January 2018

REPORT ON

Foundation Investigation
Innes Road Underpass Rehabilitation
Site No. 3-305
Highway 417
Ottawa, Ontario
G.W.P. 4145-10-00

Submitted to:
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REPORT

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FOUNDATION INVESTIGATION REPORT
INNES ROAD UNDERPASS REHABILITATION
SITE NO. 3-305
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 bridges and structural culverts rehabilitation and/or replacements on Highway 417 between the Aviation Parkway and Ramsayville Road and also includes 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 to collect subsurface information required for the static and seismic assessment of the bridge foundations as input to the rehabilitation of the Innes Road Underpass, Site No. 3-305 located on Highway 417 in Ottawa, Ontario (G.W.P. 4145-10-00 and W.P. 4156-10-01). 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, dated May 2016, and subsequent addenda. Golder's scope of work for foundation engineering services associated with the Innes Road Underpass at Highway 417 is contained in Table 17.8.3 of WSP's Technical Proposal for this assignment and in the emails with WSP, dated April 10 and April 13, 2017. 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 Site Description

The Innes Road Underpass is located within a mixed use area of the City of Ottawa, and is located approximately 600 m south of the Cyrville Road and 1.5 km east of St. Laurent Boulevard in the township of Gloucester. At this location, Highway 417 is a divided highway with two travel lanes in each direction separated by a median approximately 25 m wide.

The existing bridge was constructed in 1973 and is a two-span structure, about 85 m long with span lengths of about 42.7 m. It is a concrete post-tensioned voided structure with ten rectangular voids. The overall structure width is about 29 m including barrier walls, a concrete median, and sidewalks. The centre pier consists of three circular columns supported by spread footings founded on bedrock. The bridge abutments sit on “perched” pile caps supported on battered steel HP12×24 (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 2 horizontal to 1 vertical (2H:1V). 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.

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

2.2 Regional Geology

As delineated in *The Physiography of Southern Ontario*[1], 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 bedrock[2]. 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.

2.3 Regional Tectonic and Seismic Setting

The project site falls within the Western Quebec Seismic Zone (WQSZ) according to the Geological Survey of Canada. The WQSZ constitutes a large area that extends from Montreal to Témiscaming, and which encompasses the Ottawa area. Within the WQSZ recent seismic activity has been concentrated in two subzones; one along the Ottawa River and another more active subzone along the Montreal-Maniwaki axis. Historical seismicity within the WQSZ from 1900 to 2001 is given on Figure 5.2 and includes the 1935 Témiscaming event which had a magnitude (i.e., a measure of the local intensity of the earthquake, M_{bLg} or MN) of 6.2 and the 1944 Cornwall-Massena event which had a magnitude of 5.6. The most recent significant earthquake in the Ottawa area, on May 17, 2013, had a magnitude of 5.2 and was centered about 18 km northeast of Shawville, Québec.

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[1] 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.

[2] 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.

3.0 INVESTIGATION PROCEDURES

3.1 Current Investigation (2017)

The field work for the current subsurface investigation was carried out on May 23, 2017. One borehole (17-1201, see Drawing 1) was advanced at the Highway 417 level near the existing centre pier. The borehole was advanced using a truck mounted drill rig supplied and operated by George Downing Estate Drilling Ltd. of Hawkesbury, Ontario. Traffic control required to access the borehole location was provided by Beacon Lite Ltd. of Ottawa, Ontario. The borehole was advanced to about 8.2 m depth below the ground surface.

Samples of the overburden were obtained at regular intervals of depth using 50 mm outside diameter split-spoon samplers in accordance with the Standard Penetration Test (SPT) procedure. In the bedrock, rotary diamond drilling techniques were used to retrieve NQ sized core. A water truck was on site to supply the drill rig with water for the coring of the bedrock. The bedrock was cored for 3.2 m after practical refusal to augering had been reached. One monitoring well was installed in the borehole to a depth of about 4.9 m to monitor the groundwater level at the site. The monitoring well consists of 50 mm outside diameter PVC tubing with a flush mount cap. 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 by a member 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 London for testing. Index and classification tests consisting of water content determinations and grain size distribution analyses were carried out on selected soil samples at the London laboratory.

The groundwater levels were subsequently measured in the monitoring well on June 22, 2017.

In addition to the borehole investigation, shear wave velocity profiling at the site was completed using the Multichannel Analysis of Surface Waves (MASW) technique. The MASW profiling was conducted on May 9, 2017 by personnel from the Golder Associates' Mississauga and Ottawa offices. Traffic control required to access the MASW locations was provided by Beacon Lite Ltd. of Ottawa, Ontario. A series of 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 various distances beyond the end and collinear with the geophone array.

The borehole location was surveyed by Golder using a Trimble R8 GPS unit. The borehole location in 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.

Borehole Number	Borehole Location	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
BH17-1201	Pier	5030866.8	374440.8	65.3	8.2

3.2 Previous Investigation (1971)

A previous investigation was carried out in 1971 by the MTO (then the Department of Transportation and Communications) for the design of the existing bridge. The results of that investigation are contained in the report titled "*Foundation Investigation Report for Proposed Underpass Structure at the Crossing of Hwy. #417 and Innes Rd., Regional Municipality of Ottawa-Carleton, District #9 (Ottawa), W.O. 71-11127, W.P. 13-68-05*", dated February 8, 1972 (GEOCRES No. 31G5-81).

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

Five boreholes and two Dynamic Cone Penetration Tests (DCPTs) were put down at the site as part of the original investigation in 1971 along the then-proposed bridge alignment. The approximate borehole and DCPT ground surface elevations are included on the Record of Borehole sheets included in Appendix B and are shown on Drawing 1. The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are given on the borehole records from the 1971 investigation.

4.0 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 General

The Record of Borehole and Drillhole 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 Boreholes sheets and on Figures A1 to A4, which are also included in Appendix A. Photographs of the recovered bedrock core are included on Figures A5 and A6 included in Appendix A. The Record of Borehole sheets and associated laboratory test results from the 1971 investigation are provided in Appendix B.

The borehole locations from the current and previous investigations are shown on Drawing 1. The interpreted stratigraphic profile projected along the Innes Road underpass is also shown on Drawing 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. Further, the boreholes from the 1971 investigation were put down prior to construction of the bridge and the ground surface conditions represented on those Record of Borehole sheets may not be fully representative of the post-construction subsurface conditions, particularly at the pier foundations.

The MASW test results and report are presented in Appendix C 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. The results of chemical testing carried out on a sample of soil from Borehole 17-1201 are included in Appendix D.

In general, the subsurface conditions at the borehole location consists of a layer of fill underlain by loose to very dense sand and silt overlying shale bedrock. A detailed description of the subsurface conditions encountered in the current and historic boreholes is provided in the following sections.

4.2 Granular Fill

Borehole 17-1201 was put down on the inside shoulder of the westbound lanes of Highway 417. At that location, the asphaltic concrete is about 200 mm thick and is underlain by granular fill.

The granular fill extends to about 2.1 m below ground surface and consists of gravelly sand to sandy gravel with some silt. SPT ‘N’ values obtained within this fill generally range from about 20 to 65 blows per 0.3 m of penetration indicating a compact to very dense compactness.

Grain size distribution testing was carried out on one sample of the fill from Borehole 17-1201, the results of which are provided on Figure A1 in Appendix A. The measured water content of the fill samples from Borehole 17-1201 ranges from approximately 2.5 to 9 percent.

4.3 Sand and Silt

A deposit of silty sand to sandy silt was encountered beneath the granular fill at Borehole 17-1201, and from ground surface in the 1971 boreholes. In the boreholes put down near the pier (17-1201 and BH 1) SPT “N” values in the sand and silt ranged from 3 to 50 blows per 0.3 m of penetration, indicating a very loose to dense compactness. One SPT ‘N’ value of 65 blows per 0.3 m of penetration was recorded at about 4.9 m depth in Borehole 17-1201 but is likely indicative of refusal on the weathered bedrock. In the boreholes put down near the abutments (BH 1 and BH 4), SPT ‘N’ values in the deposit ranged from 9 to 41 blows per 0.3 m of penetration, indicating a loose to dense compactness.

Grain size distribution testing was carried out on two samples of the deposit from Borehole 17-1201 and the results are provided on Figures A2 and A3 in Appendix A. The measured water contents of three samples of this deposit from Borehole 17-1201 ranged from about 20 to 29 percent.

4.4 Bedrock

The bedrock encountered at the site consists of thinly to thickly bedded, grey to black shale. The bedrock surface generally slopes down to the east, from about Elevation 59.6 m at BH 4 (west abutment) to about 58.3 m at BH 1 (east abutment). The Rock Quality Designation (RQD) values of the cored bedrock at Borehole 17-1201 were about 70 to 100 percent, indicating a fair to excellent quality rock. The lowest rock quality was recorded for the upper 0.7 m of the bedrock in Borehole 17-1201.

Photos of the bedrock core obtained from Borehole 17-1201 during the current investigation are provided in Appendix A on Figures A5 and A6.

Due to the fragile nature of the recovered shale bedrock core, unconfined compressive strength testing was not possible. However, point load testing was carried out on four pieces of the shale from Borehole 17-1201. The results of the point load testing indicate compressive strengths ranging from about 10 to 28 MPa, as shown on Figure A4 in Appendix A, indicating a weak to medium strong rock.

4.5 Groundwater Conditions

The groundwater level was measured in the Borehole 17-1201 on June 22, 2017. At that time, the groundwater level was 2.0 metres below existing ground surface (i.e., elevation 63.3 metres). The ground water levels measured during the 1971 investigation indicate the water table ranged from about Elevation 61.9 m to 62.8 m at the time of that investigation. The recorded water levels are summarized in the table below.

Borehole Number	Borehole Location	Screened Interval	Date	Depth (m)	Elevation (m)
17-1201	Pier (North)	Sand and Silt	June 22, 2017	2.0	63.3
BH 1	East Abutment	n/a [1]	November 29, 1971	2.0 [1]	61.9 [1]
BH 2	Pier (North)	n/a [1]	November 30, 1971	2.6 [1]	62.3 [1]
BH 3	Pier (South)	n/a [1]	November 29, 1971	2.9 [1]	62.3 [1]
BH 4	West Abutment	n/a [1]	November 30, 1971	2.6 [1]	62.8 [1]
BH 5	West Embankment	n/a [1]	December 1, 1971	2.8 [1]	62.8 [1]

Note[1]: Water level recorded in open borehole during 1971 investigation.

The water level at the site is expected to fluctuate seasonally in response to changes in precipitation and snow melt, and is expected to be higher during the spring and periods of precipitation.

5.0 CLOSURE

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

Golder Associates Ltd.

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MSS/MJK/FJH/mvrd
https://golderassociates.sharepoint.com/sites/11263g/shared documents/01_foundations/6 - reports/1120 - innes road/final/1662565-1120 final fir innes rd rpt-001 january 2018.docx

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

CONT No.
GWP No. 4145-10-00

INNES ROAD UNDERPASS

HIGHWAY 417
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

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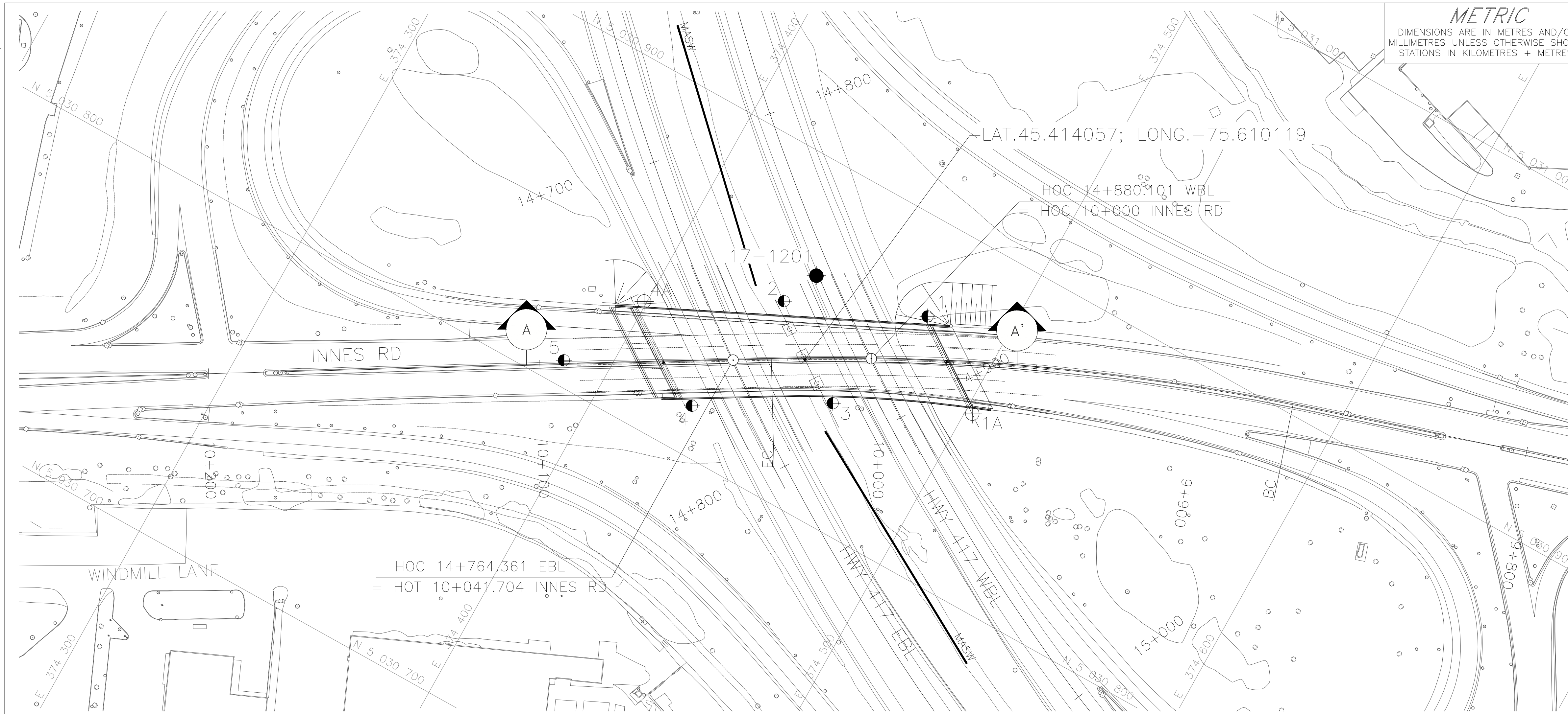
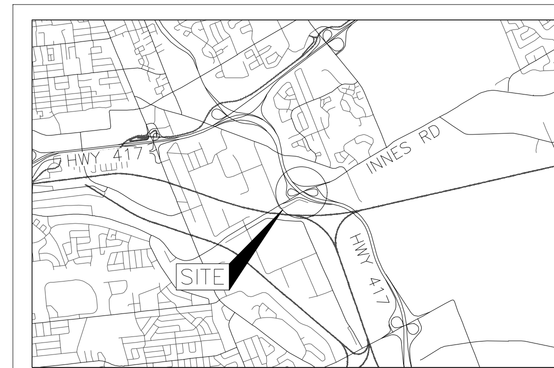


PLAN

SCALE 15 0 15 30 m



KEY PLAN

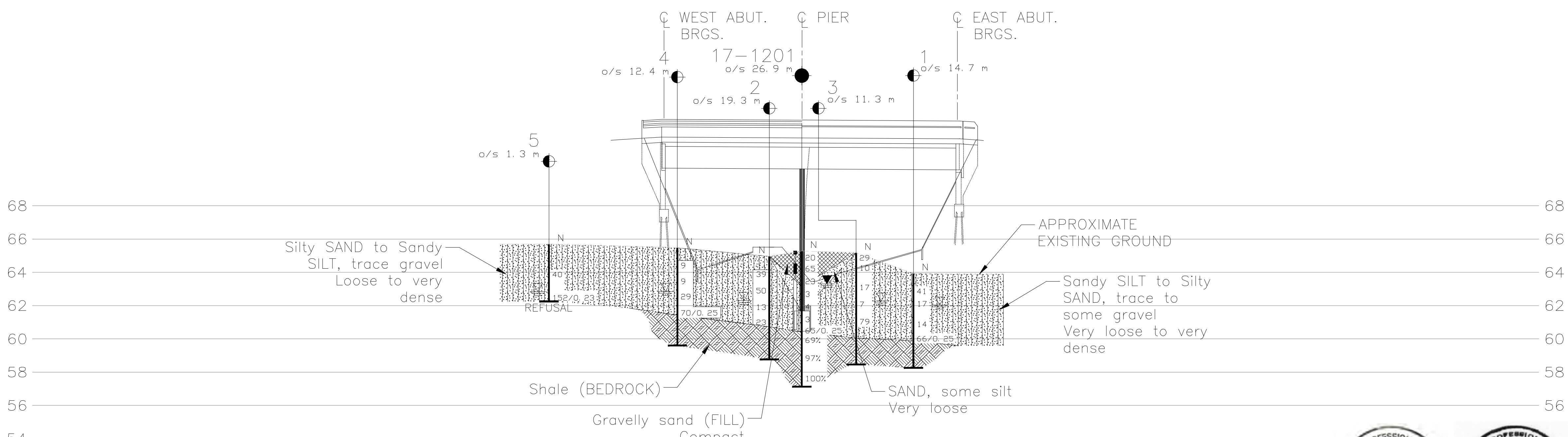
SCALE 1 0 1 2 km

LEGEND

- Borehole – Current Investigation
- Borehole – Previous Investigation (Geocres No. 31G5-81)
- Dynamic Cone Penetration Test – Previous Investigation (Geocres No. 31G5-81)
- 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 JUN. 22, 2017
- WL in open borehole, measured on NOV./DEC., 1997

BOREHOLE CO-ORDINATES (MTM ZONE 9)

No.	ELEVATION	NORTHING	EASTING
17-1201	65.3	5030866.8	374440.8
BH 1	63.9	5030872.4	374476.1
BH 2	65.0	5030855.3	374436.0
BH 3	65.2	5030835.6	374463.9
BH 4	65.5	5030814.3	374427.1
BH 5	65.7	5030807.4	374386.8



CROSS-SECTION A-A'

SCALE 15 0 15 30 m
3 0 3 6

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 and drawing file no. 17M-00850-00-01 GA I.dwg, recieved NOV. 23, 2017.

LICENSED PROFESSIONAL ENGINEER M. J. KENNEDY 100165940 Jan 26, 2018 PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER F. J. HEFFERNAN JAN 26, 2018 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 31G5-285			
HWY. 417	PROJECT NO. 1662565		DIST. EASTERN
SUBM'D. SAT	CHKD. MJK	DATE: 11/29/2017	SITE:
DRAWN: JM	CHKD. MSS	APPD. FJH	DWG. 1

APPENDIX A

Borehole/Drillhole Record and Laboratory Test Results (Current Investigation)

Lists of Abbreviations and Symbols
Lithological and Geotechnical Rock Description Terminology
Records of Borehole and Drillhole 17-1201
Laboratory Test Results, Figures A1 to A4
Bedrock Core Photographs, Figures A5 to A6

LIST OF SYMBOLS

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

I. GENERAL

π	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

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\,\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

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

(a) Index Properties (continued)

w	water content
w_l 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_α	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
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan\delta$
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

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

LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
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, 60º cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH:	Sampler advanced by hydraulic pressure
PM:	Sampler advanced by manual pressure
WH:	Sampler advanced by static weight of hammer
WR:	Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

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

(b) Cohesive Soils
Consistency

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

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

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

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	Sand and Gravel
	With (cohesive)	Silty Clay with sand / Clayey Silt with sand

WEATHERINGS STATE

Fresh: no visible sign of weathering

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^{o} 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		

Golder Associates

Foundation Design

RECORD OF BOREHOLE No 17-1201

SHEET 1 OF 2 **METRIC**

PROJECT 1662565-1120			
G.W.P. 4145-10-00	LOCATION N 5030866.8; E 374440.8 MTM ZONE 9 (LAT. 45.414272; LONG. -75.610235)		ORIGINATED BY DG
DIST Eastern HWY 417	BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem)/Rotary Drill		COMPILED BY ZS
DATUM Geodetic	DATE May 23, 2017		CHECKED BY WAM

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
65.3	GROUND SURFACE				
65.1 / 0.0	ASPHALTIC CONCRETE				
0.2	(SW) Gravelly sand (FILL) Compact Dry	1	SS	20	
64.5 / 0.8	(GW) Sandy gravel (FILL) Very dense Grey Dry	2	SS	65	
63.8 / 1.5	(SP) Gravelly sand, some silt (FILL) Compact Brown Dry to moist	3	SS	23	24 49 18 9
63.2 / 2.1	(SM) SAND, some silt Very loose Brown Wet	4	SS	3	0 80 19 1
		5	SS	4	
61.6 / 3.7	(SM/ML) SAND and SILT, trace clay Very loose Grey Wet	6	SS	3	0 34 63 3
60.9 / 4.4	(SM) Silty SAND Grey Wet	7	SS	65/0.25	
60.4	Weathered Shale (BEDROCK)				
5.0	Shale (BEDROCK) Bedrock cored from depths 5.0 m to 8.2 m For bedrock coring details refer to Record of Drillhole 17-1201	1	RC	REC 100%	RQD = 69%
		2	RC	REC 100%	RQD = 97%
		3	RC	REC 100%	RQD = 100%
57.1 / 8.2	END OF BOREHOLE				

Column headings: STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (65, 64, 63, 62, 61, 60, 59, 58); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 25 50 75; UNIT WEIGHT γ kN/m³.

NOTES:

1. Water level in well screen at a depth of 2.0 m below ground surface (Elev. 63.3 m), measured on Jun. 22, 2017.

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

RECORD OF DRILLHOLE: 17-1201

PROJECT: 1662565-1120
LOCATION: N 5030866.8 ;E 374440.8
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: May 23, 2017
DRILL RIG: CME 75
DRILLING CONTRACTOR: Downing Drilling

DATUM: Geodetic

NOTE: For abbreviations, symbols and descriptions refer to **LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY**

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	FLUSH RETURN
		BEDROCK SURFACE	60.28		
5	Rotary Drill, NQ Core	Shale (BEDROCK) Thinly to thickly bedded Grey to black Fine grained Porous Weak to medium strong	5.00	1	100
6				2	100
7				3	100
8			57.13 8.15		
		END OF DRILLHOLE			

Column headings: RECOVERY (TOTAL CORE %, SOLID CORE %; 80 60 40 20), R.Q.D. % (80 60 40 20), FRACT. INDEX PER (5 10 15 20), DISCONTINUITY DATA (DIP w.r.t. CORE AXIS 0 30 60 90; TYPE AND SURFACE DESCRIPTION; Jr; Ja), HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-6} 10^{-5} 10^{-4} 10^{-3}), WEATHERING INDEX (W1 W2 W3 W4 W5 W6), FEATURES

DEPTH SCALE
1 : 50

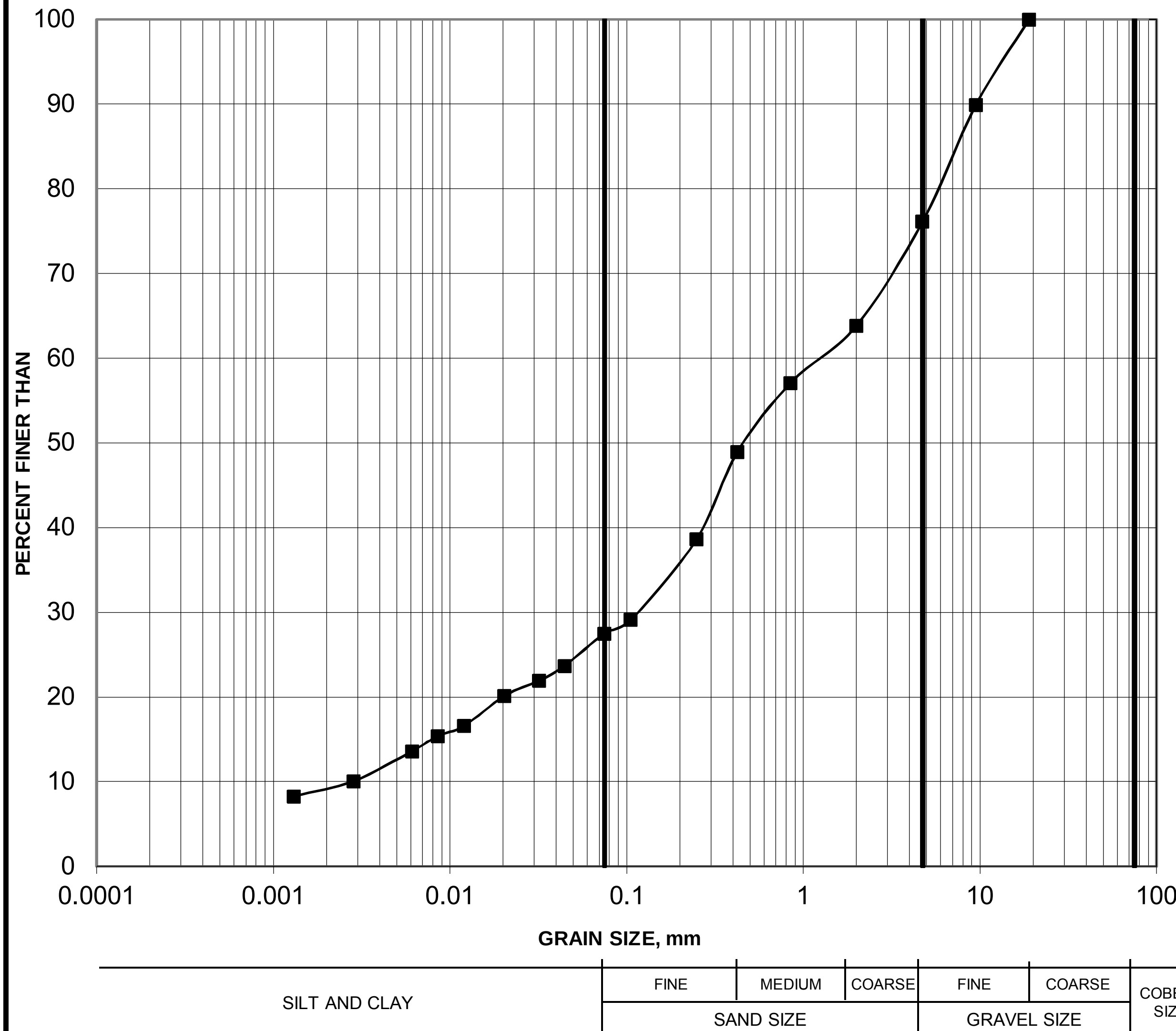
Golder Associates

LOGGED: DG
CHECKED: WAM

GRAIN SIZE DISTRIBUTION

FIGURE A1

Gravelly SAND, some silt (FILL)



Borehole	Sample	Depth (m)
17-1201	3	1.52-2.13

Project: 1662565 /1120

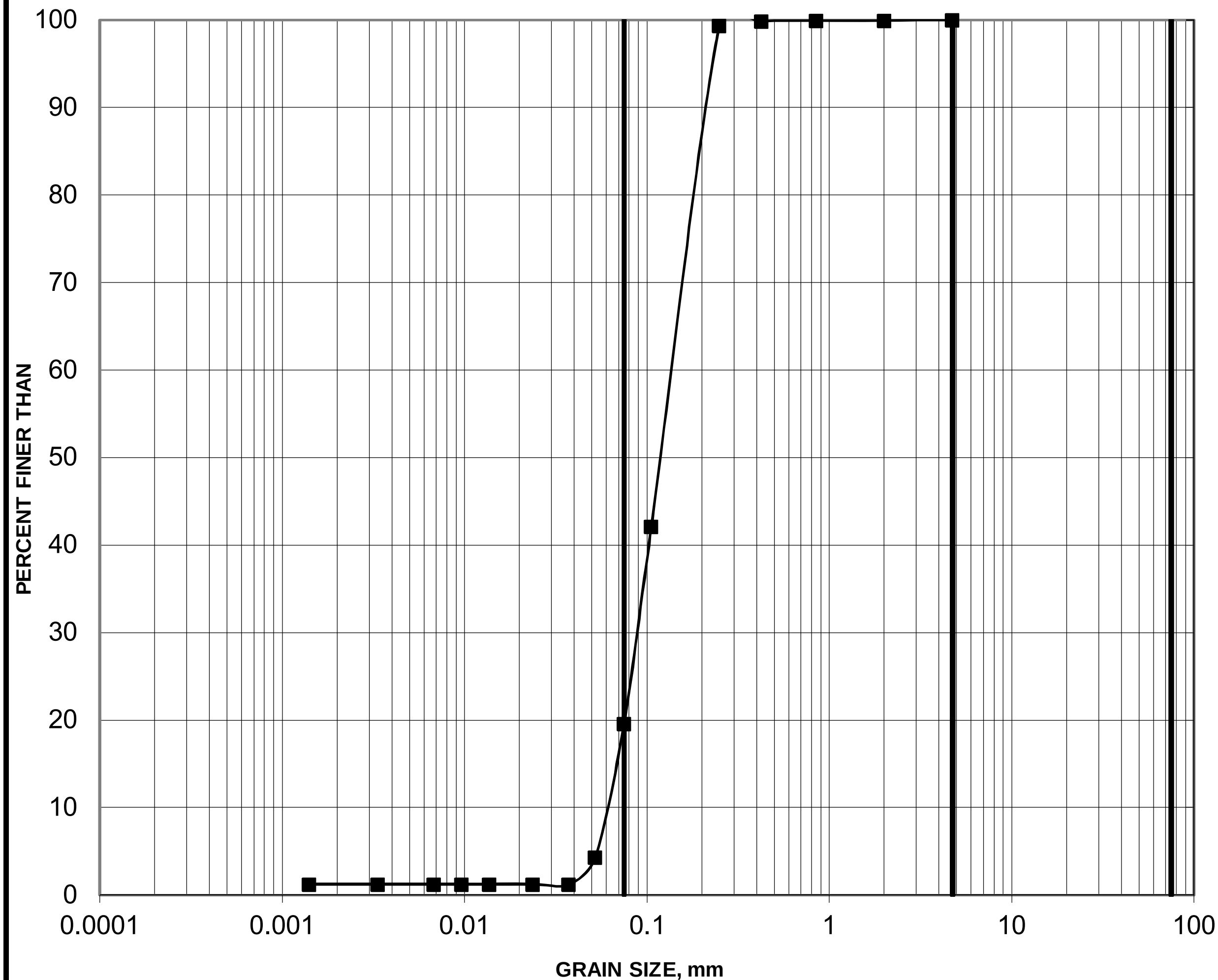
Golder Associates

Created by: AC

Checked by: CNM

GRAIN SIZE DISTRIBUTION	FIGURE A2

SAND, some silt



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

Borehole	Sample	Depth (m)
17-1201	4	2.29-2.90

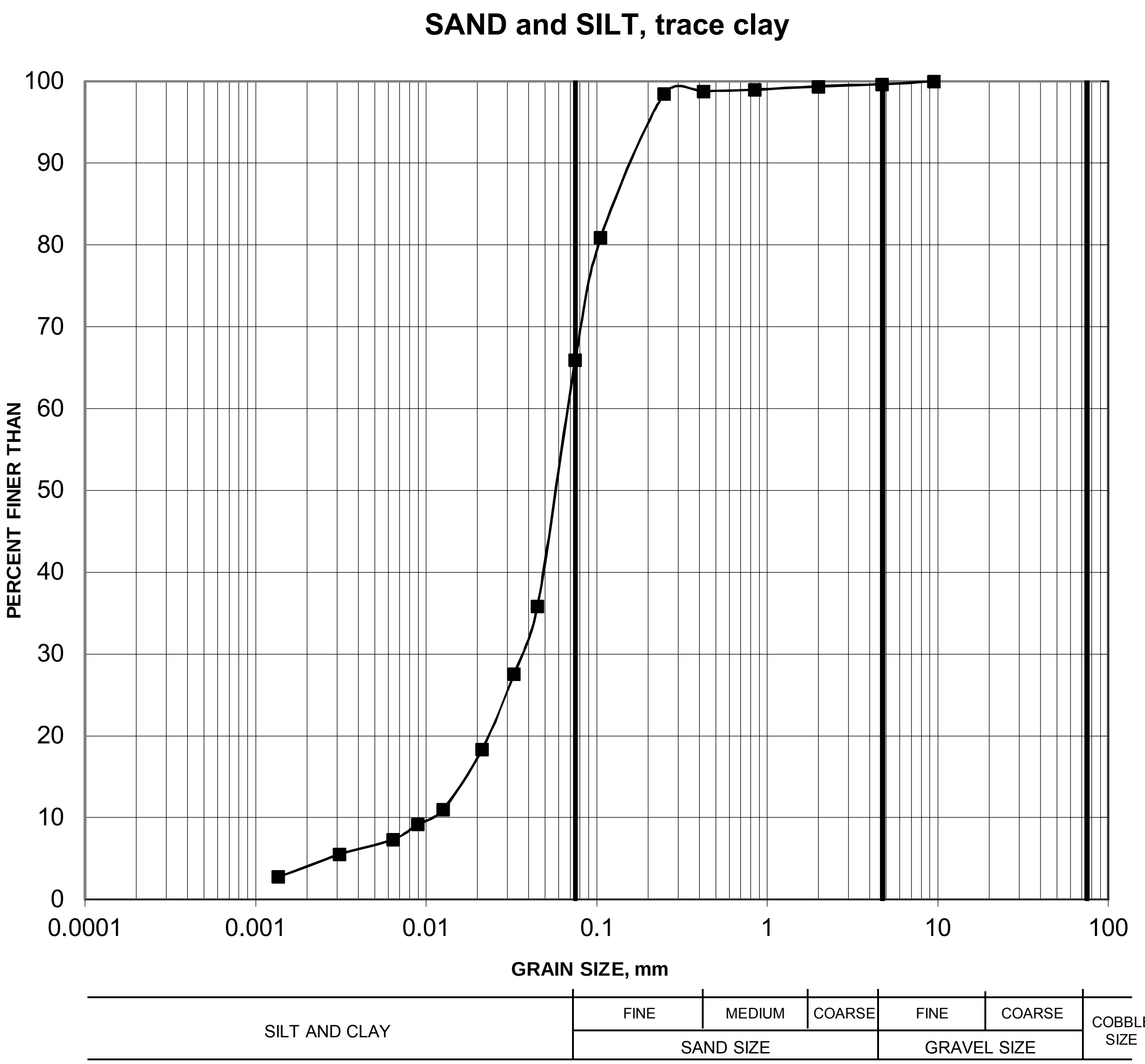
Project: 1662565 /1120

Golder Associates

Created by: AC
Checked by: CNM

GRAIN SIZE DISTRIBUTION

FIGURE A3



Borehole	Sample	Depth (m)
17-1201	6	3.81-4.42

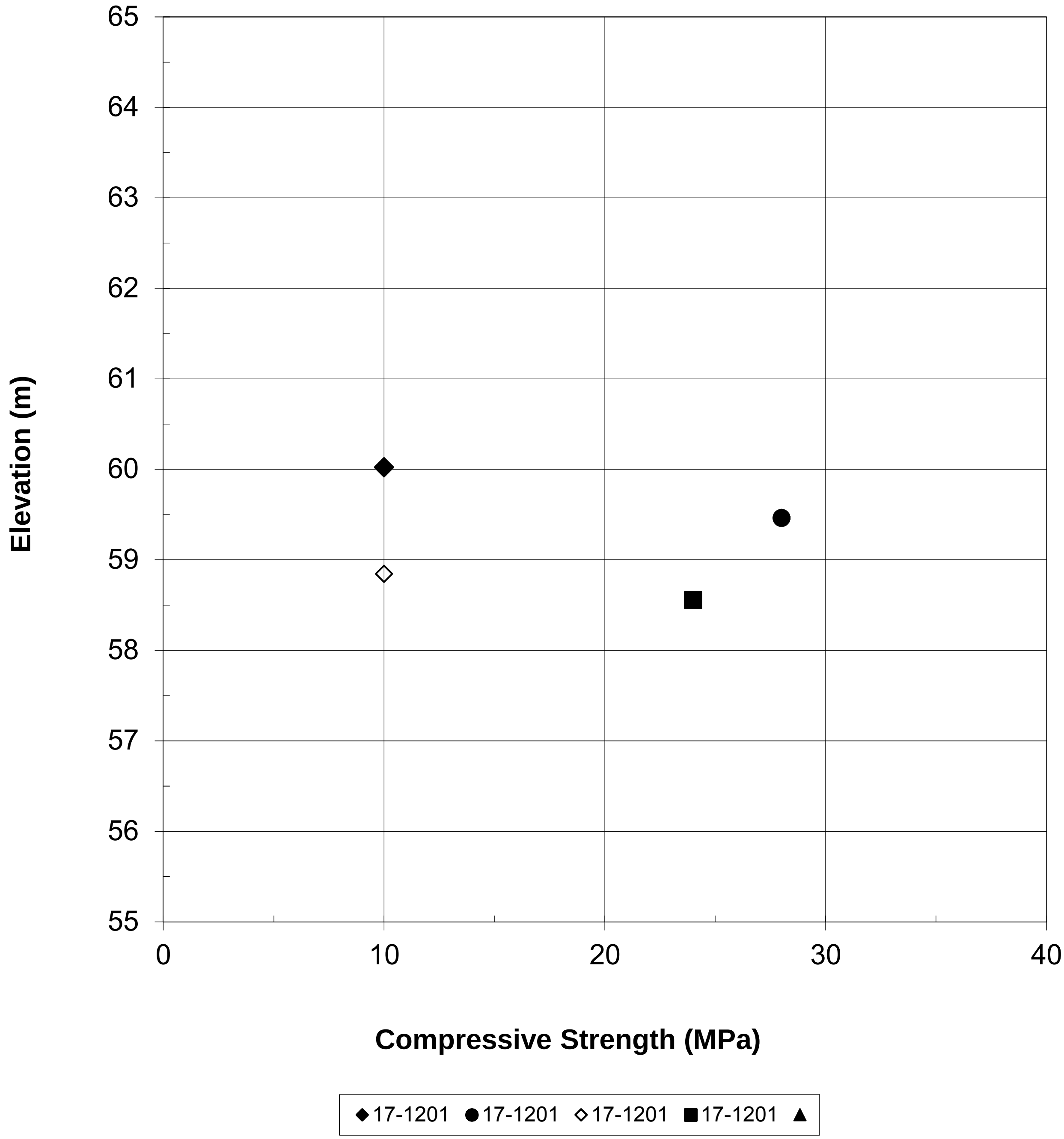
Project: 1662565 /1120

Golder Associates

Created by: AC

Checked by: CNM

SUMMARY OF LABORATORY COMPRESSIVE STRENGTH POINT LOAD TESTING	FIGURE A4



Project: 1662565 /1120

Golder Associates

Created by: MI
Checked by: CNM

BH 17-1201 (Wet)

Cored Length of 5.00 to 8.15 metres

Core Box 1 and 2 of 2

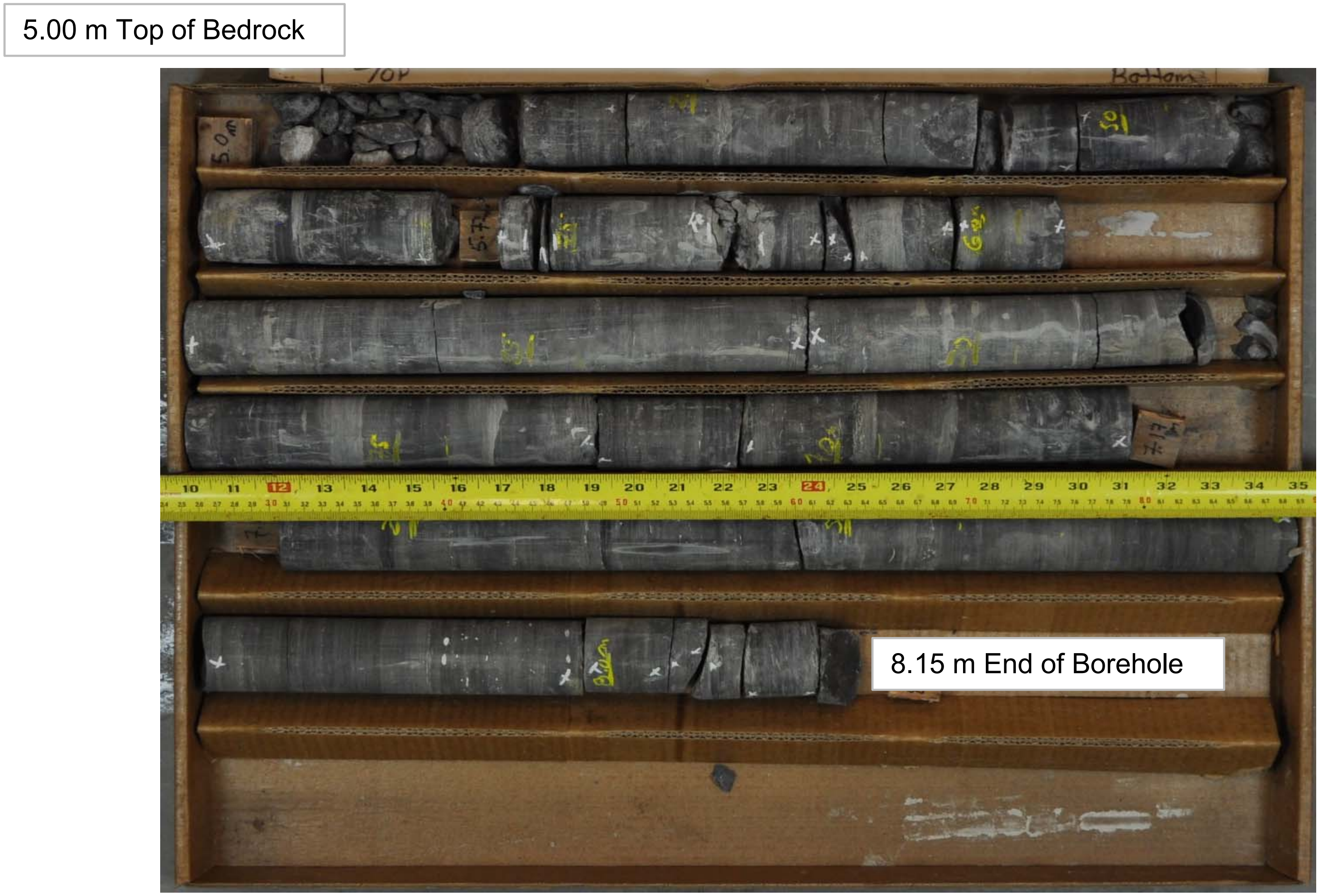
5.00 m Top of Bedrock

Golder Associates	**Geotechnical Investigation** **Innes Road Underpass** **Ottawa, Ontario**	Project No.: 1662565 Drawn: WAM Date: 2017/07/19 Checked: MJK Review:	**Figure A5**

BH 17-1201 (Dry)

Cored Length of 5.00 to 8.15 metres

Core Box 1 and 2 of 2



Golder Associates	**Geotechnical Investigation** **Innes Road Underpass** **Ottawa, Ontario**	Project No. 1662565 Drawn: WAM Date: 2017/07/19 Checked: MJK Review:	**Figure A6**

APPENDIX B

Borehole/Drillhole Record and Laboratory Test Results (Previous Investigation, GEOCRES No. 31G5-81)

Records of Previous Boreholes BH 1 to BH 5
Laboratory Test Results

FORM OD-MT-126 (REV 1969)

OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 1

FOUNDATION SECTION

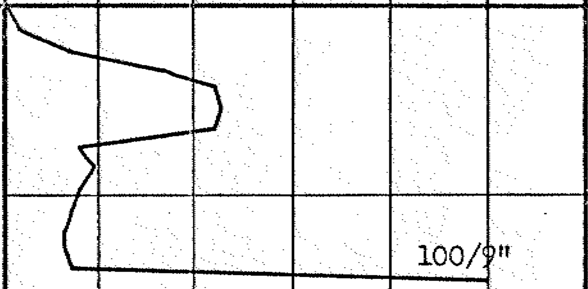
JOB 71-11127
W.P. 13-68-05
DATUM Geodetic

LOCATION CO-ORD'S. 16,504,750 N; 1,228,523 E
BORING DATE NOVEMBER 29, 1971
BOREHOLE TYPE WASHBORING - NX CASING

ORIGINATED BY S. A. A.
COMPILED BY S. A. A.
CHECKED BY [illegible]

SOIL PROFILE: ELEV. DEPTH	SOIL PROFILE: DESCRIPTION	STRAT. PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/FOOT	ELEV. SCALE	REMARKS GR.SA.SI.CL
209.6	GROUND LEVEL						
	Topsoil						
0.8	Sandy Silt with trace of gravel seams of clayey silt Compact to V. Dense Brown-Grey		1	SS	41		▼203.2
			2	SS	17		
			3	SS	14	200	
196.3			4	SS	66/10"		7 26 64 3
13.3	Calcareous Shale Sound - Grey		5	RC	99.5%		
191.0							
18.6	End Of Borehole					190	

DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT
20 40 60 80 100
SHEAR STRENGTH P.S.F.
O UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB. VANE



LIQUID LIMIT — W_L
PLASTIC LIMIT — W_P
WATER CONTENT — W

WATER CONTENT %

BULK DENSITY γ P.C.F.

FORM OD-MT - 126 (REV. 1969)

OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 1A

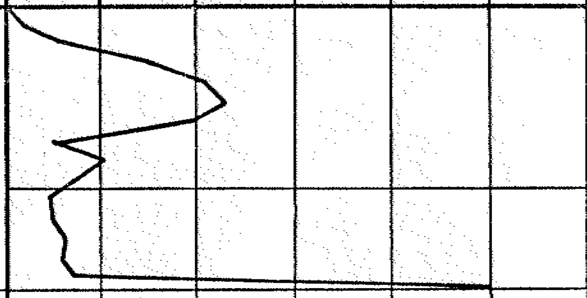
FOUNDATION SECTION

JOB 71-11127
W.P. 13-68-05
DATUM Geodetic

LOCATION Co-Ord's. 16,504,689 N; 1,228,612 E
BORING DATE November 30, 1971.
BOREHOLE TYPE Cone Test Only

ORIGINATED BY S.A.A.
COMPILED BY S.A.A.
CHECKED BY [illegible]

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS/FOOT 20 40 60 60 100; SHEAR STRENGTH P.S.F. ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB. VANE	LIQUID LIMIT — w_L; PLASTIC LIMIT — w_P; WATER CONTENT — w; WATER CONTENT %	BULK DENSITY γ P.C.F.	REMARKS GR.SA.SI.CL
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT					
209.5	Ground Level									
	Probable Bedrock					200				
195.4 / 14.1	End of Cone Test					190				



FORM OD-MT-126 (REV 1969)

OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 2

FOUNDATION SECTION

JOB 71-11127
W.P. 13-68-05
DATUM Geodetic

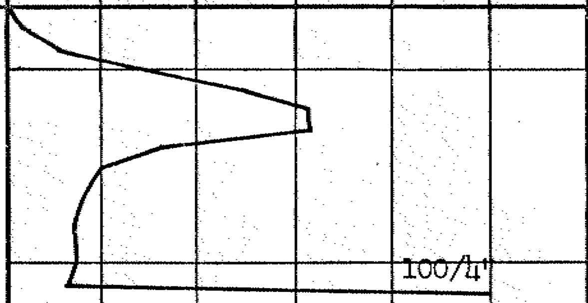
LOCATION Co-Ord's. 16,504,690 N; 1,228,400 E
BORING DATE November 30, 1971
BOREHOLE TYPE Washboring - NX Casing

ORIGINATED BY S.A.A.
COMPILED BY S.A.A.
CHECKED BY [signature]

ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT	ELEV. SCALE	REMARKS GR.SA.SI.CL
213.0	Ground Level						
	Silty Sand with some Gravel- Occ. Silt to clayey Silt Seams Compact to Dense Brown - Grey		1	SS	39	210	
			2	SS	50		24 58 18
			3	SS	13		W.L. Elev.204.4
199.1			4	SS	23	200	
13.9	Calcareous Shale		5	RC	20%		
	Sound - Grey		6	RC	91.5%		
192.7 / 20.3	End of Borehole					190	

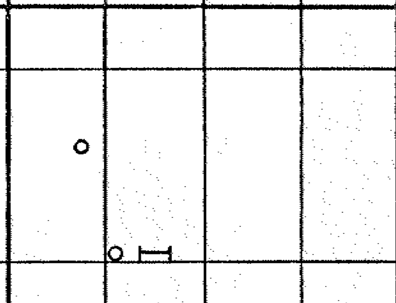
DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100

SHEAR STRENGTH P.S.F.
o UNCONFINED + FIELD VANE
⊛ QUICK TRIAXIAL × LAB. VANE



LIQUID LIMIT — w_L
PLASTIC LIMIT — w_P
WATER CONTENT — w

WATER CONTENT % 10 20 30



BULK DENSITY γ P.C.F.

FORM OD-MT-126 (REV. 1969) OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 3

FOUNDATION SECTION

JOB 71-11127 LOCATION Co-Ord's. 16,504, 625 N; 1,228,484 E ORIGINATED BY S.A.A.

W.P. 13-68-05 BORING DATE November 29, 1971 COMPILED BY S.A.A.

DATUM Geodetic BOREHOLE TYPE Washboring - NX Casing CHECKED BY

ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT	ELEV. SCALE	REMARKS
213.7	Ground Level						
	~~Topsoil~~						
0.8	Silty Sand with some Gravel Occ. Silt to Clayey Silt Seams Loose to V. Dense Brown to Grey		1	SS	29	210	
			2	SS	10		
			3	SS	17		17.70 13
			4	SS	7	200	Elev. 204.3 on Dec.1/71
			5	SS	79		
			6	RC	50%		
196.9 16.8	Calcareous Shale Sound - Grey		7	RC	97.5%		
191.7 22.0	End of Borehole					190	

DYNAMIC PENETRATION RESISTANCE BLOWS/FOOT 20 40 60 80 100

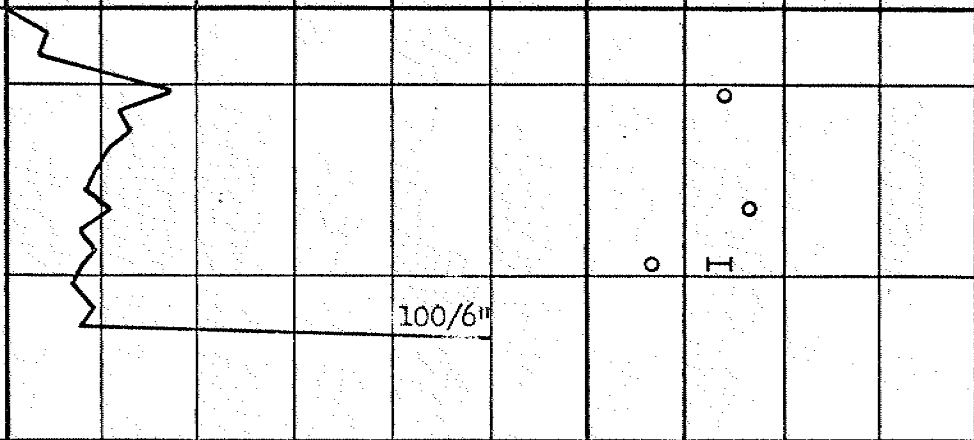
SHEAR STRENGTH P.S.F.
O UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB. VANE

LIQUID LIMIT — w_L
PLASTIC LIMIT — w_P
WATER CONTENT — w

WATER CONTENT % 10 20 30

BULK DENSITY γ P.C.F.

GR.SA.SI.CL.



FORM OD-MT-126 (REV. 1969) OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 4

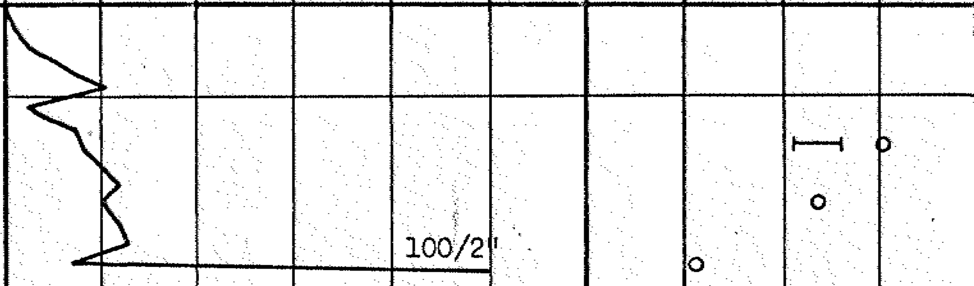
FOUNDATION SECTION

JOB 71-11127
W.P. 13-68-05
DATUM Geodetic

LOCATION Co-Ord's. 16,504,572 N; 1,228,341 E
BORING DATE Nov. 30, 1971
BOREHOLE TYPE Washboring - NX Casing

ORIGINATED BY S.A.A.
COMPILED BY S.A.A.
CHECKED BY

ELEV. DEPTH	SOIL PROFILE DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	BLOWS/FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS/FOOT 20 40 60 80 100; SHEAR STRENGTH P.S.F. o UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB. VANE	LIQUID LIMIT — w_L PLASTIC LIMIT — w_P WATER CONTENT — w; WATER CONTENT % 10 20 30	BULK DENSITY γ P.C.F.	REMARKS GR.SA.SI.CL.
214.7	Ground Level									
0.7	~~Topsoil~~									
	Silty Sand with Trace of Gravel Seams of Clayey Silt Loose to V. Dense Brown - Grey		1	SS	9	210				
			2	SS	9					Elev. 206.2 In Open BH Nov.30/71
			3	SS	29					
201.4			4	SS	70/10"		100/2"			0 - 87. 13
			5	RC	23%					
13.3	Calcareous Shale Sound - Grey		6	RC	96.5%	200				
195.4										
19.3	End of Borehole					190				



FORM OD-MT - 126 (REV. 1969) OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

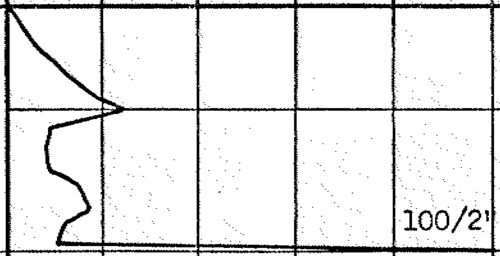
RECORD OF BOREHOLE No. 4A

FOUNDATION SECTION

JOB 71-11127
W.P. 13-68-05
DATUM Geodetic

LOCATION Co-Ord's. 16,504,616 N; 1,228,277 E
BORING DATE December 1, 1971
BOREHOLE TYPE Cone Test Only

ORIGINATED BY S.A.A.
COMPILED BY S.A.A.
CHECKED BY [signature]

SOIL PROFILE			SAMPLES				DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100; SHEAR STRENGTH P.S.F. O UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB. VANE	LIQUID LIMIT — w_L PLASTIC LIMIT — w_P WATER CONTENT — w; WATER CONTENT %	BULK DENSITY γ P.C.F.	REMARKS GR.SA.SI.CL.
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT	ELEV. SCALE				
215.0	Ground Level									
202.8	Probably Silty Sand; Trace of Gravel - Occ. Silt or Clayey Silt Seams					210				
12.2	End of Cone Test Probable Bedrock					200				

FORM OD-MT-126 (REV. 1969) OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS- ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 5

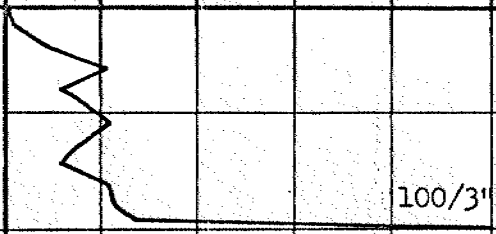
FOUNDATION SECTION

JOB 71-11127 LOCATION Co-Ord's. 16,504,523 N; 1,228,236 E ORIGINATED BY S.A.A.

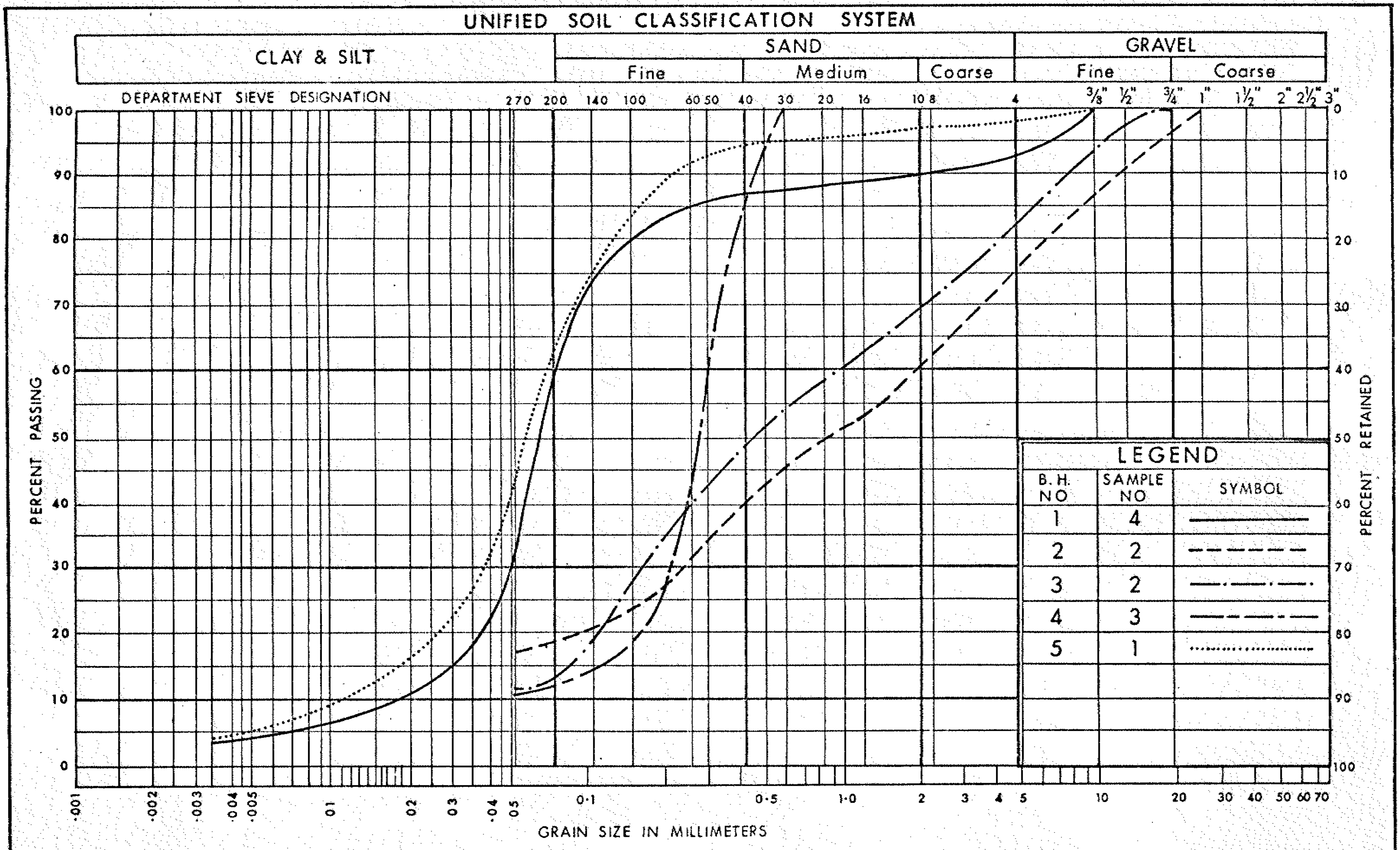
W.P. 13-68-05 BORING DATE December 1, 1971 COMPILED BY S.A.A.

DATUM Geodetic BOREHOLE TYPE Washboring - NX Casing CHECKED BY

SOIL PROFILE			SAMPLES				DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100; SHEAR STRENGTH P.S.F. O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB. VANE	LIQUID LIMIT — w_L; PLASTIC LIMIT — w_P; WATER CONTENT — w; WATER CONTENT %	BULK DENSITY γ P.C.F.	REMARKS GR.SA.SI.CL.
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT	ELEV. SCALE				
215.4	Ground Level									
0.8	~~Topsoil~~									
	Sandy Silt with Trace of Gravel Occ.Silt Seams Dense to V. Dense Brown - Grey		1	SS	40	210				2-37-58-3
204.1			2	SS	152/9"		100/3"			Elev. 206.2 Dec.2/71
11.3	Probable Bedrock					200				



FORM OD-MT-
REV. AUG. 1971



DEPARTMENT OF TRANSPORTATION AND COMMUNICATIONS ONTARIO DESIGN SERVICES BRANCH	GRAIN SIZE DISTRIBUTION SILTY SAND WITH SOME GRAVEL & SEAMS OF CLAYEY SILT	W.P. No. 13 - 68 - 05 JOB No. 71 - 11127 FIG.1

APPENDIX C

Multichannel Analysis of Surface Waves (MASW) Test Results

TECHNICAL MEMORANDUM

DATE January 25, 2018 **PROJECT No.** 1662565/1120

TO Susan Trickey
Golder Associates Ltd.

FROM Stephane Sol, Christopher Phillips **EMAIL** ssol@golder.com;cphillips@golder.com

NBCC SEISMIC SITE CLASS TESTING RESULTS
INNES RD AND HWY 417
OTTAWA, ONTARIO

This technical memorandum presents the results of two Multichannel Analysis of Surface Waves (MASW) test performed for the purpose of the Canadian Highway Bridge Design Code (CHBDC 2014) Seismic Site Classification for a bridge investigation (Figure1). The tests are located on each side of the Innes Road at the intersection with the HWY417 in Ottawa. The geophysical testing was performed by Golder Associates Ltd. (Golder) personnel on May 9, 2017.

Figure 1: MASW Location Site Map (MASW Line in red)

Golder Associates Ltd.
6925 Century Avenue, Suite #100, Mississauga, Ontario, Canada L5N 7K2
Tel: +1 (905) 567 4444 Fax: +1 (905) 567 6561 www.golder.com

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 May 9, 2017, by personnel from the Golder Mississauga and Ottawa offices. For the MASW line, a series of 24 low frequency (4.5 Hz) geophones were laid out at 3 metre intervals. Both active and passive readings were recorded along the MASW line. 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 metres from and collinear to the geophone array. An example of active seismic records collected at each line are shown in Figures 2 and 3, below.

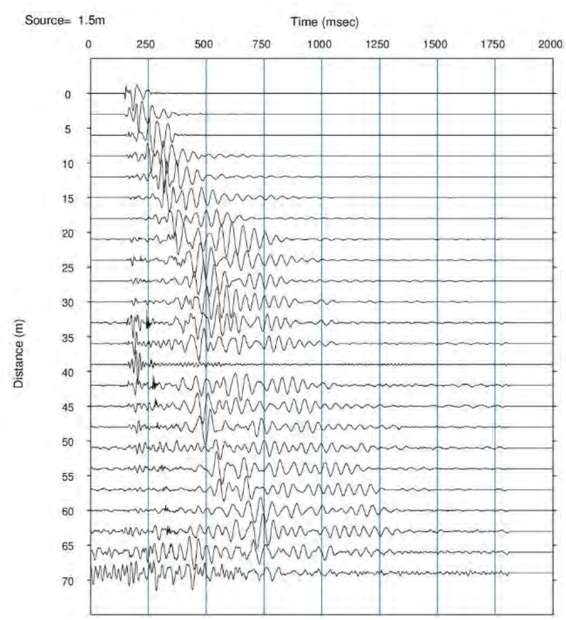


Figure 2: Typical seismic record collected at the site of MASW Line 1.

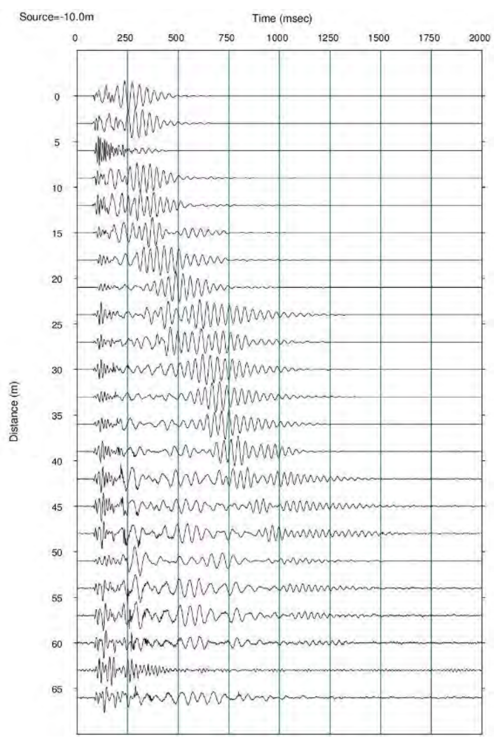


Figure 3: Typical seismic record collected at the site of MASW Line 2.

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 (r2) 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 (12-22 Hz). The active survey of Line 2 provided a dispersion curve with a suitable frequency range (12-22 Hz). At both lines the minimum measured surface wave frequency with sufficient signal-to-noise ratio to accurately measure phase velocity was approximately 12 Hz.

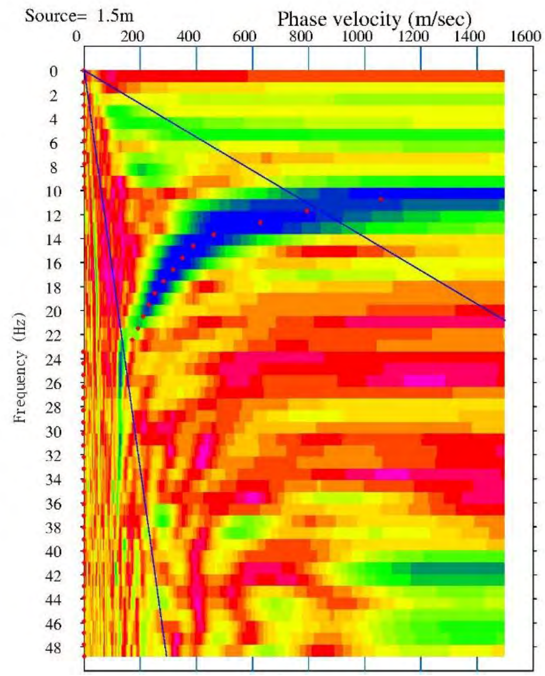


Figure 4: Active MASW Dispersion Curve Picks (red dots) along MASW Line 1

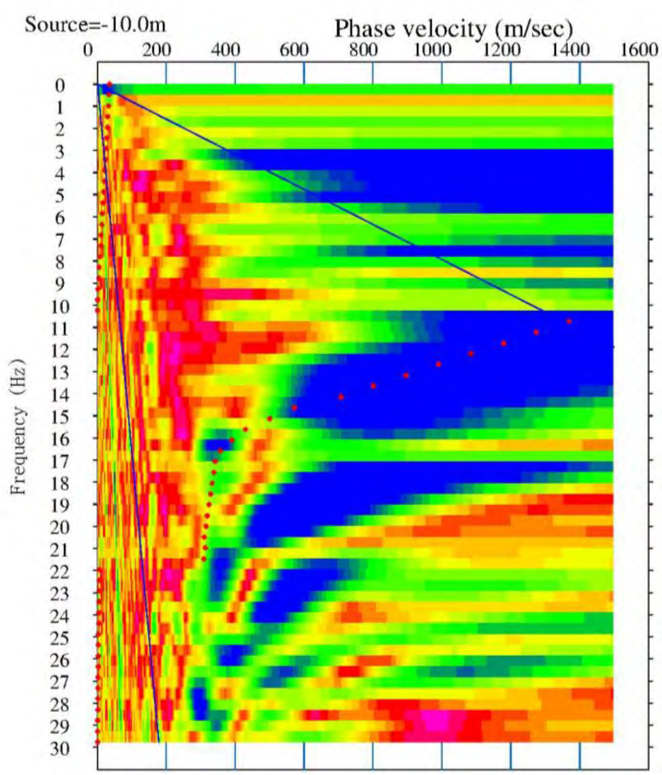


Figure 5: Active MASW Dispersion Curve Picks (red dots) along MASW Line 2

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 weight-drop located at 10 metres from the last geophone. The results along MASW Line 1 have been calculated using weight-drop located at 5 metres 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 4% along both lines.

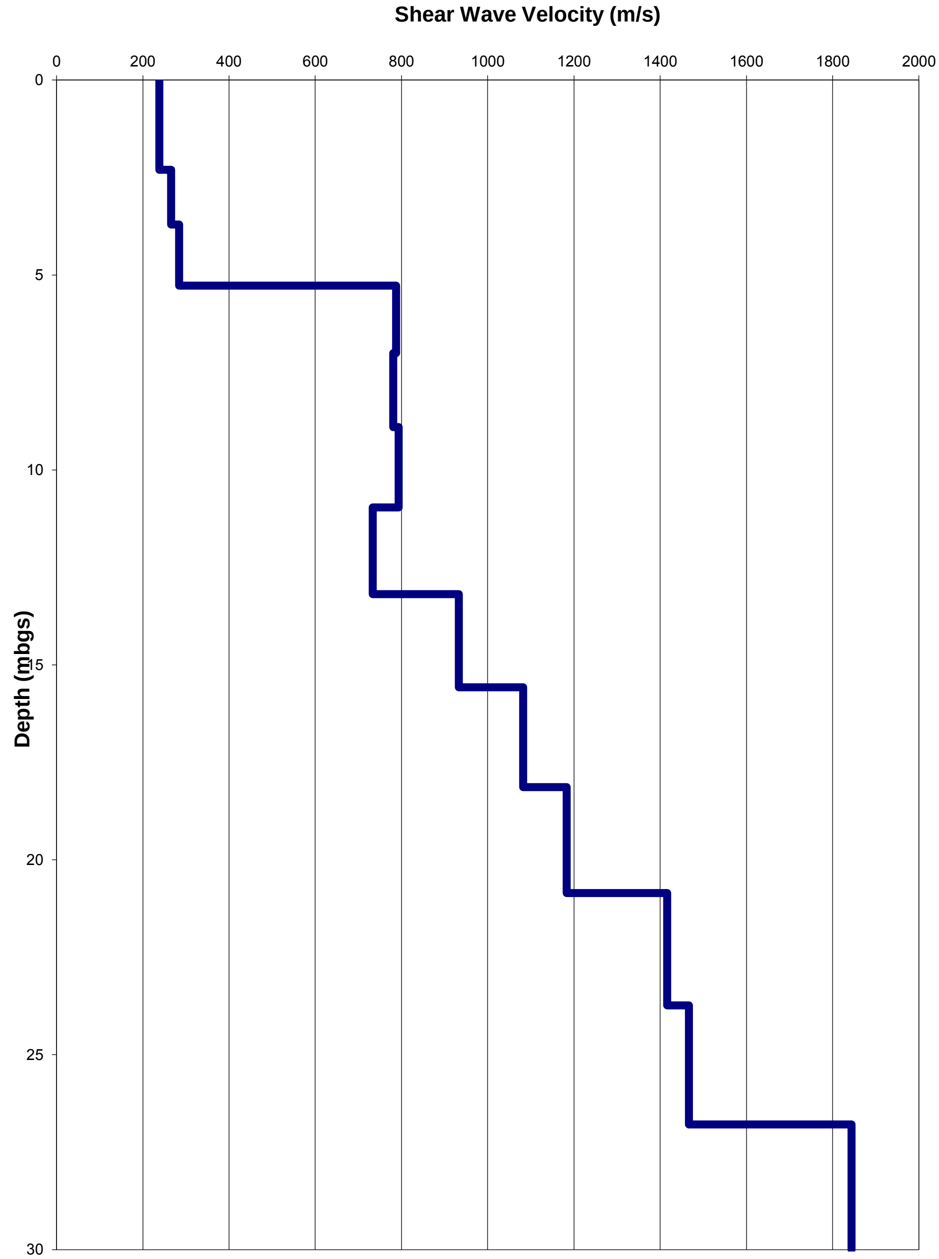


Figure 6: MASW Modelled Shear-Wave Velocity Depth profile along MASW Line 1

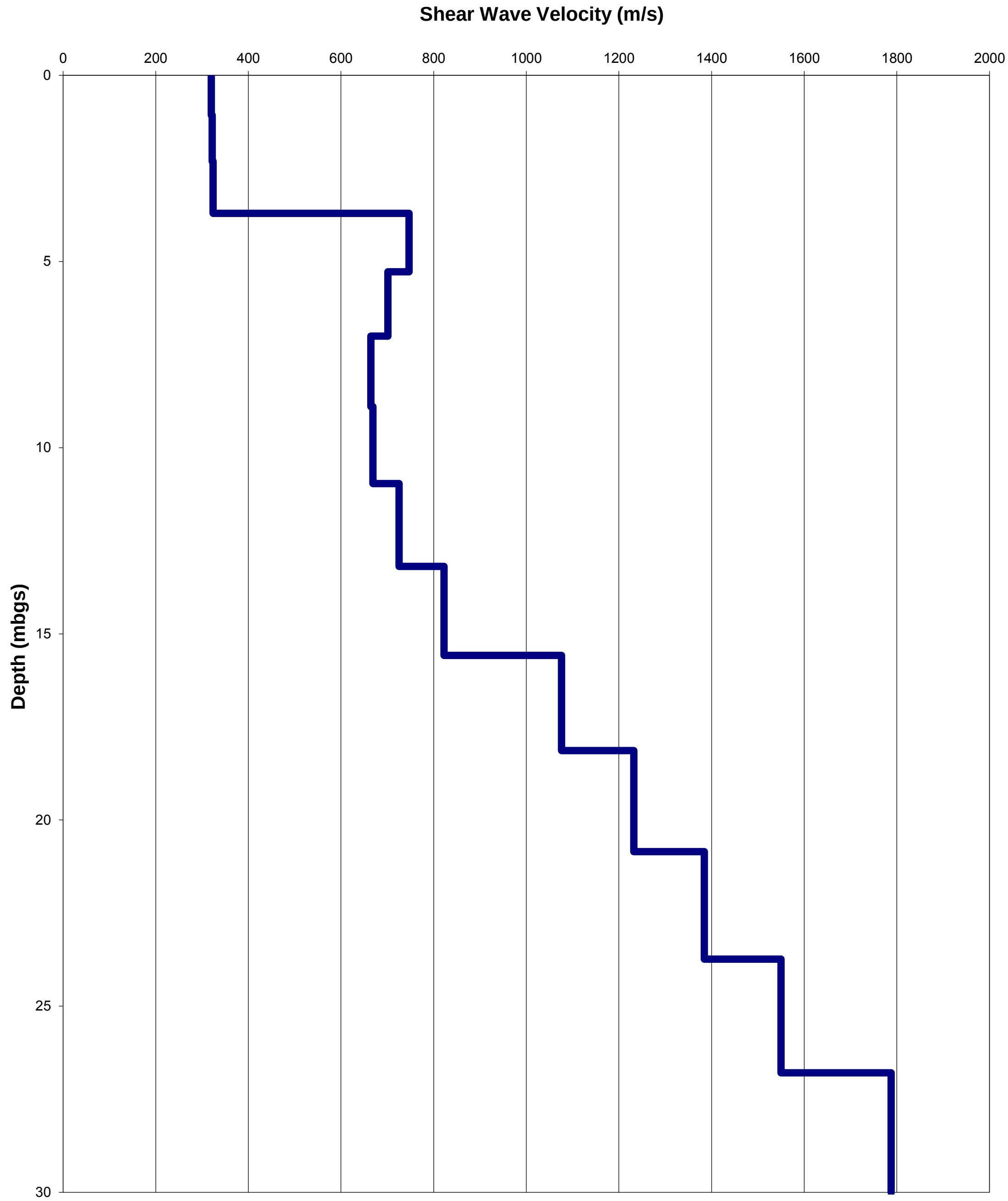


Figure 7: MASW Modelled Shear-Wave Velocity Depth profile along MASW Line 2

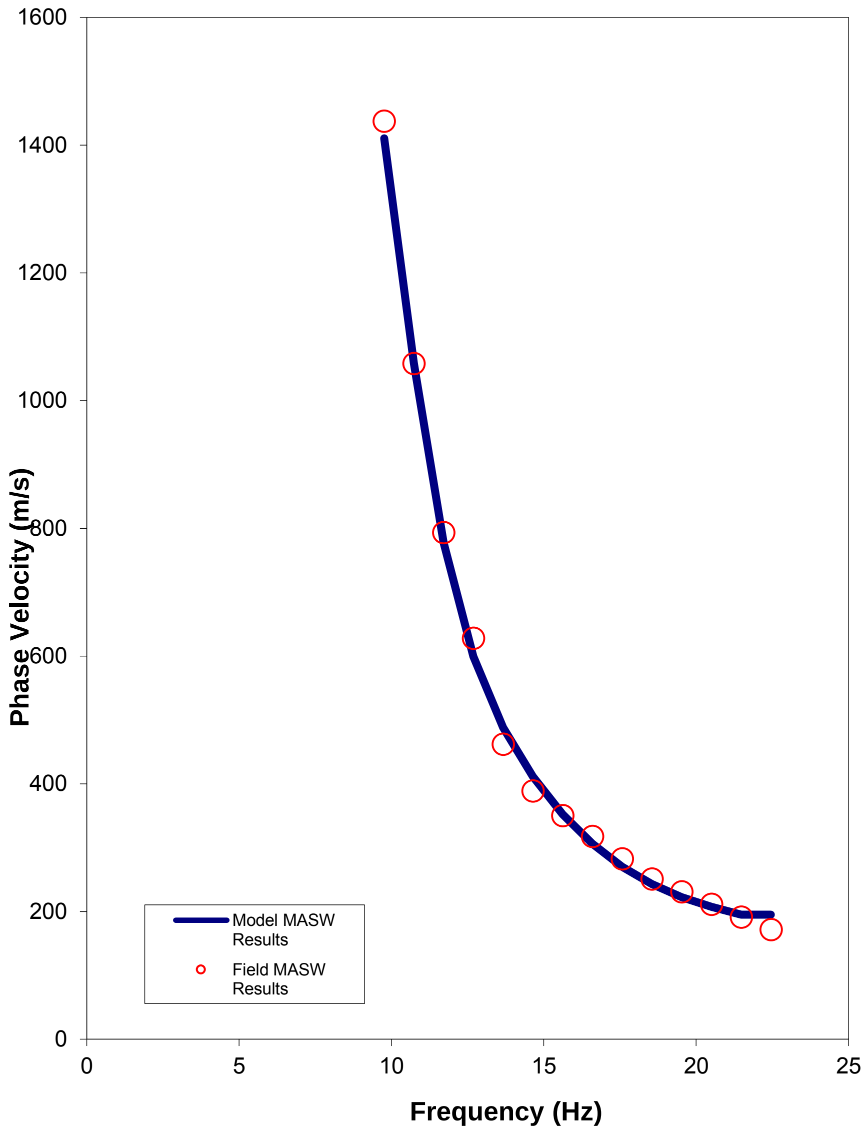


Figure 8: Comparison of Field (red dots) vs. Modelled Data (blue line) along MASW Line 1

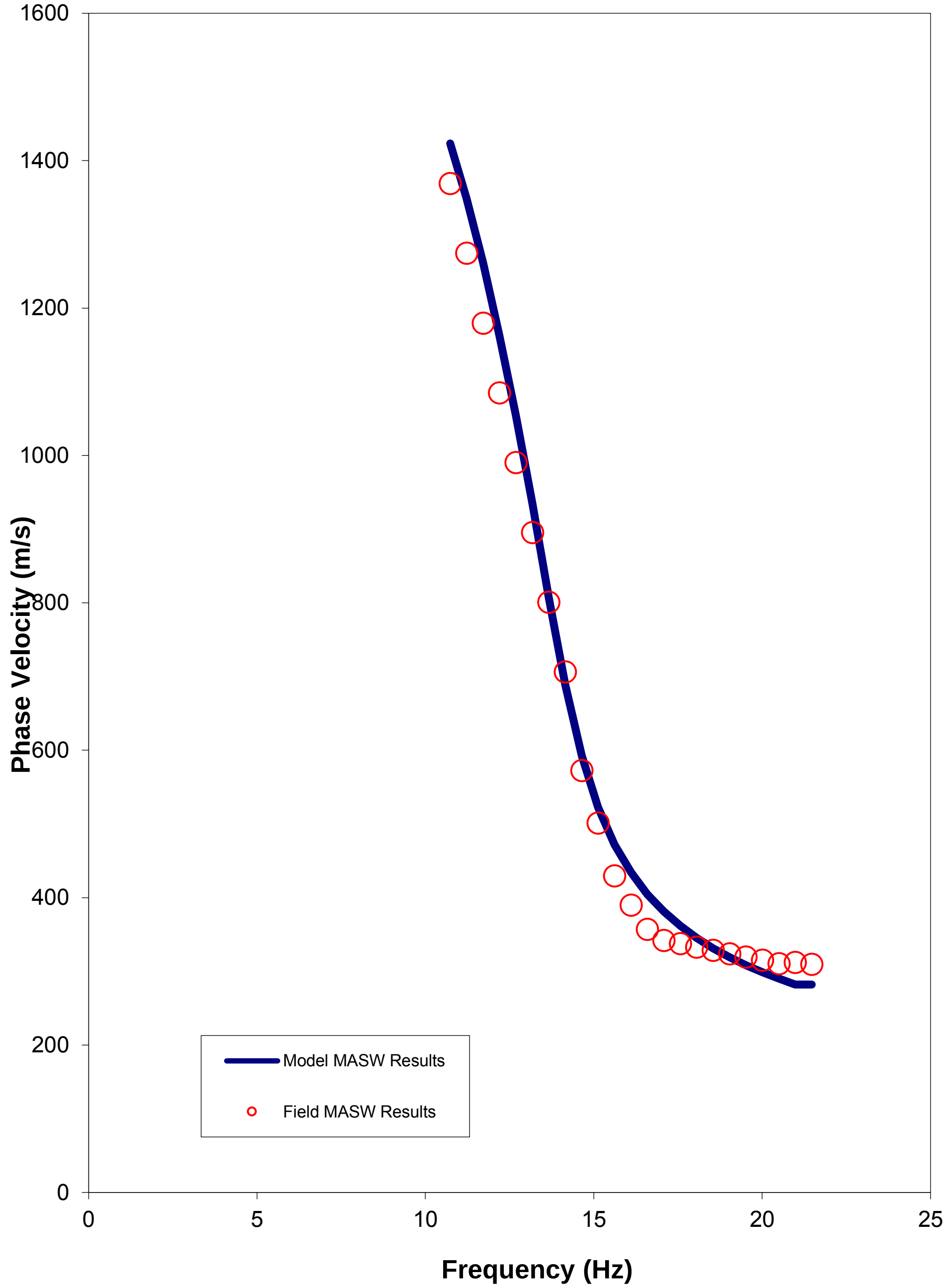


Figure 9: Comparison of Field (red dots) vs. Modelled Data (blue line) along MASW Line 2

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 was found to be 685 m/s (Table 1). The average shear-wave velocity along MASW Line 2 was found to be 781 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	238	0.004495
1.07	2.31	1.24	238	0.005186
2.31	3.71	1.40	265	0.005278
3.71	5.27	1.57	284	0.005506
5.27	7.01	1.73	788	0.002197
7.01	8.90	1.90	781	0.002427
8.90	10.96	2.06	793	0.002597
10.96	13.19	2.23	733	0.003034
13.19	15.58	2.39	933	0.002561
15.58	18.13	2.55	1083	0.002360
18.13	20.85	2.72	1183	0.002299
20.85	23.74	2.88	1417	0.002036
23.74	26.79	3.05	1467	0.002079
26.79	30.00	3.21	1844	0.001743
Vs Average to 30 mbgs (m/s)				**685**

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	320	0.003348
1.07	2.31	1.24	322	0.003839
2.31	3.71	1.40	324	0.004323
3.71	5.27	1.57	747	0.002097
5.27	7.01	1.73	701	0.002467
7.01	8.90	1.90	664	0.002853
8.90	10.96	2.06	669	0.003080
10.96	13.19	2.23	725	0.003068
13.19	15.58	2.39	822	0.002906
15.58	18.13	2.55	1076	0.002374
18.13	20.85	2.72	1232	0.002208
20.85	23.74	2.88	1385	0.002083
23.74	26.79	3.05	1550	0.001968
26.79	30.00	3.21	1788	0.001798
Vs Average to 30 mbgs (m/s)				**781**

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

Christopher Phillips, M. SC., P. Geo
Senior Geophysicist, Principal

SS/CRP/jl

https://golderassociates.sharepoint.com/sites/11263g/shared documents/01_foundations/12_geophysics/innes road - phase 1120 - masw/report/1662565 1120 tech memo 2018jan25 mto innes.docx

APPENDIX D

Results of Chemical Analysis

Eurofins Environment Testing Report No. 1709117

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:	1709117
Date Submitted:	2017-06-07
Date Reported:	2017-06-28
Project:	1662565
COC #:	818719

				Lab I.D. Sample Matrix Sample Type Sampling Date Sample I.D.	1297088 Soil 2017-06-07 BH 17-1201 Sa5/10-12
Group	**Analyte**	**MRL**	**Units**	**Guideline**	
Agri. - Soil	pH	2.0			8.6
	SO4	0.01	%		<0.01
General Chemistry	Cl	0.002	%		0.019
	Electrical Conductivity	0.05	mS/cm		0.73
	Resistivity	1	ohm-cm		1370

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.

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

Selected Site Photographs

Photograph 1: South of east abutment, looking west (June 14, 2017).

Photograph 2: North of west abutment, looking east (June 14, 2017).

CLIENT
WSP CANADA GROUP LIMITED

PROJECT
INNES ROAD UNDERPASS REHABILITATION
SITE NO. 3-305
HIGHWAY 417, OTTAWA, ONTARIO

CONSULTANT

Golder Associates

YYYY-MM-DD	2018/01/25
PREPARED	SM
DESIGN	--
REVIEW	MJK
APPROVED	FJH

TITLE
SELECTED SITE PHOTOGRAPHS

PROJECT No.	Phase	Rev.	Figure
1662565	1120	1	E1

Photograph 3: Northeast of west abutment, looking east (June 14, 2017).

CLIENT WSP CANADA GROUP LIMITED		PROJECT INNES ROAD UNDERPASS REHABILITATION SITE NO. 3-305 HIGHWAY 417, OTTAWA, ONTARIO	
CONSULTANT Golder Associates	YYYY-MM-DD: 2018/01/25 PREPARED: SM DESIGN: -- REVIEW: MJK APPROVED: FJH	TITLE **SELECTED SITE PHOTOGRAPHS**	
		PROJECT No. **1662565** · Phase **1120**	Rev. **1** · Figure **E2**

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

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