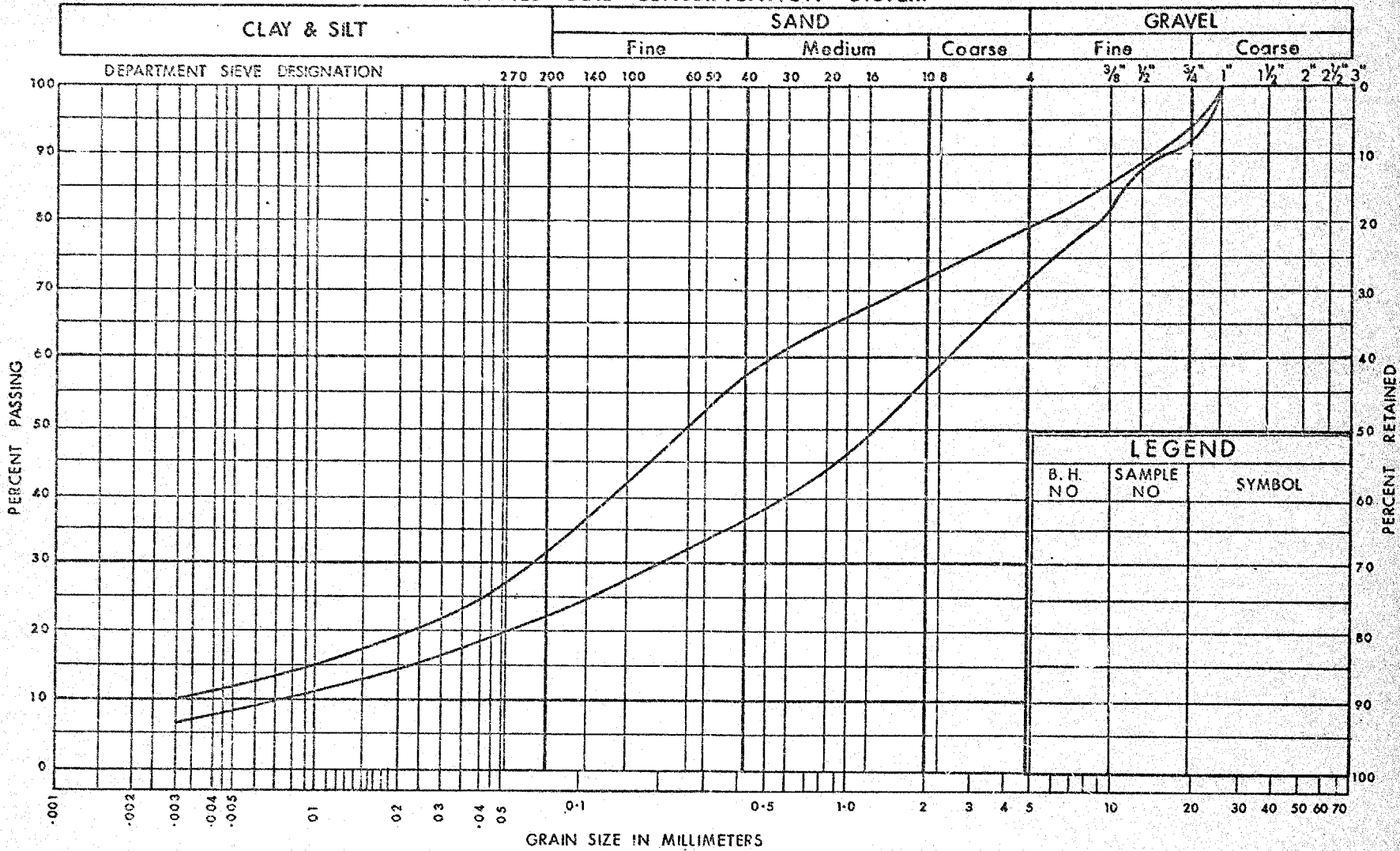


DEPARTMENT OF TRANSPORTATION AND COMMUNICATIONS  
DESIGN SERVICES BRANCH

## GRAIN SIZE DISTRIBUTION SILTY SAND TO SANDY SILT

W.P. No. 13-68-04  
JOB No. 72-11109  
FIG. 1

UNIFIED SOIL CLASSIFICATION SYSTEM

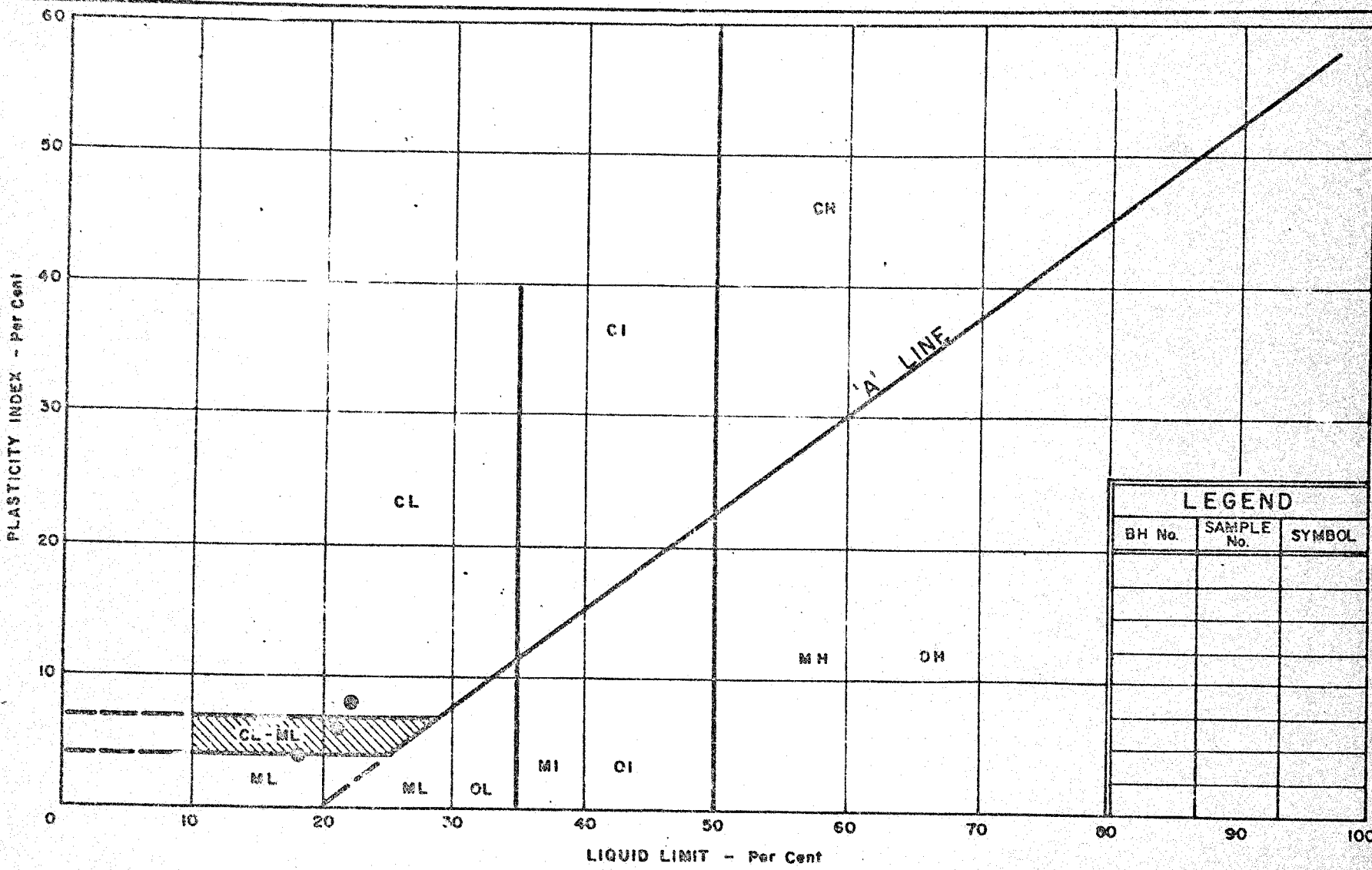


LEGEND		
B. H. NO	SAMPLE NO	SYMBOL

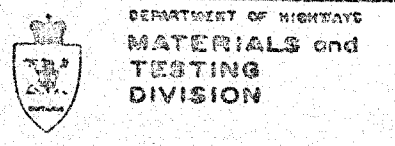
DEPARTMENT OF TRANSPORTATION AND COMMUNICATIONS  
DESIGN SERVICES BRANCH  
ONTARIO

GRAIN SIZE DISTRIBUTION  
GLACIAL TILL

W.P. No. 13-68-04  
JOB No. 72-11109  
FIG. 2



LEGEND		
BH No.	SAMPLE No.	SYMBOL



PLASTICITY CHART  
 GLACIAL TILL

WP. No. 13-68-04  
 JOB No. 72-11109  
 FIG. 3

**APPENDIX D**

**Basic Chemical Analysis – Eurofins Report Number 1814197**

**Certificate of Analysis**

Client: Golder Associates Ltd. (Ottawa)  
 1931 Robertson Road  
 Ottawa, ON  
 K2H 5B7  
 Attention: Mr. Alex Meacoe  
 PO#:  
 Invoice to: Golder Associates Ltd. (Ottawa)

Report Number: 1814197  
 Date Submitted: 2018-08-09  
 Date Reported: 2018-08-14  
 Project: 1662565/1240  
 COC #: 834574

Lab I.D. 1379724  
 Sample Matrix Soil  
 Sample Type  
 Sampling Date 2018-08-09  
 Sample I.D. 18-2401Sa3/5-5.42'

Group	Analyte	MRL	Units	Guideline	
Anions	Cl	0.002	%		0.030
	SO4	0.01	%		0.07
General Chemistry	Electrical Conductivity	0.05	mS/cm		0.78
	pH	2.00			8.11
	Resistivity	1	ohm-cm		1280

**Guideline =**                      \* = **Guideline Exceedence**

Results relate only to the parameters tested on the samples submitted.  
 Methods references and/or additional QA/QC information available on request.

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

**APPENDIX E**

**Results of MASW Testing**

## TECHNICAL MEMORANDUM

DATE July 16, 2018

Project No. 1662565/1240

TO Susan Trickey, Golder Associates Ltd.

FROM Stephane Sol, Christopher Phillips

EMAIL [ssol@golder.com](mailto:ssol@golder.com), [cphillips@golder.com](mailto:cphillips@golder.com)

### CHBDC SEISMIC SITE CLASS TESTING RESULTS CYRVILLE ROAD AND HIGHWAY 417, OTTAWA, ONTARIO

This technical memorandum presents the results of two Multichannel Analysis of Surface Waves (MASW) tests performed for the purpose of the Canadian Highway Bridge Design Code (CHBDC 2014) Seismic Site Classification (Figure 1). The tests are located on each side of the interchange between Cyrville Road and Highway 417 in Ottawa. The geophysical testing was performed by Golder Associates Ltd. (Golder) personnel on June 26, 2018.



Figure 1: MASW Location Site Map. MASW Lines in red – Line 1 (Northbound) and Line 2 (Southbound).

## Methodology

The MASW method measures variations in surface-wave velocity with increasing distance and wavelength and can be used to infer the rock/soil types, stratigraphy and soil conditions.

A typical MASW survey requires a seismic source, to generate surface waves, and a minimum of two geophone receivers, to measure the ground response at some distance from the source. Surface waves are a special type of seismic wave whose propagation is confined to the near surface medium.

The depth of penetration of a surface wave into a medium is directly proportional to its wavelength. In a non-homogeneous medium, surface waves are dispersive, i.e., each wavelength has a characteristic velocity owing to the subsurface heterogeneities within the depth interval that particular wavelength of surface wave propagates through. The relationship between surface-wave velocity and wavelength is used to obtain the shear-wave velocity and attenuation profile of the medium with increasing depth.

The seismic source used can be either active or passive, depending on the application and location of the survey. Examples of active sources include explosives, weight-drops, sledge hammer and vibrating pads. Examples of passive sources are road traffic, micro-tremors, and water-wave action (in near-shore environments).

The geophone receivers measure the wave-train associated with the surface wave travelling from a seismic source at different distances from the source.

The participation of surface waves with different wavelengths can be determined from the wave-train by transforming the wave-train results into the frequency domain. The surface-wave velocity profile with respect to wavelength (called the 'dispersion curve') is determined by the delay in wave propagation measured between the geophone receivers. The dispersion curve is then matched to a theoretical dispersion curve using an iterative forward-modelling procedure. The result is a shear-wave velocity profile of the tested medium with depth, which can be used to estimate the dynamic shear-modulus of the medium as a function of depth.

## Field Work

The MASW field work was conducted on June 26, 2018, by personnel from the Golder Mississauga office. For each MASW line, a series of 24 low frequency (4.5 Hz) geophones were laid out at 3 m intervals. Both active and passive readings were recorded along the MASW lines. For the active investigation, a seismic drop of 45 kg and a 9.9 kg sledge hammer were used as seismic sources. Active seismic records were collected with seismic sources located 5, 10, and 15 m from and collinear to the geophone array. A seismic refraction survey was also conducted along both lines to be able to determine the depth to bedrock as well as to estimate the shear wave velocity of the overburden. An example of active seismic records collected at each line are shown in Figures 2 and 3, below.

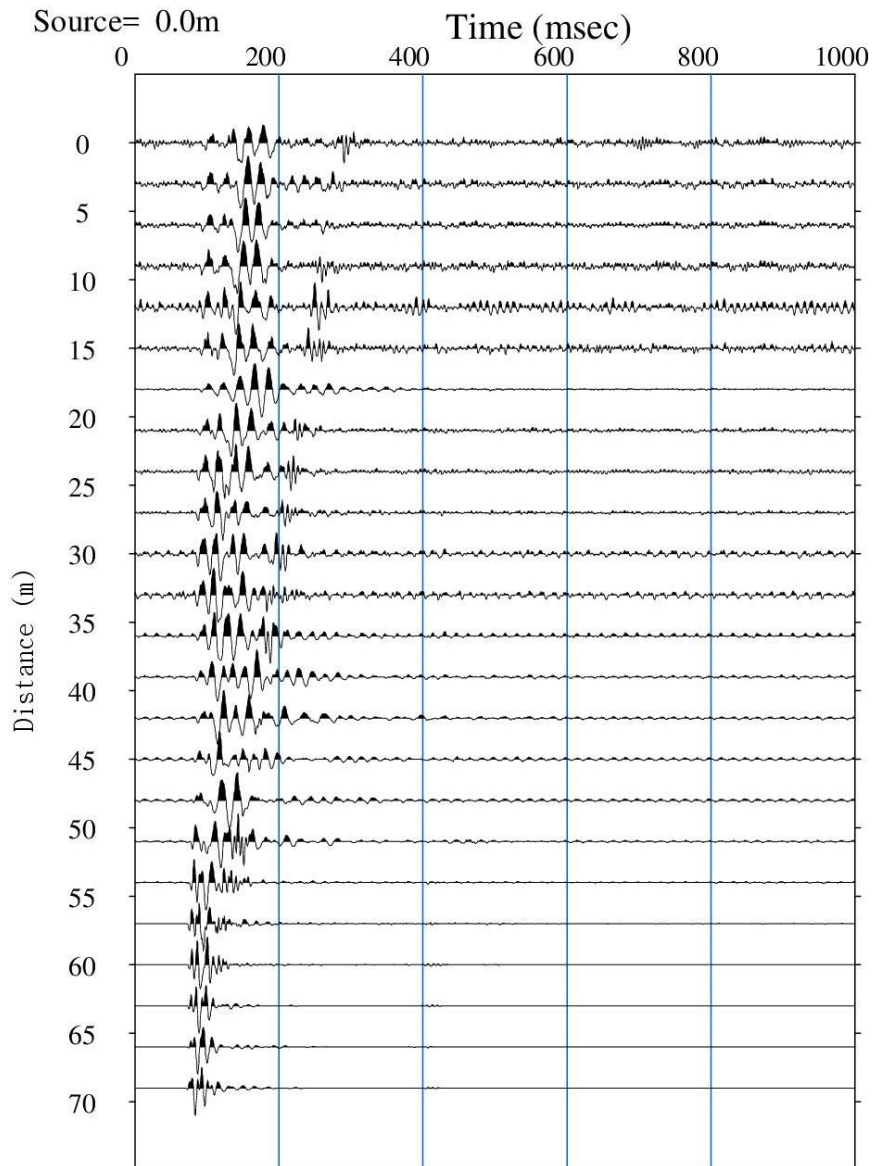


Figure 2: Typical seismic record collected at the site of MASW Line 1.

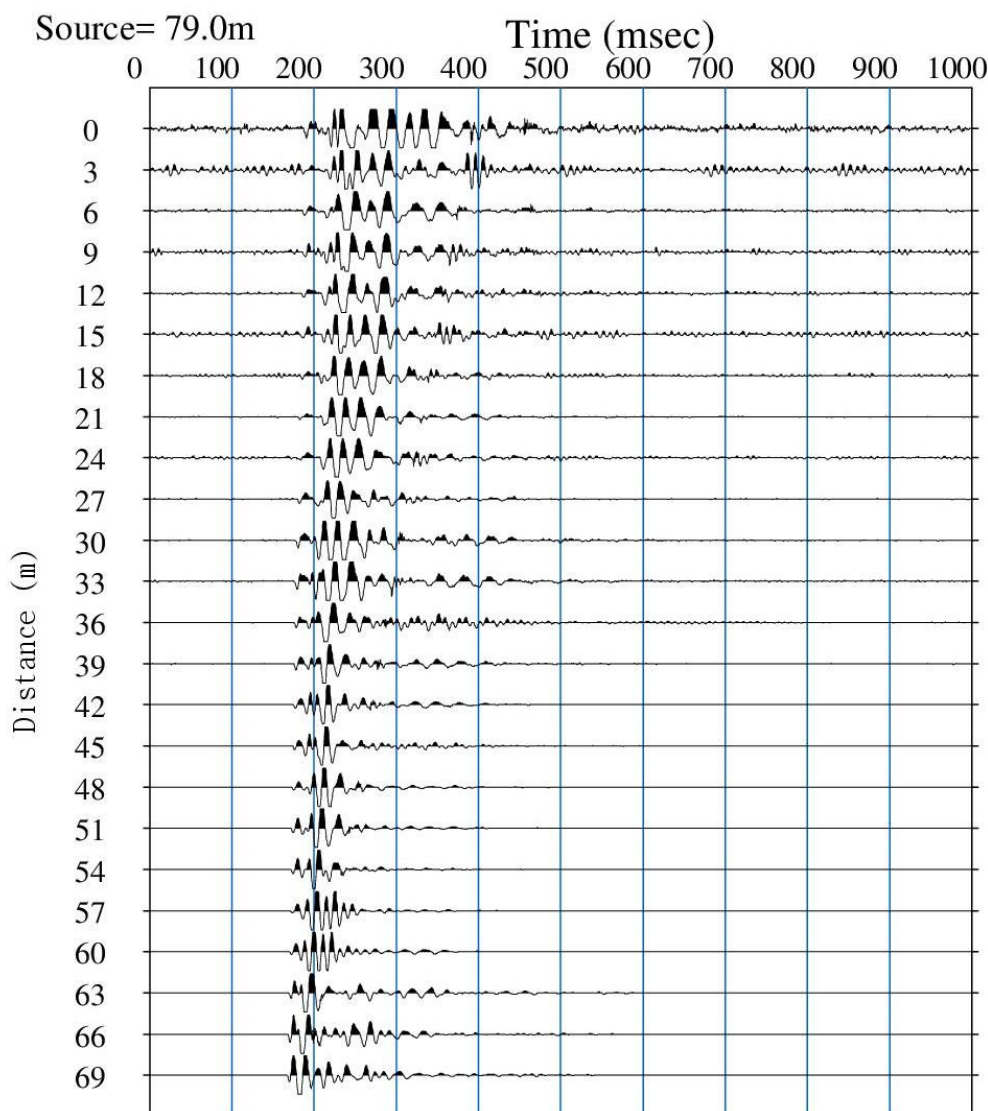


Figure 3: Typical seismic record collected at the site of MASW Line 2.

## Data Processing

Processing of the MASW test results consisted of the following main steps:

- 1) Transformation of the time domain data into the frequency domain using a Fast-Fourier Transform (FFT) for each source location;
- 2) Calculation of the phase for each frequency component;
- 3) Linear regression to calculate phase velocity for each frequency component;
- 4) Filtering of the calculated phase velocities based on the Pearson correlation coefficient ( $r^2$ ) between the data and the linear regression best fit line used to calculate phase velocity;
- 5) Generation of the dispersion curve by combining calculated phase velocities for each shot location of a single MASW test; and,

- 6) Generation of the stiffness profile, through forward iterative modelling and matching of model data to the field collected dispersion curve.

Processing of the MASW data was completed using the SeisImager/SW software package (Geometrics Inc.). The calculated phase velocities for a seismic shot point were combined and the dispersion curve generated by choosing the minimum phase velocity calculated for each frequency component as shown on Figure 4 for Line 1 and Figure 5 for Line 2. Shear wave velocity profiles were generated through inverse modelling to best fit the calculated dispersion curves. The active survey of Line 1 provided a dispersion curve with a suitable frequency range (9-31 Hz). The active survey of Line 2 provided a dispersion curve with a suitable frequency range (9-81 Hz). The minimum measured surface wave frequency with sufficient signal-to-noise ratio to accurately measure phase velocity was approximately 9 Hz at Lines 1 and 2.

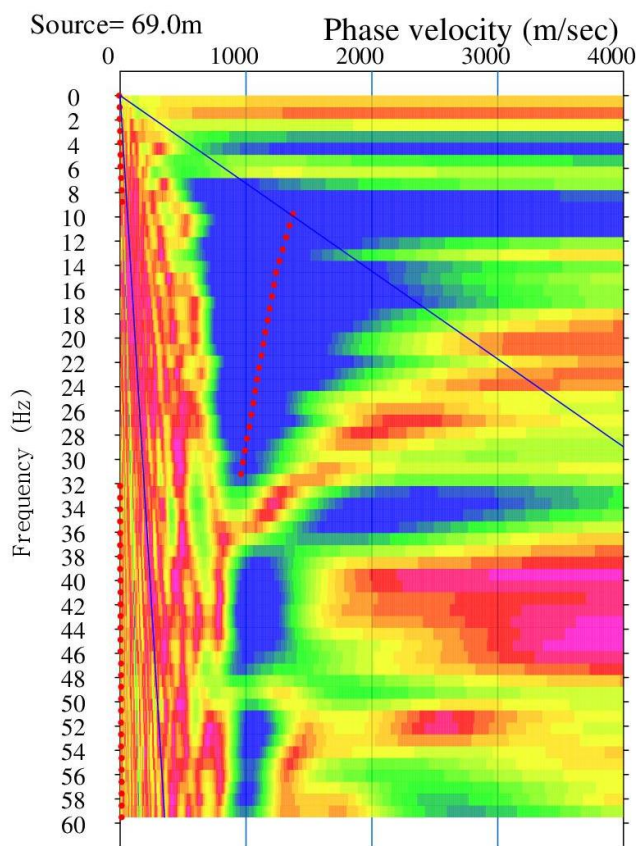


Figure 4: Active MASW Dispersion Curve Picks (red dots) along MASW Line 1

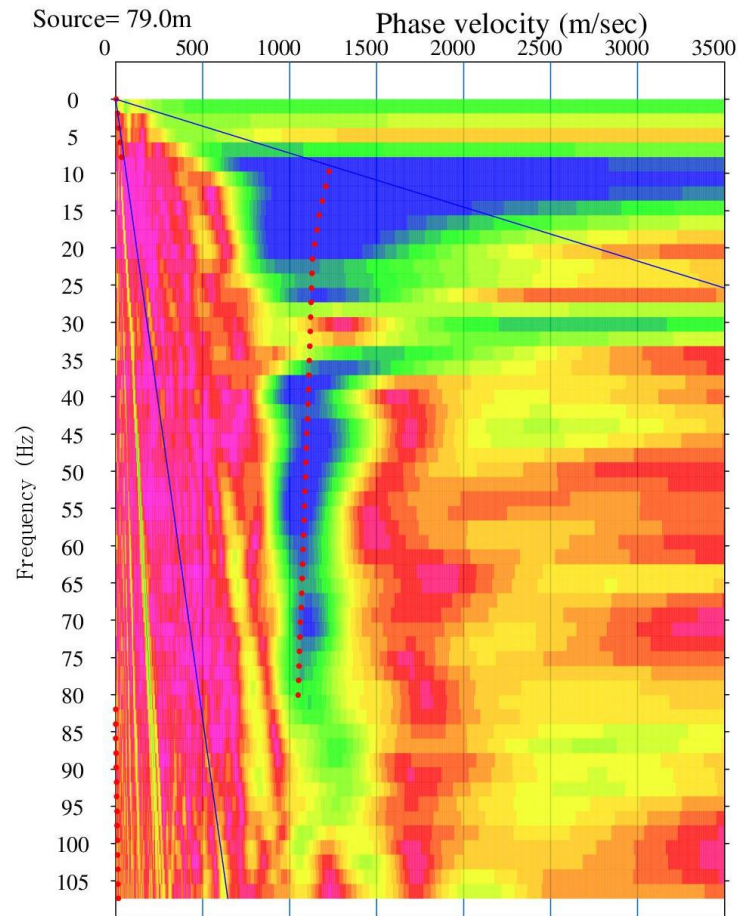


Figure 5: Active MASW Dispersion Curve Picks (red dots) along MASW Line 2

## Results

The MASW test results are presented in Figures 6 and 7, which present the calculated shear wave velocity profile derived from the field testing along MASW Lines 1 and 2, respectively. The results along MASW Line 1 have been calculated using a weight-drop located 5 m from the last geophone. The results along MASW Line 2 have also been calculated using a weight-drop located 5 m from the last geophone. The field collected dispersion curves are compared with the model generated dispersion curves on Figures 8 and 9 for MASW Lines 1 and 2, respectively. There is a satisfactory correlation between the field collected and model calculated dispersion curves, with a root mean squared error of less than 1% along both lines.



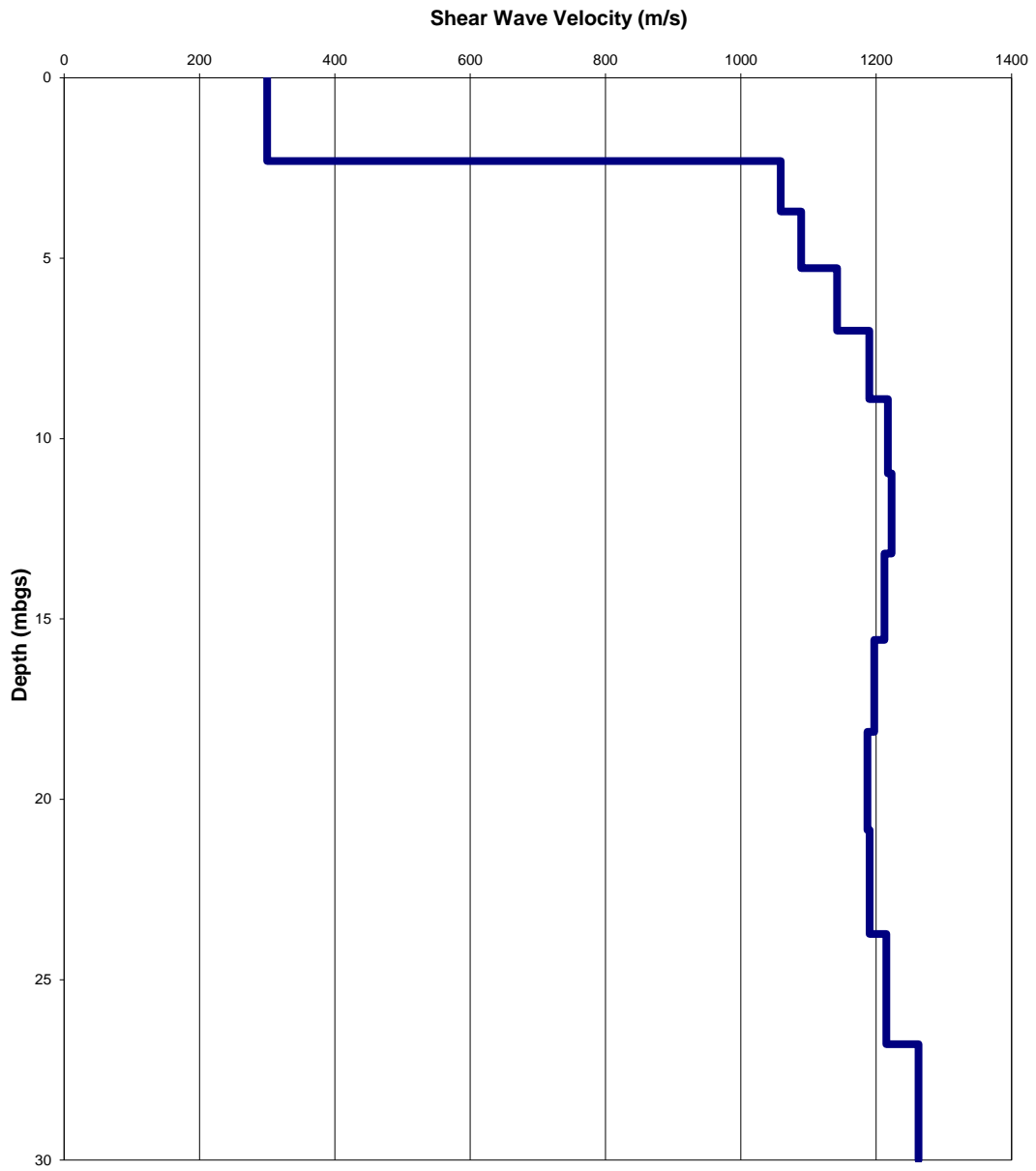


Figure 7: MASW Modelled Shear-Wave Velocity Depth profile along MASW Line 2

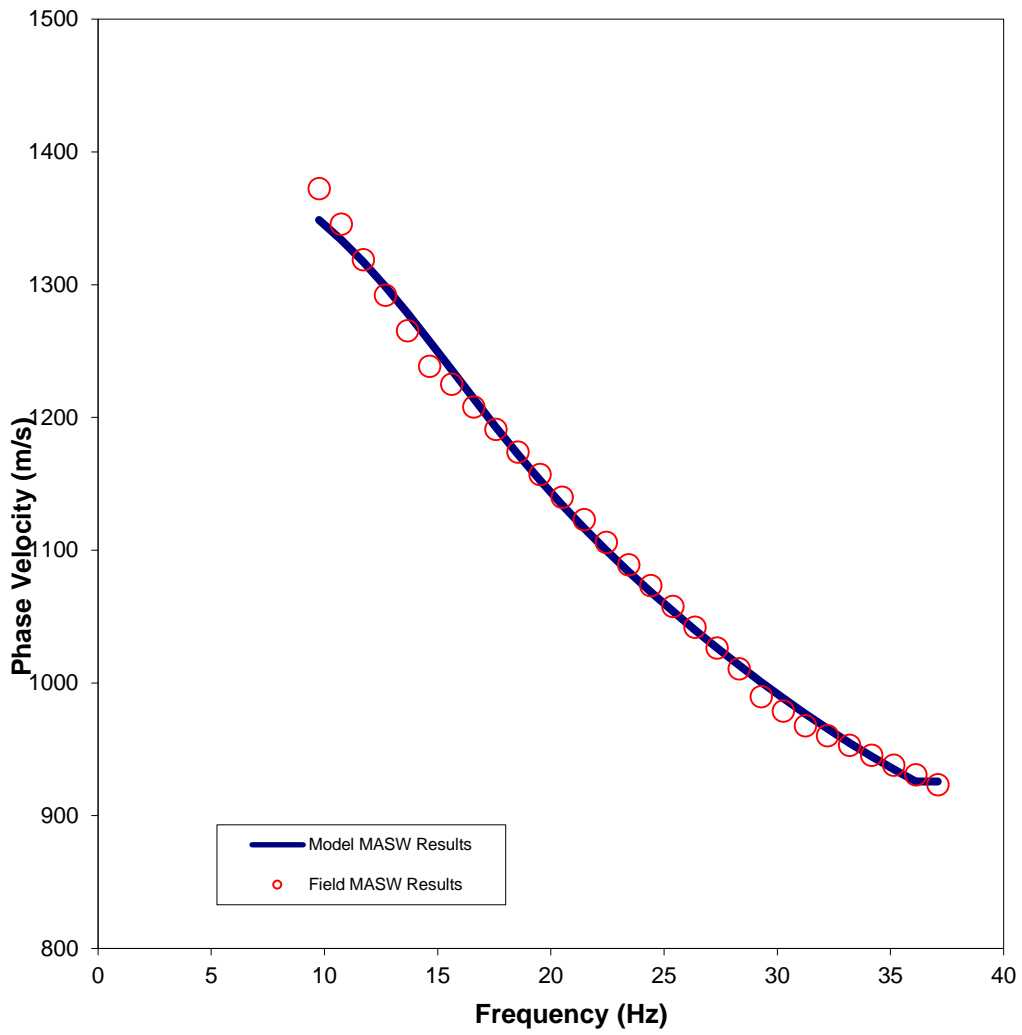
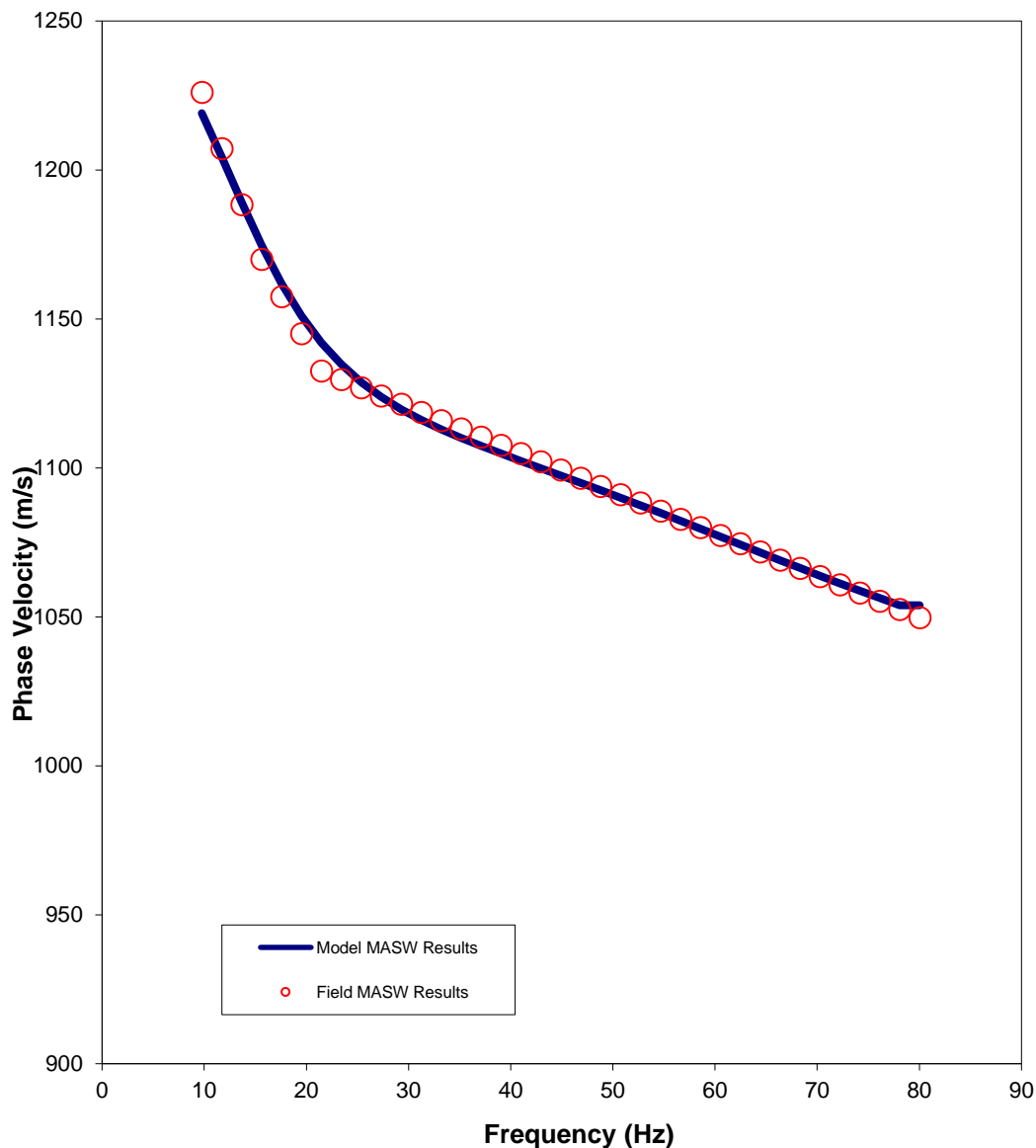


Figure 8: Comparison of Field (red dots) vs. Modelled Data (blue line) along MASW Line 1



**Figure 9: Comparison of Field (red dots) vs. Modelled Data (blue line) along MASW Line 2**

To calculate the average shear-wave velocity as required by the CHBDC 2014, the results were modelled to 30 metres below ground surface. The average shear-wave velocity along MASW Line 1 in the north was found to be 863 m/s (Table 1). The average shear-wave velocity along MASW Line 2 in the south was found to be 969 m/s (Table 2).

**Table 1: Shear-Wave Velocity Profile along MASW Line 1**

Model Layer (mbgs)		Layer Thickness (m)	Shear Wave Velocity (m/s)	Shear Wave Travel Time Through Layer (s)
Top	Bottom			
0.00	1.07	1.07	250	0.004286
1.07	2.31	1.24	250	0.004945
2.31	3.71	1.40	823	0.001703
3.71	5.27	1.57	829	0.001889
5.27	7.01	1.73	847	0.002044
7.01	8.90	1.90	885	0.002143
8.90	10.96	2.06	964	0.002138
10.96	13.19	2.23	1073	0.002074
13.19	15.58	2.39	1160	0.002060
15.58	18.13	2.55	1206	0.002118
18.13	20.85	2.72	1223	0.002224
20.85	23.74	2.88	1234	0.002338
23.74	26.79	3.05	1261	0.002417
26.79	30.00	3.21	1346	0.002387
<b>Vs Average to 30 mbgs (m/s)</b>				<b>863</b>

**Table 2: Shear-Wave Velocity Profile along MASW Line 2**

Model Layer (mbgs)		Layer Thickness (m)	Shear Wave Velocity (m/s)	Shear Wave Travel Time Through Layer (s)
Top	Bottom			
0.00	1.07	1.07	300	0.003571
1.07	2.31	1.24	300	0.004121
2.31	3.71	1.40	1059	0.001323
3.71	5.27	1.57	1089	0.001438
5.27	7.01	1.73	1142	0.001515
7.01	8.90	1.90	1190	0.001593
8.90	10.96	2.06	1217	0.001693
10.96	13.19	2.23	1223	0.001820
13.19	15.58	2.39	1212	0.001972
15.58	18.13	2.55	1197	0.002134
18.13	20.85	2.72	1187	0.002291
20.85	23.74	2.88	1190	0.002424
23.74	26.79	3.05	1215	0.002511
26.79	30.00	3.21	1262	0.002546
<b>Vs Average to 30 mbgs (m/s)</b>				<b>969</b>

The CHBDC 2014 requires special site specific evaluation if certain soil types are encountered on the site, so the site classification stated here should be reviewed, and modified if necessary, according to borehole stratigraphy, standard penetration resistance results, and undrained shear strength measurements, if available for this site.

## Limitations

This technical memorandum is based on data and information collected by Golder Associates Ltd. and is based solely on the conditions of the properties at the time of the work, supplemented by historical information and data obtained by Golder Associates Ltd. as described in this memo.

Golder Associates Ltd. has relied in good faith on all information provided and does not accept responsibility for any deficiency, misstatements, or inaccuracies contained in the reports as a result of omissions, misinterpretation, or fraudulent acts of the persons contacted or errors or omissions in the reviewed documentation.

The services performed, as described in this memo, were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

Any use which a third party makes of this memo, or any reliance on, or decisions to be made based on it, are the responsibilities of such third parties. Golder Associates Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this memo.

The findings and conclusions of this memo are valid only as of the date of this memo. If new information is discovered in future work, including excavations, borings, or other studies, Golder Associates Ltd. should be requested to re-evaluate the conclusions of this memo, and to provide amendments as required.

## Closure

We trust that this technical memorandum meets your needs at the present time. If you have any questions or require clarification, please contact the undersigned at your convenience.

### **GOLDER ASSOCIATES LTD.**



Stephane Sol, Ph.D., P. Geo.  
*Senior Geophysicist*

SS/CRP/jl



Christopher Phillips, M.Sc., P. Geo.  
*Senior Geophysicist, Principal*

**APPENDIX F**

**Site Photographs (provided by WSP)**



**South Elevation - Looking towards HWY 417 WB**



**North Elevation - Looking towards Cyrville Road EB**



**[golder.com](http://golder.com)**