



## REPORT

# Foundation Investigation

*Highway 417 Walkley Road Underpass Rehabilitation*

*Site No. 3-306*

*Highway 417, Ottawa, Ontario*

*W.P. 4116-01-01*

*Assignment No. 4016-E-0008*

Submitted to:

**WSP Canada Group Limited**

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**Report No. 1662565/1230**

**Geocres No. 31G5-303**

Latitude: 45.398115 Longitude: -75.592834

June 2019

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**PART A – FOUNDATION INVESTIGATION**

Highway 417 Underpass at Walkley Road  
Bridge Rehabilitation  
Site No. 3-306  
Ottawa, Ontario  
Assignment No. 4016-E-0008  
G.W.P. 4074-11-00  
W.P. 4116-01-01

## 1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by WSP Canada Group Limited (WSP) (formerly MMM Group) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations associated with the detail design of numerous bridge replacements and rehabilitations including seismic retrofits, several culvert rehabilitations and culvert removals, and overhead sign support structures on Highway 417 from Aviation Parkway to Ramsayville Road and Highway 417 expansion from Ottawa Road 147 to Hunt Club Road in Ottawa, Ontario (Assignment number 4016-E-0008).

This report presents the results of the foundation investigation carried out for the rehabilitation of the Highway 417 Underpass at Walkley Road, Site No. 3-306 (G.W.P. No. 4074-11-00 and W.P. 4116-01-01). The rehabilitation of the structure is to be carried out in accordance with the current version of the Canadian Highway Bridge Design Code (CHBDC, S6-14).

The terms of reference and scope of work for the foundation investigation are outlined in the MTO's Request for Proposal, dated May 2016, and subsequent addenda. Golder's scope of work for foundation engineering services associated with the Highway 417 Underpass at Walkley Street is contained in Table 17.8.3 of WSP's Technical Proposal for this assignment dated June 28, 2016. The work has been carried out in accordance with Golder's Quality Control Plan for foundation engineering services for the project dated March 13, 2017.

## 2.0 SITE DESCRIPTION AND GEOLOGY

### 2.1 Site Description

The Highway 417 Underpass at Walkley Road is located just east of the Hawthorne Meadows/Sheffield Glen neighbourhoods within the City of Ottawa. The site is on Highway 417 (Ottawa Queensway) approximately 160 m east of the Hydro Easement. At this location, Highway 417 is a divided highway with two lanes in each direction separated by a grass swale median. One speed change lane is also present in each direction at the underpass location for oncoming traffic from the Walkley Road bridge on-ramps.

The existing underpass bridge structure was built in 1973 and consists of an 83.1 m two-span cast-in-place post-tensioned concrete slab structure. The average deck width is 31.2 m with a roadway width of 26.1 m. The bridge consists of four lanes (two lanes in each direction) and two on-ramp lanes.

Photographs of the east and west bridge abutments and approach embankments taken on June 19, 2019 are attached to this report (Photographs 1 and 2). Based on visual observations, no visible signs of foundation settlement and/or erosion/instability of the approach embankments were noted.

### 2.2 Regional Geology

As delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984), 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 former Champlain Sea basin. These deposits, known as the Champlain Sea clay or Leda clay, overlie relatively thin, commonly reworked glacial till and glaciofluvial deposits, that in turn overlie bedrock (Belanger, 1998). 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. Regional bedrock mapping indicates that the bedrock at this site is primarily shale of the Carlsbad Formation (Williams, Rae, and Wolf, 1984). The shales were described as thinly bedded and fine grained.

### 3.0 INVESTIGATION PROCEDURES

#### 3.1 Current Investigation

The field work for the current subsurface investigation was carried out on June 19 and 20, 2018. During that time, one (1) borehole (numbered 18-2301) was advanced at the location shown in plan on Drawing 1. The borehole was located just south of the bridge structure on the left shoulder of eastbound Highway 417. The borehole was advanced using truck-mounted drilling equipment supplied and operated by George Downing Estate Drilling Limited. The borehole was advanced through the asphaltic concrete (asphalt) shoulder and overburden to a depth of about 10 m (Elevation 56.1 m) below the surface of the existing roadway. The bedrock was then cored to a depth of 13.2 m (Elevation 52.9 m) using HQ-size coring equipment.

Soil samples were obtained at vertical intervals of about 0.75 m, using a 50 mm outer diameter split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures. A grab sample within the upper 300 mm of the granular fill underlying the asphalt was also recovered. Field vane tests were carried out in the clay deposit using a MTO “N” Vane to obtain undrained and remoulded shear strengths

A monitoring well was installed to observe the groundwater level at the site. The monitoring well consists of 32 mm outside diameter PVC tubing with a 3.0 m long screen sealed at a selected interval within the borehole. The monitoring well installation was completed with a flushmount casing at the ground surface. The groundwater level was measured on July 26, 2018, some five weeks after installation. The site conditions were restored following completion of the field work. The monitoring well was decommissioned in accordance with Ontario Regulation 903 (as amended) following the field investigation.

One soil sample was submitted to Eurofins Environment Testing for chemical analysis related to potential corrosion of buried steel and potential sulphate attack on buried concrete elements (corrosion and sulphate attack).

In addition to the borehole investigation, shear wave velocity testing at the site was completed using the Multichannel Analysis of Surface Waves (MASW) technique. The MASW testing was conducted on July 17, 2018 by personnel from Golder’s 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 sources. The source locations were offset at various distances from, and collinear to, the geophone array.

The field work was supervised by a member of Golder’s staff who located the borehole in the field, directed the drilling, sampling, and in-situ testing operations, and logged the borehole. The soil and bedrock samples were identified in the field, placed in labelled containers, and transported to Golder’s laboratory in Ottawa for further examination and testing. Index and classification tests consisting of water content determinations, grain size distribution analyses, and Atterberg Limits tests were carried out on selected soil samples at the Ottawa laboratory. An unconfined compressive strength test was carried out on a sample of the bedrock core at Golder’s Mississauga laboratory. The laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate.

The borehole elevation was surveyed by Golder using a Trimble R8 GPS unit. The borehole location in MTM NAD83 Zone 9 northing and easting coordinates, ground surface elevation referenced to geodetic datum and drilled depth are summarized below and are shown on Drawing 1. Northing and easting grid coordinates and latitude and longitude geographic coordinates are also indicated on the Record of Borehole.

| Borehole Number | Borehole Location                      | MTM NAD83 Northing (m) | MTM NAD83 Easting (m) | Ground Surface Elevation (m) | Borehole Depth (m) |
|-----------------|--|------------------------|-----------------------|------------------------------|--------------------|
| 18-2301         | Left shoulder of Highway 417 Eastbound | 5029057.3              | 375809.7              | 66.1                         | 13.2               |

## 3.2 Previous Investigations (1971 and 1972)

As part of the current assignment, previously collected subsurface information pertinent to the site was reviewed and compiled. This existing subsurface information was contained in the following report:

- Report prepared by the Ontario Department of Transportation and Communications titled “*Foundation Investigation Report for Proposed Structure at the Crossing of Hwy #417 and Walkley Road Extension Regional Municipality of Ottawa-Carleton, District #9 (Ottawa), W.O. 71-11125, W.P. 10-69-08*”, dated May 16, 1972 (Geocres No. 31G05-113).

Five sampled boreholes accompanied by dynamic cone penetration tests (Boreholes 1, 2, 4, 5, and 7) and two dynamic cone penetration tests (Boreholes 3 and 6) were advanced at the site as part of the 1971 investigation. Four sampled boreholes with dynamic cone penetration tests (Boreholes 1A to 4A) along with one in situ field vane test hole (Borehole 5A) were advanced as part of the 1972 investigation. The approximate borehole and ground surface elevations are shown on the existing borehole records included in Appendix B and are also shown on Drawing 1. The locations of the previous boreholes should be considered approximate since the locations were referenced to an imperial borehole location plan rather than metric MTM coordinates.

## 4.0 DESCRIPTION OF SUBSURFACE CONDITIONS

### 4.1 General

The Record of Borehole and Drillhole Sheets from the current investigation are presented in Appendix A. The results of the laboratory testing carried out during the current investigation are presented on the Record of Borehole and Drillhole Sheets as well as on Figures A1 and A2 in Appendix A. A photograph of the bedrock core recovered is shown on Figure A3 in Appendix A. The existing borehole record sheets from the 1971 and 1972 investigations are provided in Appendix B. The results of chemical testing carried out on a soil sample from Borehole 18-2301 is included in Appendix C.

The MASW test results and associated technical memorandum 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.

The borehole locations from the current and previous investigations along with the interpreted stratigraphic profile projected along the centreline of the Highway 417 underpass are shown on Drawing 1. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile are inferred from observations of drilling progress and non-continuous sampling and, therefore, represent transitions between soil and rock types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations. Further, the boreholes from the 1971 and 1972 investigations were put down prior to construction of the bridge and the ground surface conditions presented on those borehole records may not be representative of the post-construction subsurface conditions, particularly with respect to the composition and thickness of overburden and fill.

### 4.2 Overburden

In general, the subsurface condition at the borehole location (18-2301) consist of asphaltic concrete overlying granular fill, overlying clayey silt to clay, which is in turn underlain by glacial till over shale bedrock. Embankment fill materials at the west and east approaches are expected behind the abutments and retaining walls of the bridge structure, although they were not investigated as part of the current program. Due to the age of the structure, it is



possible that remnants of temporary works abandoned after construction of the existing structure may be buried in the fill. The boreholes drilled in the 1971 and 1972 investigations appeared to be consistent with the native materials encountered in Borehole 18-2301.

A more detailed description of the soil deposit, bedrock and groundwater conditions encountered in the boreholes from the present and previous investigations is provided below.

#### 4.2.1 Pavement Structure and Fill

A layer of asphaltic concrete was encountered at the ground surface at borehole 18-2301, which was advanced along the Highway 417 Eastbound Lanes paved shoulder, with a thickness of about 100 mm.

Granular fill was found underlying the asphaltic concrete surface of Borehole 18-2301 and extends to a depth of 1.5 m below existing ground surface. The fill consists of gravelly sand to sandy gravel, containing shale fragments.

The measured value of one Standard Penetration Test (SPT) “N” in the fill gave 23 blows per 0.3 m of penetration, indicated a compact state of packing.

#### 4.2.2 Silty Clay

Underlying the fill at Borehole 18-2301, and at surface at previous boreholes BH 1 to BH 7, inclusively, and BH 1A to BH 5A, inclusively, there is a deposit of silty clay to clay. The base of the deposit was observed at depths of approximately 3.5 m to 5.5 m below the existing ground surface at the time of drilling (i.e. Elevations ranging from about 61.5 to 59.3 m).

At borehole 18-2301, the upper portion of the silty clay deposit has been weathered to a grey-brown crust. The weathered crust extends to a depth of about 3.1 m below the existing ground surface (i.e., Elevation of 63.1 m). SPT ‘N’ values measured in the weathered silty clay crust at borehole 18-2301 ranged from 4 to 6 blows per 0.3 m of penetration, indicating a stiff consistency.

The results of Atterberg limit testing on one sample of the weathered silty clay deposit gave a plasticity index value of about 39 percent and liquid limit value of 60 percent, indicating a clay of high plasticity. The results of the Atterberg limits testing are presented on Figure A1.

Below the depth of weathering at borehole 18-2301, and through the deposit at all previous boreholes BH 1 to BH7, inclusively, and BH 1A to BH 5A, inclusively, the silty clay is grey in colour. In situ shear vane testing carried out within this deposit measured undrained shear strengths ranging from about 40 to 115 kPa, but more generally around 50 to 80 kPa, indicating that the deposit has a firm to very stiff consistency.

The results of Atterberg limit testing on one sample of the grey silty clay deposit gave a plasticity index value of about 16 percent and liquid limit value of about 34 percent, indicating a deposit of low plasticity. The results of the Atterberg limit testing are provided on Figure A1. The measured water content on two samples of the grey silty clay deposit ranges from approximately 29 to 51 percent.

#### 4.2.3 Glacial Till

A till deposit was encountered below the fill and/or silty clay at all of the borehole locations. The till generally consists of a heterogeneous mixture of gravel, cobbles, and boulders in a matrix of sand and silt to silty sand, with some clay, and gravel.

The till deposit was fully penetrated in Borehole 18-2301 and previous boreholes BH2, BH 4, BH 5, BH 1A and BH 2A. Where penetrated, the till ranges in thickness from about 3.1 to 5.2 m and extends to depths of about 8.4 to 10.4 m below existing ground surface (i.e. Elevations of 55.4 to 57.2 m). At previous boreholes BH 1, BH 3,

BH 6, BH 7, BH 3A, BH 4A, and BH 5A, the glacial till was proven to depths of about 5.7 to 9.2 m below ground surface (Elevations 56.3 to 59.7m).

Measured SPT “N” values within the till range from 10 to 104 blows per 0.3 metres of penetration, indicating a generally compact to very dense state of compactness. Values greater than 50 are considered to likely reflect cobbles/boulders in the till or refusal on the bedrock surface rather than the relative density of the till.

The results of grain size distribution testing on two samples of the sand and silt to silty sand till are shown on Figure A2. It should be noted that the samples were retrieved using a 50 mm outside diameter sampler and therefore the samples do not properly reflect the cobble and boulder portions of the deposit.

The measured natural water content of the till ranges from about 6 to 12 to percent.

### 4.3 Bedrock

Shale bedrock was encountered beneath the glacial till layer in Borehole 18-2301 at a depth of about 10.0 m below the existing ground surface (i.e., Elevation 56.1m). The bedrock was cored between depths of about 10.0 and 13.2 m using HQ diamond drilling techniques. The following table summarizes the bedrock surface depths and elevations as encountered at the current borehole location as well as the previous Boreholes 1 to 7 and 1A to 5A (Geocres No. 31G05-113). Note that certain previous boreholes were not advanced to the bedrock; only those boreholes that reached bedrock are included below.

| Borehole Number | Borehole Location  | Existing Ground Surface Elevation (m) | Depth to Bedrock Surface (m) | Bedrock Surface Elevation (m) |
|-----------------|--|---------------------------------------|------------------------------|-------------------------------|
| 18-2301         | Left shoulder of Highway 417 Eastbound                                       | 66.1                                  | 10.0                         | 56.1                          |
| 2               | Intersection of Highway 417 and Walkley Road prior to underpass construction | 65.5                                  | 9.0                          | 56.5                          |
| 4               |  | 65.6                                  | 8.4                          | 57.2                          |
| 5               |  | 65.5                                  | 9.4                          | 56.1                          |
| 7               |  | 65.5                                  | 9.2*                         | 56.3*                         |
| 1A              |  | 65.7                                  | 10.4                         | 55.3                          |
| 2A              |  | 65.7                                  | 8.9                          | 56.8                          |
| 3A              |  | 65.7                                  | 9.0*                         | 56.7*                         |
| 4A              |  | 65.7                                  | 8.8*                         | 56.9*                         |

**Note:** \*Inferred bedrock surface based on auger refusal.

The shale bedrock at the site is a member of the Carlsbad Formation. It is fresh and thinly bedded. Rock Quality Designation (RQD) values measured on recovered bedrock core samples ranged from about 90 to 100 percent below the surface at 0.5 m, indicating very good to excellent quality rock.

The result of an unconfined compressive strength (UCS) test carried out on one bedrock core sample is presented on the borehole record in Appendix A. The sample tested had a UCS value of about 42 MPa, indicating medium strong bedrock. A photograph of the bedrock core obtained during the current investigation is provided in Appendix A on Figure A3. A description 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 and Drillhole sheets included with this report.

## 4.4 Groundwater Conditions

The water level in the monitoring well installed in Borehole 18-2301 was measured on July 26, 2018 and is summarized in the following table.

| Borehole Number | Borehole Location                   | Screened Interval                  | Groundwater Level Depth (m) | Groundwater Elevation (m) | Date of Reading |
|-----------------|-------------------------------------|------------------------------------|-----------------------------|---------------------------|-----------------|
| 18-2301         | Highway 417 Eastbound left shoulder | Sand and Silt to Silty Sand (Till) | 2.1                         | 64.0                      | July 26, 2018   |

Geocres Report No. 31G05-113 reported that the groundwater level was in the overburden between elevations 64.9 and 65.5 m which, at the time, corresponded to depths ranging from ground surface to about 0.6 m below the ground surface at the time of drilling. The water levels which were measured in the open boreholes are shown on the 1971 and 1972 borehole records (Appendix B).

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

## 5.0 CLOSURE

This report was prepared by Mr. Pierre-Philippe Levasseur, P.Eng., and Michael Snow, P.Eng., both Senior Geotechnical Engineers with Golder, and Mr. Fintan Heffernan, P.Eng., a Senior Consultant with Golder and the Designated MTO Foundations Contact for this project, conducted an independent quality control review of this report.

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PPL/MSS/FJH/mvrd

[https://golderassociates.sharepoint.com/sites/11263g/shared documents/01\\_foundations/6 - reports/1230 walkley/1662565-1230-001-rev0-walkley road fir-june 2019.docx](https://golderassociates.sharepoint.com/sites/11263g/shared%20documents/01_foundations/6%20reports/1230_walkley/1662565-1230-001-rev0-walkley%20road%20fir-june%202019.docx)

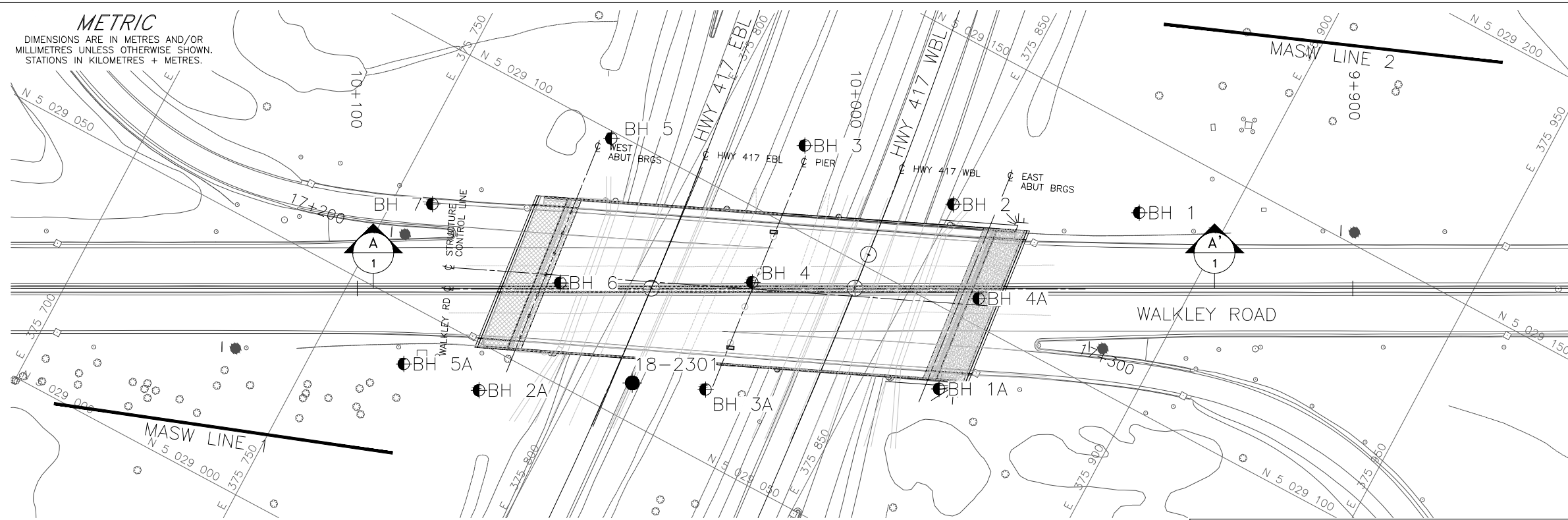
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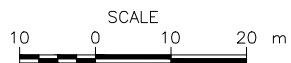
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**METRIC**  
DIMENSIONS ARE IN METRES AND/OR  
MILLIMETRES UNLESS OTHERWISE SHOWN.  
STATIONS IN KILOMETRES + METRES.



PLAN

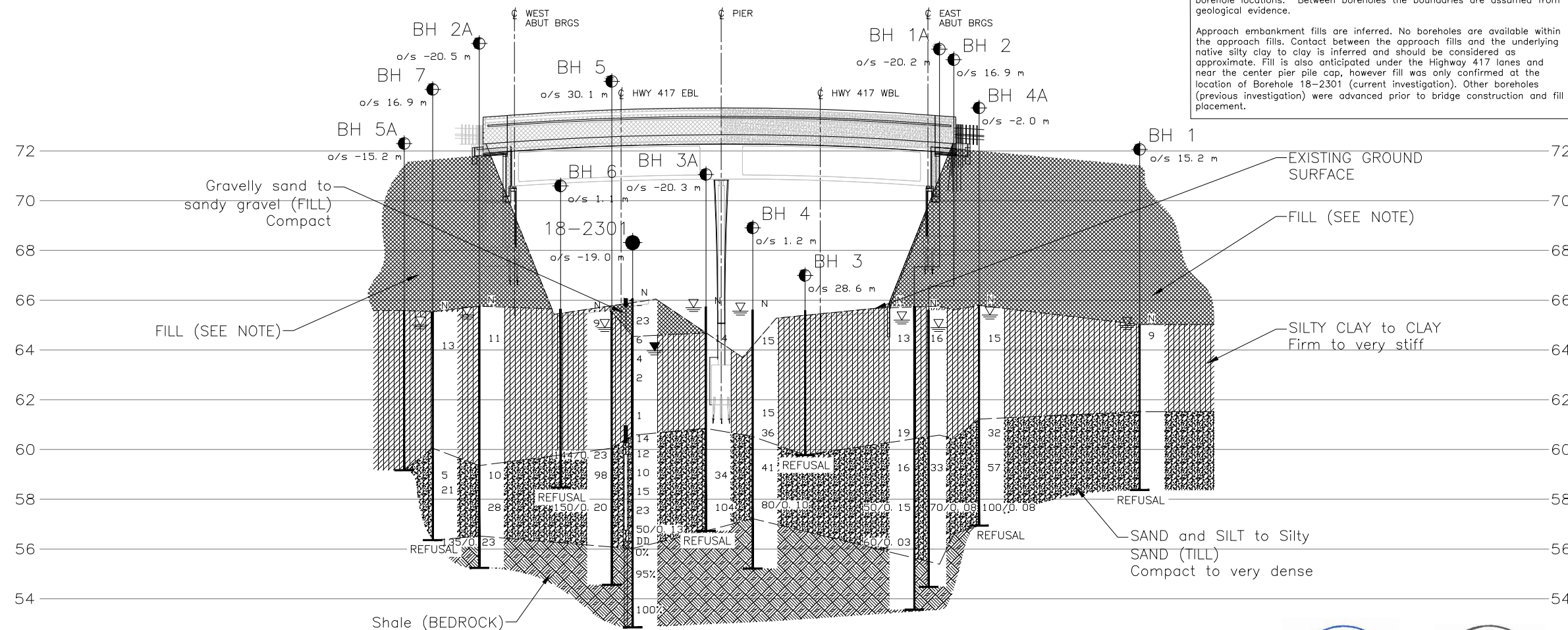


## NOTES

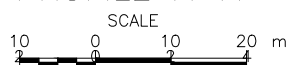
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

Approach embankment fills are inferred. No boreholes are available within the approach fills. Contact between the approach fills and the underlying native silty clay to clay is inferred and should be considered as approximate. Fill is also anticipated under the Highway 417 lanes and near the center pier pile cap, however fill was only confirmed at the location of Borehole 18-2301 (current investigation). Other boreholes (previous investigation) were advanced prior to bridge construction and fill placement.



PROFILE A-A'



52

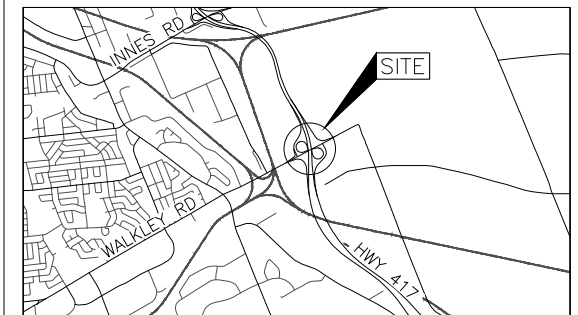


CONT No.  
WP No. 4116-01-01

WALKLEY ROAD UNDERPASS  
HIGHWAY 417  
BOREHOLE LOCATIONS AND SOIL STRATA  
LAT. 45.398123 LONG. -75.592854



SHEET



KEY PLAN



SCALE  
1 0 1 2 km

## LEGEND

- Borehole - Current Investigation
- Borehole - Previous Investigation (Geocres No. 31G05-113)
- ⊥ Seal
- ⊥ Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)
- ≡ WL in piezometer, measured on July 26, 2018
- ≡ WL in open borehole, measured during drilling

## BOREHOLE CO-ORDINATES (MTM ZONE 9)

| No.     | ELEVATION | NORTHING  | EASTING  |
|---------|-----------|-----------|----------|
| 18-2301 | 66.1      | 5029057.3 | 375809.7 |
| BH 1    | 65.0      | 5029135.4 | 375883.5 |
| BH 1A   | 65.8      | 5029085.3 | 375864.6 |
| BH 2    | 65.6      | 5029119.3 | 375849.8 |
| BH 2A   | 65.8      | 5029041.5 | 375783.2 |
| BH 3    | 65.6      | 5029115.6 | 375817.9 |
| BH 3A   | 65.7      | 5029063.1 | 375823.3 |
| BH 4    | 65.6      | 5029086.5 | 375821.5 |
| BH 4A   | 65.8      | 5029105.0 | 375863.1 |
| BH 5    | 65.5      | 5029098.6 | 375782.9 |
| BH 5A   | 65.6      | 5029039.1 | 375767.4 |
| BH 6    | 65.6      | 5029068.3 | 375787.5 |
| BH 7    | 65.5      | 5029070.1 | 375757.4 |

## REFERENCE

Base plans provided in digital format by WSP, drawing file nos. XA1-NAD 83.dwg, XB1-NAD 83 (CSRS).dwg, received APR. 19, 2017 and S17M-00850-300-311-001GA.dwg, received JUN. 14, 2019.

| NO. | DATE | BY | REVISION |
|-----|------|----|----------|
|     |      |    |          |

Geocres No. 31G5-303

|            |                     |                 |
|------------|---------------------|-----------------|
| HWY. 417   | PROJECT NO. 1662565 | DIST. EASTERN   |
| SUBM'D. BB | CHKD. BB            | DATE: 6/20/2019 |
| DRAWN: JM  | CHKD. MSS           | APPD. FJH       |
|            |                     | SITE: 3-306     |
|            |                     | DWG. 1          |



**Photograph 1: East Abutment (looking southeast, June 19, 2019)**



**Photograph 2: West Abutment (looking south, June 19, 2019)**

**APPENDIX A**

**Borehole Records and Laboratory Test Results  
(Current Investigation)**

Lists of Abbreviations and Symbols

Lithological and Geotechnical Rock Description Terminology

Record of Borehole

Laboratory Test Results, Figures A1 to A2

Bedrock Core Photograph, Figure A3



## LIST OF SYMBOLS

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

|                                |  |  |  |
|--------------------------------|--|--|--|
| <b>I. GENERAL</b>              |  | <b>(a) Index Properties (continued)</b>    |  |
| $\pi$                          | 3.1416   | w  | water content  |
| $\ln x$ ,                      | natural logarithm of x   | $w_l$ or LL                                | liquid limit   |
| $\log_{10}$                    | x or log x, logarithm of x to base 10  | $w_p$ or PL                                | plastic limit  |
| g                              | acceleration due to gravity  | $I_p$ or PI                                | plasticity index = $(w_l - w_p)$   |
| t                              | time   | $w_s$                                      | shrinkage limit  |
| FoS                            | factor of safety   | $I_L$                                      | liquidity index = $(w - w_p) / I_p$  |
|                                |  | $I_C$                                      | consistency index = $(w_l - w) / I_p$  |
|                                |  | $e_{max}$                                  | void ratio in loosest state  |
|                                |  | $e_{min}$                                  | void ratio in densest state  |
|                                |  | $I_D$                                      | density index = $(e_{max} - e) / (e_{max} - e_{min})$<br>(formerly relative density) |
| <b>II. STRESS AND STRAIN</b>   |  | <b>(b) Hydraulic Properties</b>            |  |
| $\gamma$                       | shear strain   | h  | hydraulic head or potential  |
| $\Delta$                       | change in, e.g. in stress: $\Delta \sigma$   | q  | rate of flow   |
| $\varepsilon$                  | linear strain  | v  | velocity of flow   |
| $\varepsilon_v$                | volumetric strain  | i  | hydraulic gradient   |
| $\eta$                         | coefficient of viscosity   | k  | hydraulic conductivity<br>(coefficient of permeability)                              |
| $\nu$                          | Poisson's ratio  | j  | seepage force per unit volume  |
|                                | total stress   |  |  |
| $\sigma'$                      | effective stress ( $\sigma' = \sigma - u$ )  | <b>(c) Consolidation (one-dimensional)</b> |  |
| $\sigma'_{vo}$                 | initial effective overburden stress  | C  | compression index<br>(normally consolidated range)                                   |
| $\sigma_1, \sigma_2, \sigma_3$ | principal stress (major, minor)  | $C_r$                                      | recompression index<br>(over-consolidated range)                                     |
| $\sigma_{oct}$                 | mean stress or octahedral stress<br>= $(\sigma_1 + \sigma_2 + \sigma_3)/3$                           | $C_s$                                      | swelling index   |
| $\tau$                         | shear stress   | $C_\alpha$                                 | secondary compression index  |
| u                              | porewater pressure   | $m_v$                                      | coefficient of volume change   |
| E                              | modulus of deformation   | $c_v$                                      | coefficient of consolidation (vertical direction)                                    |
| G                              | shear modulus of deformation   | $C_h$                                      | coefficient of consolidation (horizontal direction)                                  |
| K                              | bulk modulus of compressibility  | $T_v$                                      | time factor (vertical direction)   |
|                                |  | U  | degree of consolidation  |
| <b>III. SOIL PROPERTIES</b>    |  | $\sigma'_p$                                | pre-consolidation stress   |
| <b>(a) Index Properties</b>    |  | OCR  | over-consolidation ratio = $\sigma'_p / \sigma'_{vo}$                                |
| $\rho(\gamma)$                 | bulk density (bulk unit weight)*   | <b>(d) Shear Strength</b>                  |  |
| $\rho_d(\gamma_d)$             | dry density (dry unit weight)  | $\tau_p, \tau_r$                           | peak and residual shear strength   |
| $\rho_w(\gamma_w)$             | density (unit weight) of water   | $\phi'$                                    | effective angle of internal friction   |
| $\rho_s(\gamma_s)$             | density (unit weight) of solid particles   | $\delta$                                   | angle of interface friction  |
| $\gamma'$                      | unit weight of submerged soil<br>( $\gamma' = \gamma - \gamma_w$ )                                   | $\mu$                                      | coefficient of friction = $\tan \delta$  |
| $D_R$                          | relative density (specific gravity) of solid particles ( $D_R = \rho_s / \rho_w$ ) (formerly $G_s$ ) | $c'$                                       | effective cohesion   |
| e                              | void ratio   | $C_u, S_u$                                 | undrained shear strength ( $\phi = 0$ analysis)                                      |
| n                              | porosity   | p  | mean total stress $(\sigma_1 + \sigma_3)/2$  |
| S                              | degree of saturation   | $p'$                                       | mean effective stress $(\sigma'_1 + \sigma'_3)/2$                                    |
|                                |  | q  | $(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$                             |
|                                |  | $q_u$                                      | compressive strength $(\sigma_1 - \sigma_3)$   |
|                                |  | $S_t$                                      | sensitivity  |

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

Notes: 1  
2

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



## LIST OF ABBREVIATIONS

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

### I. SAMPLE TYPE

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

### II. PENETRATION RESISTANCE

#### Standard Penetration Resistance (SPT), N:

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

#### Dynamic Cone Penetration Resistance; $N_d$ :

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

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

**WH:** Sampler advanced by static weight of hammer

**WR:** Sampler advanced by weight of sampler and rod

#### Piezo-Cone Penetration Test (CPT)

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

### III. SOIL DESCRIPTION

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

| Condition  | N<br>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

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

### IV. SOIL TESTS

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

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

### V. MINOR SOIL CONSTITUENTS

| Per cent by Weight | Modifier   | Example   |
|--------------------|--|---|
| 0 to 5             | Trace  | Trace sand  |
| 5 to 12            | Trace to Some (or Little)                            | Trace to some sand  |
| 12 to 20           | Some   | Some sand   |
| 20 to 30           | (ey) or (y)  | Sandy   |
| over 30            | And (non-cohesive (cohesionless)) or With (cohesive) | Sand and Gravel<br>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

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

### JOINT OR FOLIATION SPACING

| <u>Description</u> | <u>Spacing</u>   |
|--------------------|------------------|
| Very wide          | Greater than 3 m |
| Wide               | 1 m to 3 m       |
| Moderately close   | 0.3 m to 1 m     |
| Close              | 50 mm to 300 mm  |
| Very close         | Less than 50 mm  |

### GRAIN SIZE

| <u>Term</u>         | <u>Size*</u>            |
|---------------------|-------------------------|
| Very Coarse Grained | Greater than 60 mm      |
| Coarse Grained      | 2 mm to 60 mm           |
| Medium Grained      | 60 microns to 2 mm      |
| Fine Grained        | 2 microns to 60 microns |
| Very Fine Grained   | Less than 2 microns     |

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

### CORE CONDITION

#### Total Core Recovery (TCR)

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

#### Solid Core Recovery (SCR)

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

#### Rock Quality Designation (RQD)

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

### DISCONTINUITY DATA

#### Fracture Index

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

#### Dip with Respect to Core Axis

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

#### Description and Notes

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

#### Abbreviations


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

| PROJECT      |       | 1662565-1230  |            | RECORD OF BOREHOLE No 18-2301 |      | SHEET 1 OF 2   |  | METRIC        |                 |  |  |  |  |  |   |  |  |             |  |  |                                       |  |  |  |
|--------------|-------|---|------------|-------------------------------|------|--|--|---------------|-----------------|--|--|--|--|--|---|--|--|-------------|--|--|---------------------------------------|--|--|--|
| G.W.P.       |       | 4116-01-01  |            | LOCATION                      |      | N 5029057.3; E 375809.7 NAD 83 MTM ZONE 9 (LAT. 45.397850; LONG. -75.593010) |  | ORIGINATED BY |                 |  |  |  |  |  |   |  |  |             |  |  |                                       |  |  |  |
| DIST         |       | Eastern HWY 417   |            | BOREHOLE TYPE                 |      | Power Auger, 200 mm Diam. (Hollow Stem)/Rotary Drill, HQ Casing              |  | COMPILED BY   |                 |  |  |  |  |  |   |  |  |             |  |  |                                       |  |  |  |
| DATUM        |       | Geodetic  |            | DATE                          |      | June 19-20, 2018   |  | CHECKED BY    |                 |  |  |  |  |  |   |  |  |             |  |  |                                       |  |  |  |
|              |       |   |            |                               |      |  |  | PPL           |                 |  |  |  |  |  |   |  |  |             |  |  |                                       |  |  |  |
| SOIL PROFILE |       |   | SAMPLES    |                               |      | GROUND WATER CONDITIONS  |  |               | ELEVATION SCALE |  |  | DYNAMIC CONE PENETRATION RESISTANCE PLOT |  |  | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT |  |  | UNIT WEIGHT |  |  | REMARKS & GRAIN SIZE DISTRIBUTION (%) |  |  |  |
| ELEV         | DEPTH | DESCRIPTION   | STRAT PLOT | NUMBER                        | TYPE | "N" VALUES   |  |               |                 |  |  |  |  |  |   |  |  |             |  |  |                                       |  |  |  |
| 66.1         | 0.0   | GROUND SURFACE  |            |                               |      |  |  |               |                 |  |  |  |  |  |   |  |  |             |  |  |                                       |  |  |  |
| 65.5         | 0.1   | ASPHALTIC CONCRETE  |            | 1                             | GRAB | -  |  |               |                 |  |  |  |  |  |   |  |  |             |  |  |                                       |  |  |  |
| 65.5         | 0.6   | (SP) Gravelly sand (FILL)<br>Grey<br>Moist  |            | 2                             | SS   | 23   |  |               |                 |  |  |  |  |  |   |  |  |             |  |  |                                       |  |  |  |
| 64.6         | 1.5   | (GP) Sandy gravel, contains shale fragments (FILL)<br>Compact<br>Grey<br>Moist  |            | 3                             | SS   | 6  |  |               |                 |  |  |  |  |  |   |  |  |             |  |  |                                       |  |  |  |
| 63.1         | 3.1   | (CI/CH) SILTY CLAY to CLAY (WEATHERED CRUST)<br>Stiff<br>Grey-brown<br>Moist  |            | 4                             | SS   | 4  |  |               |                 |  |  |  |  |  |   |  |  |             |  |  |                                       |  |  |  |
| 63.1         | 3.1   | (CI/CH) SILTY CLAY to CLAY<br>Stiff<br>Grey<br>Wet  |            | 5                             | SS   | 2  |  |               |                 |  |  |  |  |  |   |  |  |             |  |  |                                       |  |  |  |
| 60.6         | 5.5   | (SM) SAND and SILT to Silty SAND, some gravel to gravelly, trace clay, contains cobbles and boulders (TILL)<br>Compact<br>Grey<br>Wet |            | 6                             | SS   | 1  |  |               |                 |  |  |  |  |  |   |  |  |             |  |  |                                       |  |  |  |
| 60.6         | 5.5   | (SM) SAND and SILT to Silty SAND, some gravel to gravelly, trace clay, contains cobbles and boulders (TILL)<br>Compact<br>Grey<br>Wet |            | 7                             | SS   | 14   |  |               |                 |  |  |  |  |  |   |  |  |             |  |  |                                       |  |  |  |
| 60.6         | 5.5   | (SM) SAND and SILT to Silty SAND, some gravel to gravelly, trace clay, contains cobbles and boulders (TILL)<br>Compact<br>Grey<br>Wet |            | 8                             | SS   | 12   |  |               |                 |  |  |  |  |  |   |  |  |             |  |  |                                       |  |  |  |
| 60.6         | 5.5   | (SM) SAND and SILT to Silty SAND, some gravel to gravelly, trace clay, contains cobbles and boulders (TILL)<br>Compact<br>Grey<br>Wet |            | 9                             | SS   | 10   |  |               |                 |  |  |  |  |  |   |  |  |             |  |  |                                       |  |  |  |
| 60.6         | 5.5   | (SM) SAND and SILT to Silty SAND, some gravel to gravelly, trace clay, contains cobbles and boulders (TILL)<br>Compact<br>Grey<br>Wet |            | 10                            | SS   | 15   |  |               |                 |  |  |  |  |  |   |  |  |             |  |  |                                       |  |  |  |
| 60.6         | 5.5   | (SM) SAND and SILT to Silty SAND, some gravel to gravelly, trace clay, contains cobbles and boulders (TILL)<br>Compact<br>Grey<br>Wet |            | 11                            | SS   | 23   |  |               |                 |  |  |  |  |  |   |  |  |             |  |  |                                       |  |  |  |
| 60.6         | 5.5   | (SM) SAND and SILT to Silty SAND, some gravel to gravelly, trace clay, contains cobbles and boulders (TILL)<br>Compact<br>Grey<br>Wet |            | 12                            | SS   | 50/0.13  |  |               |                 |  |  |  |  |  |   |  |  |             |  |  |                                       |  |  |  |
| 56.5         | 9.7   | COBBLES and BOULDERS (TILL)   |            | 13                            | RC   | DD   |  |               |                 |  |  |  |  |  |   |  |  |             |  |  |                                       |  |  |  |

Continued Next Page

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

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IM\IMTO\HWY417\REHAB&amp;WIDENING\02\_DATA\GINT\1662565.GPJ GAL-GTA.GDT 19-6-20 ZS

| PROJECT              |  | RECORD OF BOREHOLE No 18-2301   |        |      |                         | SHEET 2 OF 2     |  | METRIC             |    |    |     |   |                   |                |  |                                       |            |
|----------------------|--|---|--------|------|-------------------------|------------------|--|--------------------|----|----|-----|---|-------------------|----------------|--|---------------------------------------|------------|
| G.W.P. 1662565-1230  |  | LOCATION N 5029057.3; E 375809.7 NAD 83 MTM ZONE 9 (LAT. 45.397850; LONG. -75.593010) |        |      |                         | ORIGINATED BY DG |  |                    |    |    |     |   |                   |                |  |                                       |            |
| DIST Eastern HWY 417 |  | BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem)/Rotary Drill, HQ Casing         |        |      |                         | COMPILED BY ZS   |  |                    |    |    |     |   |                   |                |  |                                       |            |
| DATUM Geodetic       |  | DATE June 19-20, 2018   |        |      |                         | CHECKED BY PPL   |  |                    |    |    |     |   |                   |                |  |                                       |            |
| SOIL PROFILE         |  | SAMPLES   |        |      | GROUND WATER CONDITIONS | ELEVATION SCALE  | DYNAMIC CONE PENETRATION RESISTANCE PLOT |                    |    |    |     | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT |                   |                | UNIT WEIGHT $\gamma$ kN/m <sup>3</sup> | REMARKS & GRAIN SIZE DISTRIBUTION (%) |            |
| ELEV DEPTH           | DESCRIPTION  | STRAT PLOT  | NUMBER | TYPE |                         |                  | "N" VALUES                               | SHEAR STRENGTH kPa |    |    |     |   | WATER CONTENT (%) |                |  |                                       |            |
|                      | --- CONTINUED FROM PREVIOUS PAGE ---   |   |        |      |                         |                  | 20                                       | 40                 | 60 | 80 | 100 | W <sub>p</sub>                                      | W                 | W <sub>L</sub> |  |                                       |            |
| 60.0                 | Shale (BEDROCK)<br><br>Bedrock cored from depths of 10.0 m to 13.2 m<br><br>For bedrock coring details refer to Record of Drillhole 18-2301            |      | 1      | RC   | REC 100%                |                  |  |                    |    |    |     |   |                   |                |  | UC=42 MPa                             | RQD = 0%   |
|                      |  |   | 2      | RC   | REC 100%                |                  |  |                    |    |    |     |   |                   |                |  |                                       | RQD = 95%  |
|                      |  |   | 3      | RC   | REC 100%                |                  |  |                    |    |    |     |   |                   |                |  |                                       | RQD = 100% |
| 52.9<br>13.2         | END OF BOREHOLE<br><br>NOTES:<br><br>1. Water level in well screen at a depth of 2.1 m below ground surface (Elev. 64.0 m), measured on July 26, 2018. |   |        |      |                         |                  |  |                    |    |    |     |   |                   |                |  |                                       |            |

GTA-MTO 001 N:\ACTIVE\SPATIAL\_IMMITO\HWY417REHAB&amp;WIDENING\02\_DATA\GINT\1662565.GPJ GAL-GTA.GDT 19-6-20 ZS

PROJECT: 1662565-1230

**RECORD OF DRILLHOLE: 18-2301**

SHEET 1 OF 1

LOCATION: N 5029057.3 ;E 375809.7

DRILLING DATE: June 19-20, 2018

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 75

DRILLING CONTRACTOR: Downing Drilling

| DEPTH SCALE<br>METRES | DRILLING RECORD | DESCRIPTION     | SYMBOLIC LOG | ELEV.<br>DEPTH<br>(m) | RUN No. | NOTE:<br>For abbreviations, symbols and descriptions refer to<br>LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY |                 |             |                        |                                |                                 |    |  |                  |                          |                  |                  |    |    | FEATURES |    |    |    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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|                       |                 |                 |              |                       |         | RECOVERY  |                 | R.Q.D.<br>% | FRACT.<br>INDEX<br>PER | DIP w.r.t<br>CORE<br>AXIS<br>° | DISCONTINUITY DATA              |    | HYDRAULIC<br>CONDUCTIVITY<br>K, cm/sec |                  | WEATH-<br>ERING<br>INDEX |                  |                  |    |    |          |    |    |    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|                       |                 |                 |              |                       |         | TOTAL<br>CORE %   | SOLID<br>CORE % |             |                        |                                | TYPE AND SURFACE<br>DESCRIPTION | Jr | Ja                                     | 10 <sup>-9</sup> | 10 <sup>-8</sup>         | 10 <sup>-7</sup> | 10 <sup>-6</sup> | W1 | W2 |          | W3 | W5 | W6 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|                       |                 |                 |              |                       |         |   |                 |             |                        |                                |                                 |    |  |                  |                          |                  |                  |    |    |          |    |    |    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|                       |                 | BEDROCK SURFACE |              | 56.02                 |         |   |                 |             |                        |                                |                                 |    |  |                  |                          |                  |                  |    |    |          |    |    |    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

DEPTH SCALE

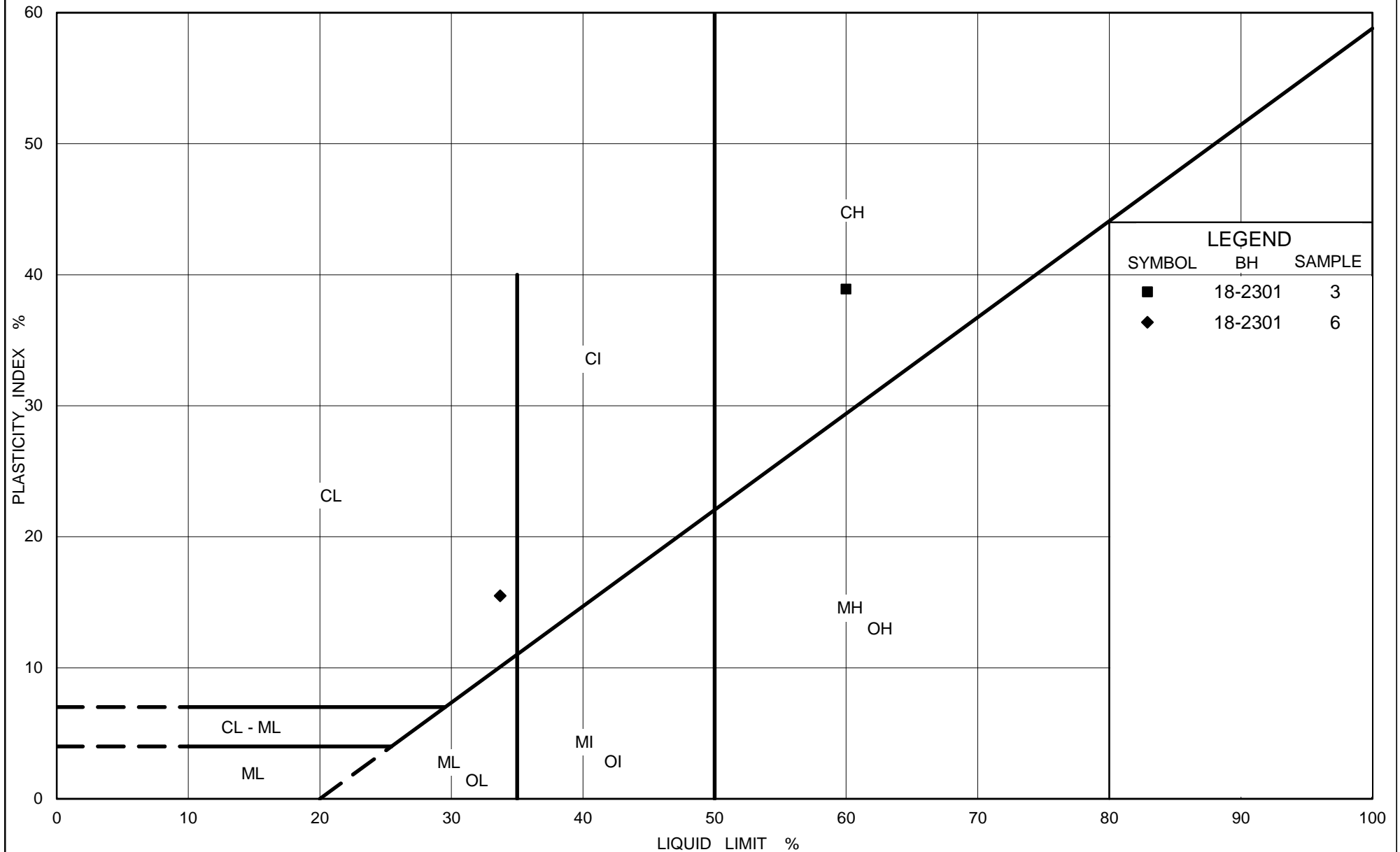
1 : 50

**GOLDER**

LOGGED: DG

CHECKED: PPL

GTA-RCK 031 N:\ACTIVE\SPATIAL\_IMMTO\HWY417\REHAB&amp;WIDENING\02\_DATA\GINT\1662565.GPJ GAL-MISS.GDT 19-6-20 ZS



Ministry of Transportation

Ontario

## PLASTICITY CHART

FIG No. A1

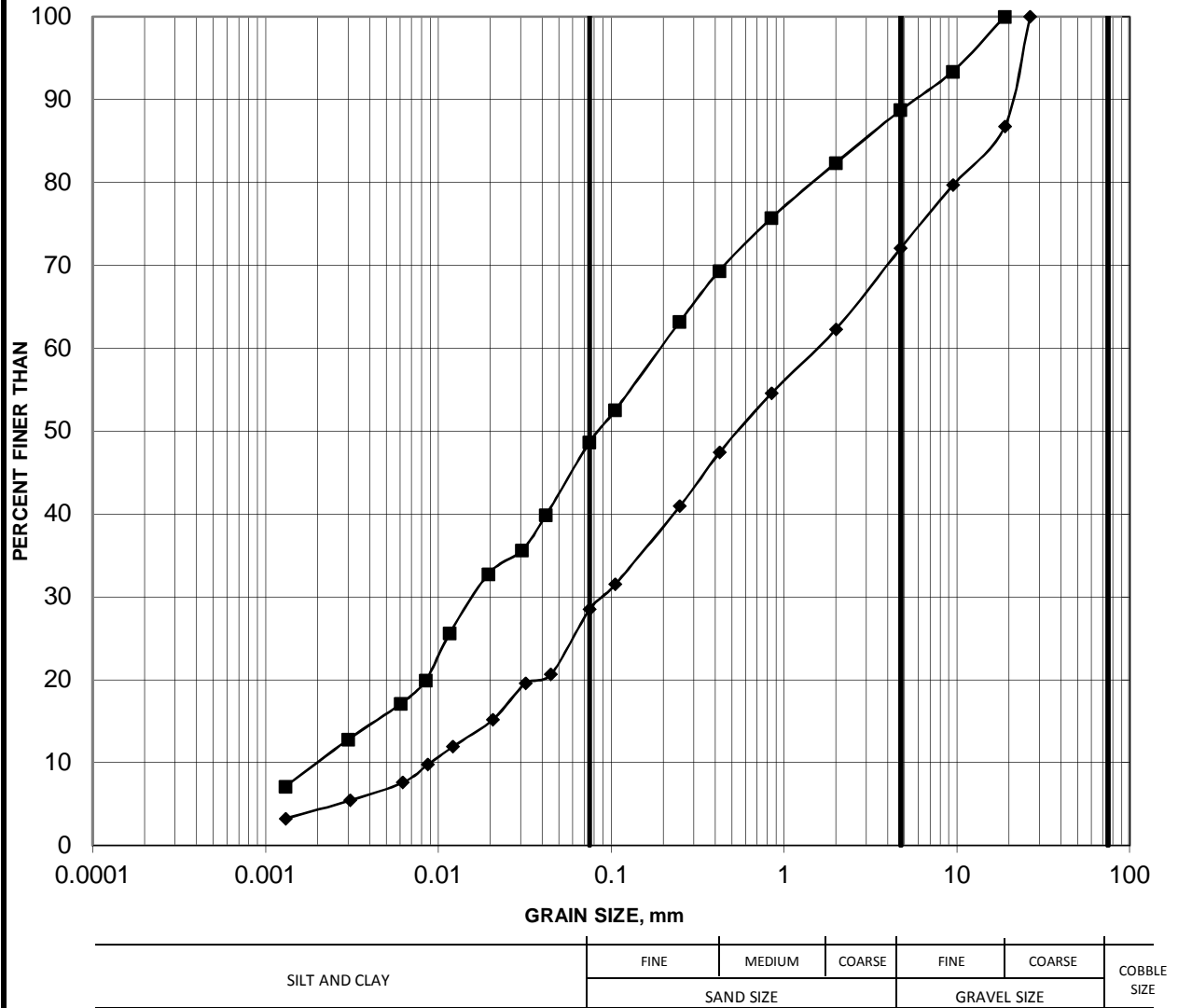
Project No. 1662565/1230

Compiled By : MI Checked By : CW

# GRAIN SIZE DISTRIBUTION

FIGURE A2

## (SM/ML) SAND AND SILT TO SILTY SAND (TILL)



| Borehole | Sample | Depth (m) |
|----------|--------|-----------|
| 18-2301  | 7      | 5.49-6.10 |
| 18-2301  | 10     | 7.62-8.23 |

BH 18-2301 (Wet)  
Cored Length of 10.08 to 13.21 metres  
Core Box 1 to 2 of 2

10.08 m Top of Bedrock



13.24 m End of Borehole

CLIENT  
MMM

CONSULTANT



DD/MM/YYYY 2018-08-16

PREPARED

DESIGN

REVIEW

APPROVED

PROJECT

Foundation Investigation and Design  
Highway 417 Walkley Road Underpass Rehabilitation

TITLE

**BOREHOLE 18-2301 (WET)  
CORE PHOTOGRAPHS**

PROJECT No  
1662565

PHASE  
1230

Rev.  
A

FIGURE  
A3



**APPENDIX B**

**Borehole Records**  
**(Previous Investigation, Geocres No. 31G05-113)**  
**Records of Previous Boreholes BH 1 to BH 7 and BH1A to BH5A**

FOUNDATION SECTION

CHECKED BY

| SOIL PROFILE |              |             | SAMPLES |      |              | ELEV. SCALE | DYNAMIC PENETRATION    | RESISTANCE                   | LIQUID LIMIT — $w_L$ | PLASTIC LIMIT — $w_p$ | WATER CONTENT — $w$ | BULK DENSITY<br>$\gamma$ | REMARKS |
|--------------|--------------|-------------|---------|------|--------------|-------------|------------------------|------------------------------|----------------------|-----------------------|---------------------|--------------------------|---------|
| ELEV. DEPTH  | DESCRIPTION  | STRAT. PLOT | NUMBER  | TYPE | BLOWS / FOOT |             | BLOWS / FOOT           | SHEAR STRENGTH P.S.F.        |                      | $w_p$                 | $w$                 |                          |         |
| 213.2        | Ground Level |             |         |      |              |             | 20 40 60 80 100        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             | 400 800 1200 1600 2000 |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        | ○ UNCONFINED + FIELD VANE    |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        | ● QUICK TRIAXIAL x LAB. VANE |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
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|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
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|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
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|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
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|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |
|              |              |             |         |      |              |             |                        |                              |                      |                       |                     |                          |         |

DEPARTMENT OF HIGHWAYS- ONTARIO  
MATERIALS & TESTING OFFICE

## RECORD OF BOREHOLE No. 2

FOUNDATION SECTION

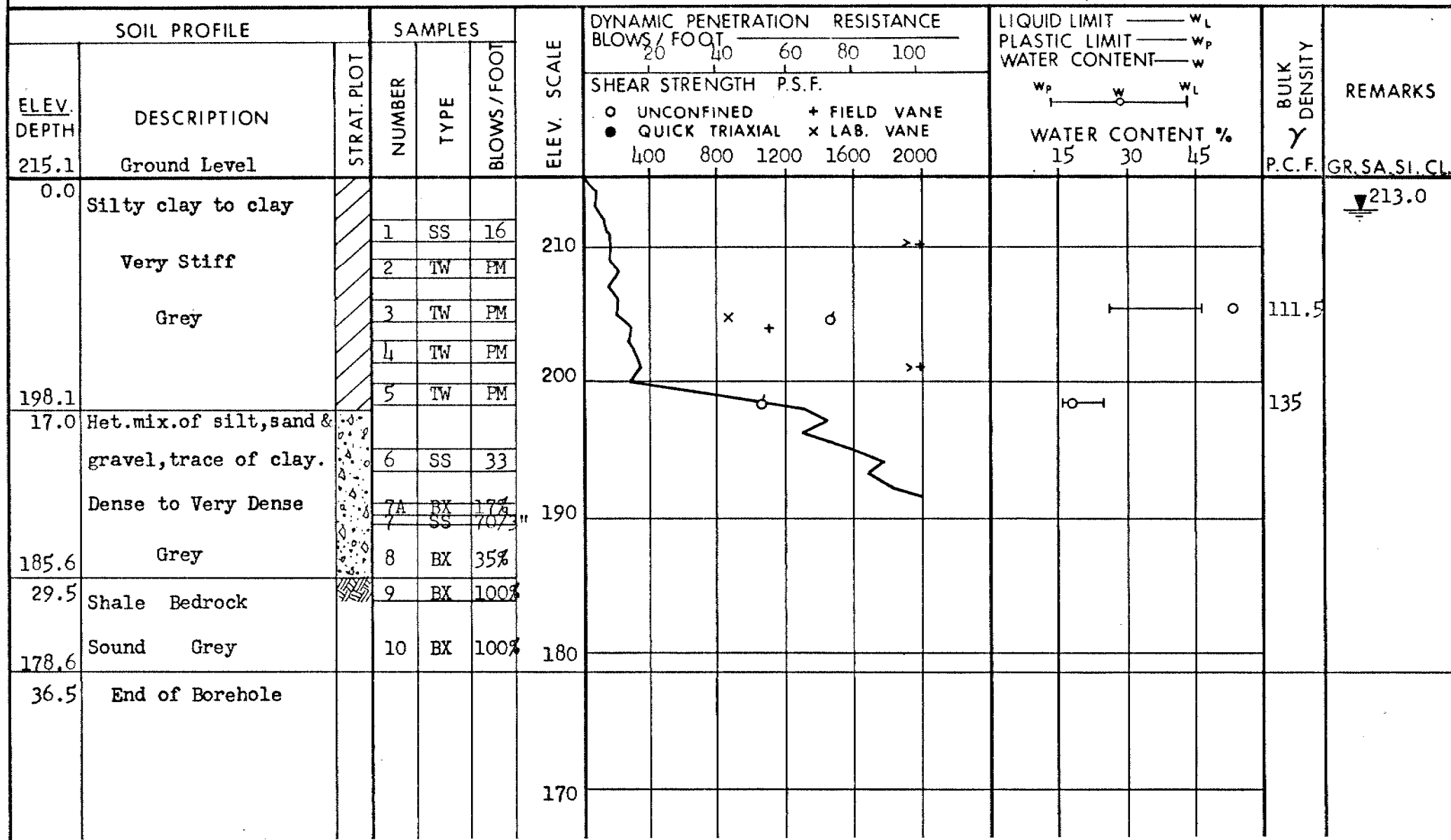
JOB 71-11125 LOCATION Co-ords. 499,002 N; 233,025 E.

ORIGINATED BY WH

W.P. 10-69-08 BORING DATE Nov. 16 &amp; 17, 1971

COMPILED BY SO

DATUM Geodetic BOREHOLE TYPE NX Washboring

CHECKED BY *HR*

DEPARTMENT OF HIGHWAYS- ONTARIO

## RECORD OF BOREHOLE No. 3

FOUNDATION SECTION

JOB 71-11125

LOCATION Co-ords. 498,990 N; 232,920 E.

ORIGINATED BY M.D.

W.P. 10-69-08

BORING DATE Dec. 18, 1971

COMPILED BY SO

DATUM      Geodetic

BOREHOLE TYPE Cone Test Only

CHECKED BY *ME*

[illegible]

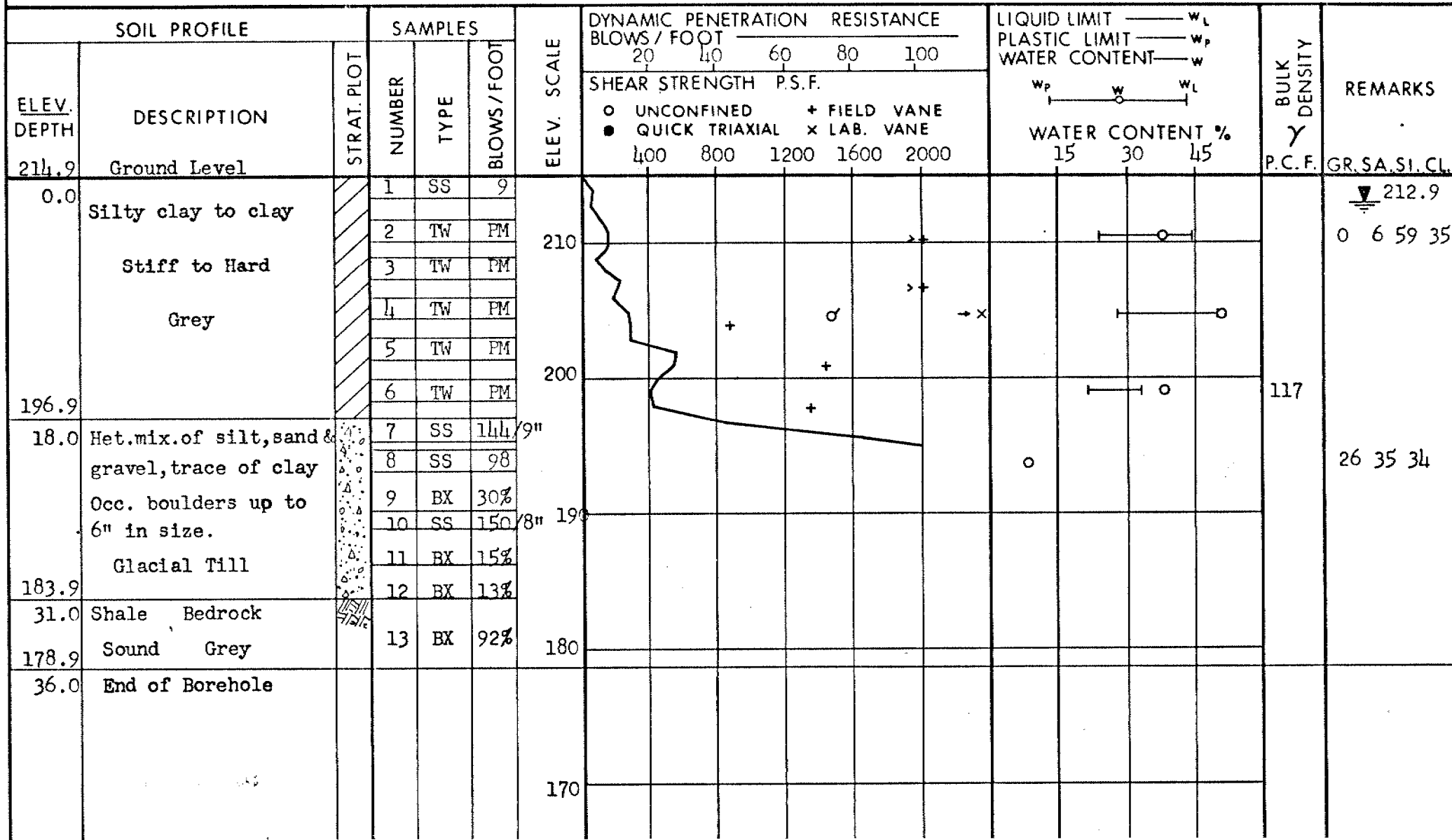


DEPARTMENT OF HIGHWAYS- ONTARIO  
MATERIALS & TESTING OFFICE

## RECORD OF BOREHOLE No. 5

FOUNDATION SECTION

JOB 71-11125 LOCATION Co-ords. 498,934 N; 232,805 E. ORIGINATED BY JS  
 W.P. 10-69-08 BORING DATE Dec. 16 & 17, 1971 COMPILED BY SO  
 DATUM Geodetic BOREHOLE TYPE NX Washboring CHECKED BY 4/R



DEPARTMENT OF HIGHWAYS- ONTARIO  
MATERIALS & TESTING OFFICE

## RECORD OF BOREHOLE No. 6

FOUNDATION SECTION

JOB 71-11125 LOCATION Co-ords. 498,834 N; 232,820 E. ORIGINATED BY MD  
 W.P. 10-69-08 BORING DATE Dec. 18, 1971 COMPILED BY SO  
 DATUM Geodetic BOREHOLE TYPE Cone Test Only CHECKED BY W.L.

| SOIL PROFILE |              |             | SAMPLES |      |              | ELEV. SCALE | DYNAMIC PENETRATION RESISTANCE<br>BLOWS / FOOT |    | LIQUID LIMIT — $w_L$<br>PLASTIC LIMIT — $w_p$<br>WATER CONTENT — $w$ |    | BULK DENSITY<br>$\gamma$<br>P.C.F. | REMARKS |
|--------------|--------------|-------------|---------|------|--------------|-------------|--|----|--|----|------------------------------------|---------|
| ELEV. DEPTH  | DESCRIPTION  | STRAT. PLOT | NUMBER  | TYPE | BLOWS / FOOT |             | 20   | 40 | 60   | 80 |                                    |         |
| 215.2        | Ground Level |             |         |      |              |             |  |    |  |    |                                    |         |
| 0.0          |              |             |         |      |              |             |  |    |  |    |                                    |         |
|              |              |             |         |      |              | 210         |  |    |  |    |                                    |         |
|              |              |             |         |      |              | 200         |  |    |  |    |                                    |         |
| 191.7        |              |             |         |      |              |             |  |    |  |    |                                    |         |
| 23.5         | End of Cone  |             |         |      |              | 190         |  |    |  |    |                                    |         |





DEPARTMENT OF TRANSPORTATION AND COMMUNICATIONS

DESIGN SERVICES BRANCH

RECORD OF BOREHOLE No. 1A

FOUNDATION SECTION

JOB71-11125

W.P.10-69-08

DATUMGeodetic

LOCATIONCo-ords. 16,498,890 N; 1,233,074 E.

BORING DATEApril 21, 1972

BOREHOLE TYPEAuger and BX Rock Core

ORIGINATED BYSAA

COMPILED BYSAA

CHECKED BY

| SOIL PROFILE |  |             | SAMPLES |      |              | ELEV. SCALE | DYNAMIC PENETRATION RESISTANCE<br>BLOWS / FOOT |     |      |      |      | LIQUID LIMIT — $w_L$<br>PLASTIC LIMIT — $w_p$<br>WATER CONTENT — $w$ |    |    | BULK DENSITY<br>$\gamma$<br>P.C.F. | REMARKS                           |
|--------------|--|-------------|---------|------|--------------|-------------|--|-----|------|------|------|--|----|----|------------------------------------|-----------------------------------|
| ELEV. DEPTH  | DESCRIPTION                                      | STRAT. PLOT | NUMBER  | TYPE | BLOWS / FOOT |             | 20   | 40  | 60   | 80   | 100  | $w_p$ — $w$ — $w_L$  |    |    |                                    |                                   |
|              |  |             |         |      |              |             | SHEAR STRENGTH P.S.F.                          |     |      |      |      | WATER CONTENT %  |    |    |                                    |                                   |
|              |  |             |         |      |              |             | 400  | 800 | 1200 | 1600 | 2000 | 15   | 30 | 45 |                                    |                                   |
| 215.6        | Ground Level                                     |             |         |      |              |             |  |     |      |      |      |  |    |    | GR. SA. SI. CL.                    |                                   |
| 0.0          | Silty clay, trace of sand.                       |             | 1       | SS   | 13           | 210         |  |     |      |      |      |  |    |    | 112<br>117.5<br>127.5              | 214.0<br>in open BH<br>Apr. 21/72 |
|              | Stiff to Very Stiff                              |             | 2       | TW   | PH           |             |  |     |      |      |      |  |    |    |                                    |                                   |
|              |  |             | 3       | TW   | PH           |             |  |     |      |      |      |  |    |    |                                    |                                   |
|              | Grey   |             | 4       | TW   | PH           |             |  |     |      |      |      |  |    |    |                                    |                                   |
| 198.6        |  |             | 5       | SS   | 19           |             |  |     |      |      |      |  |    |    |                                    |                                   |
| 17.0         | Het. mix. of silt, sand & gravel, trace of clay. |             | 6       | SS   | 16           | 190         |  |     |      |      |      |  |    |    | 41 31 22 6                         |                                   |
|              | Glacial Till                                     |             | 7       | SS   | 50/6"        |             |  |     |      |      |      |  |    |    |                                    |                                   |
|              | Compact to Very Dense                            |             | 8       | SS   | 60/1"        |             |  |     |      |      |      |  |    |    |                                    |                                   |
|              | Grey   |             | 9       | BX   | 15%          |             |  |     |      |      |      |  |    |    |                                    |                                   |
| 181.6        | Grey boulders up to 6" in size                   |             | 10      | BX   | 10%          | 180         |  |     |      |      |      |  |    |    |                                    |                                   |
| 34.0         | Sound Shale Bedrock                              |             |         |      |              |             |  |     |      |      |      |  |    |    |                                    |                                   |
| 175.6        |  |             |         |      |              | 170         |  |     |      |      |      |  |    |    |                                    |                                   |
| 40.0         | End of Borehole                                  |             |         |      |              |             |  |     |      |      |      |  |    |    |                                    |                                   |

## OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF TRANSPORTATION AND COMMUNICATIONS

DESIGN SERVICES BRANCH

JOB 71-11125

W.P. 10-69-08

DATUM Geodetic

LOCATION Co-ords. 16,498,746 N; 1,232,806 E.

BORING DATE April 24, 1972

BOREHOLE TYPE Auger and BX Rock Core

FOUNDATION SECTION

ORIGINATED BY SAA

COMPILED BY SAA

CHECKED BY

| SOIL PROFILE |   |             | SAMPLES |      |            | ELEV. SCALE | DYNAMIC PENETRATION RESISTANCE |    |    |    |     | LIQUID LIMIT — $w_L$<br>PLASTIC LIMIT — $w_P$<br>WATER CONTENT — $w$ |  |  | BULK DENSITY<br>$\gamma$<br>P.C.F. | REMARKS |  |  |  |
|--------------|---|-------------|---------|------|------------|-------------|--------------------------------|----|----|----|-----|--|--|--|------------------------------------|---------|--|--|--|
| ELEV. DEPTH  | DESCRIPTION                                     | STRAT. PLOT | NUMBER  | TYPE | BLOWS/FOOT |             | SHEAR STRENGTH P.S.F.          |    |    |    |     | WATER CONTENT %  |  |  |                                    |         |  |  |  |
|              |   |             |         |      |            |             | BLows / FOOT                   |    |    |    |     |  |  |  |                                    |         |  |  |  |
|              |   |             |         |      |            |             |                                |    |    |    |     |  |  |  |                                    |         |  |  |  |
| 15.6         | Ground Level                                    |             |         |      |            |             | 20                             | 40 | 60 | 80 | 100 |  |  |  |                                    |         |  |  |  |
| 0.0          | Silty clay, trace of sand and gravel            |             | 1       | SS   | 11         |             |                                |    |    |    |     |  |  |  |                                    |         |  |  |  |
|              | Firm to Stiff                                   |             | 2       | TW   | PH         |             |                                |    |    |    |     |  |  |  |                                    |         |  |  |  |
|              | Grey  |             | 3       | TW   | PH         |             |                                |    |    |    |     |  |  |  |                                    |         |  |  |  |
|              |   |             | 4       | TW   | PH         |             |                                |    |    |    |     |  |  |  |                                    |         |  |  |  |
|              |   |             | 5       | TW   | PH         |             |                                |    |    |    |     |  |  |  |                                    |         |  |  |  |
| 4.6          |   |             | 6       | TW   | PH         |             |                                |    |    |    |     |  |  |  |                                    |         |  |  |  |
| 1.0          | Het. mix. of silt, sand & gravel, trace of clay |             | 7       | SS   | 10         |             |                                |    |    |    |     |  |  |  |                                    |         |  |  |  |
|              | Glacial Till                                    |             | 8       | SS   | 28         |             |                                |    |    |    |     |  |  |  |                                    |         |  |  |  |
| 0.3          | Compact Grey                                    |             | 9       | RC   | 60%        |             |                                |    |    |    |     |  |  |  |                                    |         |  |  |  |
| 0.3          | Shale Bedrock                                   |             | 10      | RC   | 100%       |             |                                |    |    |    |     |  |  |  |                                    |         |  |  |  |
| 0.1          | Sound Grey                                      |             |         |      |            |             |                                |    |    |    |     |  |  |  |                                    |         |  |  |  |
| 0.5          | End of Borehole                                 |             |         |      |            |             |                                |    |    |    |     |  |  |  |                                    |         |  |  |  |

DYNAMIC PENETRATION RESISTANCE

BLOWS / FOOT

SHEAR STRENGTH P.S.F.

○ UNCONFINED + FIELD VANE  
 ● QUICK TRIAXIAL x LAB. VANE

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

WATER CONTENT %  
 15 30 45

BULK DENSITY

P.C.F.

GR. SA. SI. CL.

214.6  
 in open BH  
 Apr. 24/72

0 3 51 46

16 33 46 5

125/11"

RECORD OF BOREHOLE No. 3A

FOUNDATION SECTION

JOB 71-11125

LOCATION Co-ords. 16,498,817 N; 1,232,938 E.

ORIGINATED BY SAA

W.P. 10-69-08

BORING DATE April 25, 1972

COMPILED BY SAA

DATUM      Geodetic

BOREHOLE TYPE Auger and BX Rock Core

CHECKED BY

[illegible]

DEPARTMENT OF TRANSPORTATION AND COMMUNICATIONS

DESIGN SERVICES BRANCH

## RECORD OF BOREHOLE No. 4A

FOUNDATION SECTION

JOB 71-11125

LOCATION Co-ords. 16,498,955 N; 1,233,069 E.

ORIGINATED BY SAA

W.P. 10-69-08

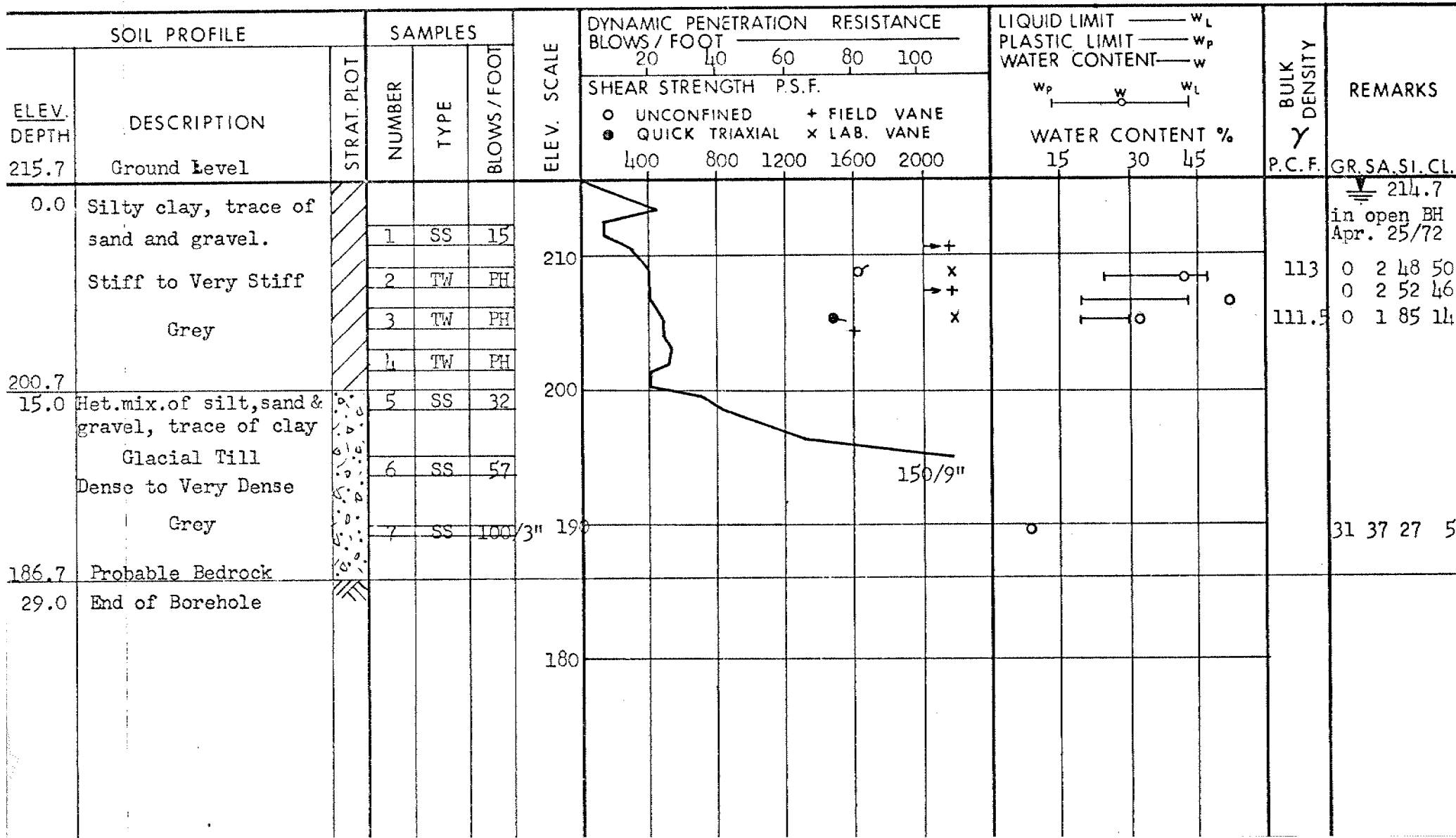
BORING DATE April 25, 1972

COMPILED BY SAA

DATUM Geodetic

BOREHOLE TYPE Auger - BX Rock Core

CHECKED BY



FOUNDATION SECTION

ORIGINATED BY SAA

COMPILED BY SAA

CHECKED BY 

[illegible]

**APPENDIX C**

**Results of Chemical Analysis**  
**Eurofins Environment Testing Report No. 1811817**



## Environment Testing

### Certificate of Analysis

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

Report Number: 1811817  
Date Submitted: 2018-07-09  
Date Reported: 2018-07-13  
Project: 1662565/1230  
COC #: 188737

|                   |                         |       |        |           | Lab I.D.<br>Sample Matrix<br>Sample Type<br>Sampling Date<br>Sample I.D. |
|-------------------|-------------------------|-------|--------|-----------|--|
| Group             | Analyte                 | MRL   | Units  | Guideline |  |
| Anions            | Cl                      | 0.002 | %      |           | 1372546<br>Soil  |
|                   | SO4                     | 0.01  | %      |           | 2018-07-09<br>BH 18-2301 SA<br>6/15-17                                   |
| General Chemistry | Electrical Conductivity | 0.05  | mS/cm  |           |  |
|                   | pH                      | 2.00  |        |           |  |
|                   | Resistivity             | 1     | ohm-cm |           |  |

Guideline =

\* = Guideline Exceedence

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

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

**APPENDIX D**

## Multichannel Analysis of Surface Waves (MASW) Test Result



## TECHNICAL MEMORANDUM

**DATE** June 06, 2019

**Project No.** 1662565 / 1230

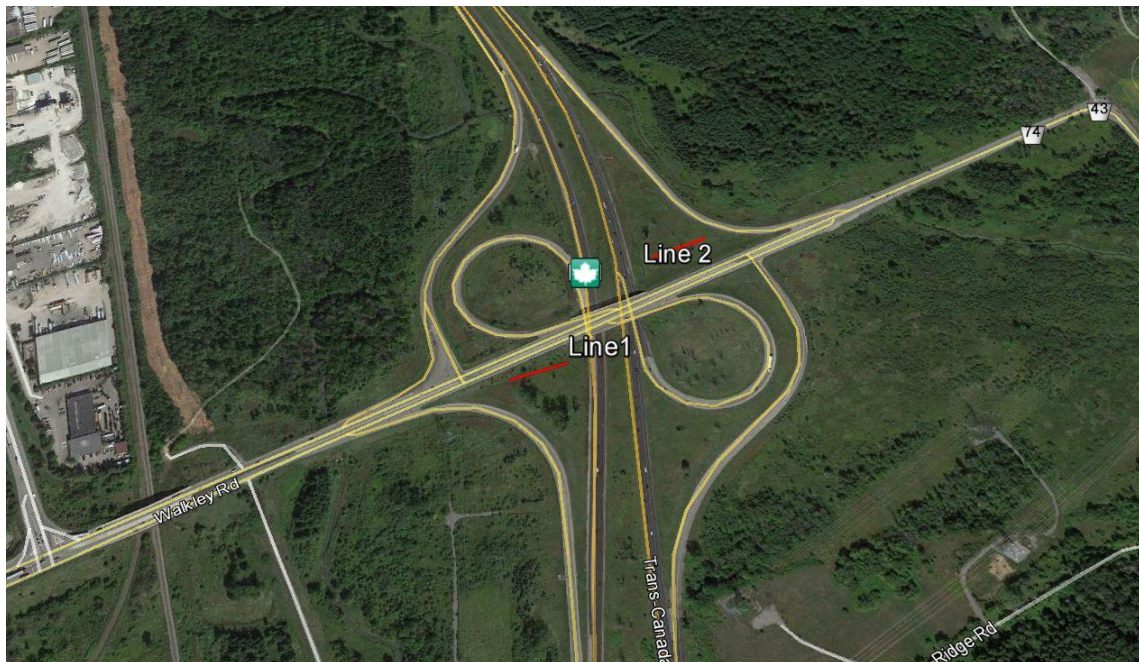
**TO** Susan Trickey  
Golder Associates Ltd.

**FROM** Stephane Sol / Christopher Phillips

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

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

This technical memorandum presents the results of two Multichannel Analysis of Surface Waves (MASW) tests performed for the purpose of the Canadian Highway Bridge Design Code (CHBDC 2014) Seismic Site Classification (Figure 1). The tests are located on each side of the interchange between Walkley Road and Highway 417 in Ottawa. The geophysical testing was performed by Golder Associates Ltd. (Golder) personnel on July 17, 2018.



*Figure 1: MASW Location Site Map (MASW Lines in red – Line 1 (South) and Line 2 (North))*

## 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.

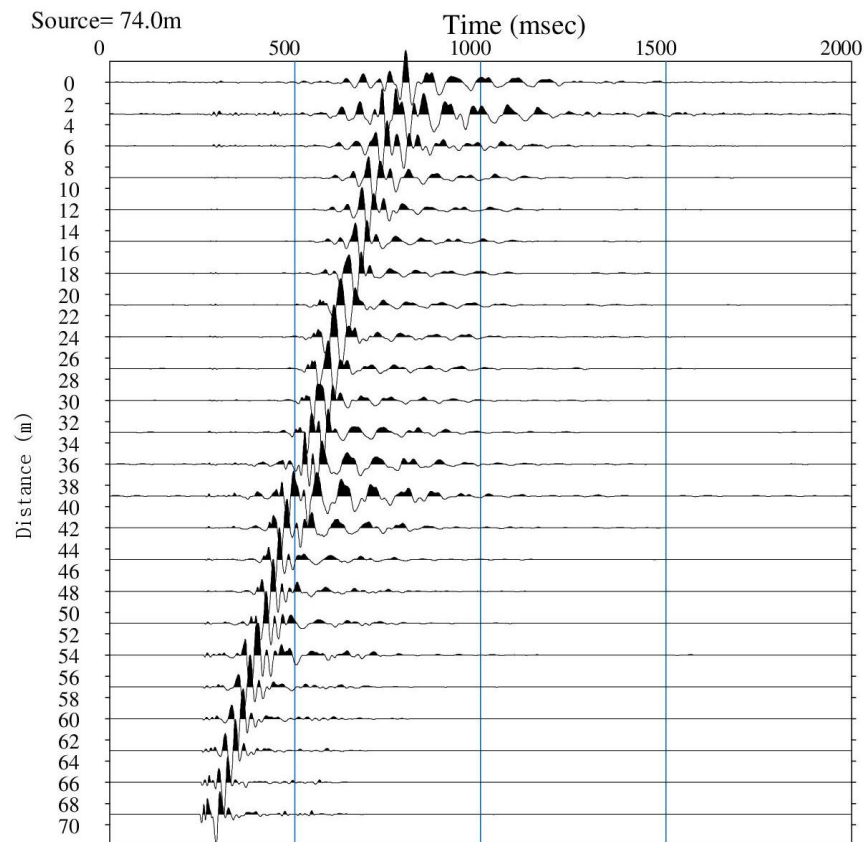
## Field Work

The MASW field work was conducted on July 17, 2018, by personnel from the Golder Mississauga office. Two MASW were collected and their location is indicated in Table 1. For each MASW line, a series of 24 low frequency (4.5 Hz) geophones were laid out at 3 m intervals. Both active and passive readings were recorded along the MASW lines. For the active investigation, a seismic drop of 45 kg and a 9.9 kg sledge hammer were used as seismic sources. Active seismic records were collected with seismic sources located 5, 10, and 15 m from and collinear to the geophone array. An example of active seismic records collected at each line are shown in Figures 2 and 3, below.

**Table 1: Location of MASW Lines**

| Location       | MTM NAD83<br>Zone 9<br>Northing<br>(m) | MTM NAD83<br>Zone 9<br>Easting<br>(m) |
|----------------|--|---------------------------------------|
| Line 1 - Start | 5029022                                | 375773                                |
| Line 1 - End   | 5028999                                | 375709                                |
| Line 2 - Start | 5029171                                | 375870                                |
| Line 2 - End   | 5029196                                | 375933                                |

The horizontal datum is MTM NAD83 Zone 9.



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

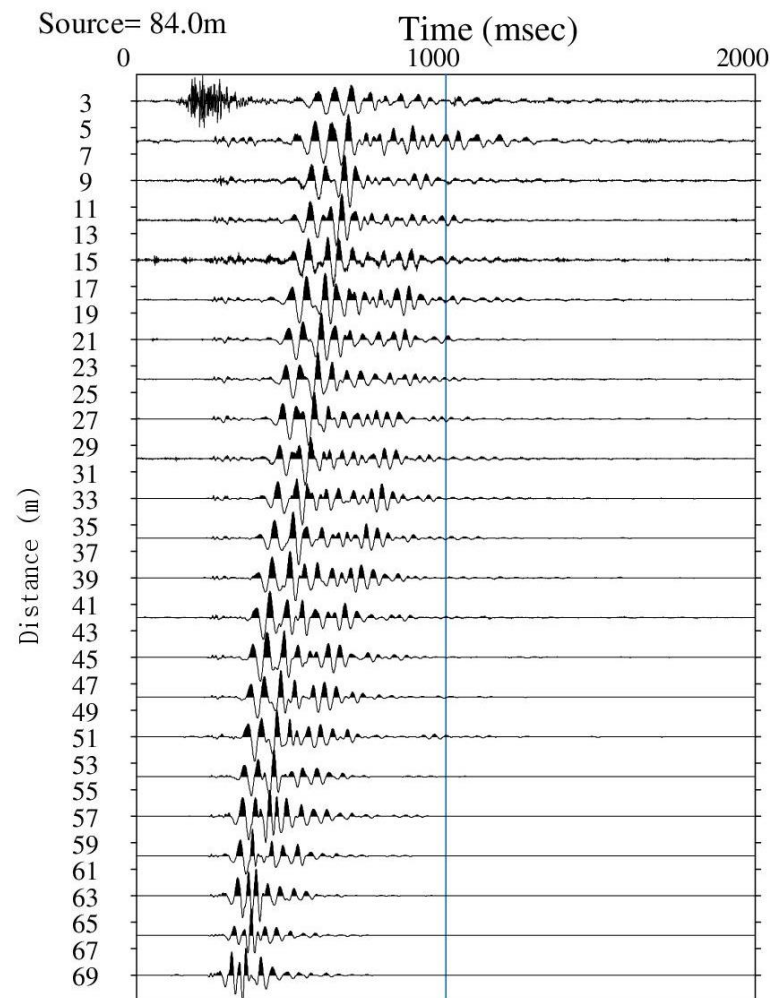


Figure 3: Typical seismic record collected at the site of MASW Line 2.

## Data Processing

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

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

- 5) Generation of the dispersion curve by combining calculated phase velocities for each shot location of a single MASW test; and,
- 6) Generation of the stiffness profile, through forward iterative modelling and matching of model data to the field collected dispersion curve.

Processing of the MASW data was completed using the SeisImager/SW software package (Geometrics Inc.). The calculated phase velocities for a seismic shot point were combined and the dispersion curve generated by choosing the minimum phase velocity calculated for each frequency component as shown on Figure 4 for Line 1 and Figure 5 for Line 2. Shear wave velocity profiles were generated through inverse modelling to best fit the calculated dispersion curves. The active survey of Line 1 provided a dispersion curve with a suitable frequency range (6-40 Hz). The active survey of Line 2 provided a dispersion curve with a suitable frequency range (9-27 Hz). The minimum measured surface wave frequency with sufficient signal-to-noise ratio to accurately measure phase velocity was approximately 6 Hz at Line 1 and 9 Hz at Line 2.

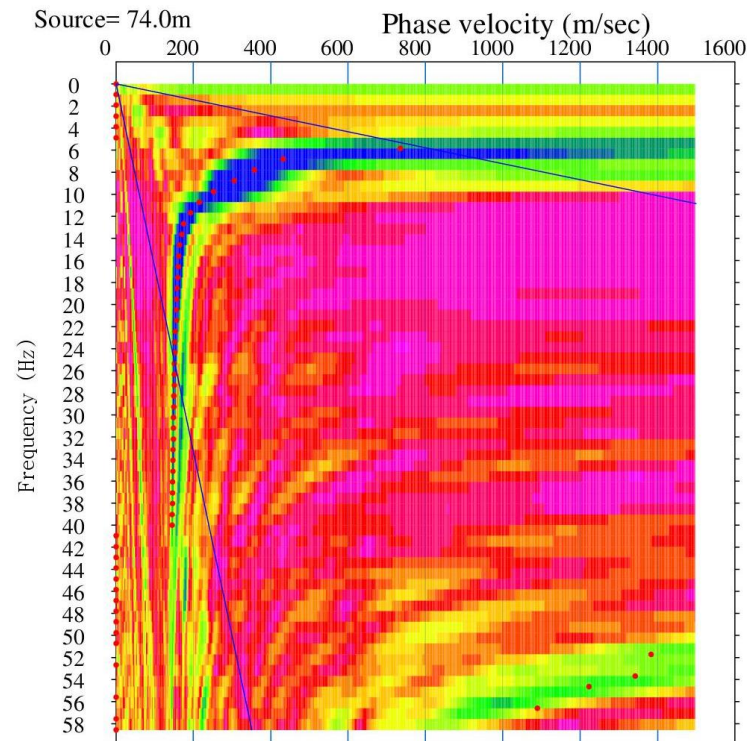


Figure 4: Active MASW Dispersion Curve Picks (red dots) along MASW Line 1



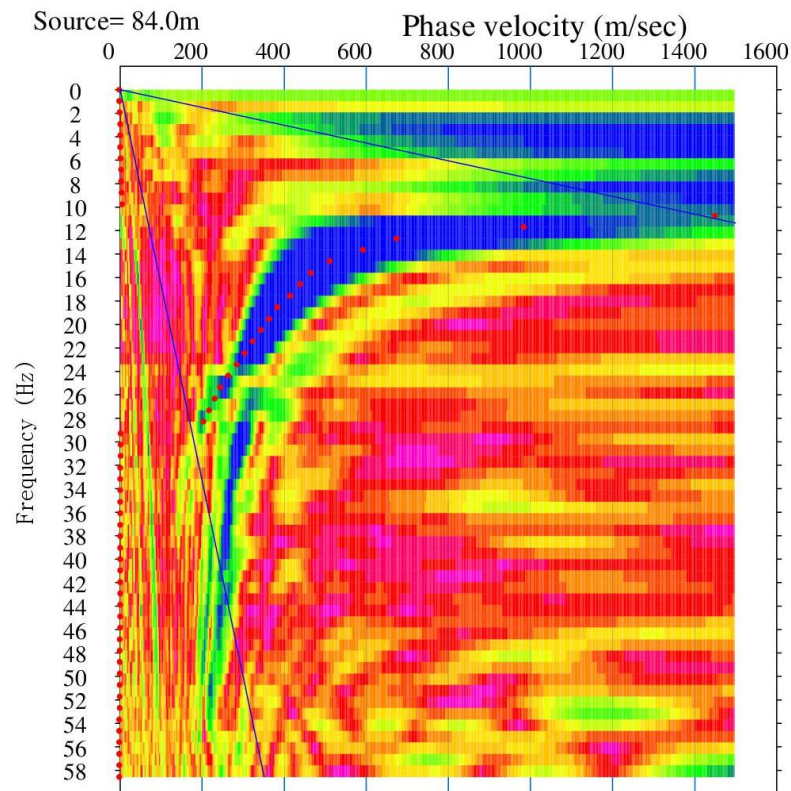
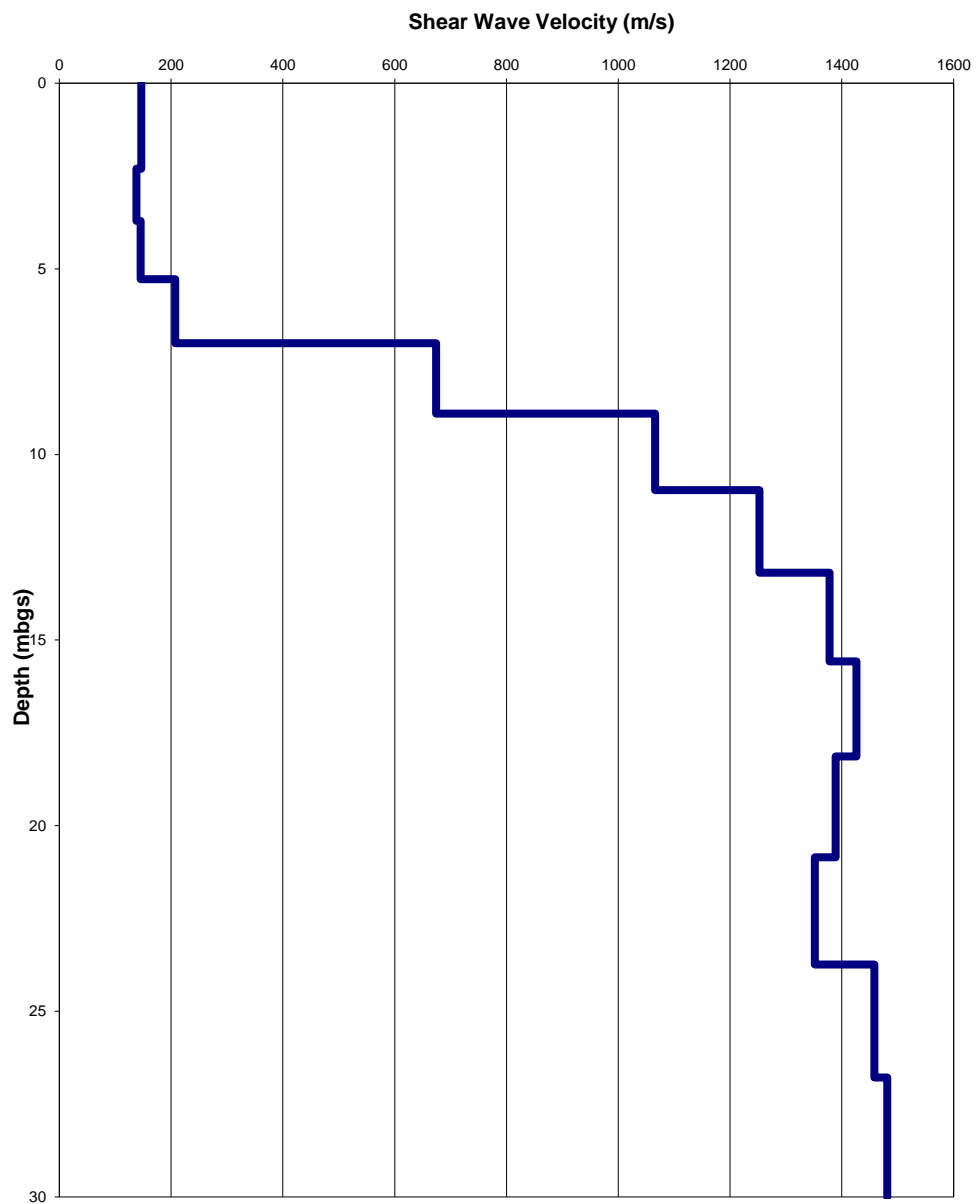


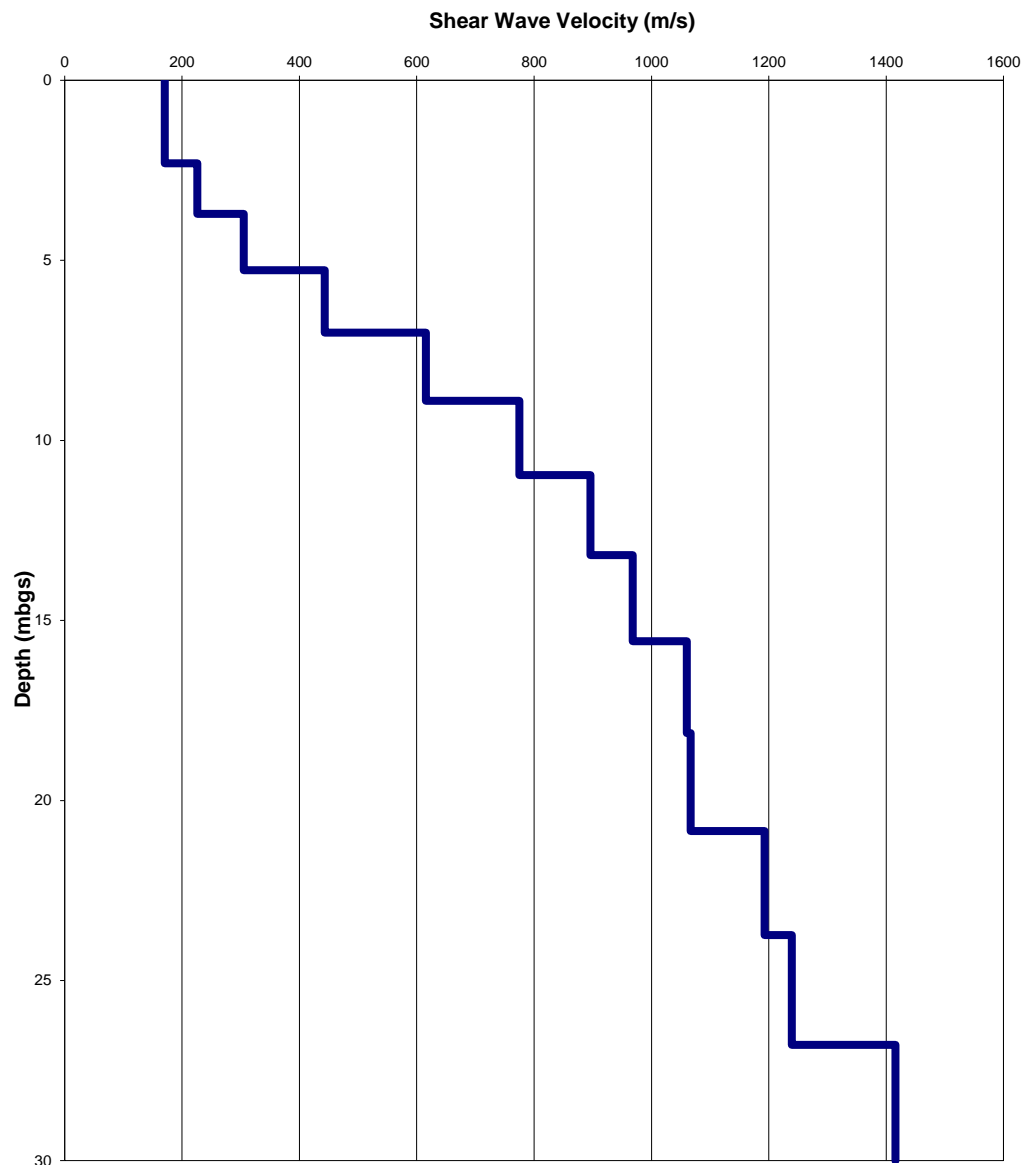
Figure 5: Active MASW Dispersion Curve Picks (red dots) along MASW Line 2

## Results

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



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



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



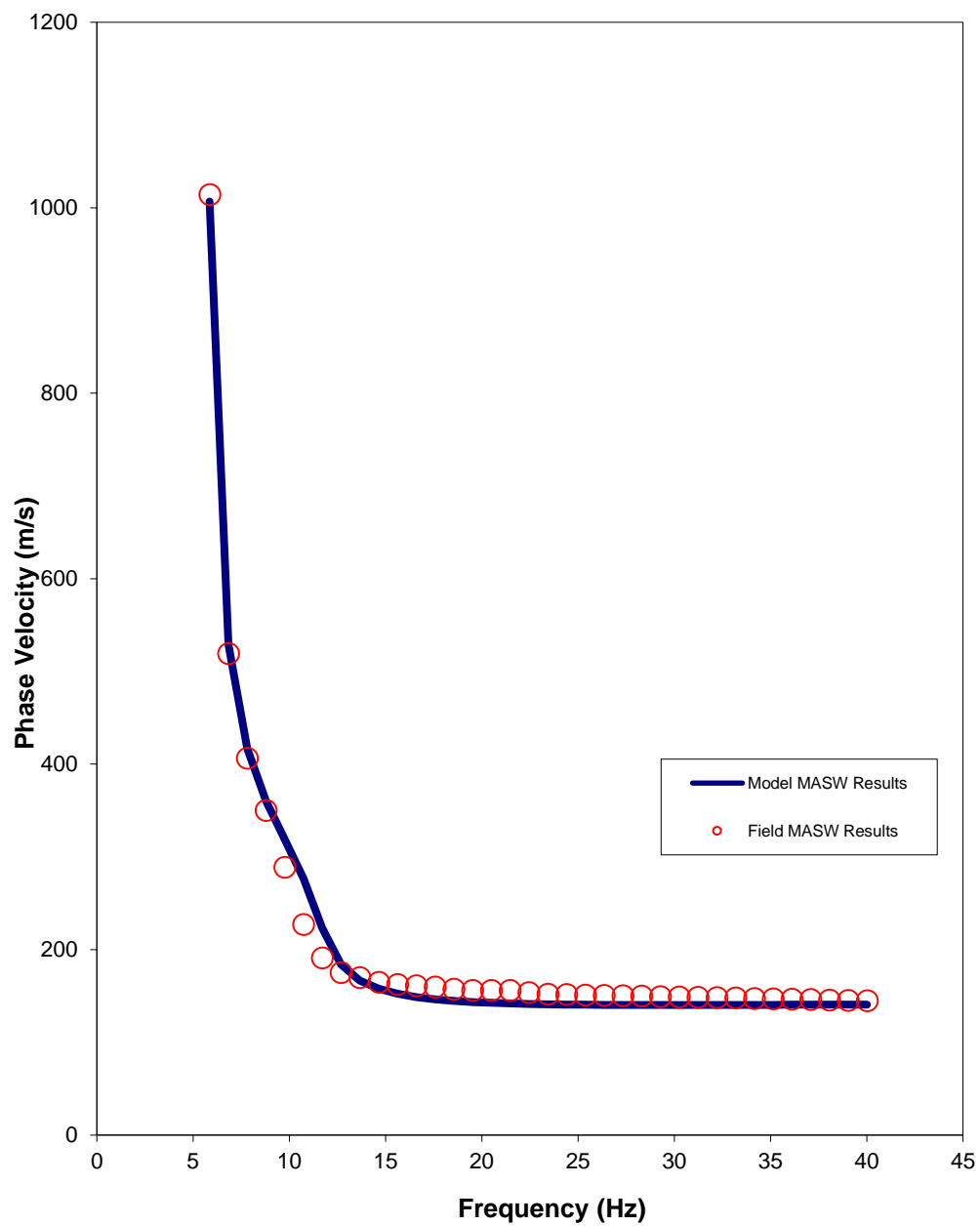


Figure 8: Comparison of Field (red dots) vs. Modelled Data (blue line) along MASW Line 1

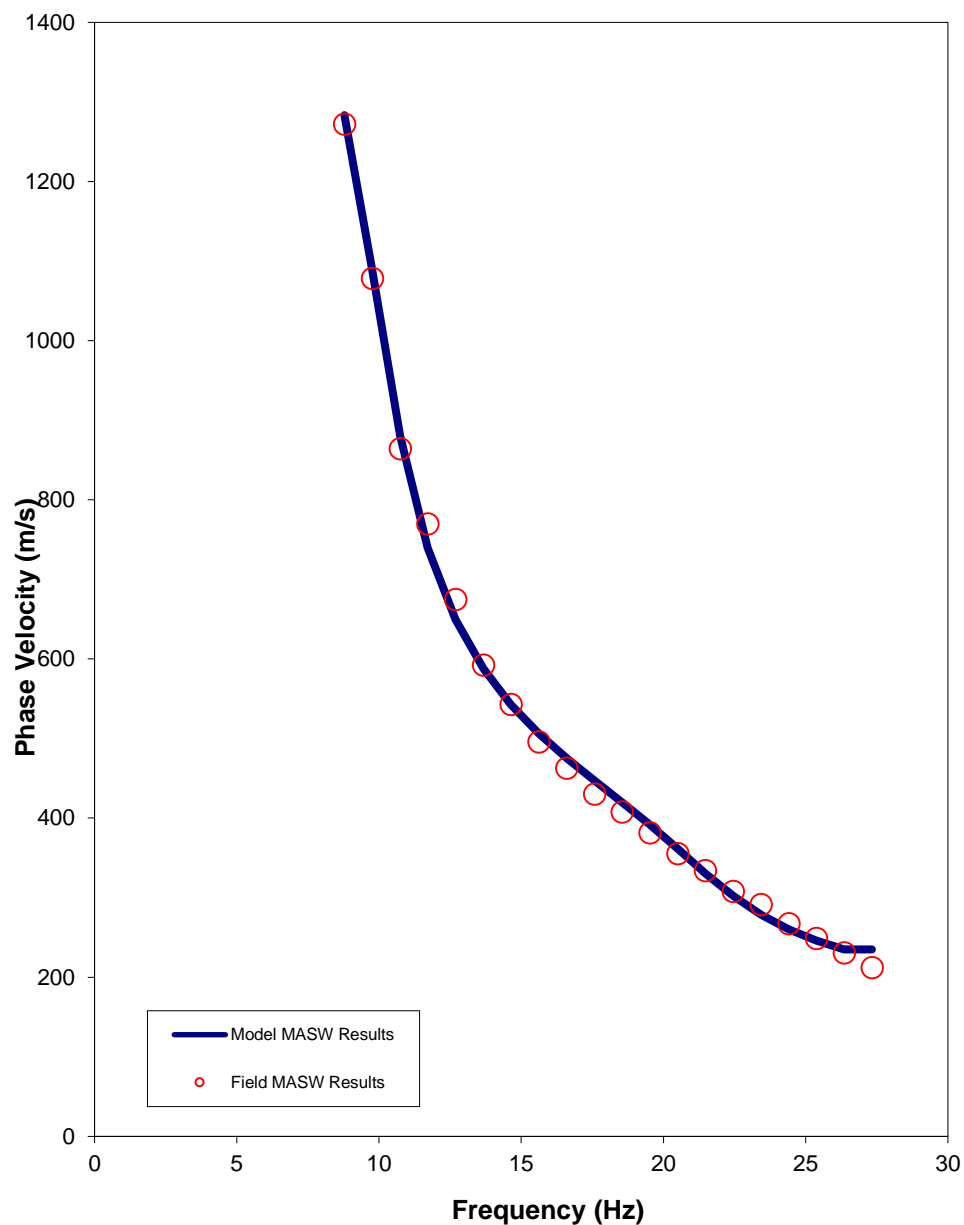


Figure 9: Comparison of Field (red dots) vs. Modelled Data (blue line) along MASW Line 2

To calculate the average shear-wave velocity as required by the CHBDC 2014, the results were modelled to 30 metres below ground surface. The average shear-wave velocity along MASW Line 1 in the north was found to be 473 m/s (Table 1). The average shear-wave velocity along MASW Line 2 in the south was found to be 582 m/s (Table 2).

**Table 2: Shear-Wave Velocity Profile along MASW Line 1**

| Model Layer (mbgs)                 |        | Layer Thickness (m) | Shear Wave Velocity (m/s) | Shear Wave Travel Time Through Layer (s) |
|------------------------------------|--------|---------------------|---------------------------|--|
| Top                                | Bottom |                     |                           |  |
| 0.00                               | 1.07   | 1.07                | 147                       | 0.007296                                 |
| 1.07                               | 2.31   | 1.24                | 147                       | 0.008419                                 |
| 2.31                               | 3.71   | 1.40                | 138                       | 0.010161                                 |
| 3.71                               | 5.27   | 1.57                | 146                       | 0.010762                                 |
| 5.27                               | 7.01   | 1.73                | 207                       | 0.008358                                 |
| 7.01                               | 8.90   | 1.90                | 674                       | 0.002812                                 |
| 8.90                               | 10.96  | 2.06                | 1066                      | 0.001933                                 |
| 10.96                              | 13.19  | 2.23                | 1253                      | 0.001777                                 |
| 13.19                              | 15.58  | 2.39                | 1378                      | 0.001734                                 |
| 15.58                              | 18.13  | 2.55                | 1426                      | 0.001791                                 |
| 18.13                              | 20.85  | 2.72                | 1389                      | 0.001959                                 |
| 20.85                              | 23.74  | 2.88                | 1351                      | 0.002135                                 |
| 23.74                              | 26.79  | 3.05                | 1458                      | 0.002091                                 |
| 26.79                              | 30.00  | 3.21                | 1481                      | 0.002170                                 |
| <b>Vs Average to 30 mbgs (m/s)</b> |        |                     |                           | <b>473</b>                               |

**Table 3: Shear-Wave Velocity Profile along MASW Line 2**

| Model Layer (mbgs)                 |        | Layer Thickness (m) | Shear Wave Velocity (m/s) | Shear Wave Travel Time Through Layer (s) |
|------------------------------------|--------|---------------------|---------------------------|--|
| Top                                | Bottom |                     |                           |  |
| 0.00                               | 1.07   | 1.07                | 171                       | 0.006282                                 |
| 1.07                               | 2.31   | 1.24                | 171                       | 0.007249                                 |
| 2.31                               | 3.71   | 1.40                | 226                       | 0.006205                                 |
| 3.71                               | 5.27   | 1.57                | 305                       | 0.005131                                 |
| 5.27                               | 7.01   | 1.73                | 443                       | 0.003906                                 |
| 7.01                               | 8.90   | 1.90                | 616                       | 0.003079                                 |
| 8.90                               | 10.96  | 2.06                | 775                       | 0.002659                                 |
| 10.96                              | 13.19  | 2.23                | 896                       | 0.002483                                 |
| 13.19                              | 15.58  | 2.39                | 968                       | 0.002469                                 |
| 15.58                              | 18.13  | 2.55                | 1060                      | 0.002409                                 |
| 18.13                              | 20.85  | 2.72                | 1067                      | 0.002549                                 |
| 20.85                              | 23.74  | 2.88                | 1193                      | 0.002418                                 |
| 23.74                              | 26.79  | 3.05                | 1239                      | 0.002460                                 |
| 26.79                              | 30.00  | 3.21                | 1416                      | 0.002270                                 |
| <b>Vs Average to 30 mbgs (m/s)</b> |        |                     |                           | <b>582</b>                               |

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

## Limitations

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

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

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

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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.



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SS/CP/jl



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