



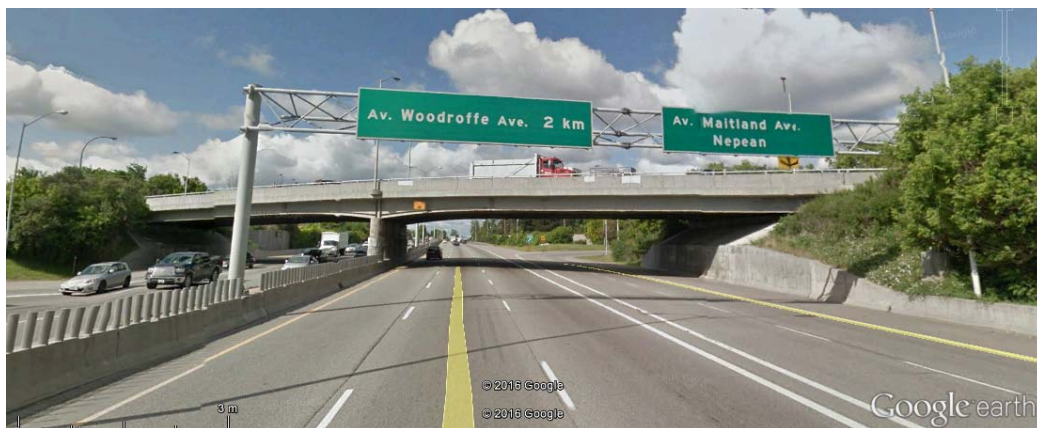
March 2017

REPORT ON

**FOUNDATION INVESTIGATION
MAITLAND AVENUE UNDERPASS
SITE NO. 3-042
HIGHWAY 417 WIDENING AND REHABILITATION
FROM WEST OF HIGHWAY 416 TO EAST OF MAITLAND AVENUE
G.W.P. 4124-14-00**

Submitted to:

MMM Group Limited
1145 Hunt Club Road, Suite 300
Ottawa, Ontario
K1V 0Y3



REPORT



GEOCRES NO: 31G5-275

Report Number: 1546542-1040

Distribution:

3 copies – Ministry of Transportation, Kingston
1 copy – Ministry of Transportation, Downsview
2 copies – MMM Group Limited
1 copy – Golder Associates Ltd.



Table of Contents

PART A – FOUNDATION INVESTIGATION REPORT

1.0 INTRODUCTION.....	1
2.0 SITE DESCRIPTION AND GEOLOGY	2
2.1 Site Description	2
2.2 Regional Geology	2
3.0 INVESTIGATION PROCEDURES	3
4.0 DESCRIPTION OF SUBSURFACE CONDITIONS	5
4.1 General.....	5
4.2 Topsoil and Fill	5
4.3 Silty Clay to Clayey Silt to Clay.....	6
4.4 Till	6
4.5 Bedrock	7
4.6 Groundwater Conditions	8
5.0 CLOSURE	9

DRAWINGS

Drawings 1&2 Highway 417 Rehabilitation and Widening, Maitland Avenue Underpass - Borehole Locations and Soil Strata

APPENDICES

APPENDIX A Borehole and Drillhole Records, Current Investigation

Lists of Abbreviations and Symbols
Lithological and Geotechnical Rock Description Terminology
Records of Boreholes 16-401 to 16-408
Bedrock Core Photographs, Figures A1 to A6

APPENDIX B Laboratory Test Results, Current Investigation

Figure 1 - Grain Size Distribution Test Results – Silty Sand to Sand (FILL)
Figure 2 - Plasticity Chart – Silty Clay (Fill)
Figure 3 - Plasticity Chart – Silty Clay to Clayey Silt (Weathered Crust)
Figure 4 - Grain Size Distribution Test Results – Silty Clay to Clayey Silt (Weathered Crust)
Figure 5 - Plasticity Chart – Silty Clay to Clayey Silt to Clay
Figure 6 - Grain Size Distribution Test Results – Silty Clay to Clayey Silt
Figure 7 - Grain Size Distribution Test Results – Silty Sand (Till)
Figure 8 - Summary of Laboratory Compressive Strength Unconfined Compression Tests



FOUNDATION REPORT HIGHWAY 417 MAITLAND AVENUE UNDERPASS

APPENDIX C Record of Boreholes, Previous Investigations

Records of Previous Boreholes 1 to 6 (Geocres No. 31G5-022)

Records of Previous Boreholes 98-1 to 98-4 (Geocres No. 31G5-190)

APPENDIX D Results of MASW Testing



**FOUNDATION REPORT
HIGHWAY 417 MAITLAND AVENUE UNDERPASS**

PART A

**FOUNDATION INVESTIGATION REPORT
MAITLAND AVENUE UNDERPASS
SITE NO. 3-042
HIGHWAY 417 WIDENING AND REHABILITATION
FROM WEST OF HIGHWAY 416 TO EAST OF MAITLAND AVENUE
G.W.P. 4124-14-00**



FOUNDATION REPORT HIGHWAY 417 MAITLAND AVENUE UNDERPASS

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by MMM Group Limited (MMM) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services in support of the design for the widening of the Maitland Avenue Underpass at Highway 417 in the City of Ottawa. The proposed work is part of the design associated with the Highway 417 widening from west of Highway 416 to east of Maitland Avenue (Assignment Number 4015-E-0017) in Ottawa, Ontario.

This report addresses the proposed widening of the Maitland Avenue Underpass (MTO Structure Site No. 3-042) and the associated retaining walls and underpass approach embankments only. The proposed widening of the existing bridge to the east by 4.4 metres is required to accommodate a lengthened northbound left hand turn lane on Maitland Avenue to westbound Highway 417, due to projected increased traffic demands. The highway platform beneath the Maitland Avenue structure is of sufficient width to accommodate the addition of new travel lanes.

The terms of reference and scope of work for the foundation investigation are outlined in the MTO's Request for Proposal, dated May 2015, and subsequent addenda. Golder's scope of work for foundation engineering services associated with the Maitland Avenue Underpass widening is contained in Table 17.8.3 of MMM'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 May 2, 2016.



2.0 SITE DESCRIPTION AND GEOLOGY

2.1 Site Description

The Maitland Avenue Underpass is located within a mixed use (commercial-residential) area of the City of Ottawa, and is located approximately 6 kilometers east of the junction of Highway 416 and Highway 417. At this location, Highway 417 is a divided highway with three travel lanes in each direction separated by a concrete median. In the westbound direction, there are two off-ramp lanes exiting to Maitland Avenue. In the eastbound direction, there is a single off-ramp lane with a wide shoulder.

The existing Maitland Avenue Underpass is a two span continuous steel girder bridge with composite concrete deck. The spans are each approximately 35 m in length. The central piers are founded on spread footings on rock. The bridge abutments are supported on “perched” foundations on piles end bearing on bedrock. The front row of piles are battered towards Highway 417. The existing approach embankments are about 6 metres high relative to the highway profile. The foreslopes of both the north and south abutments were originally constructed at 2 Horizontal to 1 Vertical grade extending down to the roadway shoulders. In 1999, as part of intersection improvement works (GWP 203-86-02), the foreslope paving and approach fills in front of both the north and south bridge abutments were cut back to form a “truncated toe” with a retaining wall.

Based on the underground service locates completed, it is understood that hydro conduits are present within the existing underpass structure and that buried hydro conduits are located along the west and south fence lines for the St-Basil’s Church, in the northwest quadrant of the site.

Previous investigations were conducted for the design of the existing bridge by McRostie & Associates (McRostie) in 1958. The results of that investigation are contained in the report titled “Report on Foundation Investigation at Ottawa Queensway and Maitland Avenue, Bridge No. 3, to Deleuw, Cather and Company of Canada Limited” (Geocres 31G5-022). A subsequent investigation was carried out by Jacques Whitford Limited (JWL) for McCormick Rankin Corporation in 1998. The results of that investigation are contained in the report titled “Foundation Investigation Report to McCormick Rankin Corporation on GWP 203-86-02, Highway 417/Maitland Avenue Bridge Rehabilitation, District 42, Ottawa, Ministry of Transportation Ontario” (Geocres No. 31G5-190).

2.2 Regional Geology

As delineated in *The Physiography of Southern Ontario*¹, this section of Highway 417 lies within the minor physiographic region known as the Ottawa Valley Clay 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 bedrock². 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 igneous and metamorphic bedrock of the Precambrian Shield.

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

The field work for this subsurface investigation was carried out between June 14 and July 27, 2016. During that time, a total of 8 boreholes were advanced at the locations shown on Drawing 1. Borehole 16-401 was advanced at the pier location, Boreholes 16-402 and 16-403 were advanced adjacent to the abutments at the east toe of each of the existing embankments, Boreholes 16-404 and 16-405 were advanced through each of the existing approach embankments, and Boreholes 16-406 to 16-408 were advanced within the currently proposed 'Construction Staging Area' within the northwest quadrant of the Maitland Avenue interchange. The boreholes were advanced using a combination of truck and track mounted drill rigs supplied and operated by CCC Geotechnical and Environmental Drilling Ltd. of Ottawa, Ontario. The boreholes were advanced to depths of between 2.5 m and 9.2 m below present ground surface.

Samples of the overburden were obtained at 0.6 m to 1.5 m 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 HQ sized core. The bedrock was cored for depths of 3.2 to 3.7 m, after practical refusal to augering had been reached. Three monitoring wells were installed (in Boreholes 16-402, 16-403, and 16-406) to monitor the groundwater levels at the site. The monitoring wells consist of 50 mm outside diameter PVC tubing with a 1.5 to 3.0 m long slotted tip. The boreholes were 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 boreholes in the field, directed the drilling, sampling, and in situ testing operations, and logged the boreholes. 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 and Mississauga for testing. Index and classification tests consisting of water content determinations, Atterberg Limit testing, and grain size distribution analyses were carried out on selected soil samples at the London laboratory. Unconfined compressive strength testing was carried out on one sample of the bedrock core at the Mississauga laboratory.

The groundwater levels were measured in the monitoring wells in Boreholes 16-402, 16-403 and 16-406 on August 2 and September 30, 2016.

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 between May 26 and 27, 2016, 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, 15, and 20 m off the end and collinear with the geophone array. A relatively high noise level was recorded at this site due to large amounts of road traffic.

The borehole locations were determined by Golder relative to existing site features. The borehole elevations were surveyed by Golder using a Trimble R8 GPS unit. The borehole locations in MTM NAD83 northing and easting coordinates, ground surface elevations referenced to geodetic datum and drilled depths are summarized in the following table and are shown on Drawing 1.



FOUNDATION REPORT HIGHWAY 417 MAITLAND AVENUE UNDERPASS

Borehole Number	Borehole Location	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
BH16-401	Pier	5025894.5	363195.9	82.1	7.9
BH16-402	South Embankment Toe	5025866.3	3623230.0	83.0	9.2
BH16-403	North Embankment Toe	5025947.4	363199.0	82.3	8.9
BH16-404	South Approach Embankment	5025829.0	363211.3	87.4	3.6
BH16-405	North Approach Embankment	5025938.7	363166.4	87.2	9.0
BH16-406	Staging Area	5025923.6	363102.7	83.5	3.3
BH16-407	Staging Area	5025898.4	363142.9	82.9	3.4
BH16-408	Staging Area	5025880.4	363097.4	82.9	2.5



4.0 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 General

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 Boreholes sheets and on Figures 1 to 7 in Appendix B. The Record of Borehole sheets from the previous investigations at the site (Geocres No. 31G5-022 and 31G5-190) are provided for reference in Appendix C.

The MASW test results and report are presented in Appendix D 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.

As part of the current subsurface investigation at this site, five boreholes were advanced within or near the limits of the foundation elements for the proposed widening of the Maitland Avenue Underpass. The borehole locations from the current and previous investigations are shown on Drawing 1. The interpreted stratigraphic profile projected along the Maitland Avenue centreline is also shown on Drawing 1. An interpreted stratigraphic profile projected through the staging area is shown on Drawing 2.

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.

In general, the subsurface conditions at the site consist of a layer of fill and/or topsoil underlain by silty clay to clayey silt and glacial till overlying limestone bedrock.

A detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections. In the following discussion, emphasis is placed on the subsurface conditions indicated in the boreholes from the present investigation. The boreholes from the original 1958 investigation were advanced prior to the highway construction and therefore the ground conditions shown on those logs are different than what currently exist, particularly with respect to the composition and thickness of overburden and fill. The Geocres information is referenced herein only in regard to the bedrock surface elevation, which is in general agreement with the results from the present investigation. The bedrock depths from the subsequent 1998 investigation were inferred from auger refusal and could therefore indicate the bedrock surface or refusal on cobbles/boulders in the glacial till.

4.2 Topsoil and Fill

Topsoil exists at ground surface at Boreholes 16-402, 16-403, and 16-406 to 16-408, with thicknesses of about 100 to 200 mm.

Asphaltic concrete exists at ground surface at Boreholes 16-401, 16-404 and 16-405, with thicknesses of about 200 to 300 mm.

Fill was encountered beneath the topsoil/asphaltic concrete at all boreholes with the exception of Borehole 16-408. Fill materials are quite variable between locations, consisting of sand, gravel, silty sand, silty clay and clayey silt. Cobbles and boulders were encountered in the fill at Boreholes 16-404 and 16-405 within the approach embankments. The layer of fill was fully penetrated in all of the boreholes, with the exception of Borehole 16-404, which was terminated due to refusal of auger advancement. At this location, the fill was proven to extend to a depth of about 3.6 m below the existing ground surface. Where fully penetrated, the fill varies from about 0.5 to 5.9 m in thickness, and is thickest at the approach embankments. SPT 'N' values obtained within this material generally range from about 7 to 44 blows per 0.3 m of penetration indicating a compact to dense state of packing.



Two higher blow counts within the fill (i.e., in Boreholes 16-404 and 16-405) likely reflect the presence of cobbles and boulders, rather than the state of packing of the soil matrix.

Grain size distribution testing was carried out on five samples of the fill, the results of which are provided on Figure 1. The results of Atterberg limit testing carried out on two samples of the cohesive fill are summarized on Figure 2 and indicate plasticity index values of 19 and 22 percent and liquid limit values of 37 and 40 percent, reflecting a silty clay of intermediate plasticity. The measured water content of the fill ranges from approximately 3 to 20 percent.

4.3 Silty Clay to Clayey Silt to Clay

The fill is underlain by a deposit of sensitive silty clay to clayey silt to clay at all of the borehole locations, with the exception of borehole 16-404 (where the fill was not penetrated) and Borehole 16-408. Where encountered, the clayey deposit was fully penetrated and varies from about 1.4 to 3.9 m in thickness.

The upper portion of the silty clay to clayey silt at Boreholes 16-401 to 16-403, and the full thickness of the deposit at Boreholes 16-405 to 16-407, has been weathered to form a grey brown crust. Standard penetration tests carried out within the weathered crust gave 'N' values ranging from 3 to 18 blows per 0.3 m of penetration, indicating a generally stiff to very stiff consistency.

The results of Atterberg limit testing carried out on five samples of the weathered silty clay to clayey silt are summarized on Figure 3 and indicate plasticity index values generally ranging from 9 to 17 percent and liquid limit values ranging from 33 to 40 percent, reflecting a soil of low to intermediate plasticity. The measured water content of the weathered silty clay to clayey silt ranges from approximately 29 to 52 percent. Grain size distribution testing was carried out on two samples of the weathered silty clay to clayey silt, the results of which are provided on Figure 4.

A layer of unweathered grey silty clay to clayey silt to clay was encountered at Boreholes 16-401 to 16-403, below the upper weathered crust. This unweathered silty clay to clayey silt to clay is about 1.0 to 1.5 m thick at the borehole locations. Standard penetration tests carried out within the unweathered portion of the deposit gave 'N' values 1 and 2 blows per 0.3 m of penetration. In situ shear vane testing carried out where possible within this deposit measured undrained shear strengths of 63 and 65 kPa, indicating a stiff consistency. The calculated sensitivity ratio based on remoulded shear strengths of 11 kPa in this deposit is about 6, indicating a sensitive material in accordance with the CFEM.

The results of Atterberg limit testing carried out on three samples of the unweathered silty clay to clayey silt to clay are shown on Figure 5 and gave plasticity index values of 13, 18, and 51 percent and liquid limit values of 36, 38, and 71 percent, respectively, indicating intermediate and high plasticity soil. The measured water contents of three samples of unweathered portion of the deposit were between about 52 and 56 percent. Grain size distribution testing was carried out on one sample of the unweathered silty clay to clayey silt, the results of which are provided on Figure 6.

4.4 Till

A deposit of glacial till was encountered directly beneath the topsoil at Borehole 16-408, and below the silty clay at the other borehole locations (except for Borehole 16-404) at depths of about 2.9 to 7.6 m below the existing ground surface. The till consists of a heterogeneous mixture of gravel, cobbles, and boulders in a matrix of sandy silt with some clay.

The till was fully penetrated at Boreholes 16-401 to 16-403 and about 0.7 to 1.4 m in thickness, extending to about 4.6 to 6.0 m depth below the existing ground surface (i.e., Elevations 77.0 to 77.6 m). The till was not fully penetrated at Boreholes 16-405 to 16-408 but was proven to extend to depths of about 2.5 to 9.0 m below the ground surface (i.e., Elevations 78.2 to 80.4 m). Standard penetration test 'N' values of 1 to in excess of 50 blows



FOUNDATION REPORT HIGHWAY 417 MAITLAND AVENUE UNDERPASS

per 0.3 m of penetration were measured in the glacial till, indicating a very loose to very dense state of packing, although the higher 'N' values could reflect the presence of cobbles and boulders, rather than the state of packing of the soil matrix.

The measured water contents of three samples of till were between about 8 and 14 percent. Grain size distribution testing was carried out on two samples of the till, the results of which are provided on Figure 7. The results indicate that the till matrix consists of a silty sand with some clay and trace amounts of gravel. These samples were, however, retrieved using a 50 mm diameter sampler and therefore the results do not reflect the larger gravel, cobble and boulder content of the deposit.

4.5 Bedrock

The bedrock encountered at the bridge foundation elements consists of limestone with thin shale interbeds.

Fresh, thinly to medium bedded, limestone bedrock with thin shale interbeds was encountered at Boreholes 16-401, 16-402, and 16-403 at depths ranging from about 4.6 to 6.0 m below the existing ground surface (i.e., Elevations 77.0 to 77.6 m). At Borehole 16-401, the upper 0.3 m of limestone bedrock is weathered. These boreholes were advanced 3.2 to 3.7 m into the bedrock.

Photos of the bedrock core obtained during the current investigation are provided in Appendix A on Figures A1 to A6, inclusive.

The following table summarizes the bedrock surface (and refusal) depths and elevations as encountered at Boreholes 16-401 through 16-408 as part of the current investigations, and as encountered at the previous Boreholes 1 to 6 (Geocres 31G5-022) and 98-1 through 98-4 (Geocres 31G5-190). The bedrock was cored in Boreholes 16-401 to 16-403, and 1 to 6, inclusive. Boreholes 98-1 to 98-4, inclusive, were advanced to auger refusal on the inferred bedrock surface.

Borehole Location	Borehole Number	Ground Surface Elevation (m)	Depth to Bedrock Surface (m)	Bedrock Surface Elevation (m)
North Abutment (east side)	16-403	82.3	5.2	77.1
	98-2	81.8	2.8 ^R	79.0 ^R
	6	82.3	5.0	77.4
North Abutment (west side)	98-1	82.3	5.2 ^R	77.1 ^R
	1	82.6	4.7	77.9
North Approach Embankment	16-405	87.2	> 9.0	< 78.2
Pier (west side)	2	83.0	3.7	79.3
Pier (east side)	16-401	82.1	4.6	77.6
	5	82.7	4.7	78.0
South Approach Embankment	16-404	87.4	> 3.6	< 83.8
South Abutment (east side)	16-402	83.0	6.0	77.0
	98-4	82.0	4.2	77.8 ^R
	4	82.9	4.8	78.1
	98-3	84.4	5.9 ^R	78.5 ^R



FOUNDATION REPORT HIGHWAY 417 MAITLAND AVENUE UNDERPASS

Borehole Location	Borehole Number	Ground Surface Elevation (m)	Depth to Bedrock Surface (m)	Bedrock Surface Elevation (m)
South Abutment (west side)	3	82.9	3.7	79.3
Staging Area (NW)	16-406	83.5	3.3 ^R	80.3 ^R
	16-407	82.9	3.4 ^R	79.5 ^R
	16-408	82.9	2.5 ^R	80.4 ^R

Note: ^R = Auger refusal on inferred bedrock surface.

The limestone bedrock at the site is a member of the Gull River Formation and medium strong to strong. Thin shale interbeds were also present in the rock core. Rock Quality Designation (RQD) values measured on recovered bedrock core samples ranged from about 47 to 100 percent. The lowest rock quality was recorded for the upper 0.3 m of the bedrock in Borehole 16-401. The result of one unconfined compressive strength test on a sample of the bedrock from Borehole 16-401 was 76.5 MPa, as shown on Figure 8. A description of some of the terms used in the description of the bedrock samples from this site is provided on the Lithological and Geotechnical Rock Description Terminology sheet which precedes the Record of Borehole sheets included with this report.

4.6 Groundwater Conditions

Monitoring wells were installed in Boreholes 16-402, 16-403, and 16-406. The water levels measured in the wells are summarized in the following table:

Borehole Number	Borehole Location	Screened Interval	Date	Depth (m)	Elevation (m)
16-402	South Abutment (east side)	Silty Clay/Glacial Till	August 2, 2016	3.0	79.9
			September 30, 2016	3.0	79.9
16-403	North Abutment (east side)	Limestone Bedrock	August 2, 2016	2.7	79.6
			September 30, 2016	3.2	79.1
16-406	Staging Area	Silty Clay/Glacial Till	August 2, 2016	Dry	< 80.3
			September 30, 2016	Dry	< 80.3

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.

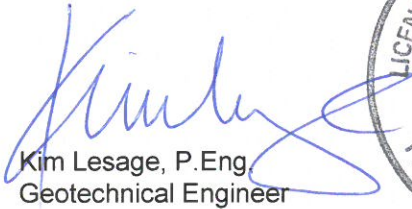


FOUNDATION REPORT HIGHWAY 417 MAITLAND AVENUE UNDERPASS

5.0 CLOSURE


The field operations were supervised by Mr. Doug Grylls and Mr. Jason Derouin. This report was prepared by Ms. Kim Lesage, P.Eng., and was reviewed by Ms. Erin O'Neill, P.Eng., a senior geotechnical engineer and Associate of 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.


Kim Lesage, P.Eng.
Geotechnical Engineer



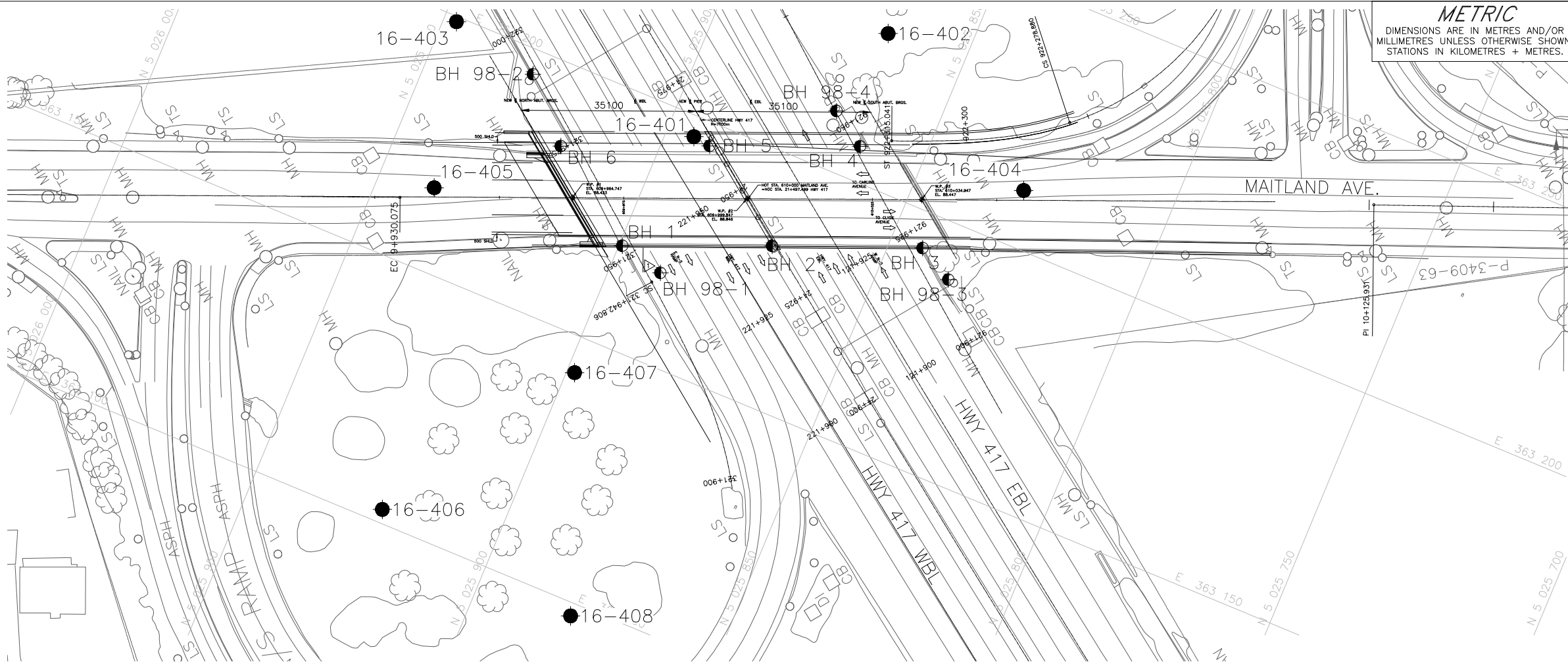

Erin O'Neill, P.Eng.
Senior Geotechnical Engineer, Associate


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



KSL/ESO/FJH/ob

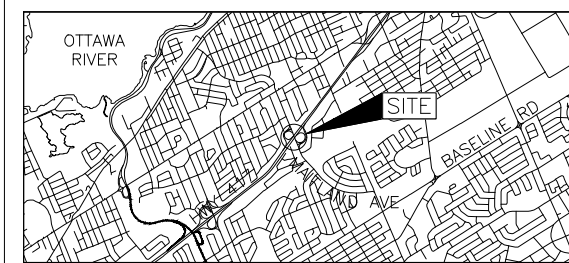
n:\active\2015\3 proj\1546542 mmm mto 4015-e-0017ottawafoundations\6 - reports\1040 - maitland avenue\1546542-1040 maitland underpass fidr march 2017.docx



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

CONT No.
WP No.4015-E-0017

HIGHWAY 417 REHABILITATION
AND WIDENING
MAITLAND AVENUE UNDERPASS
BOREHOLE LOCATIONS AND SOIL STRATA



KEY PLAN
SCALE
1 0 1 2 km

LEGEND

- Borehole - Current Investigation
- Borehole - Previous Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Total Core Recovery (REC)
- WL in piezometer, measured on Sept. 30, 2016
- WL upon completion of drilling

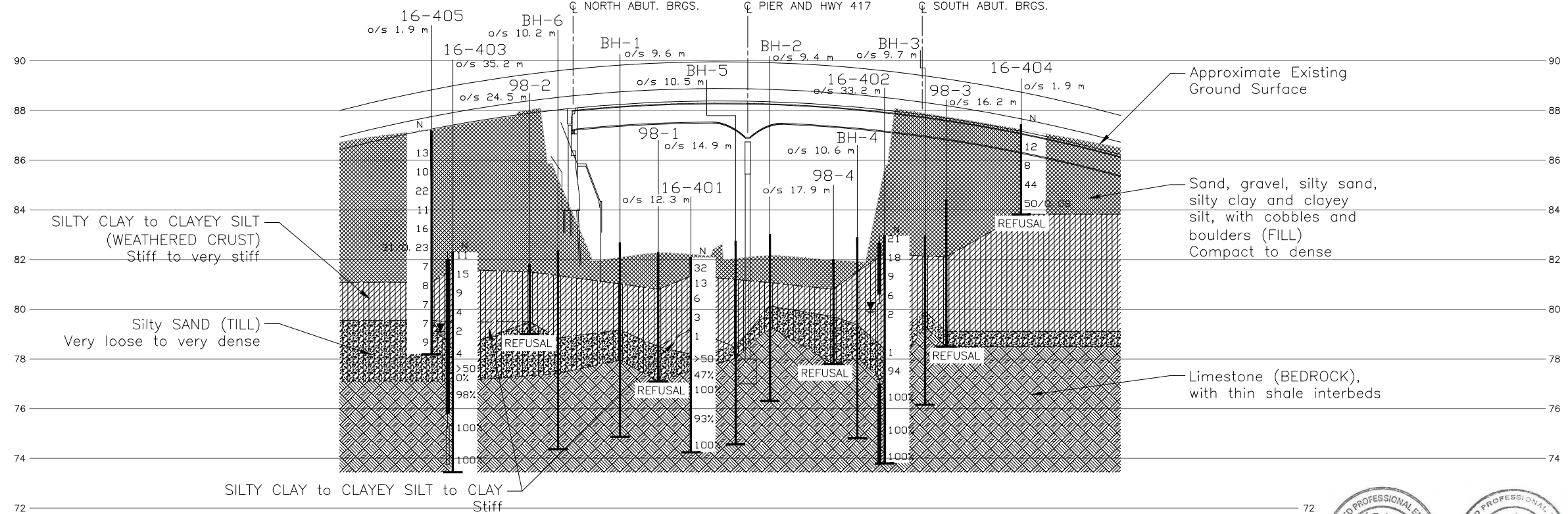
BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
16-401	82.1	5025894.5	363195.9
16-402	83.0	5025866.3	363230.0
16-403	82.3	5025947.4	363199.0
16-404	87.4	5025829.0	363211.3
16-405	87.2	5025938.7	363166.4
16-406	83.5	5025923.6	363102.7
16-407	82.9	5025898.4	363142.9
16-408	82.9	5025880.4	363097.4
98-1	82.3	5025890.2	363168.0
98-2	81.8	5025929.1	363195.1
98-3	84.4	5025836.2	363189.0
98-4	82.0	5025869.9	363211.7
BH-1	82.7	5025899.3	363170.1
BH-2	83.0	5025871.5	363181.7
BH-3	83.0	5025843.4	363192.8
BH-4	82.9	5025862.8	363206.9
BH-5	82.7	5025890.8	363195.4
BH-6	82.4	5025918.4	363183.9

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.



PROFILE ALONG MAITLAND AVE.

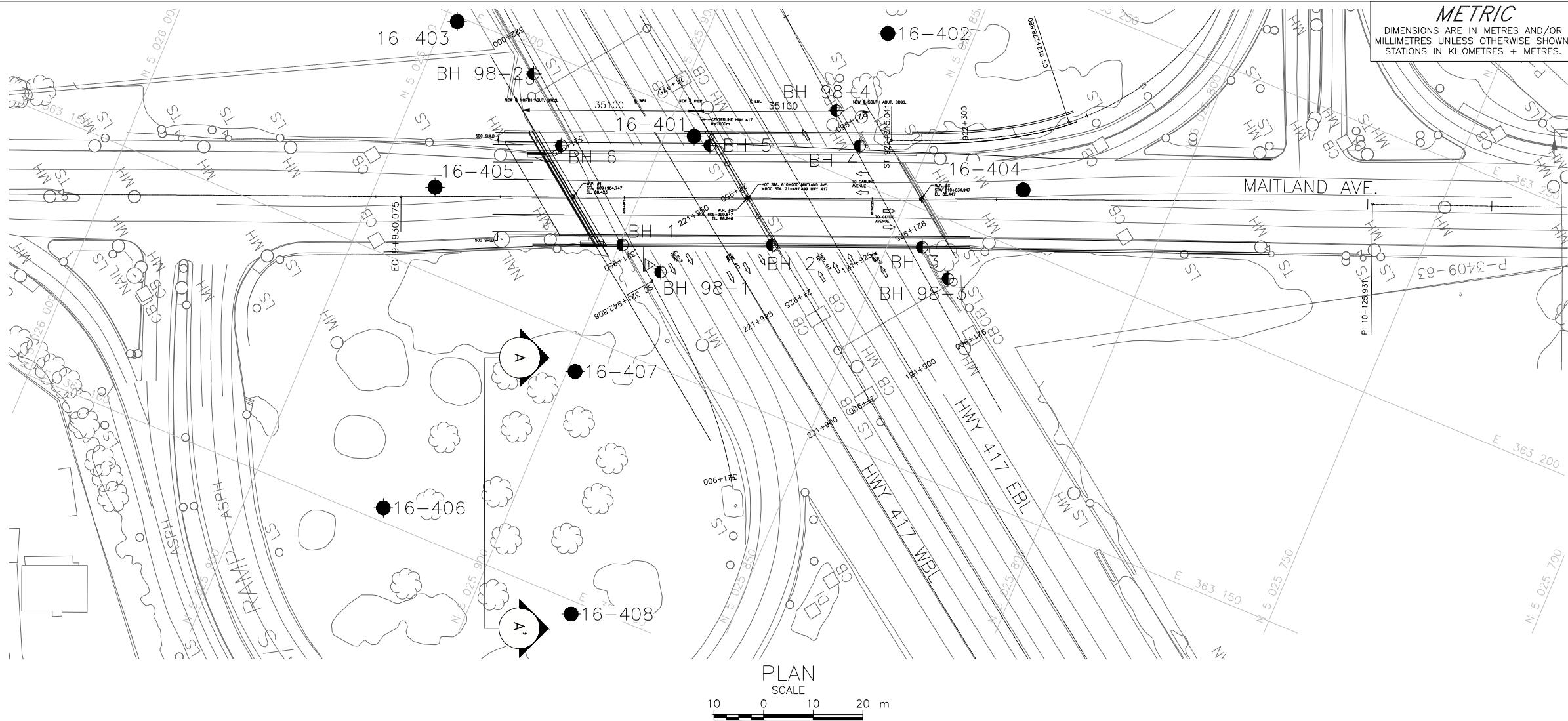
HORIZ. SCALE
10 0 10 20 m
VERT. SCALE
2 0 2 4 m

REFERENCE

Base plans provided in digital format by MMM Group, drawing file no. GG_3416012-305-001_General-Arrangement.dwg, received October 26, 2016.



NO.	DATE	BY	REVISION
Geocres No. 31G5-275			
HWY. 417		PROJECT NO. 1546542-1040	DIST. EASTERN
SUBM'D. KSL	CHKD. KSL	DATE: 11/01/2016	SITE: 3-042
DRAWN: JM	CHKD. ESO	APPD. FJH	DWG. 1



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

CONT No.
WP No.4015-E-0017



HIGHWAY 417 REHABILITATION
AND WIDENING
MAITLAND AVENUE UNDERPASS
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



KEY PLAN
SCALE
1 0 1 2 km

LEGEND

- Borehole - Current Investigation
- Borehole - Previous Investigation
- ⊥ Seal
- ⊥ Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Total Core Recovery (REC)
- ⊥ WL in piezometer, measured on Sept. 30, 2016
- ⊥ WL upon completion of drilling

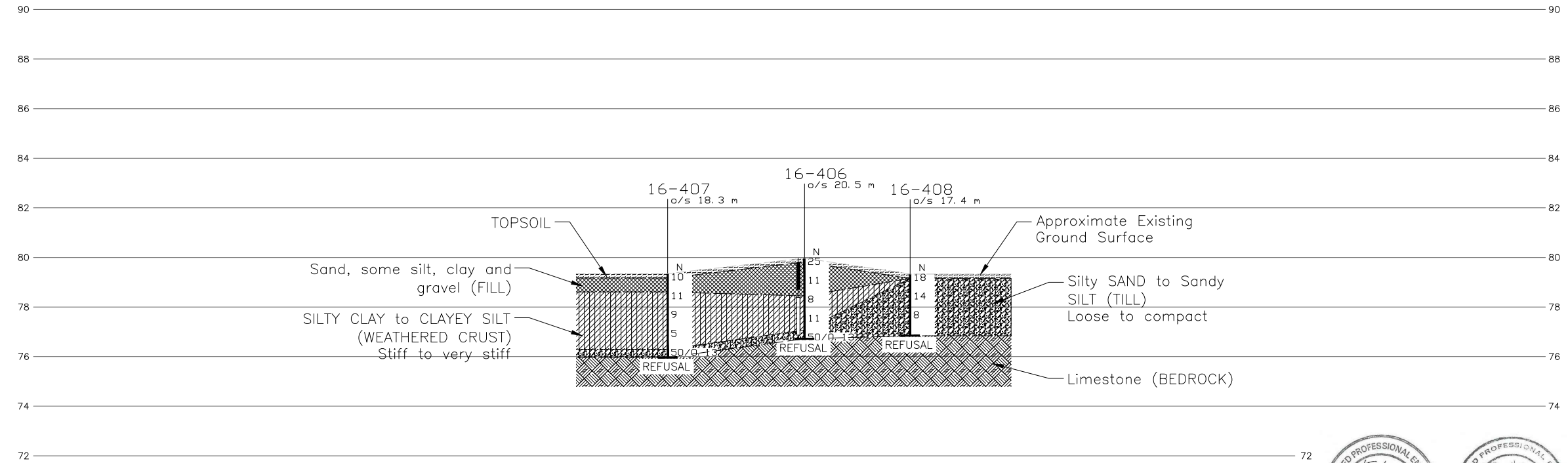
BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
16-401	82.1	5025894.5	363195.9
16-402	83.0	5025866.3	363230.0
16-403	82.3	5025947.4	363199.0
16-404	87.4	5025829.0	363211.3
16-405	87.2	5025938.7	363166.4
16-406	83.5	5025923.6	363102.7
16-407	82.9	5025898.4	363142.9
16-408	82.9	5025880.4	363097.4
BH-1	82.3	5025890.2	363168.0
BH-2	81.8	5025929.1	363195.1
BH-3	84.4	5025836.2	363189.0
BH-4	82.0	5025869.9	363211.7
BH-5	82.7	5025899.3	363170.1
BH-6	82.4	5025918.4	363183.9

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.

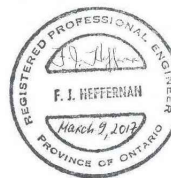


CROSS-SECTION A-A'

HORIZ. SCALE
10 0 10 20 m
VERT. SCALE
2 0 2 4 m

REFERENCE

Base plans provided in digital format by MMM Group, drawing file no. GG_3416012-305-001_General-Arrangement.dwg, received October 26, 2016.



NO.	DATE	BY	REVISION
1	11/22/2016	JM	Initial Design
2	11/22/2016	ES	Revised Design
3	11/22/2016	FJH	Final Design

Geocres No. 3165-275

HWY. 417	PROJECT NO. 1546542-1040	DIST. EASTERN
SUBM'D. KSL	CHKD. KSL	DATE: 11/22/2016
DRAWN: JM	CHKD. ESO	APPD. FJH



APPENDIX A

Borehole and Drillhole Records, Current Investigation

Lists of Abbreviations and Symbols

Lithological and Geotechnical Rock Description Terminology

Records of Boreholes 16-401 to 16-408

Bedrock Core Photographs, Figures A1 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
ν	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

(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

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

Notes: 1
2

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$



LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d :

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² 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	N
Relative Density	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils Consistency

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

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test 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 With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand



LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERINGS STATE

Fresh: no visible sign of weathering

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

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

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

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

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

BEDDING THICKNESS

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

JOINT OR FOLIATION SPACING

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

GRAIN SIZE

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

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

CORE CONDITION

Total Core Recovery (TCR)

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

Solid Core Recovery (SCR)

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

Rock Quality Designation (RQD)

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

DISCONTINUITY DATA

Fracture Index

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

Dip with Respect to Core Axis

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

Description and Notes

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

Abbreviations

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

PROJECT		1546542-1040		RECORD OF BOREHOLE No 16-401		SHEET 1 OF 2		METRIC									
W.P.		4015-E-0017		LOCATION		N 5025894.5 ; E 363195.9		ORIGINATED BY									
DIST		Eastern HWY 417		BOREHOLE TYPE		Power Auger 200 mm Diam. (Hollow Stem)/Rotary Drill, NQ Core		COMPILED BY									
DATUM		Geodetic		DATE		June 22, 2016		CHECKED BY									
								KSL									
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)	
82.1	GROUND SURFACE							20	40	60	80	100					
0.0	ASPHALTIC CONCRETE							20	40	60	80	100					
81.8																	
0.3	Gravelly sand (FILL) Dense Grey Moist		1	SS	32												
81.3																	
0.8	SILTY CLAY to CLAYEY SILT (WEATHERED CRUST) Stiff to very stiff Grey brown Moist		2	SS	13												
			3	SS	6												
			4	SS	3												
79.2																	
2.9	SILTY CLAY to CLAYEY SILT, some sand Stiff Grey Wet		5	SS	1												
78.2																	
3.9	Silty SAND, some clay, trace gravel (TILL) Dense Wet		6	SS	>50												
77.6																	
4.6	Limestone (BEDROCK) Bedrock cored from depths of 4.6 m to 7.9 m For bedrock coring details refer to Record of Drillhole 16-401		1	RC	REC 80%											RQD = 47%	
			2	RC	REC 100%												RQD = 100%
			3	RC	REC 100%												RQD = 93%
			4	RC	REC 100%												RQD = 100%
74.3																	
7.9	END OF BOREHOLE																

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMTOHWY417REHAB&WIDENING\02_DATA\GINT\1546542.GPJ GAL-GTA.GDT 03/09/17 JM

PROJECT: 1546542-1040

RECORD OF DRILLHOLE: 16-401

SHEET 2 OF 2

LOCATION: N 5025894.5 ; E 363195.9

DRILLING DATE: June 22, 2016

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 750

DRILLING CONTRACTOR: CCC

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY														FEATURES																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
							RECOVERY		R.Q.D. %	FRACT. INDEX PER	DISCONTINUITY DATA			HYDRAULIC CONDUCTIVITY K, cm/sec	WEATH- ERING INDEX																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
							TOTAL CORE %	SOLID CORE %			DIP w.r.t CORE AXIS °	TYPE AND SURFACE DESCRIPTION	Jr		Js	W1	W2	W3	W4	W5		W6																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
																							10 ⁰	10 ¹	10 ²																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
																							10 ⁰	10 ¹	10 ²																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
5	Rotary Drill NQ Core	Continued from Record of Borehole 16-401		77.54																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		

DEPTH SCALE

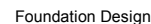
1 : 50



LOGGED: DG

CHECKED: KSL

GTA-RCK 031 N:\ACTIVE\SPATIAL_IMMTO\HWY417\REHAB&WIDENING\02_DATA\GINT\1546542.GPJ GAL-MISS.GDT 03/09/17 JM



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



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

N:\ACTIVE\SPATIAL_IMMTO\HWY417REHAB&WIDENING\02_DATA\GIN\1546542.GPJ GAL-GTA.GDT 03/09/17 JM

PROJECT: 1546542-1040

RECORD OF DRILLHOLE: 16-402

SHEET 3 OF 3

LOCATION: N 5025866.3 ;E 363230.0

DRILLING DATE: June 27, 2016

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 750

DRILLING CONTRACTOR: CCC

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY														FEATURES
						RECOVERY		R.Q.D. %	FRACT. INDEX PER	DIP w.r.t CORE AXIS °	DISCONTINUITY DATA		HYDRAULIC CONDUCTIVITY K, cm/sec		WEATH- ERING INDEX					
						TOTAL CORE %	SOLID CORE %				TYPE AND SURFACE DESCRIPTION	Jr	Ja	10 ⁻⁶ 10 ⁻⁵ 10 ⁻⁴ 10 ⁻³	W1 W2 W3 W4 W5 W6					
						000000 000000														

DEPTH SCALE

1 : 50



LOGGED: DG

CHECKED: KSL

GTA-RCK 031 N:\ACTIVE\SPATIAL_IMMTO\HWY417\REHAB&WIDENING\02_DATA\GINT\1546542.GPJ GAL-MISS.GDT 03/09/17_JM

PROJECT		1546542-1040		RECORD OF BOREHOLE No 16-403		SHEET 1 OF 2		METRIC						
W.P.		4015-E-0017		LOCATION		N 5025947.4 ; E 363199.0		ORIGINATED BY DG						
DIST		Eastern HWY 417		BOREHOLE TYPE		Power Auger 200 mm Diam. (Hollow Stem)/Rotary Drill, NQ Core		COMPILED BY ZS						
DATUM		Geodetic		DATE		July 5, 2016		CHECKED BY KSL						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
82.3	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100					
0.0	Silty sand (TOPSOIL)													
0.1	Brown Dry		1	SS	11									
	Sand, trace silt (FILL)													
81.6	Compact Brown Moist													
0.7	SILTY CLAY to CLAYEY SILT (WEATHERED CRUST)		2	SS	15									
	Stiff to very stiff Grey-brown													
			3	SS	9									
			4	SS	4									
79.5	Silty CLAY to CLAY													
2.8	Stiff Grey		5	SS	2									
78.4	Silty SAND, some clay, trace gravel, contains cobbles and boulders (TILL)		6	SS	4									3 51 34 12
3.9	Loose to dense Grey Wet		7	SS	>50									
			1	RC	REC 58%									RQD = 0%
77.1	Limestone (BEDROCK)													
5.2	Bedrock cored from depths of 5.2 m to 8.9 m		2	RC	REC 100%									RQD = 98%
	For bedrock coring details refer to Record of Drillhole 16-403													
			3	RC	REC 100%									RQD = 100%
			4	RC	REC 100%									RQD = 100%
73.4	END OF BOREHOLE													
8.9	NOTES:													
	1. Water level in well screen at a depth of 3.2 m below ground surface (Elev. 79.1 m), measured on September 30, 2016.													

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMTOHWY417REHAB&WIDENING\02_DATA\GINT\1546542.GPJ GAL-GTA.GDT 03/09/17 JM

PROJECT: 1546542-1040

RECORD OF DRILLHOLE: 16-403

SHEET 2 OF 2

LOCATION: N 5025947.4 ; E 363199.0

DRILLING DATE: July 5, 2016

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 750

DRILLING CONTRACTOR: CCC

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY												FEATURES																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
						RECOVERY		R.Q.D. %	FRACT. INDEX PER	DIP w.r.t CORE AXIS	DISCONTINUITY DATA		HYDRAULIC CONDUCTIVITY K, cm/sec		WEATH- ERING INDEX																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
						TOTAL CORE %	SOLID CORE %				Jr	Ja	10 ⁻⁶	10 ⁻⁵	10 ⁻⁴	10 ⁻³	W1		W2	W3	W4	W5	W6																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
						888888	888888																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
						888888	888888																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
		Continued from Record of Borehole 16-403		77.09																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															

DEPTH SCALE

1 : 50



LOGGED: DG

CHECKED: KSL

GTA-RCK 031 N:\ACTIVE\SPATIAL_IMMTO\HWY417\REHAB&WIDENING\02_DATA\GINT\1546542.GPJ GAL-MISS.GDT 03/09/17 JM

PROJECT		1546542-1040		RECORD OF BOREHOLE No 16-404		SHEET 1 OF 1		METRIC										
W.P.		4015-E-0017		LOCATION		N 5025829.0 ; E 363211.3		ORIGINATED BY										
DIST		Eastern HWY 417		BOREHOLE TYPE		Power Auger 200 mm Diam. (Hollow Stem)		COMPILED BY										
DATUM		Geodetic		DATE		July 27, 2016		CHECKED BY										
								KSL										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60						80	100	25
87.4	GROUND SURFACE																	
0.0	ASPHALTIC CONCRETE																	
87.2																		
86.9	Sandy gravel (FILL) Brown Dry																	
86.7	Sand (FILL) Brown Moist																	
0.7	Gravel and silty clay, some sand, contains sand seams, cobbles and boulders (FILL) Grey to grey-brown		1	SS	12													
			2	SS	8													
			3	SS	44													
			4	SS	50/0.08													
83.8	END OF BOREHOLE AUGER REFUSAL																	
3.6																		

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMTOHWY417REHAB&WIDENING\02_DATA\GINT\1546542.GPJ GAL-GTA.GDT 03/09/17 JM



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

PROJECT		1546542-1040		RECORD OF BOREHOLE No 16-406		SHEET 1 OF 1		METRIC						
W.P.		4015-E-0017		LOCATION		N 5025923.6 ; E 363102.7		ORIGINATED BY						
DIST		Eastern HWY 417		BOREHOLE TYPE		Power Auger 200 mm Diam. (Hollow Stem)		COMPILED BY						
DATUM		Geodetic		DATE		July 14, 2016		CHECKED BY						
								KSL						
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
83.5	GROUND SURFACE													
0.0	Silty sand (TOPSOIL) Dark brown Moist		1	SS	25									
0.2	Silt and sand, some clay, trace gravel (FILL) Brown to black Moist		2	SS	11									3 43 38 16
82.0														
1.5	SILTY CLAY to CLAYEY SILT (WEATHERED CRUST) Very stiff Grey-brown Moist		3	SS	8									
80.6			4	SS	11									
2.9	Silty SAND, some clay, trace gravel (TILL) Very dense Grey-brown Moist		5	SS	50/0.13									
80.3														
3.3	END OF BOREHOLE AUGER REFUSAL													
NOTES: 1. Well screen dry on September 30, 2016.														

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMTOHWY417REHAB&WIDENING\02_DATA\GINT\1546542.GPJ GAL-GTA.GDT 03/09/17 JM

PROJECT		1546542-1040		RECORD OF BOREHOLE No 16-407		SHEET 1 OF 1		METRIC										
W.P.		4015-E-0017		LOCATION		N 5025898.4 ; E 363142.9		ORIGINATED BY										
DIST		Eastern HWY 417		BOREHOLE TYPE		Power Auger 200 mm Diam. (Hollow Stem)		COMPILED BY										
DATUM		Geodetic		DATE		June 14, 2016		CHECKED BY										
								KSL										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)
82.9	GROUND SURFACE							20	40	60	80	100						
82.7	Silty sand (TOPSOIL) Dark brown Moist		1	SS	10													
82.2	SAND, some silt, clay and gravel (FILL) Compact Brown Moist		2	SS	11													
82.0																		
81.7	SILTY CLAY to CLAYEY SILT, some sand (WEATHERED CRUST) Stiff to very stiff Grey-brown Moist		3	SS	9													
81.5																		
81.2			4	SS	5													
81.0																		
80.7																		
80.4																		
80.1																		
79.9																		
79.7	Silty SAND, some clay, trace gravel (TILL) Very dense Brown Wet		5	SS	50/0.13													
79.5																		
79.3	END OF BOREHOLE AUGER REFUSAL																	

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMTOHWY417REHAB&WIDENING\02_DATA\GINT\1546542.GPJ GAL-GTA.GDT 03/09/17 JM

PROJECT		1546542-1040		RECORD OF BOREHOLE No 16-408		SHEET 1 OF 1		METRIC								
W.P.		4015-E-0017		LOCATION		N 5025880.4 ;E 363097.4		ORIGINATED BY								
DIST		Eastern HWY 417		BOREHOLE TYPE		Power Auger 200 mm Diam. (Hollow Stem)		COMPILED BY								
DATUM		Geodetic		DATE		June 14, 2016		CHECKED BY								
								KSL								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
82.9	GROUND SURFACE															
82.7	Sandy silt (TOPSOIL) Dark brown Moist		1	SS	18											
0.2	Silty SAND to Sandy SILT, some clay, trace gravel (TILL) Loose to compact Brown Moist		2	SS	14											
			3	SS	8											
80.4	END OF BOREHOLE AUGER REFUSAL															
2.5																

GTA-MTO 001 N:\ACTIVE\SPATIAL_IMMTOHWY417REHAB&WIDENING\02_DATA\GINT\1546542.GPJ GAL-GTA.GDT 03/09/17 JM

BH 16-401 (Wet)
Cored Length of 4.55 to 7.85 metres
Core Box 1 to 2 of 2

4.55 m Top of bedrock



7.85 m EOH

CLIENT
MMM Group Limited

PROJECT
MMM/ MTO 4014-E-0017 HIGHWAY 417/ OTTAWA
MAITLAND UNDERPASS

CONSULTANT



YYY/MM/DD	3/2/2017
PREPARED	KM
DESIGN	KM
REVIEW	KSL
APPROVED	ESO

TITLE
**BOREHOLE 16-401 (WET)
CORE PHOTOGRAPHS**

PROJECT No.	PHASE	Rev.	FIGURE
1546542	1040	0a	A2

BH 16-401 (Dry)
Cored Length of 4.55 to 7.85 metres
Core Box 1 to 2 of 2

4.55 m Top of bedrock



7.85 m EOH

CLIENT
MMM Group Limited

PROJECT
MMM/ MTO 4014-E-0017 HIGHWAY 417/ OTTAWA
MAITLAND UNDERPASS

CONSULTANT



YYY/MM/DD	3/2/2017
PREPARED	KM
DESIGN	KM
REVIEW	KSL
APPROVED	ESO

TITLE
**BOREHOLE 16-401 (DRY)
CORE PHOTOGRAPHS**

PROJECT No.	PHASE	Rev.	FIGURE
1546542	1040	0a	A1

BH 16-402 (Wet)
Cored Length of 5.97 to 9.17 metres
Core Box 1 to 2 of 2

5.97 m Top of bedrock



9.17 m EOH

CLIENT
MMM Group Limited

CONSULTANT



YYY/MM/DD	3/2/2017
PREPARED	KM
DESIGN	KM
REVIEW	KSL
APPROVED	ESO

PROJECT
MMM/ MTO 4014-E-0017 HIGHWAY 417/ OTTAWA
MAITLAND UNDERPASS

TITLE
**BOREHOLE 16-402 (WET)
CORE PHOTOGRAPHS**

PROJECT No.	PHASE	Rev.	FIGURE
1546542	1040	0a	A4

BH 16-402 (Dry)
Cored Length of 5.97 to 9.17 metres
Core Box 1 to 2 of 2

5.97 m Top of bedrock



9.17 m EOH

CLIENT
MMM Group Limited

PROJECT
MMM/ MTO 4014-E-0017 HIGHWAY 417/ OTTAWA
MAITLAND UNDERPASS

CONSULTANT



YYY/MM/DD	3/2/2017
PREPARED	KM
DESIGN	KM
REVIEW	KSL
APPROVED	ESO

TITLE
**BOREHOLE 16-402 (DRY)
CORE PHOTOGRAPHS**

PROJECT No.	PHASE	Rev.	FIGURE
1546542	1040	0a	A3

5.21 m Top of bedrock

BH 16-403 (Wet)
Cored Length of 5.21 to 8.86 metres
Core Box 1 to 2 of 2



CLIENT
MMM Group Limited

PROJECT
MMM/ MTO 4014-E-0017 HIGHWAY 417/ OTTAWA
MAITLAND UNDERPASS

CONSULTANT



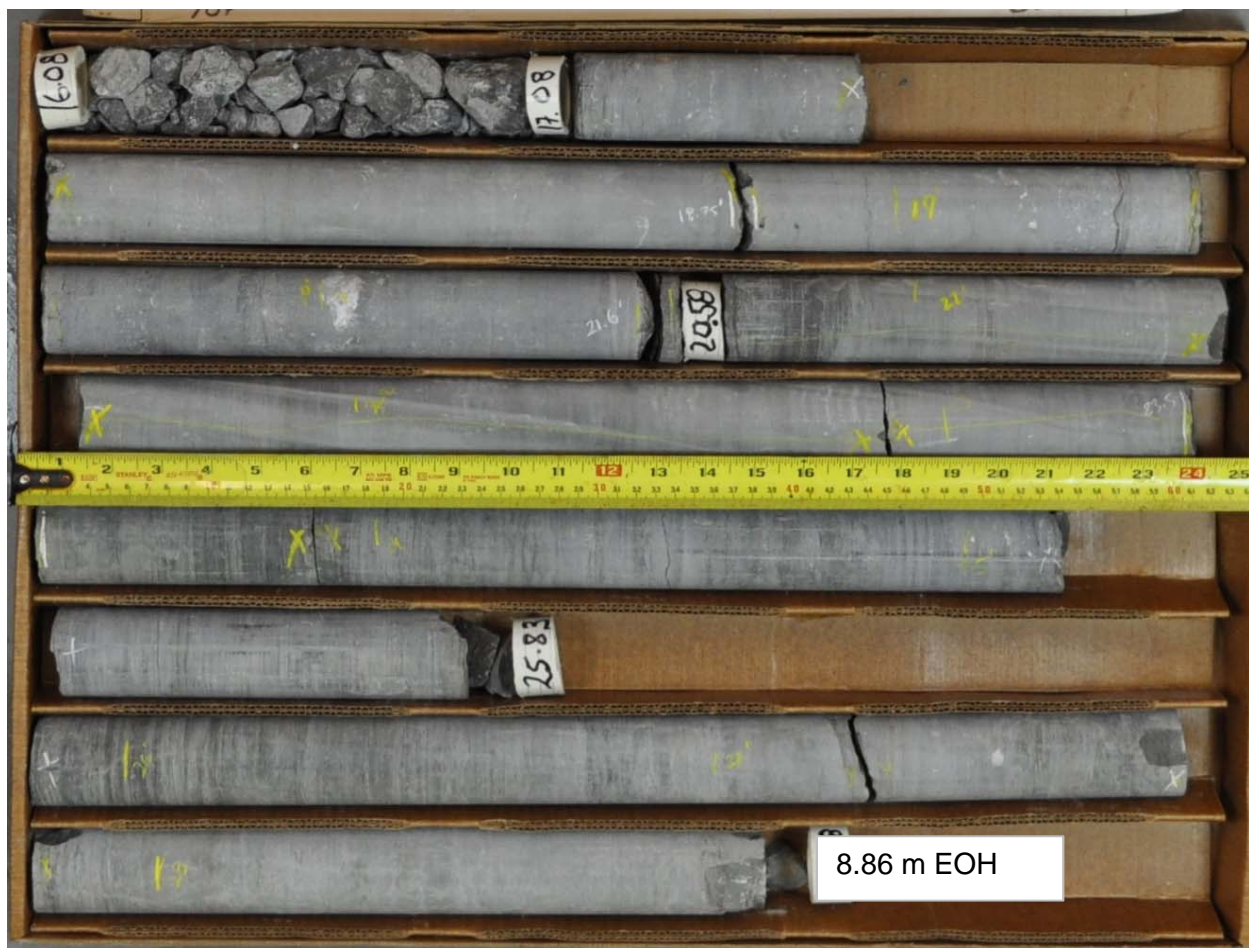
YYY/MM/DD	3/2/2017
PREPARED	KM
DESIGN	KM
REVIEW	KSL
APPROVED	ESO

TITLE
**BOREHOLE 16-403 (WET)
CORE PHOTOGRAPHS**

PROJECT No.	PHASE	Rev.	FIGURE
1546542	1040	0a	A6

5.21 m Top of bedrock

BH 16-403 (Dry)
Cored Length of 5.21 to 8.86 metres
Core Box 1 to 2 of 2



CLIENT
MMM Group Limited

PROJECT
MMM/ MTO 4014-E-0017 HIGHWAY 417/ OTTAWA
MAITLAND UNDERPASS

CONSULTANT



YYY/MM/DD	3/2/2017
PREPARED	KM
DESIGN	KM
REVIEW	KSL
APPROVED	ESO

TITLE
**BOREHOLE 16-403 (DRY)
CORE PHOTOGRAPHS**

PROJECT No.	PHASE	Rev.	FIGURE
1546542	1040	0a	A5



APPENDIX B

Laboratory Test Results, Current Investigation

Figure 1 - Grain Size Distribution Test Results – Silty Sand to Sand (FILL)

Figure 2 - Plasticity Chart – Silty Clay (Fill)

Figure 3 - Plasticity Chart – Silty Clay to Clayey Silt (Weathered Crust)

Figure 4 - Grain Size Distribution Test Results – Silty Clay to Clayey Silt (Weathered Crust)

Figure 5 - Plasticity Chart – Silty Clay to Clayey Silt to Clay

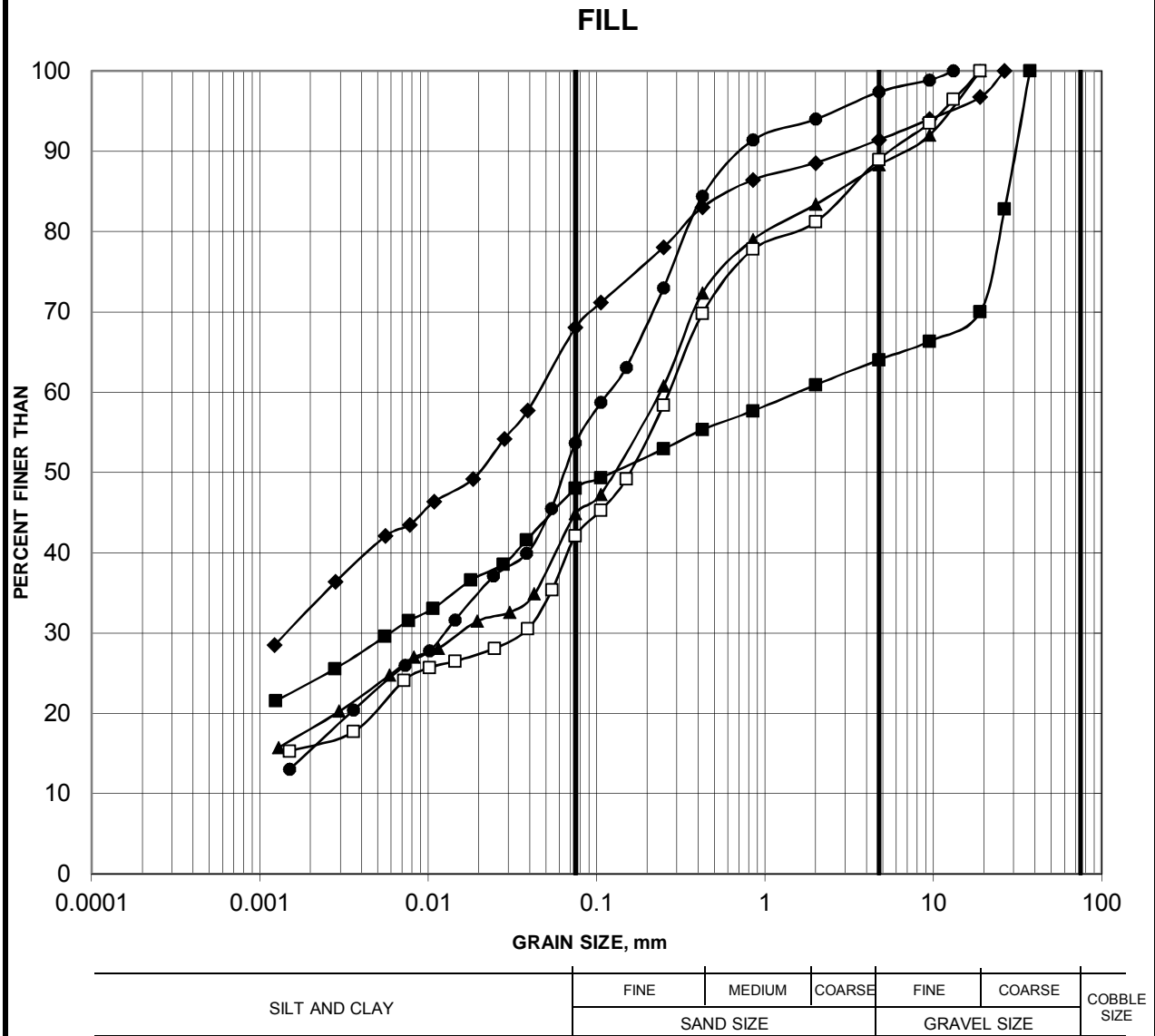
Figure 6 - Grain Size Distribution Test Results – Silty Clay to Clayey Silt

Figure 7 - Grain Size Distribution Test Results – Silty Sand (Till)

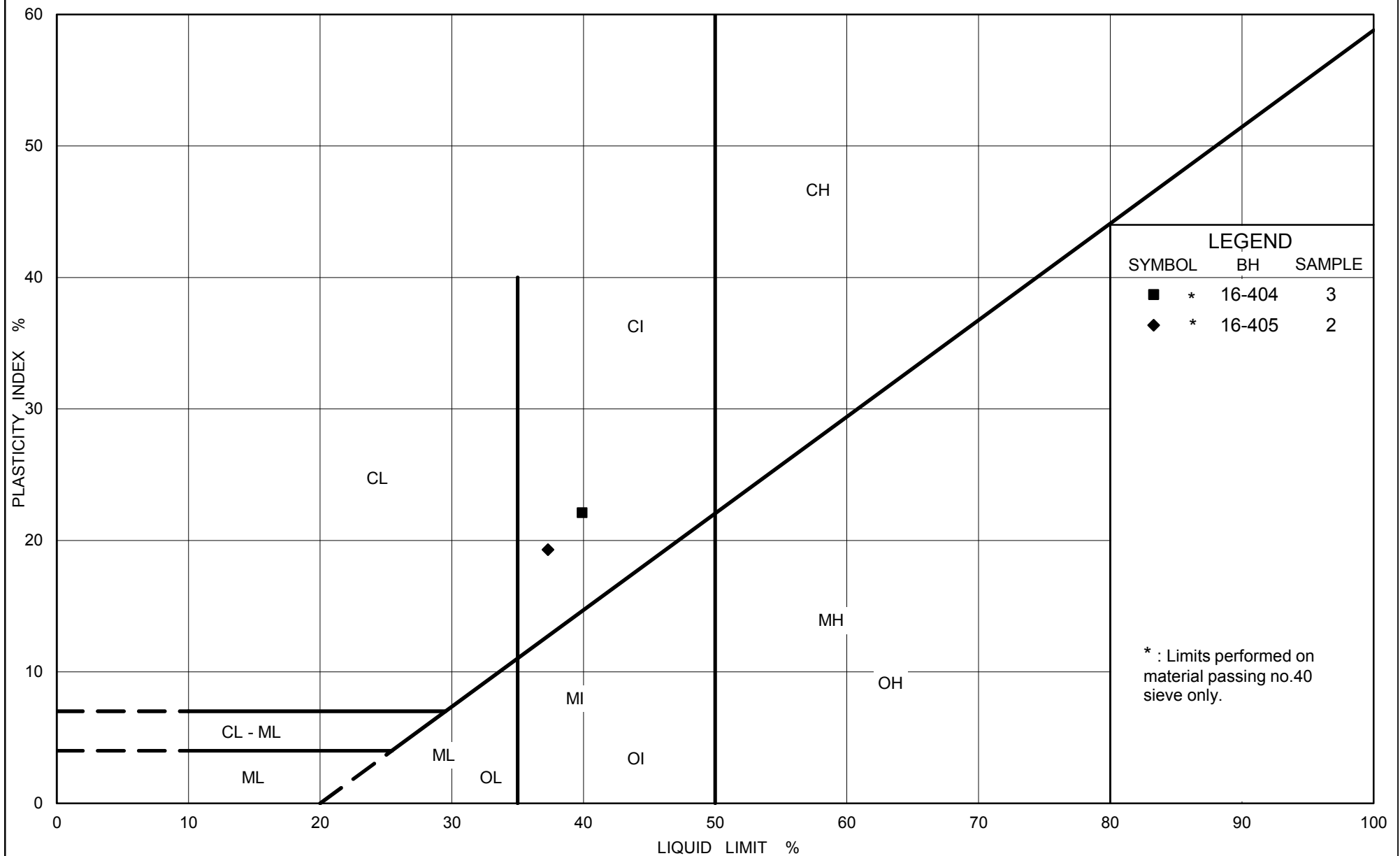
Figure 8 - Summary of Laboratory Compressive Strength Unconfined Compression Tests

GRAIN SIZE DISTRIBUTION

FIGURE 1



Borehole	Sample	Depth (m)
16-404	3	2.29-2.90
16-405	2	1.52-2.13
16-405	7	4.82-5.18
16-406	2	0.76-1.37
16-407	1B	0.18-0.61



Ministry of Transportation

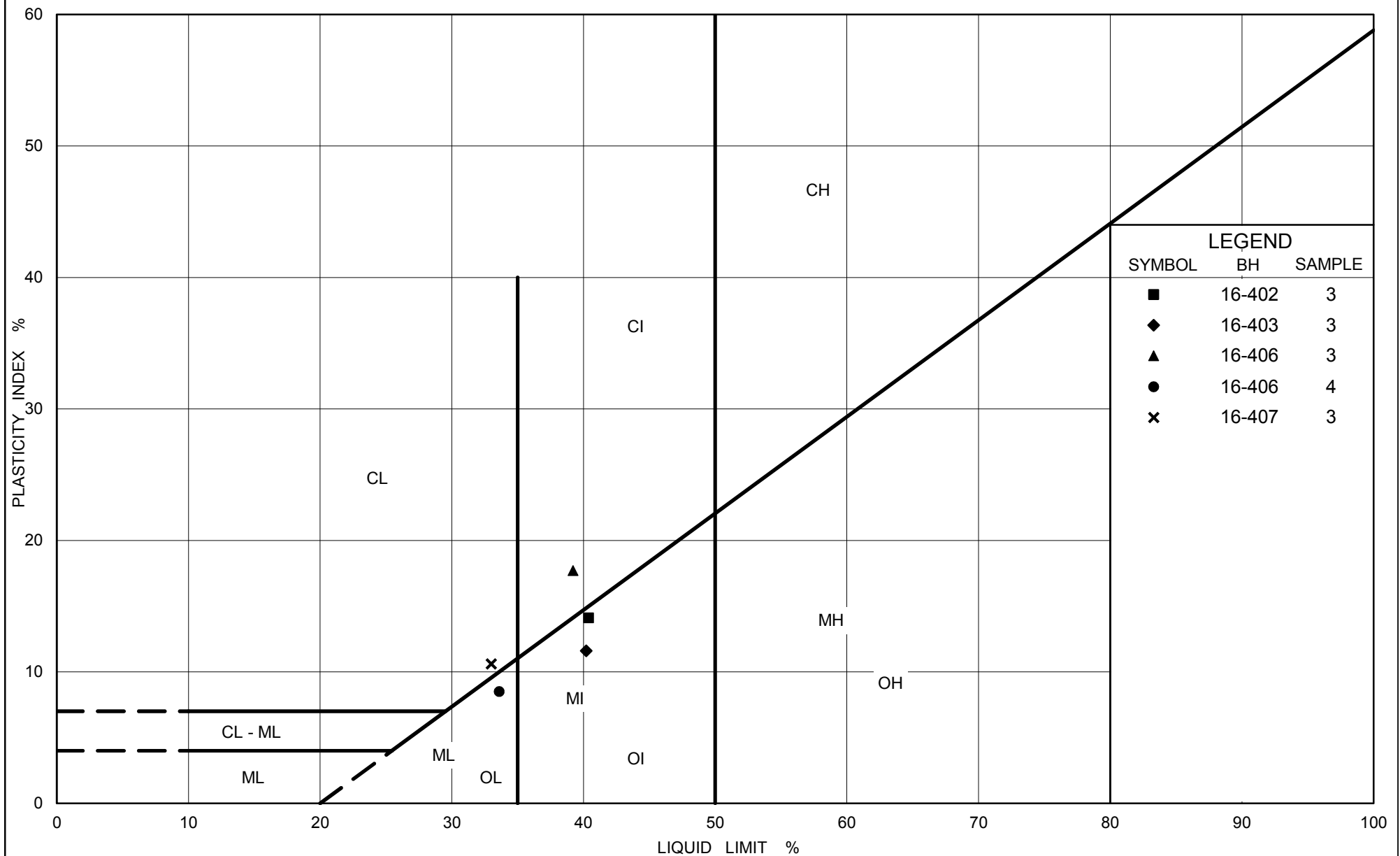
Ontario

PLASTICITY CHART Silty Clay (FILL)

FIG No. 2

Project No. 1546542-1040

Compiled By : MI Checked By : CNM



Ontario

Ministry of Transportation

PLASTICITY CHART SILTY CLAY to CLAYEY SILT (WEATHERED CRUST)

FIG No. 3

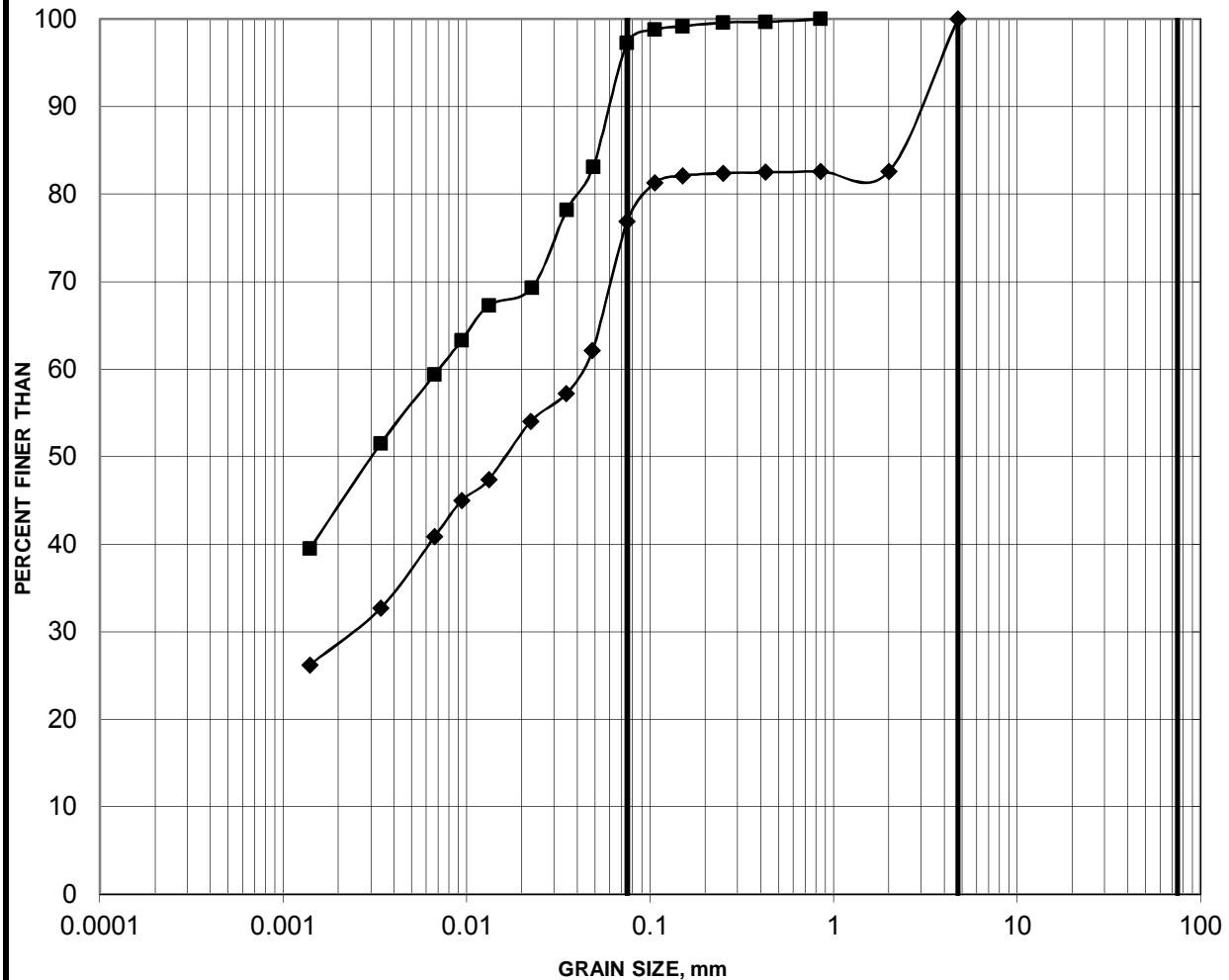
Project No. 1546542-1040

Compiled By : MI Checked By : CNM

GRAIN SIZE DISTRIBUTION

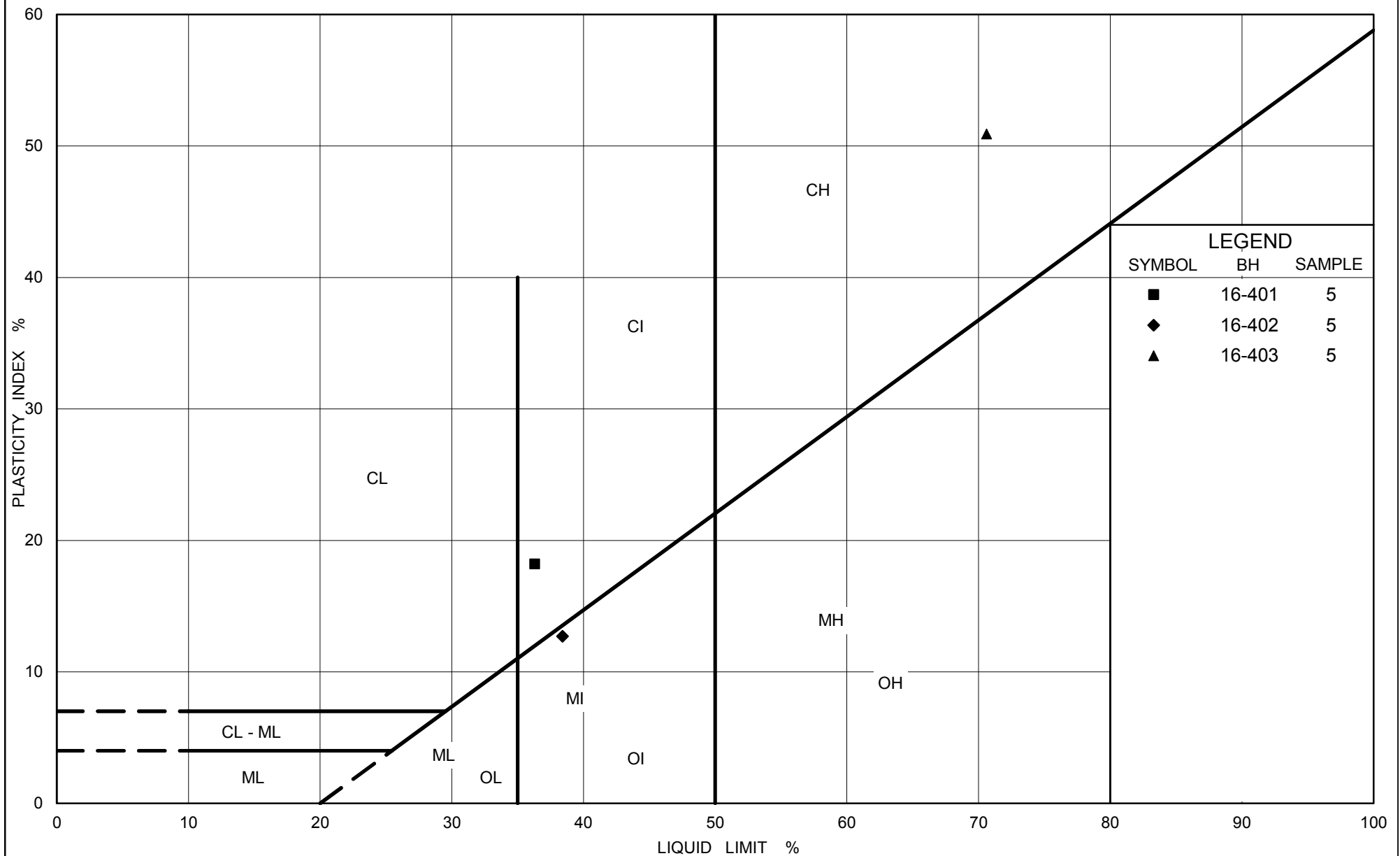
FIGURE 4

SILTY CLAY TO CLAYEY SILT (WEATHERED CRUST)



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

Borehole	Sample	Depth (m)
16-402	3	1.52-2.13
16-407	3	1.52-2.13



Ontario

Ministry of Transportation

PLASTICITY CHART SILTY CLAY to CLAYEY SILT to CLAY

FIG No. 5

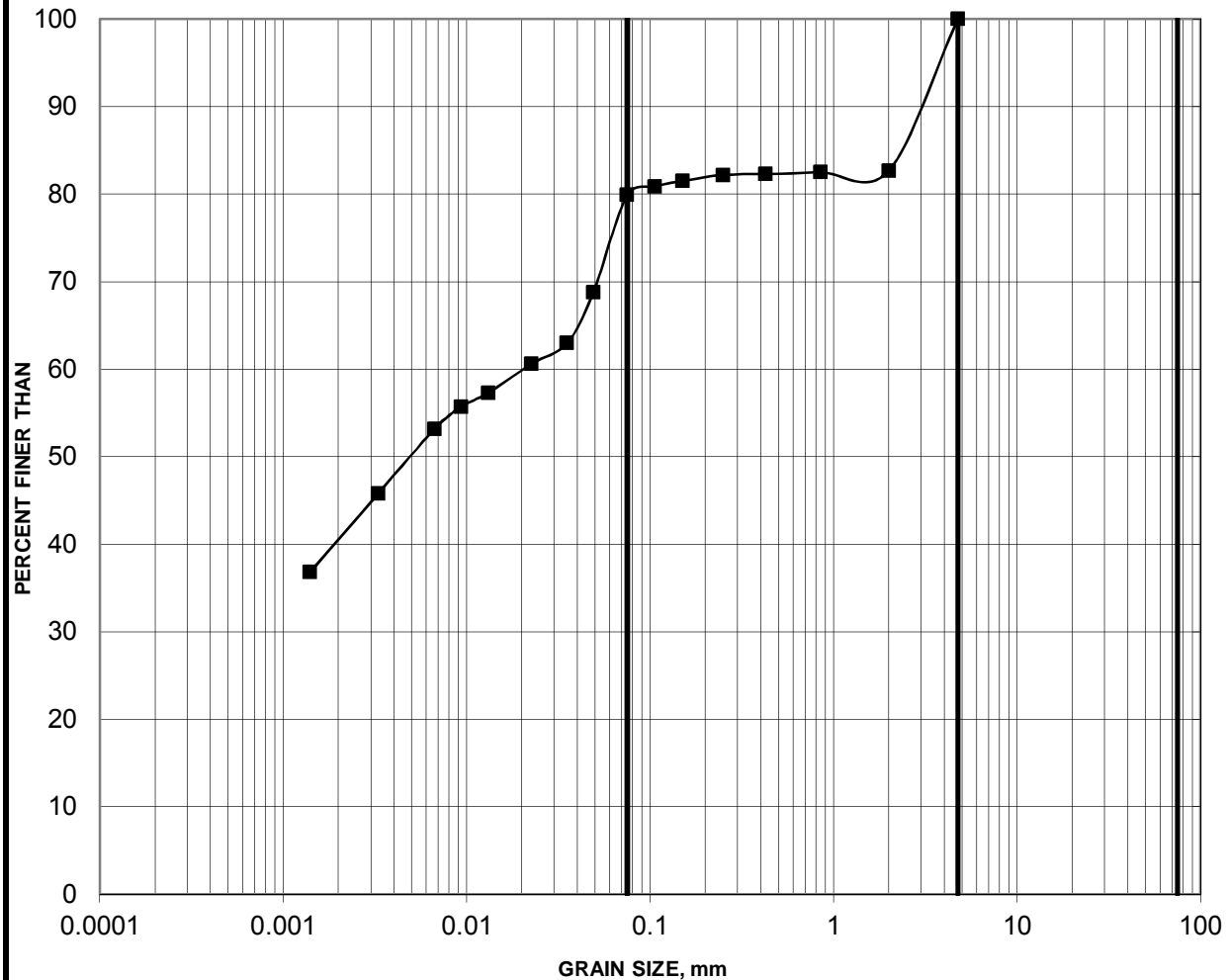
Project No. 1546542-1040

Compiled By : MI Checked By : CNM

GRAIN SIZE DISTRIBUTION

FIGURE 6

SILTY CLAY TO CLAYEY SILT



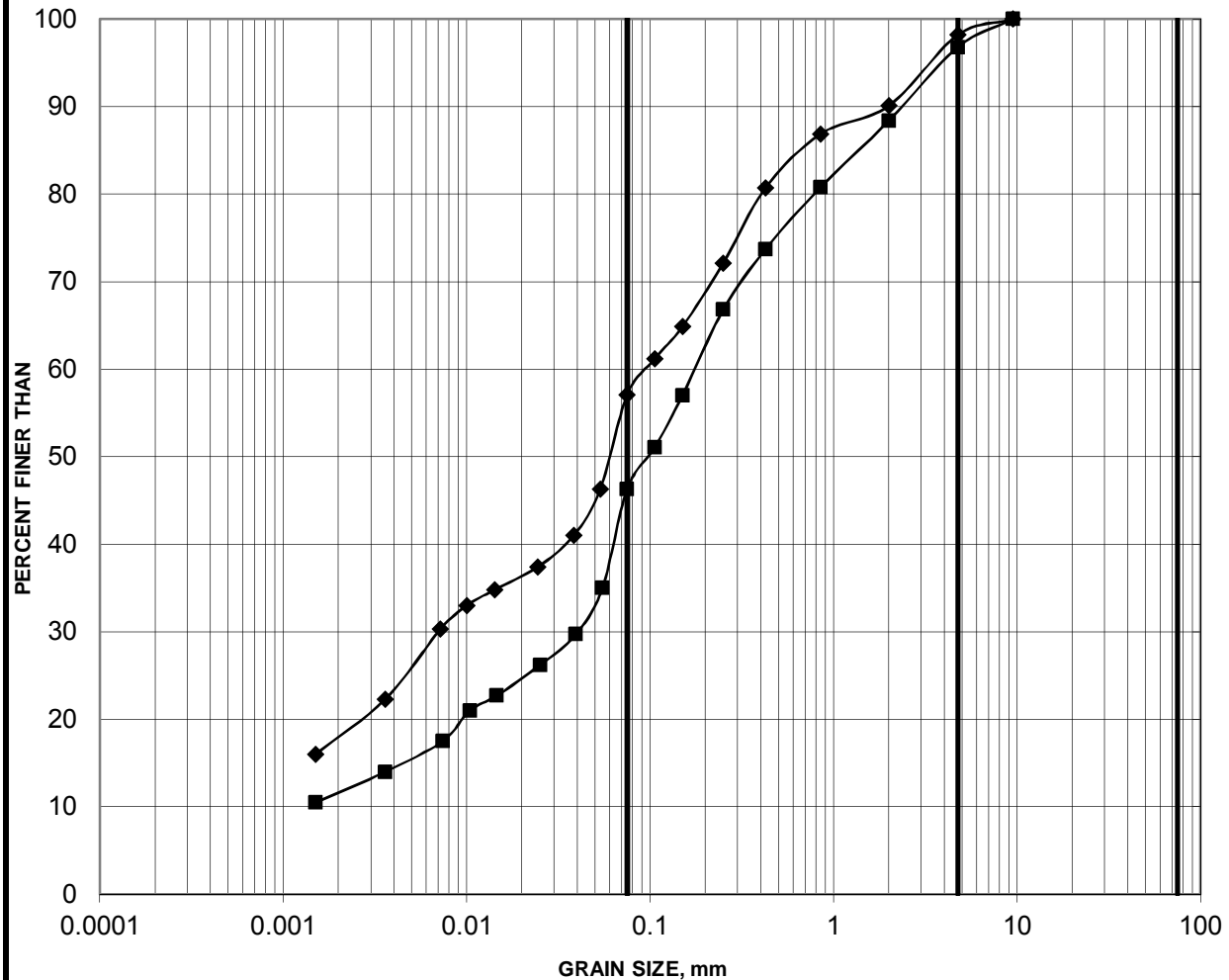
SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)
16-401	5	3.05-3.66

GRAIN SIZE DISTRIBUTION

FIGURE 7

SILTY SAND (TILL)

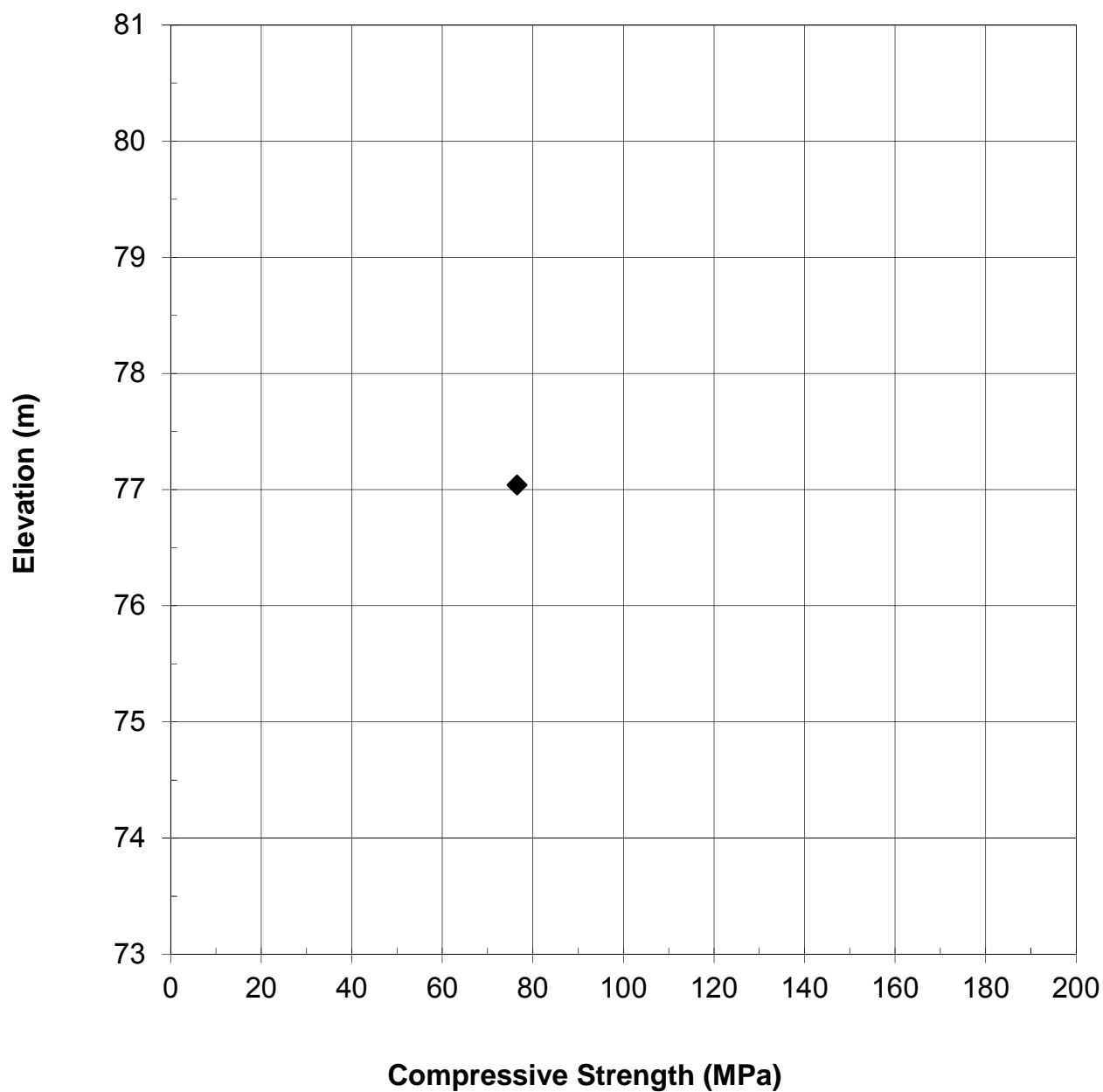


SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)
16-403	6	3.96-4.57
16-408	3	1.52-2.13

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

FIGURE 8





APPENDIX C

Previous Borehole Records

Records of Previous Boreholes 1 to 6 (Geocres No. 31G5-022)

Records of Previous Boreholes 98-1 to 98-4 (Geocres No. 31G5-190)

McROSTIE & ASSOCIATES

CONSULTING ENGINEERS

OTTAWA CANADA

SOIL PROFILE AND SUMMARY OF LABORATORY TESTS

QUEENSWAY AT MAITLAND AVE.
BRIDGE No.3

ELEVATION OF GROUND SURFACE (ZERO DEPTH) 271.1 - GEODETIC
REMARKS REF. BM. EL. 275.34

HOLE No.

1

DATE MAY 9-12-1958

UNCONFINED COMPRESSIVE STRENGTH KIPS/FT. ²	SMALL SCALE PENETROMETER KIPS/FT. ²	STANDARD PENETRATION BLOWS/FT.	SAMPLE NUMBER	DESCRIPTION OF SOIL	DEPTH IN FEET	ELEVATION	PENETRATION TEST			
						LB. HAMMER		NO CASING	
						INCH DROP	INCH DIA. ROD	
GROUND SURFACE							BLOWS PER FOOT			
				TOP SOIL	0	271.1				
					1.0	270.1				
				HARD, FISSURED, SILTY	2					
				BROWNISH-GRAY CLAY	4					
					5.0	265.1				
				VERY STIFF, FISSURED SILTY	6					
				BROWNISH-GRAY CLAY	8					
					10					
					11.5	259.6				
				DENSE SANDY TILL	12					
					14					
				LIMESTONE (DRILLED) CORE RECOVERY 71%	15.5	255.6				
				LIMESTONE (DRILLED) CORE RECOVERY 89% BEDDING THICKNESS 2 1/2"	17.4	253.7				
				LIMESTONE (DRILLED) CORE RECOVERY 96% BEDDING THICKNESS 3"	19.6	251.5				
				LIMESTONE (DRILLED) CORE RECOVERY 87% BEDDING THICKNESS 2"	23.6	247.5				
					25.6	245.5				
				BOTTOM OF HOLE	26					
							% WATER CONTENT			
							PLATE 2			

SOIL PROFILE AND SUMMARY OF LABORATORY TESTS

QUEENSWAY AT MAITLAND AVE.
BRIDGE No. 3

ELEVATION OF GROUND SURFACE (ZERO DEPTH) 271.3 GEODETIC
REMARKS SEE PLATE 2

HOLE No.

DATE MAY 14-1958

5

UNCONFINED COMPRESSIVE STRENGTH KIPS/FT. ²	SMALL SCALE PENETROMETER KIPS/FT. ²	STANDARD PENETRATION BLOWS/FT.	SAMPLE NUMBER	DESCRIPTION OF SOIL	DEPTH IN FEET	ELEVATION	WATER CONTENT	
							LIQUID LIMIT W (%)	PLASTIC LIMIT P (%)
				GROUND SURFACE				
				TOP SOIL	0	271.3		
				HARD, FISSURED, SILTY	2	270.3		
3.7 R-1.8	8.2 8.3 8.4 9.0 9.0 9.0 9.0 9.0 9.0		5-1	BROWNISH-GRAY CLAY	4.5	266.8		
1.8 R-1.2	5.6 5.6 7.0 7.2 7.0 7.8 6.8 6.8 6.4		5-2	VERY STIFF FISSURED, SILTY	6			
3.0 R-0.9	5.0 5.4 5.5 6.2 6.0 6.2 5.6 6.0 5.8		5-3	BROWNISH-GRAY CLAY	8			
0.9 R-0.3	2.4 2.0 2.2 3.0 3.2 3.0 3.4 3.2 3.2		5-4	STIFF, FISSURED, SILTY BROWNISH-GRAY CLAY	10	261.8		
			5-5	SOFT, VERY SILTY GRAY CLAY	12	259.3		
			5-6	DENSE TILL	14	257.3		
				LIMESTONE (DRILLED) CORE RECOVERY 60%	16	255.8		
				LIMESTONE (DRILLED) CORE RECOVERY 83% BEDDING THICKNESS 3"	18	254.3		
				LIMESTONE (DRILLED) CORE RECOVERY 87% BEDDING THICKNESS 3"	20	251.3		
				ONE 80° JOINT IN CORE BREAK	22			
				LIMESTONE (DRILLED) CORE RECOVERY 100% BEDDING THICKNESS 3"	24	246.1		
					26	244.5		
				BOTTOM OF HOLE	28			

McROSTIE & ASSOCIATES

CONSULTING ENGINEERS

OTTAWA CANADA

SOIL PROFILE AND SUMMARY OF LABORATORY TESTS

QUEENSWAY AT MAITLAND AVE.
BRIDGE No. 3

ELEVATION OF GROUND SURFACE (ZERO DEPTH) 270.0 - GEODETIC

HOLE NO.

REMARKS SEE PLATE 2

6

DATE MAY 13-14, 1958

UNCONFINED COMPRESSIVE STRENGTH KIPS/FT. ²	SMALL SCALE PENETROMETER KIPS/FT. ²	STANDARD PENETRATION BLOWS/FT.	SAMPLE NUMBER	DESCRIPTION OF SOIL	DEPTH IN FEET	ELEVATION	PENETRATION TEST					
							LE. HAMMER		NO. CASING			
							INCH DROP		INCH DIA. ROD			
GROUND SURFACE							BLOWS PER FOOT					
				TOP SOIL	0	270.0						
					1.0	269.0						
				HARD, FISSURED, SILTY	2							
2.5	8.4-7.8 7.4		6-1	BROWNISH-GRAY CLAY	4							
	9.0 9.0 9.0				4.5	265.5						
4.7	6.2 7.2 8.0		6-2	VERY STIFF, FISSURED SILTY	6							
	7.4 7.6 7.0			BROWNISH-GREY CLAY	7.0	263.0						
	8.0 8.0 8.0											
1.8	3.6 3.4 3.2		6-3	STIFF, FISSURED, SILTY	8							
	3.2 3.5 3.8											
	4.0 3.7 3.4											
2.0	3.4 3.6 3.4		6-4	BROWNISH-GRAY CLAY	10							
	3.6 4.0 3.8				11.5	258.5						
			7	LOOSE TILL	12							
			33 for 6"		13.5	256.5						
			44 for 3"	DENSE TILL	14							
					16.2	253.8						
				LIMESTONE (DRILLED)	18							
				CORE RECOVERY 93%								
				BEDDING THICKNESS 2"	19.7	250.3						
				LIMESTONE (DRILLED)	22							
				CORE RECOVERY 94%								
				BEDDING THICKNESS 3"	24.2	245.8						
				LIMESTONE (DRILLED)	26	243.8						
				CORE RECOVERY 95%								
				BEDDING THICKNESS 3"	26.2							
				BOTTOM OF HOLE								
							0	20	40	60	80	100
							NATURAL % WATER CONTENT SHOWN THUS ○					
							PLATE 7					

RECORD OF BOREHOLE No 98-1

1 OF 1

METRIC

W.P. 203-86-02 LOCATION Hwy 417 WBL at Maitland Avenue ORIGINATED BY LP
DIST 429 HWY 417 BOREHOLE TYPE Hollow Stem Augers COMPILED BY PC
DATUM Geodetic DATE 98.08.27 & 98.08.28 CHECKED BY PC

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		20	40	60	80	100					
82.3																
0.0	Brown, silty sand, trace organics: FILL		1	SS	5											
81.6																
0.8	Brown, silty clay, some gravel, trace organics: FILL		2	SS	8											
80.8																
1.5	Very stiff, brown, SILTY CLAY, occasional sand seams		3	SS	7											
			4	SS	4											
79.3																
3.0	Stiff		5	SS	3											
78.5																
3.8	Loose to compact, gray, silty sand with gravel, trace clay; TILL		6	SS	7											
			7	SS	16											
77.1																
5.2	End of Borehole Auger Refusal on Inferred Bedrock - standpipe installed - standard penetration tests carried out using 45 lb hammer and 30 inch freefall max. field vane capacity was 150 kPa which was exceeded by soil resistance.															

x³, x²: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 98-2

1 OF 1

METRIC

W.P. 203-86-02 LOCATION Hwy 417 WBL at Maitland Avenue ORIGINATED BY LP
 DIST 428 HWY 417 BOREHOLE TYPE Hollow Stem Augers COMPILED BY PC
 DATUM Geodetic DATE 98.06.27 & 98.06.28 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa											
81.8								20	40	60	80	100							
0.0	Dark brown, silty sand: FILL		1	SS	3		81												
81.5																			
0.3	Very stiff, brown, SILTY CLAY		2	SS	8			80											
			3	SS	7														
79.5					*REF	79													
2.3	Compact, brown, silty sand, some gravel, trace clay: TILL	4	SS																
79.0																			
2.8	End of Borehole																		
	Auger Refusal on Inferred Bedrock																		
	max. field vane capacity was 150 kPa which was exceeded by soil resistance.																		
	*REF = split spoon refusal																		

×³, ×¹: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 98-3

1 OF 1

METRIC

W.P. 203-86-02

LOCATION Hwy 417 EBL at Maitland Avenue

ORIGINATED BY LP

DIST 429 HWY 417

BOREHOLE TYPE Hollow Stem Augers

COMPILED BY PC

DATUM Geodetic

DATE 98.08.26 & 98.08.27

CHECKED BY PC



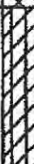


SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			20	40	60	80	100		
84.4													
0.0	Brown, sand, some silt, trace organics, clayey pockets: FILL		1	SS	6								
			2	SS	3								
			3	SS	6								
82.1													
2.3	Very stiff, brown, SILTY CLAY, occasional sand seams		4	SS	8								
			5	SS	6								
80.6													
3.8	stiff		6	SS	3								
			7	SS	5								
79.2													
5.3	Loose, brown, clayey sand, some silt, trace gravel: TILL		8	SS	7								
78.6													
5.9	End of Borehole												
	Auger Refusal on Inferred Bedrock												
	max. field vane capacity was 150 kPa which was exceeded by soil resistance.												

RECORD OF BOREHOLE No 98-4

1 OF 1

METRIC

W.P. 203-86-02 LOCATION Hwy 417 EBL at Maitland Avenue ORIGINATED BY LP
 DIST 428 HWY 417 BOREHOLE TYPE Hollow Stem Augers COMPILED BY PC
 DATUM Geodetic DATE 98.08.26 & 98.08.27 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT 7 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
82.0								20 40 60 80 100					
0.0	Brown, silty sand: FILL		1	SS	16								
80.8			2	SS	5								
1.2	Very stiff to stiff, brown, SILTY CLAY		3	SS	4								
78.7													
2.3	Loose, brown-grey, silty sand with gravel, trace clay: TILL		4	SS	8								
79.0													
3.1	Grey, silty clay, some gravel: TILL		5	SS	4								
77.8			6	SS		*REF							
4.2	End of Borehole												
	Auger Refusal on inferred Bedrock												
	- standpipe installed												
	- standard penetration tests carried out using 45 lb hammer and 30 inch freefall												
	*REF=split spoon refusal												



APPENDIX D

Results of MASW TESTING

DATE February 15, 2017**PROJECT No.** 1546542**TO** Kim Lesage
Golder Associates Ltd.**CC****FROM** Stephane Sol, Christopher Phillips**EMAIL** ssol@golder.com;cphillips@golder.com**NBCC SEISMIC SITE CLASS TESTING RESULTS - HWY417 WIDENING PROJECT
4 LOOP RAMP LOCATIONS ALONG HIGHWAY417, OTTAWA, ONTARIO**

This technical memorandum presents the results of four Multichannel Analysis of Surface Waves (MASW) tests performed for the purpose of the 2010 National Building Code of Canada (NBCC2010) Seismic Site Classification for a Highway 417 widening project located along HWY417, Ottawa, Ontario. Site 1 is located within the HWY417 southwest loop ramp just west of Richmond Road (Richmond Site - Figure 1). Site 2 is located within the HWY417 southwest loop ramp just west of Pinecrest/ Greenbank Road (Pinecrest Site - Figure 2). Site 3 is located within the HWY417 northwest loop ramp just west of Woodroffe Avenue (Woodroffe Site - Figure 3). Site 4 is located within the HWY417 northwest loop ramp just west of Maitland Avenue (Maitland Site - Figure 4).

The geophysical testing was performed by Golder personnel on May 26 and 27, 2016.





Figure 1: MASW Location Site Map at the Richmond site (MASW Line 1 in red)

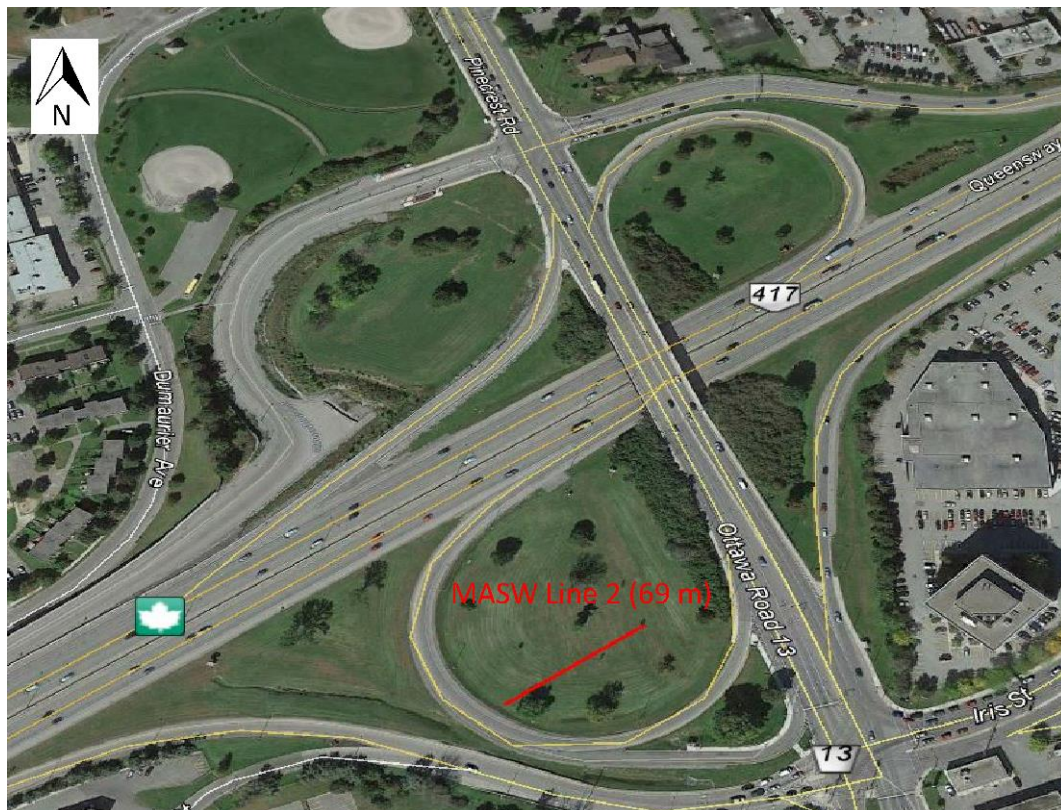


Figure 2: MASW Location Site Map at the Pinecrest site (MASW Line 2 in red)



Figure 3: MASW Location Site Map at the Woodroffe site (MASW Line 3 in red)

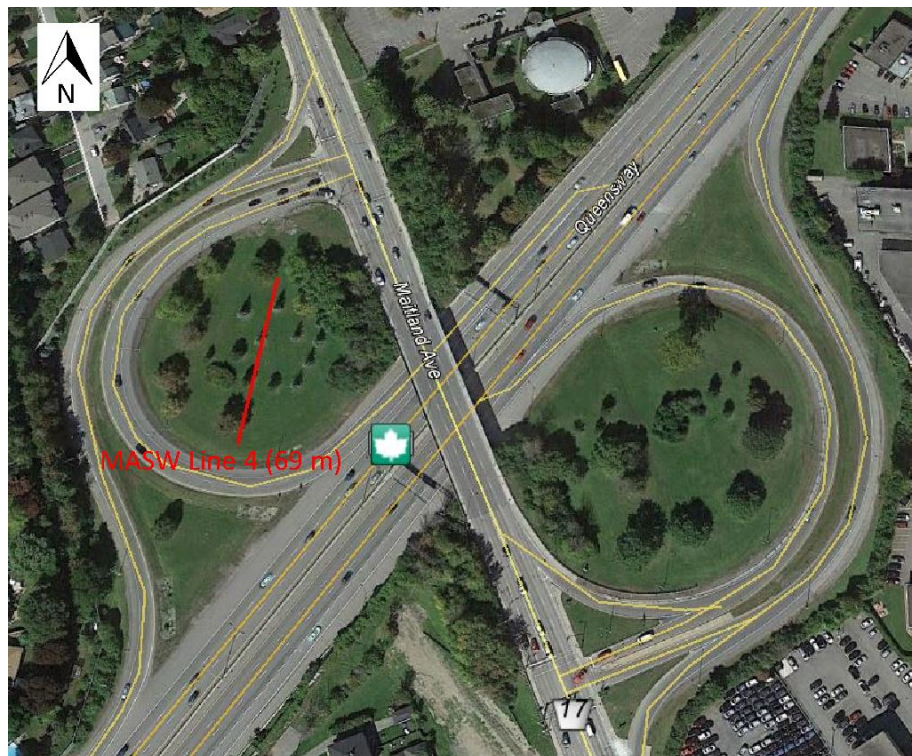


Figure 4: MASW Location Site Map at the Maitland site (MASW Line 4 in red)

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 26 and 27 by personnel from the Golder Mississauga and Ottawa offices. One MASW line was collected at each of the four sites (Figures 1, 2, 3 and 4).

For each survey 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 each 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, 15, and 20 metres from and collinear to the geophone array. An example of active seismic records collected for MASW Lines 1, 2 and 3 are shown in Figures 5, 6, 7 and 8, respectively below. MASW Line 4 located west of Maitland Avenue had a higher noise level due to large amount of road traffic.

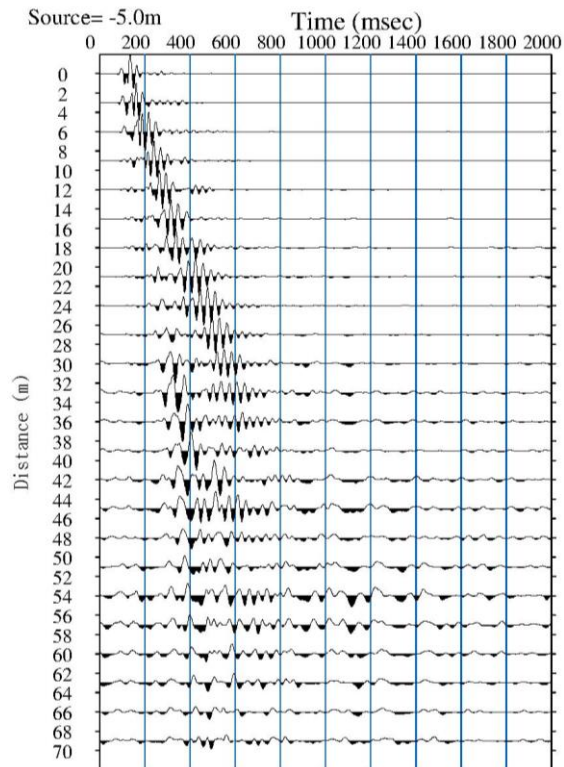


Figure 5: Typical seismic record collected along MASW Line 1

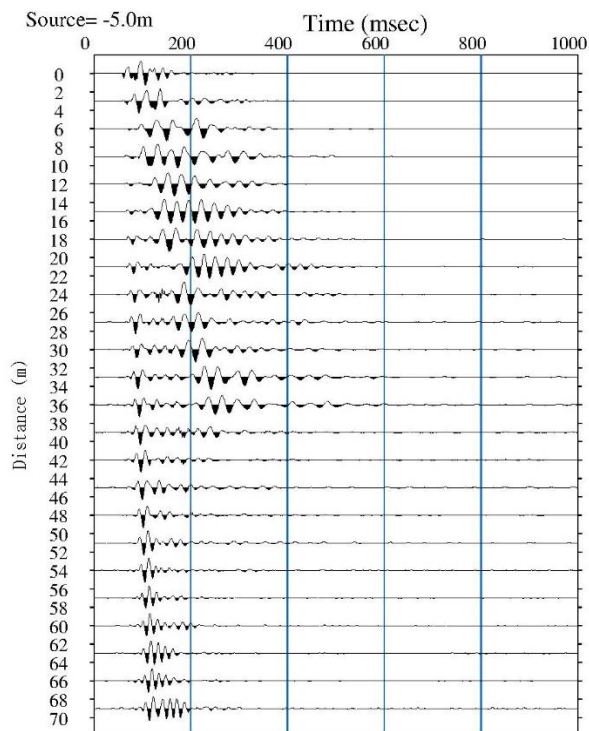


Figure 6: Typical seismic record collected along MASW Line 2

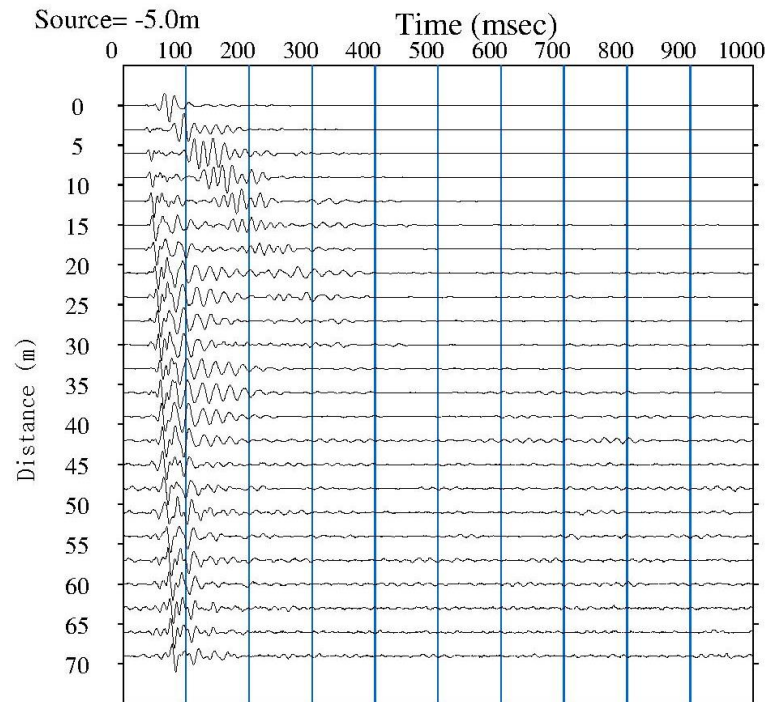


Figure 7: Typical seismic record collected along MASW Line 3

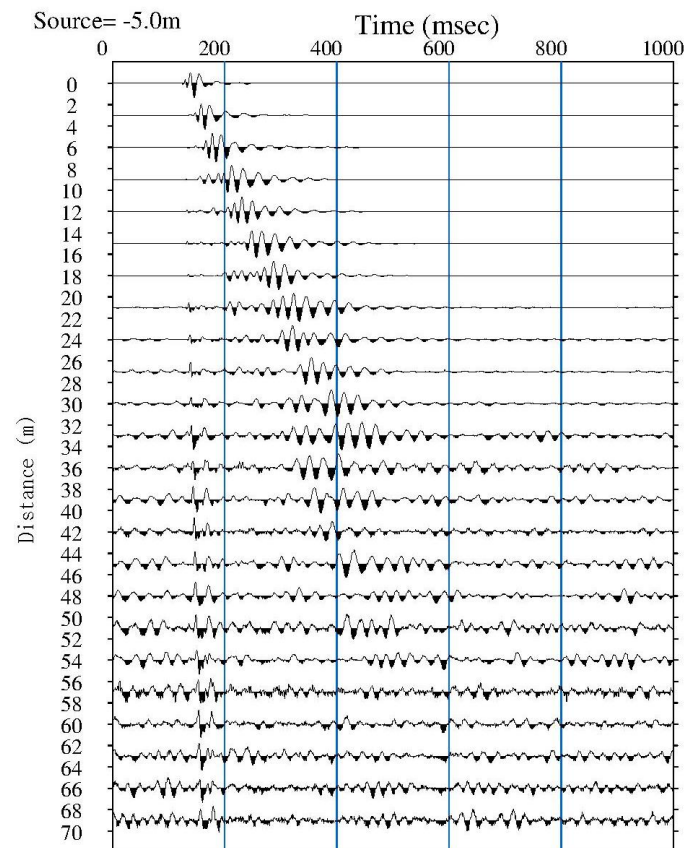


Figure 8: Typical seismic record collected along MASW Line 4

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 Figures 9, 10, 11 and 12. Shear-wave velocity profiles were generated through inverse modelling to best fit the calculated dispersion curves.

Along MASW Line 1, the active survey provided a dispersion curve with a suitable frequency range (5 to 27 Hz), providing information for both shallow and deeper depths. The minimum measured surface-wave frequency with sufficient signal-to-noise ratio to accurately measure phase velocity was approximately 5 Hz.

Along MASW Line 2, the active survey provided a dispersion curve with a suitable frequency range (30-150 Hz), providing information for both shallow and deeper depths. The minimum measured surface-wave frequency with sufficient signal-to-noise ratio to accurately measure phase velocity was approximately 30 Hz.

Along MASW Line 3, the active survey provided a dispersion curve with a suitable frequency range (35-135 Hz), providing information for both shallow and deeper depths. The minimum measured surface-wave frequency with sufficient signal-to-noise ratio to accurately measure phase velocity was approximately 35 Hz.

Along MASW Line 4, the active survey provided a dispersion curve with a suitable frequency range (17-58 Hz), providing information for both shallow and deeper depths. The minimum measured surface-wave frequency with sufficient signal-to-noise ratio to accurately measure phase velocity was approximately 17 Hz.

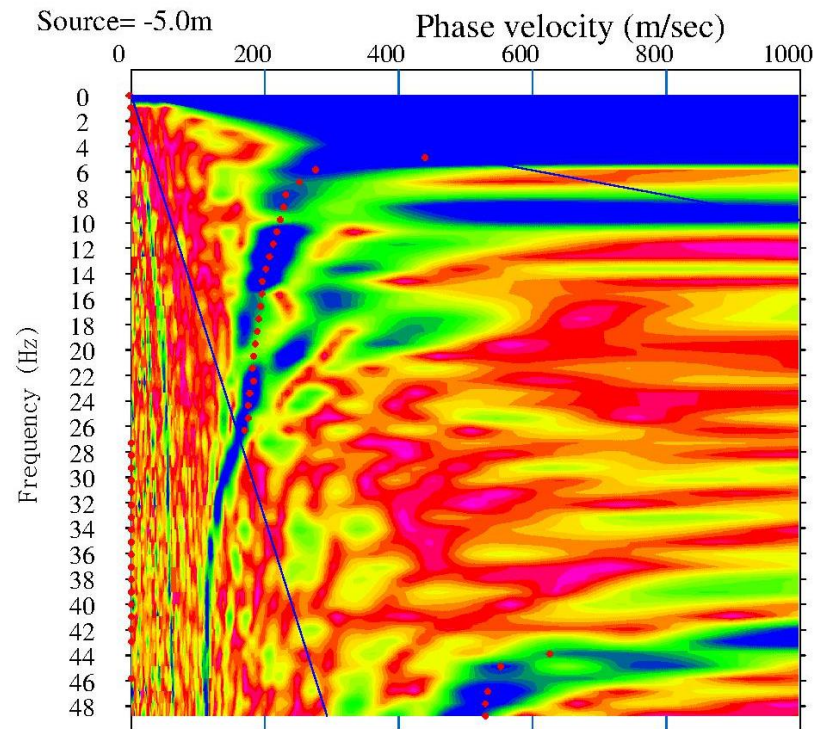


Figure 9: Active MASW Dispersion Curve Picks (red dots) along MASW Line 1 (Richmond)

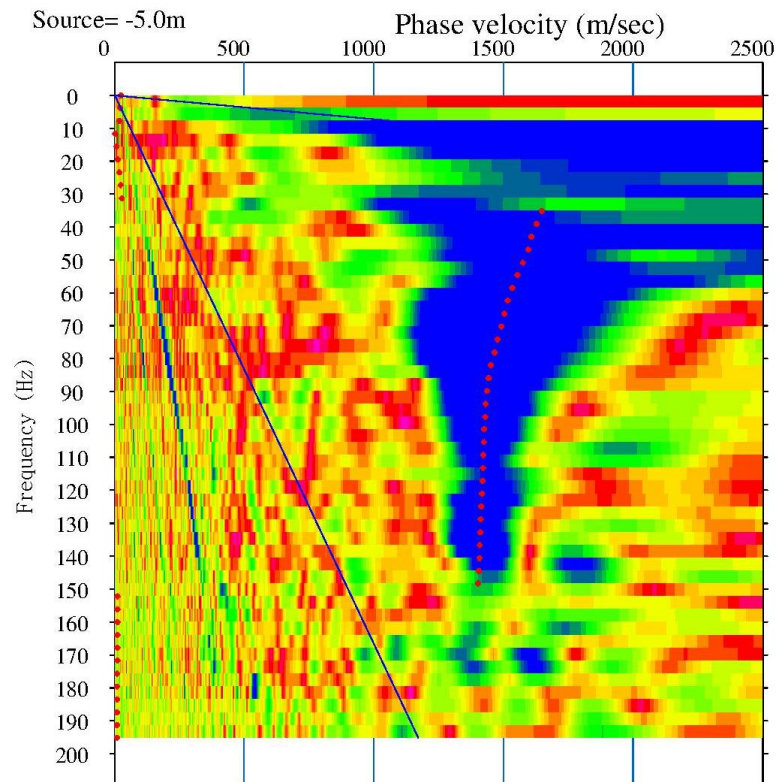


Figure 10: Active MASW Dispersion Curve Picks (red dots) along MASW Line 2 (Pinecrest).

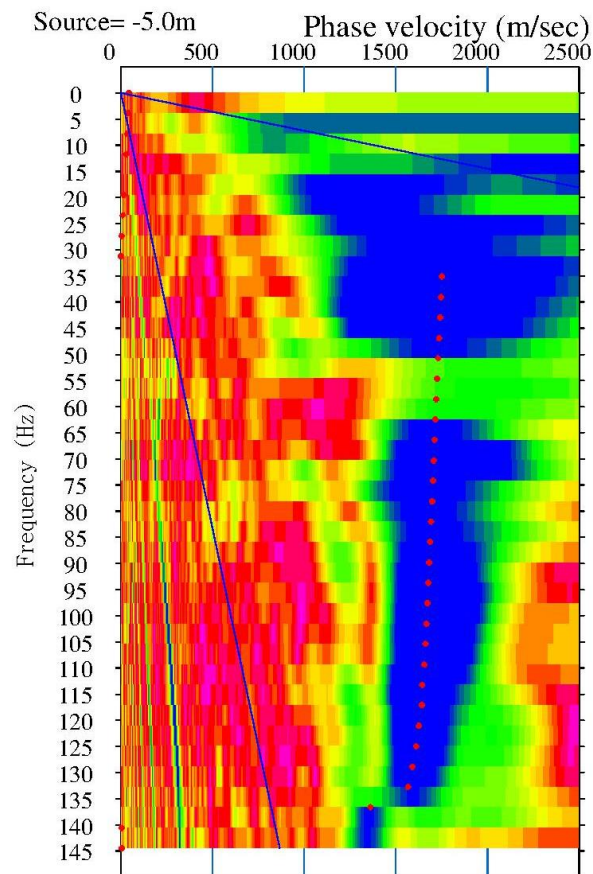


Figure 11: Active MASW Dispersion Curve Picks (red dots) along MASW Line 3 (Woodroffe).

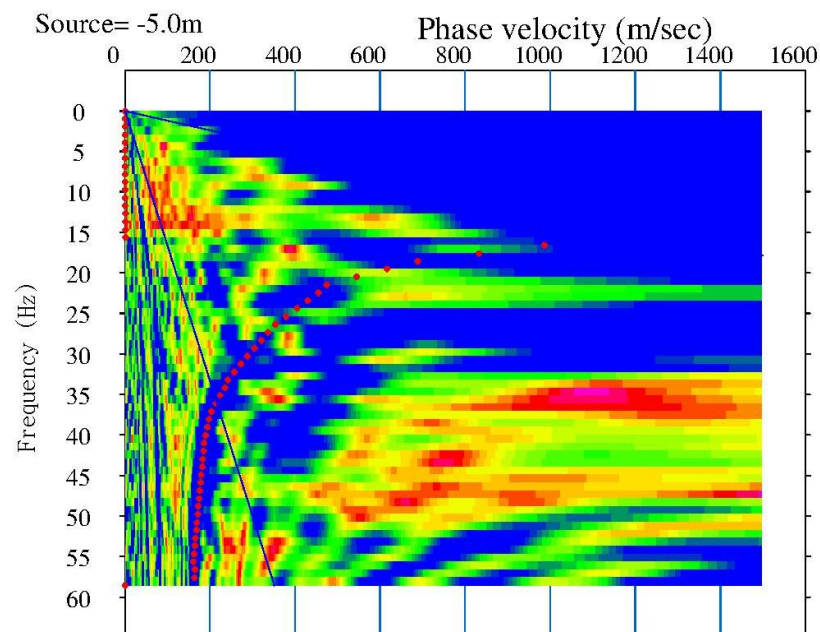


Figure 12: Active MASW Dispersion Curve Picks (red dots) along MASW Line 4 (Maitland).

Results

The MASW test results are presented in Figure 13 (MASW Line 1 - Richmond), Figure 14 (MASW Line 2 - Pinecrest), Figure 15 (MASW Line 3 - Woodroffe) and Figure 16 (MASW Line 4 - Maitland), which present the calculated shear wave velocity profile derived from the field testing. The results along MASW Lines 1, 2, and 3 have been calculated using weight-drop located at 5 metres from the last geophone, respectively. The field collected dispersion curves are compared with the model generated dispersion curves on Figures 17, 18, 19 and 20. 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 the three MASW lines.

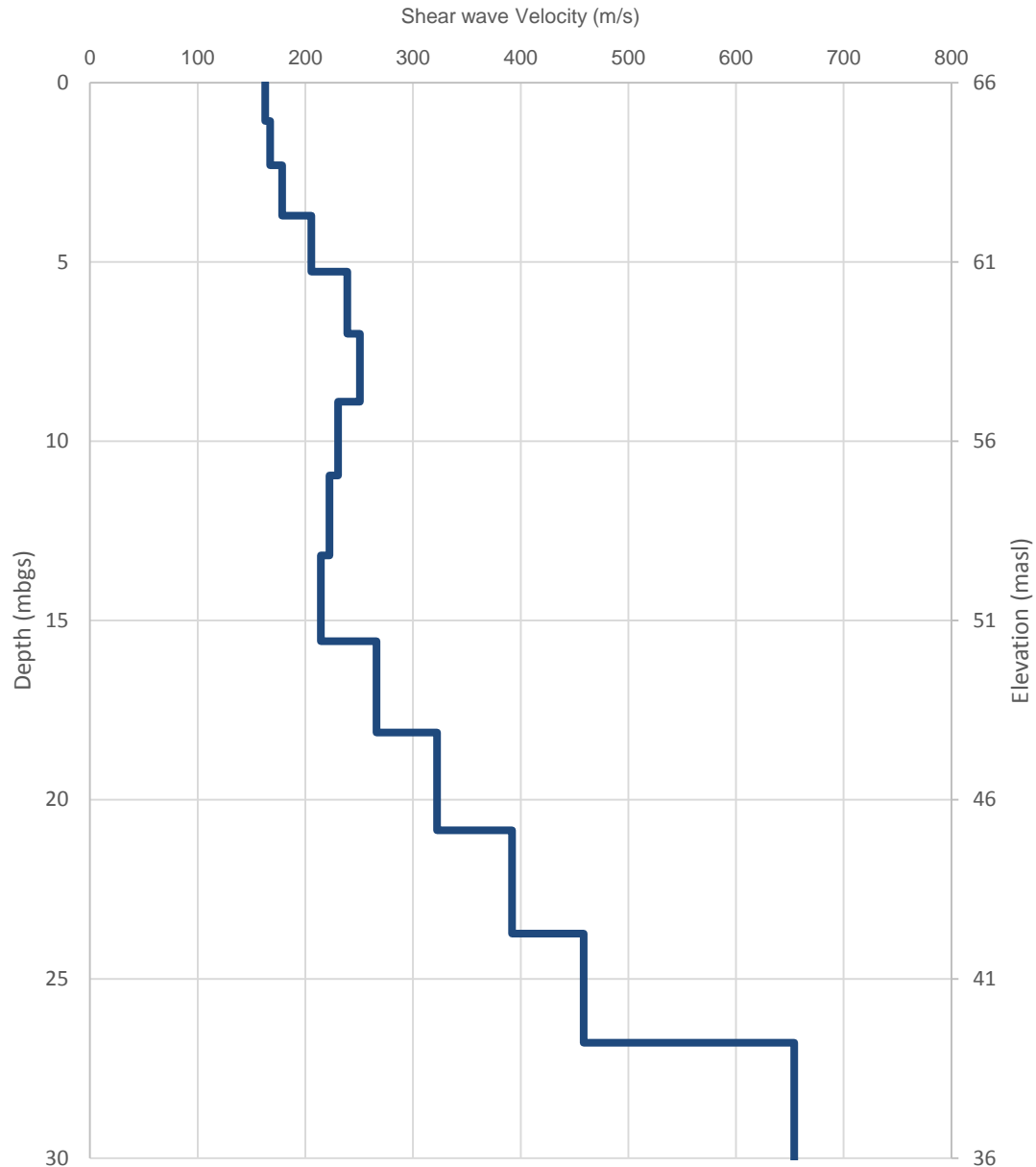


Figure 13: MASW Modelled Shear-Wave Velocity Depth profile along MASW Line 1

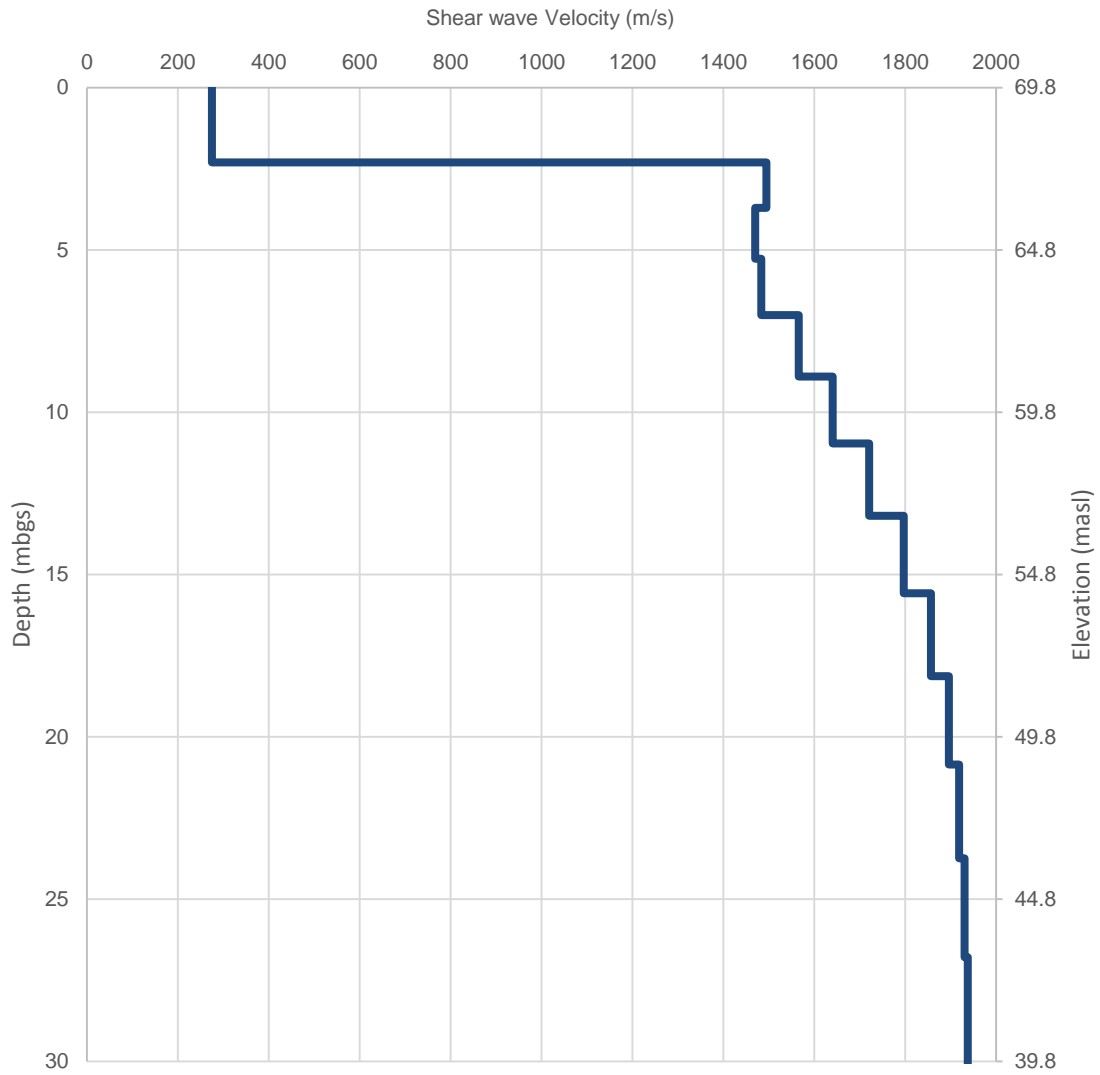


Figure 14: MASW Modelled Shear-Wave Velocity Depth profile along MASW Line 2

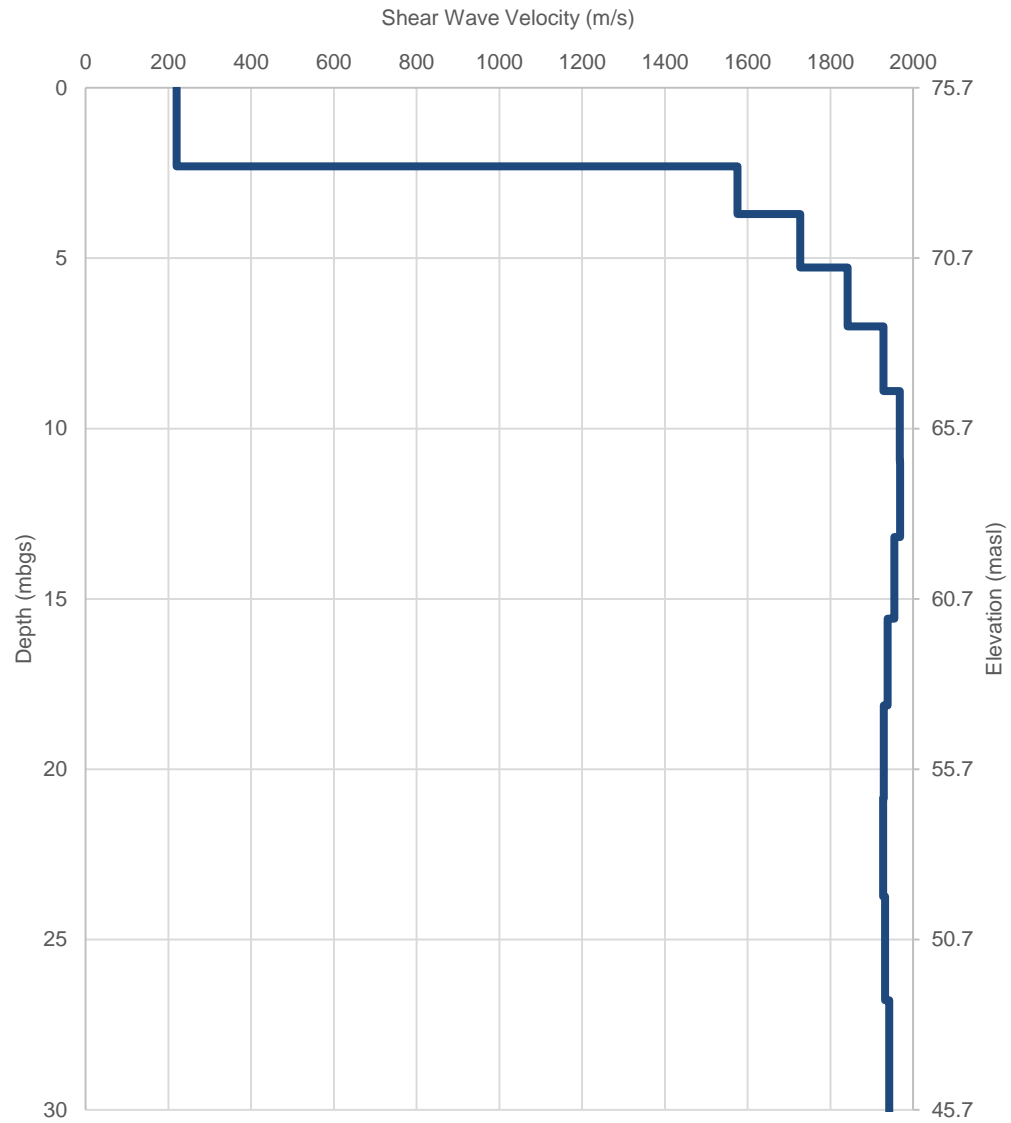


Figure 15: MASW Modelled Shear-Wave Velocity Depth profile along MASW Line 3

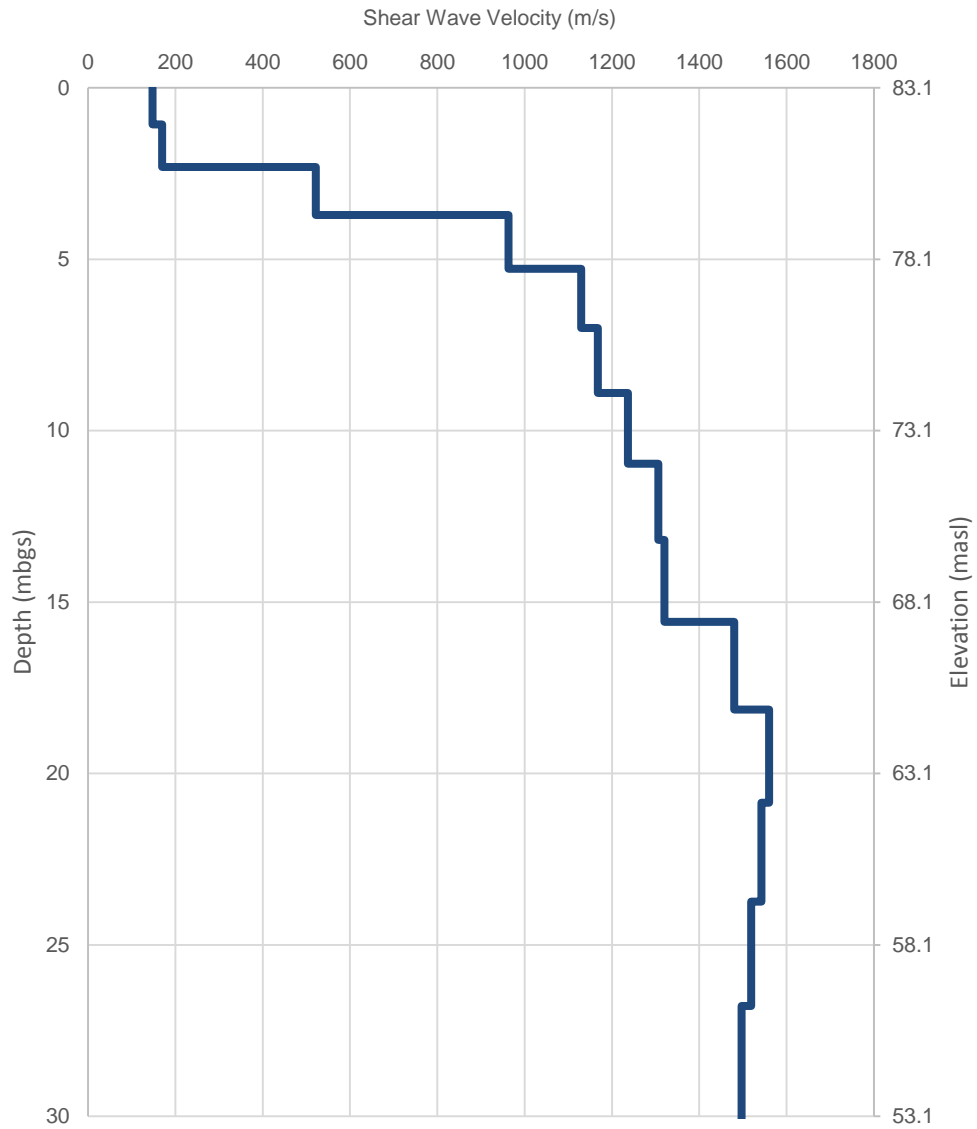


Figure 16: MASW Modelled Shear-Wave Velocity Depth profile along MASW Line 4

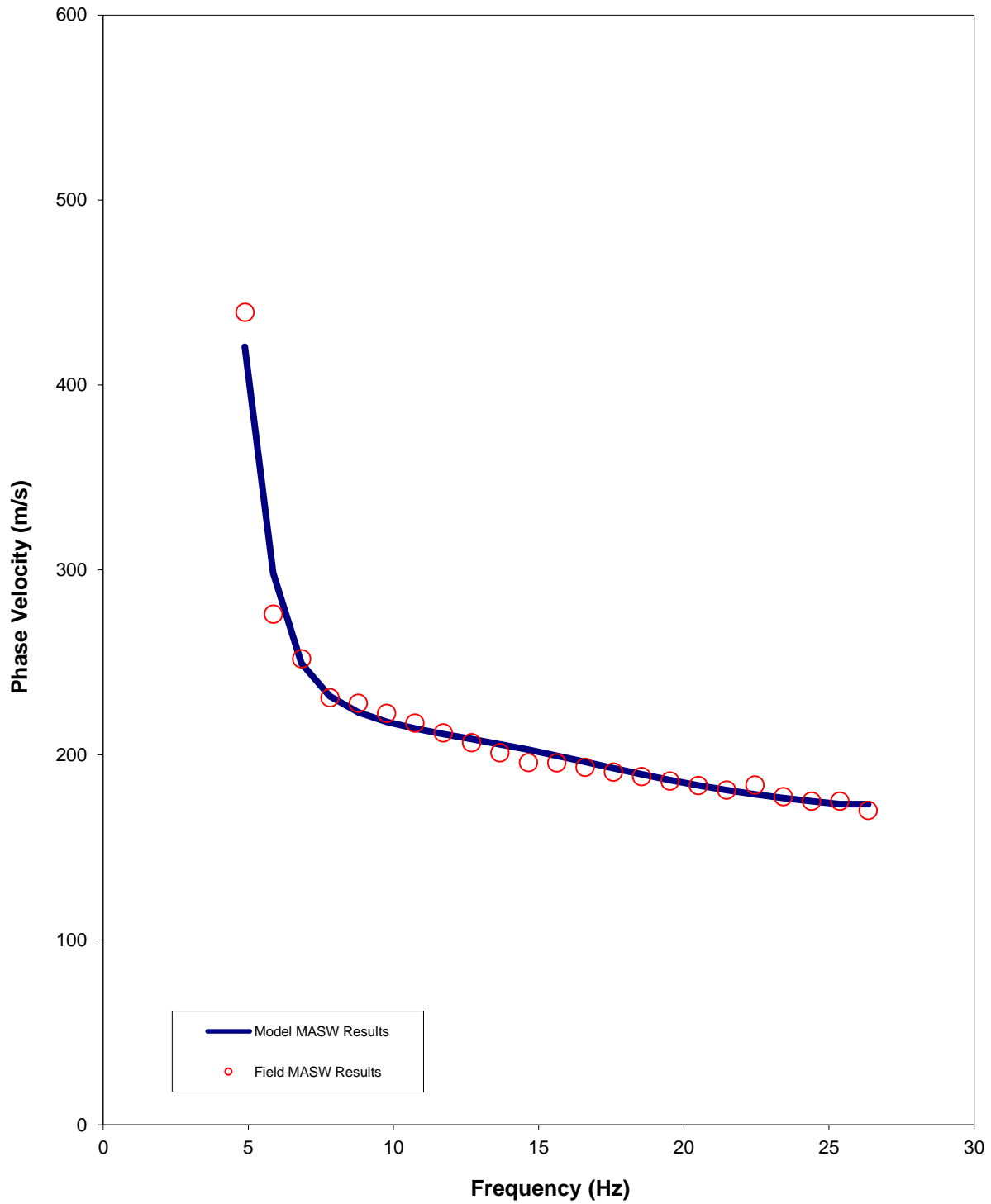


Figure 17: Comparison of Field (red dots) vs. Modelled Data (blue line) along MASW Line 1

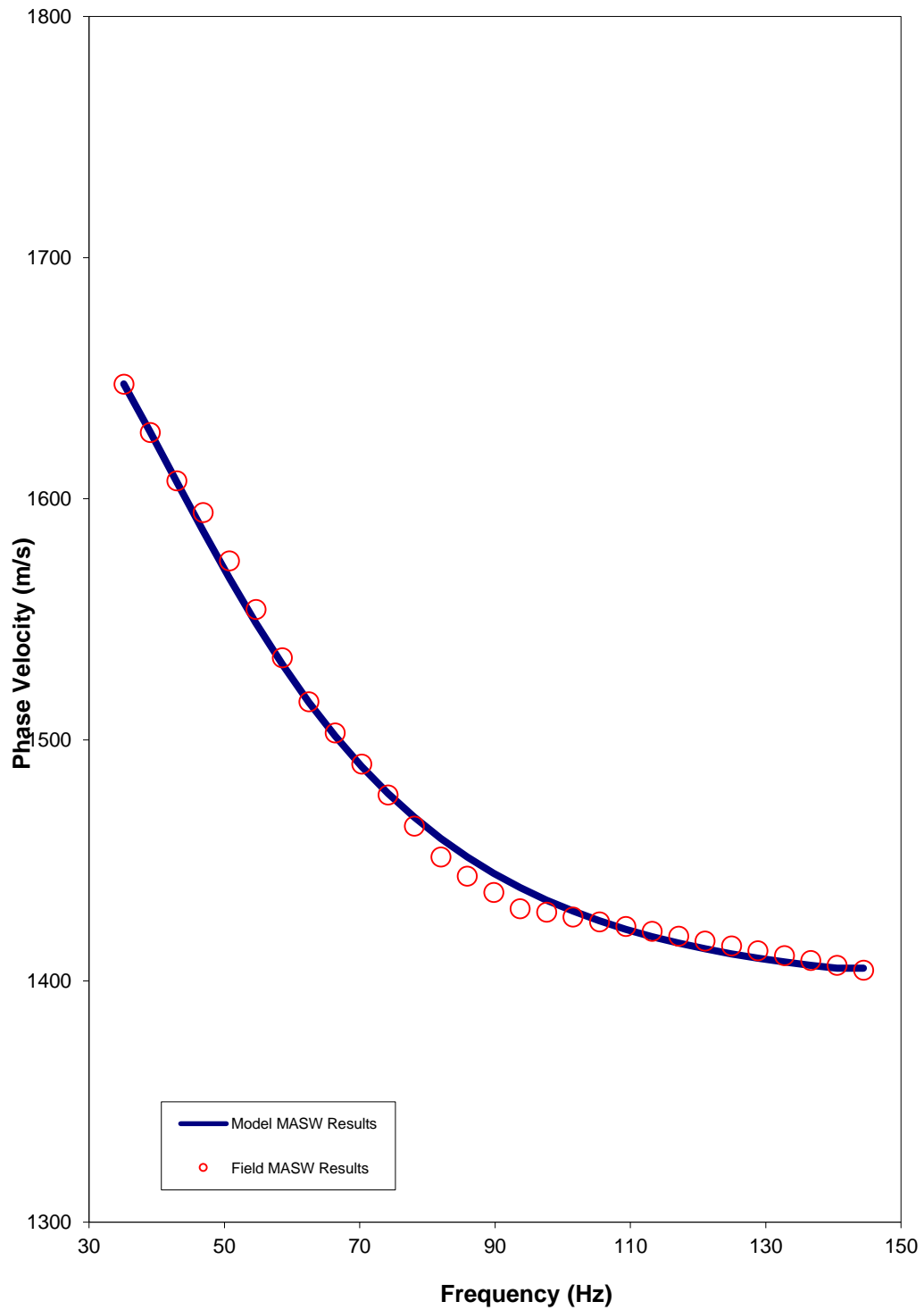


Figure 18: Comparison of Field (red dots) vs. Modelled Data (blue line) along MASW Line 2

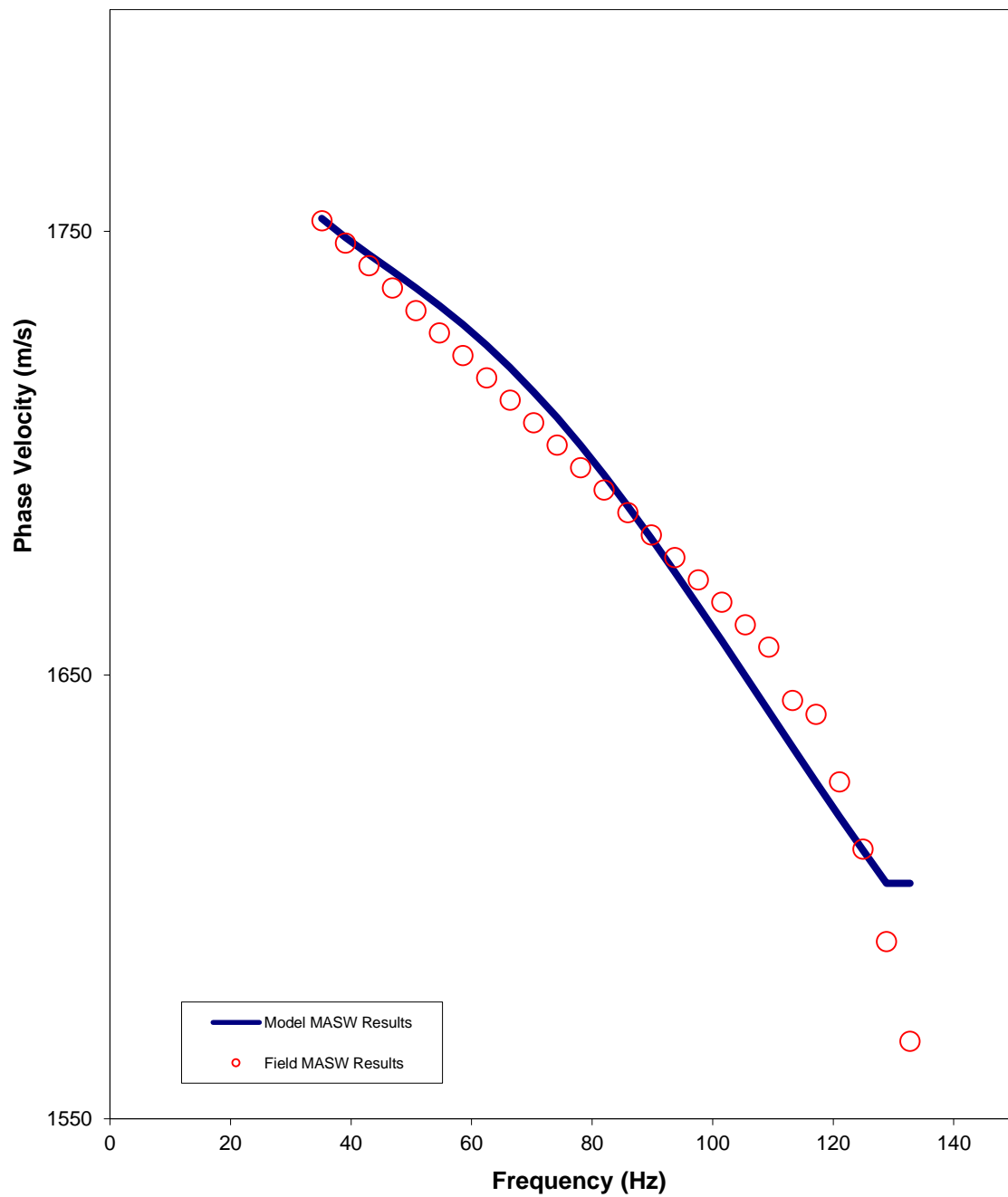


Figure 19: Comparison of Field (red dots) vs. Modelled Data (blue line) along MASW Line 3

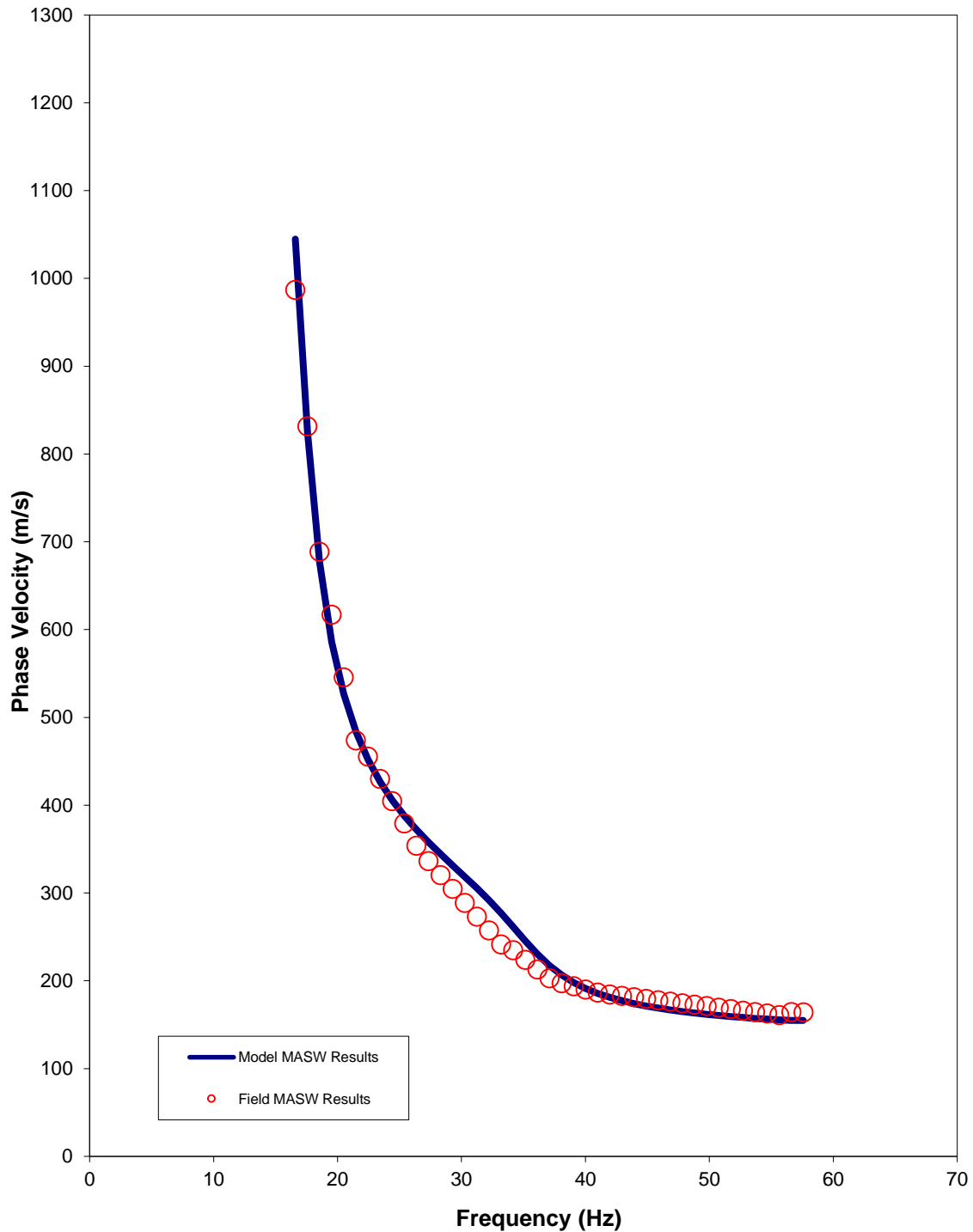


Figure 20: Comparison of Field (red dots) vs. Modelled Data (blue line) along MASW Line 3

To calculate the average shear-wave velocity as required by the NBCC2010, the results were modelled to 30 metres below ground surface. The average shear-wave velocity along MASW Line 1 (Richmond) was found

to be 270 m/s (Table 1). The average shear-wave velocity along MASW Line 2 (Pinecrest) was found to be 1,239 m/s (Table 2). The average shear-wave velocity along MASW Line 3 (Woodroffe) was found to be 1,197 m/s (Table 3). The average shear-wave velocity along MASW Line 4 (Maitland) was found to be 818 m/s (Table 4).

The NBCC2010 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.

Table 1: Shear-Wave Velocity Profile along MASW Line 1 (Richmond)

Model Layer Depth (mbgs)		Model Layer Elevation (masl)		Layer Thickness (m)	Shear Wave Velocity (m/s)	Shear Wave Travel Time Through Layer (s)
Top	Bottom	Top	Bottom			
0.00	1.07	66.00	64.93	1.07	163	0.006580
1.07	2.31	64.93	63.69	1.24	167	0.007384
2.31	3.71	63.69	62.29	1.40	178	0.007852
3.71	5.27	62.29	60.73	1.57	206	0.007613
5.27	7.01	60.73	58.99	1.73	239	0.007239
7.01	8.90	58.99	57.10	1.90	251	0.007562
8.90	10.96	57.10	55.04	2.06	230	0.008945
10.96	13.19	55.04	52.81	2.23	223	0.010001
13.19	15.58	52.81	50.42	2.39	214	0.011154
15.58	18.13	50.42	47.87	2.55	266	0.009603
18.13	20.85	47.87	45.15	2.72	322	0.008436
20.85	23.74	45.15	42.26	2.88	392	0.007361
23.74	26.79	42.26	39.21	3.05	458	0.006652
26.79	30.00	39.21	36.00	3.21	654	0.004914
Vs Average to 30 mbgs (m/s)						270

Table 2: Shear-Wave Velocity Profile along MASW Line 2 (Pinecrest):

Model Layer Depth (mbgs)		Model Layer Elevation (masl)		Layer Thickness (m)	Shear Wave Velocity (m/s)	Shear Wave Travel Time Through Layer (s)
Top	Bottom	Top	Bottom			
0.00	1.07	69.80	68.73	1.07	275	0.003896
1.07	2.31	68.73	67.49	1.24	275	0.004496
2.31	3.71	67.49	66.09	1.40	1495	0.000937
3.71	5.27	66.09	64.53	1.57	1470	0.001065
5.27	7.01	64.53	62.79	1.73	1484	0.001167
7.01	8.90	62.79	60.90	1.90	1566	0.001211
8.90	10.96	60.90	58.84	2.06	1641	0.001256
10.96	13.19	58.84	56.61	2.23	1720	0.001293
13.19	15.58	56.61	54.22	2.39	1797	0.001330
15.58	18.13	54.22	51.67	2.55	1857	0.001376
18.13	20.85	51.67	48.95	2.72	1896	0.001434
20.85	23.74	48.95	46.06	2.88	1918	0.001504
23.74	26.79	46.06	43.01	3.05	1930	0.001580
26.79	30.00	43.01	39.80	3.21	1938	0.001659
Vs Average to 30 mbgs (m/s)						1239

Table 3: Shear-Wave Velocity Profile along MASW Line 3 (Woodroffe)

Model Layer Depth (mbgs)		Model Layer Elevation (masl)		Layer Thickness (m)	Shear Wave Velocity (m/s)	Shear Wave Travel Time Through Layer (s)
Top	Bottom	Top	Bottom			
0.00	1.07	75.70	74.63	1.07	220	0.004870
1.07	2.31	74.63	73.39	1.24	220	0.005619
2.31	3.71	73.39	71.99	1.40	1575	0.000889
3.71	5.27	71.99	70.43	1.57	1727	0.000907
5.27	7.01	70.43	68.69	1.73	1841	0.000940
7.01	8.90	68.69	66.80	1.90	1929	0.000983
8.90	10.96	66.80	64.74	2.06	1968	0.001047
10.96	13.19	64.74	62.51	2.23	1969	0.001130
13.19	15.58	62.51	60.12	2.39	1955	0.001223
15.58	18.13	60.12	57.57	2.55	1939	0.001318
18.13	20.85	57.57	54.85	2.72	1929	0.001410
20.85	23.74	54.85	51.96	2.88	1928	0.001496

Model Layer Depth (mbgs)		Model Layer Elevation (masl)		Layer Thickness (m)	Shear Wave Velocity (m/s)	Shear Wave Travel Time Through Layer (s)
Top	Bottom	Top	Bottom			
23.74	26.79	51.96	48.91	3.05	1932	0.001578
26.79	30.00	48.91	45.70	3.21	1942	0.001655
Vs Average to 30 mbgs (m/s)						1197

Table 4: Shear-Wave Velocity Profile along MASW Line 4 (Maitland)

Model Layer Depth (mbgs)		Model Layer Elevation (masl)		Layer Thickness (m)	Shear Wave Velocity (m/s)	Shear Wave Travel Time Through Layer (s)
Top	Bottom	Top	Bottom			
0.00	1.07	83.10	82.03	1.07	148	0.007243
1.07	2.31	82.03	80.79	1.24	169	0.007299
2.31	3.71	80.79	79.39	1.40	521	0.002687
3.71	5.27	79.39	77.83	1.57	963	0.001626
5.27	7.01	77.83	76.09	1.73	1129	0.001533
7.01	8.90	76.09	74.20	1.90	1167	0.001624
8.90	10.96	74.20	72.14	2.06	1236	0.001667
10.96	13.19	72.14	69.91	2.23	1307	0.001703
13.19	15.58	69.91	67.52	2.39	1320	0.001810
15.58	18.13	67.52	64.97	2.55	1480	0.001726
18.13	20.85	64.97	62.25	2.72	1560	0.001744
20.85	23.74	62.25	59.36	2.88	1542	0.001870
23.74	26.79	59.36	56.31	3.05	1519	0.002008
26.79	30.00	56.31	53.10	3.21	1497	0.002148
Vs Average to 30 mbgs (m/s)						818

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

\\golder.gds\gal\ottawa\active\2015\3 proj\1546542 mmm mto 4015-e-0017ottawa\geophysics\report\final\1546542 tech memo 2017feb15 masw.docx

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

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

solutions@golder.com
www.golder.com

Golder Associates Ltd.
1931 Robertson Road
Ottawa, Ontario, K2H 5B7
Canada
T: +1 (613) 592 9600

