



## Foundation Investigation and Design Report

*Retaining Wall at McCowan Road Underpass (Site No. 37-217), Highway 401  
Westbound Core and Collector Lanes, Neilson Road to Warden Avenue, City of  
Toronto, Ontario, Ministry of Transportation, Ontario  
G.W.P. No. 2162-11-00*

Submitted to:

**WSP**

610 Chartwell Road, Suite 300  
Oakville, ON Canada  
L6J 4A5

Submitted by:

**Golder Associates Ltd.**

6925 Century Avenue, Suite #100 Mississauga, Ontario, L5N 7K2 Canada  
+1 905 567 4444

1669995-8

December 17, 2018

**GEOCRES No.: 30M14-483**

Lat. 43.781432, Long. -79.255346



## Distribution List

1 Hard Copy, 1 E-Copy - MTO Central Region

1 Hard Copy, 1 E-Copy - MTO Foundations Section

1 E-Copy - WSP

1 E-Copy - Golder Associates Ltd.



# Table of Contents

## PART A – FOUNDATION INVESTIGATION REPORT

<b>1.0 INTRODUCTION .....</b>	<b>1</b>
<b>2.0 SITE DESCRIPTION .....</b>	<b>1</b>
<b>3.0 INVESTIGATION PROCEDURES .....</b>	<b>2</b>
3.1 1967 Investigation .....	2
3.2 2011 Investigation .....	2
3.3 2018 Investigation .....	3
<b>4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS .....</b>	<b>4</b>
4.1 Regional Geology .....	4
4.2 Subsurface Conditions .....	4
4.2.1 Topsoil .....	5
4.2.2 Asphalt .....	5
4.2.3 Fill .....	5
4.2.4 Silt to Sandy Silt .....	5
4.2.5 Till .....	6
4.2.6 Clay Silt to Silt .....	6
4.2.7 Silty Sand to Sand .....	7
4.2.8 Sand and Gravel .....	7
4.3 Groundwater Conditions .....	7
4.4 Analytical Testing Results .....	8
<b>5.0 CLOSURE .....</b>	<b>9</b>

## PART B – FOUNDATION DESIGN REPORT

<b>6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS .....</b>	<b>10</b>
6.1 General .....	10
6.2 General Foundation Design Context .....	11
6.2.1 Consequence and Site Understanding Classification .....	11



6.2.2	Correlation of Automatic and Manual Hammer for SPT “N” Values .....	11
6.2.3	Seismic Design .....	11
6.2.3.1	Seismic Site Classification .....	11
6.2.3.2	Spectral Response Values and Seismic Performance Category .....	11
6.2.4	Soil Liquefaction.....	12
6.3	Design and Constructability Considerations .....	12
6.4	Assessment of Tolerable Deformations .....	13
6.5	Foundations Options for Retaining Wall .....	13
6.6	Concrete Toe Wall .....	14
6.7	Concrete Retaining Wall on a Shallow Foundation.....	15
6.7.1	Founding Elevations .....	15
6.7.2	Geotechnical Resistances .....	15
6.7.3	Resistance to Lateral Loads .....	16
6.8	Retained Soil System (RSS) Wall .....	16
6.8.1	Founding Elevations .....	16
6.8.2	Geotechnical Resistance .....	17
6.8.3	Resistance to Lateral Loads / Sliding Resistance.....	17
6.9	Soldier Pile and Concrete Panel Wall .....	17
6.9.1	Passive Resistance for Soldier Pile Sockets .....	18
6.10	Reinforced Earth Slope .....	18
6.11	Global Stability for Retaining Wall Options .....	18
6.11.1	Concrete Cantilever Retaining Wall .....	19
6.11.2	RSS Wall.....	19
6.11.3	Soldier Pile and Concrete Panel Wall .....	20
6.11.4	Reinforced Earth Slope .....	20
6.12	Lateral Earth Pressures for Design of Retaining Walls.....	20
6.12.1	Static Lateral Earth Pressures for Design.....	21
6.12.2	Seismic Lateral Earth Pressures for Design .....	21
6.13	Corrosion Assessment and Protection.....	22



6.14	Construction Considerations .....	23
6.14.1	Open Cut Excavation .....	23
6.14.2	Temporary Excavation Support .....	23
6.14.3	Vibration Monitoring .....	24
6.14.4	Groundwater Control.....	24
6.14.5	Obstructions During Installation of Temporary Protection Systems .....	24
6.14.6	Subgrade Protection .....	24
<b>7.0</b>	<b>CLOSURE .....</b>	<b>25</b>

## REFERENCES

## TABLES

Table 1	Comparison of Retained Soil Systems – McCowan Road Underpass Widening
---------	---

## DRAWINGS

Drawing 1	Borehole Locations
Drawing 2	Soil Strata

## FIGURES

Figure 1	Static Slope Stability Analysis – Proposed Retaining Wall
----------	---

## APPENDICES

### APPENDIX A - Borehole Records from 1967 and 2011 Investigations (GEOCREs Nos. 30M14-37 and 30M14-340)

### APPENDIX B - Borehole Records from 2018 Investigation

Lists of Symbols and Abbreviations  
Record of Borehole MRU-01

### APPENDIX C - Geotechnical Laboratory Test Results

Figure C-1	Grain Size Distribution – Silt and Sand (Till)
Figure C-2	Plasticity Chart – Silt and Sand (Till)
Figure C-3	Grain Size Distribution – Clayey Silt
Figure C-4	Plasticity Chart – Clayey Silt
Figure C-5	Grain Size Distribution – Silty Sand

### APPENDIX D - Analytical Laboratory Test Results

### APPENDIX E - Non-Standard Special Provisions

Protection Systems – Item No.  
Obstructions – Item No.  
Vibration Monitoring  
Working Slab  
Dewatering Structure Excavations (Special Provision No. FOUN0003)



# PART A

FOUNDATION INVESTIGATION REPORT  
MCCOWAN ROAD UNDERPASS (SITE NO. 37-217)  
HIGHWAY 401 WESTBOUND CORE AND COLLECTOR LANES, NEILSON  
ROAD TO WARDEN AVENUE, CITY OF TORONTO, ONTARIO  
MTO G.W.P. 2162-11-00



## 1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by WSP on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the rehabilitation and operational improvements of the Highway 401 westbound (WB) core and collector lanes, from Neilson Road to Warden Avenue in the City of Toronto, Ontario (GWP 2162-11-00).

This report addresses the foundation investigation carried out for the proposed retaining wall between the Highway 401 westbound collector lanes and the existing north abutment of the McCowan Road underpass, to support the northward widening of Highway 401 at McCowan Road. This report was developed based on information from the 2018 investigation, supplemented with information from 1967 and 2011 foundation investigations completed by others and by Golder at the structure site, as follows:

- **MTO GEOCREs No. 30M14-37:** Report titled “Foundation Investigation Report for the Proposed New Structure at McCowan Road and Hwy. #401, District #6 (Toronto), W.J. 67-F-41 - - W.P. 261-61”, Department of Highways Ontario (DHO), Foundation Section – Materials and Testing Division, dated June 27, 1967;
- **MTO GEOCREs No. 30M14-340:** “Preliminary Foundation Investigation and Design Report, Retaining Walls, Highway 401 Rehabilitation from Warden Avenue to Brock Road, Toronto, Ontario, W.O. 07-20012,” by Golder Associates Ltd., dated April 2012.

The Terms of Reference and Scope of Work for the foundation engineering services are outlined in MTO’s Request for Proposal, dated November 21, 2016, which forms part of the Consultant Agreement (No. 2016-E-0009) for this project. The work has been carried out in accordance with Golder’s Supplementary Specialty Plan for foundation engineering services for this project, dated July 10, 2017.

## 2.0 SITE DESCRIPTION

The Highway 401-McCowan Road underpass (Structure Site No. 37-217) is located in the City of Toronto, approximately 800 m east of the Highway 401-Brimley Road interchange and 1,650 m west of the Highway 401-Markham Road interchange, at approximately the locations shown on the Key Plan on Drawing 1. Based on the 1967 Borehole Location Plan and Section drawings, the ground surface along Highway 401 in the vicinity of the underpass was between about Elevations 162 m and 163 m, and the ground surface along McCowan Road was between about Elevations 168.5 m (south abutment) and 169.5 m (north abutment). Industrial parks are located at all four quadrants of the interchange.

The existing McCowan Road underpass is a 36.3 m wide three-span structure, with the abutment to pier spans of about 36.0 m, and a pier to pier span of 45.1 m. Based on available drawings, the existing north abutment is supported on 11.6 m long 324 mm outer diameter steel tube piles. The underside of the pile cap is at about Elevation 165.8 m, with the pile cut-off at Elevation 166.1 m. The north row of piles at the north abutment are battered away from the highway at 1 horizontal to 10 vertical (1H:10V), and the south row of piles at the abutment are battered toward the highway at 1H:3V. The pavement surface of McCowan Road is at about Elevation 168.6 m and that of Highway 401 is about Elevation 163.7 m.

The McCowan Road north approach embankment is approximately 6 m to 7 m high relative to the Highway 401 grade, with the slope in front of the abutment inclined at approximately 2H:1V.



## 3.0 INVESTIGATION PROCEDURES

### 3.1 1967 Investigation

A total of two boreholes (Borehole Nos 4 and 5) were advanced as part of the 1967 investigation (GEOCREs No. 30M14-37) at the McCowan Road underpass site. The previous boreholes used in this report have been renumbered to show the MTO GEOCREs reference number followed by the original borehole designation. For example, the boreholes from MTO GEOCREs Report No. 30M14-37 have been renumbered as 37-X, where X is the original borehole number.

The locations of the boreholes are summarized below and shown on Drawings 1 and 2. These borehole locations have been developed based on plotting the station and offset as shown on the 1967 borehole records and drawings, adjusted based on the site features shown on the drawings and converted to MTM NAD83 (Zone 10) coordinates. The borehole records from the 1967 investigation, including the results of the geotechnical laboratory tests carried out on selected soil samples, are presented in Appendix A and a summary of the borehole locations, ground surface elevation referenced to Geodetic datum and drilled depths are presented below.

Borehole No.	MTM NAD 83 (Zone 10)		Borehole Elevation (m)	Borehole Depth (m)
	Northing (m)	Easting (m)		
37-4	4,849,115.2	324,524.8	168.6	12.6
37-5	4,849,086.4	324,489.9	162.3	8.1

The Standard Penetration Test (SPT) "N"-values presented on the borehole records of the 1967 investigation were obtained using a manual hammer.

### 3.2 2011 Investigation

One borehole (Borehole 2011-03) was advanced as part of the 2011 preliminary investigation (GEOCREs No. 30M14-340) for the McCowan Road underpass. The location of the borehole is summarized below and shown on Drawings 1 and 2; the borehole location was measured on-site relative to the existing structures and site features and the ground surface elevation was obtained from the Digital Terrain Model for the site. The borehole record from the 2011 investigation, including the results of the geotechnical laboratory tests carried out on selected soil samples, is presented in Appendix A and a summary of the borehole location, ground surface elevation referenced to Geodetic datum and drilled depth is presented below.

Borehole No.	MTM NAD 83 (Zone 10)		Borehole Elevation (m)	Borehole Depth (m)
	Northing (m)	Easting (m)		
2011-03	4,849,118.4	324,528.3	169.5	23.2



### 3.3 2018 Investigation

The foundation investigation for the retaining wall along the north abutment of the McCowan Road underpass was carried out on March 19 and 20, 2018, during which time one borehole (designated as Borehole MRU-01) was advanced as close as possible to the proposed retaining wall alignment from the Highway 401 grade, at the location shown on Drawings 1 and 2.

The borehole investigation was carried out using a CME-75 truck-mounted drill rig supplied and operated by Geo-Environmental Drilling Inc. of Acton, Ontario. The borehole was advanced through the overburden using 165 mm outside diameter hollow stem augers to a depth of 11.3 m below existing ground surface.

Soil samples were obtained at 0.75 m and 1.5 m intervals of depth using a 50 mm outer diameter split-spoon sampler driven by an automatic hammer in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586)<sup>1</sup>.

The groundwater conditions in the open borehole was observed during and immediately following the drilling operations. A standpipe piezometer was installed in Borehole MRU-01 to permit monitoring of the water level. The installed piezometer consists of a 50 mm diameter PVC pipe, with a 1.5 m slotted screen within a filter sand pack with the piezometer sealed within the borehole at about 10.0 m below ground surface. The annulus between the piezometer pipe and the borehole wall above the filter sand pack was backfilled to near the pavement surface with bentonite pellets between and a 152 mm diameter 0.3 m long protective pipe/cap placed around / over the piezometer pipe at the pavement surface. Piezometer installation details and water level readings are described on the borehole record in Appendix B.

The field work was monitored on a full-time basis by a member of Golder's technical staff who located the borehole in the field, directed the sampling and in situ testing operations, logged the borehole and examined the soil samples. The soil samples were identified in the field, placed in labelled containers and transported to Golder's laboratory in Mississauga for further visual review. Geotechnical laboratory index and classification testing, consisting of natural moisture contents, Atterberg limits and grain size distributions, was conducted on selected samples in accordance with MTO and / or ASTM Standards as applicable. One sample from the borehole, obtained using appropriate sampling protocols, was submitted to a specialist accredited analytical laboratory under chain of custody procedures for testing of conductivity / resistivity, pH and chemical analysis of sulphate and chloride content, to assess the potential for the soil to cause deterioration to buried concrete and corrosion to steel.

The borehole location was laid out in the field by Golder personnel relative to existing road features and pre-selected coordinates using a hand-held global positioning system (GPS) unit with an accuracy of 1 m in the horizontal and vertical directions. The borehole location was then measured relative to existing site features and the ground surface elevation on the pavement established from the digital terrain model for the project. The location given on the borehole record and shown on Drawings 1 and 2 is positioned relative to MTM NAD 83 (Zone 10) northing and easting coordinates with an accuracy of 0.1 m or better horizontally and the ground surface elevations are referenced to Geodetic datum with an accuracy of 0.5 m or better vertically. The borehole location, including both MTM NAD 83 and geographic coordinates, ground surface elevation and drilled depth is summarized below.

---

<sup>1</sup> ASTM D1586 – Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of Soils.



Borehole No.	MTM NAD83 (Zone 10)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m) (Latitude °)	Easting (m) (Longitude °)		
MRU-01	4,849,080.4 (43.781432)	324,493.0 (-79.255346)	163.7	11.3

## 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

### 4.1 Regional Geology

This section of Highway 401 is located within the physiographic region known as the South Slope, according to *The Physiography of Southern Ontario* (Chapman and Putnam, 1984)<sup>2</sup>.

The South Slope region is comprised of calcareous clay till with lacustrine clay and silt reworked by glaciers, with numerous scattered drumlins and deep valley cuts caused by flowing streams towards Lake Ontario. The surface topography slopes gradually and uniformly southwards towards Lake Ontario. The overburden within the majority of the South Slope area is underlain by shale bedrock of the Queenston and Georgian Bay Formations which contain limestone interlayers.

### 4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the borehole advanced during the 2018 investigation and the results of the geotechnical laboratory tests carried out on selected soil samples are presented on the borehole record provided in Appendix B. The results of the in-situ field tests (i.e., SPT “N”-values) as presented on the borehole record and in Section 4.0 are uncorrected. The Standard Penetration Test “N”-values from the 1967 investigation are based on use of a manual hammer, while those in the 2011 and 2018 investigation are based on use of an automatic hammer and the values are reported with no adjustment in this report, although it is recognized that SPT “N”-values obtained using a manual hammer are frequently higher than those obtained using an automatic hammer. Plot of the results of the geotechnical laboratory testing from the current investigation are presented in Appendix C. The results of the analytical testing are provided in Appendix D.

The stratigraphic boundaries shown on the borehole records for the three investigations and on the stratigraphic profile on Drawing 2 are inferred from non-continuous sampling, observations of drilling progress and the results of Standard Penetration Tests. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Furthermore, subsurface conditions will vary between and beyond the borehole locations, however, the factual data presented in the borehole records governs any interpretation of the site conditions.

In general, the subsurface conditions encountered in the various boreholes advanced at the site consist of the Highway 401 pavement and pavement structures, embankment fill underlain by deposits of silt to sandy silt and sand till. The silt to sandy silt and till deposits are underlain by a clayey silt deposit, silty sand to sand deposit and

<sup>2</sup> Chapman, L.J. and Putman, D.F., 1984, *The Physiography of Southern Ontario*, Ontario Geological Society, Special Volume 2, Third Edition. Accompanied by Map p. 2715, Scale 1:600,000.)



by a sand and gravel deposit at one borehole location. Detailed descriptions of the subsurface conditions are provided in the following sections of this report.

#### 4.2.1 Topsoil

An approximately 150 mm thick layer of topsoil was encountered immediately below ground surface in Borehole 2011-03, which was advanced in the shoulder of the McCowan Road N-W Ramp. An approximately 900 mm thick layer of topsoil was encountered immediately below ground surface in Borehole 37-5, and an approximately 800 mm thick layer of topsoil was encountered underlying the sandy silt fill (described below) in Borehole 37-4.

#### 4.2.2 Asphalt

An approximately 250 mm thick layer of asphalt pavement was encountered immediately below ground surface in Borehole MRU-01, which was advanced on the Highway 401 roadway.

#### 4.2.3 Fill

An approximately 2.5 m thick layer of fill was encountered underlying the asphalt pavement in Borehole MRU-01. The fill extends to about Elevation 160.9 m. The fill in this borehole varies in layer thickness and composition from approximately 0.4 m of sand and gravel, underlain by 1.5 m of gravelly sand, and further underlain by 0.6 m of clayey silt.

An approximately 8.6 m and 7.9 m thick layer of non-cohesive fill comprised of sand and silt and sandy silt was encountered underlying the topsoil in Borehole 2011-03 and immediately below ground surface in Borehole 37-4, respectively. The fill layer in Borehole 37-4 was originally classified as a native deposit, however, based on the presence of topsoil beneath this layer, the thickness of fill encountered in Borehole 2011-03, and the height of the north approach embankments, this layer has been re-classified as a fill. The fill layer extends to about Elevation 160.7 m in both boreholes.

One Standard Penetration Test (SPT) “N”-value measured within the cohesive (clayey silt) fill is 9 blows per 0.3 m of penetration, suggesting a stiff consistency. The SPT “N”-values measured within the non-cohesive fill layer range between 2 blows and 77 blows per 0.3 m of penetration, indicating a very loose to very dense level of compactness.

Grain size distribution tests were carried out on two samples of the non-cohesive fill layer recovered during the 1967 investigation and one sample of the non-cohesive fill layer recovered during the 2011 investigation, and the results presented on the borehole records included in Appendix A. The natural water content measured on one selected sample of the cohesive fill is about 24 per cent. The natural water content measured selected samples of the non-cohesive fill range between about 4 and 12 per cent.

#### 4.2.4 Silt to Sandy Silt

An approximately 2.6 m thick deposit of silt to sandy silt was encountered underlying the topsoil in Borehole 37-5. The deposit extends to Elevation 158.8 m.

The SPT “N”-values measured within the silt to sandy silt deposit range from 2 blows to 12 blows per 0.3 m of penetration, indicating a very loose to compact level of compactness.

A grain size distribution test was carried out on one selected sample of the silt to sandy silt deposit recovered during the 1967 investigation and the result is present on the borehole record included in Appendix A. An Atterberg limits test was carried out on one selected sample of the silt to sandy silt deposit encountered during the 1967 investigation and measured a liquid limit of about 16 per cent, a plastic limit of about 12 per cent, and a



corresponding plasticity index of 4 per cent indicating that this material is classified as a silt / sandy silt of slight plasticity. The natural water content measured on two samples of the silt to sandy silt deposit are 13 per cent and 15 per cent.

#### 4.2.5 Till

A non-cohesive till deposit was encountered underlying the cohesive fill layer in Borehole MRU-01 and cohesive till deposit was encountered underlying the sand and silt fill in Borehole 2011-03. In Borehole MRU-01 the 0.9 m thick till deposit is comprised of silt and sand and extends to Elevation 160.0 m. In Borehole 2011-03 the till deposit is 2.7 m thick and is comprised of clayey silt underlain by a 1.8 m thick deposit of sandy silt till, which extends to Elevation 156.1 m.

The SPT “N”-values measured within the two layers of non-cohesive till are 7 blows and 18 blows per 0.3 m of penetration, indicating a loose and compact level of compactness, respectively. The SPT “N”-values measured within the cohesive till deposit are 12 blows and 17 blows per 0.3 m of penetration, suggesting a stiff to very stiff consistency.

A grain size distribution test was carried out on one selected sample of the silt and sand deposit encountered during the 2018 investigation, and the result is shown on Figure C-1 in Appendix C. Grain size distribution tests were carried out on one sample each of the cohesive and non-cohesive till deposits recovered during the 2011 investigation and the results are presented on the borehole record included in Appendix A. Atterberg limits testing was carried out on one selected sample of the silt and sand till deposit encountered during the 2018 investigation and measured a liquid limit of 15 per cent, a plastic limit of 13 per cent, and a corresponding plasticity index of 2 per cent. The result, which is plotted on a plasticity chart on Figure C-2 in Appendix C, indicate that the deposit consists of a silt of slight plasticity. The natural water content measured on selected samples of the till deposits are 11 per cent for the cohesive till and 12 per cent for the non-cohesive till.

#### 4.2.6 Clay Silt to Silt

A deposit of clayey silt to silt was encountered underlying the till deposit in Boreholes MRU-01 and 2011-03, underlying the silt to sandy silt deposit in Borehole 37-5, and underlying the topsoil in Borehole 37-4. The surface of the cohesive deposit was encountered at depths between 3.5 m and 13.4 m below ground surface, between Elevations 160.0 m and 156.1 m. Borehole 37-4 terminated within this deposit, penetrating it for a thickness of 3.9 m. The thickness of the clayey silt to silt deposit ranges from 1.5 m to 5.0 m in the remaining boreholes, extending to between Elevations 156.0 m and 154.6 m.

The SPT “N”-values measured within the clayey silt to silt deposit range between 7 blows and 115 blows per 0.3 m of penetration, suggestion a firm to hard consistency.

A grain size distribution test was carried out on one sample of the clayey silt to silt deposit encountered during the 2018 investigation, and the result is shown on Figure C-3 in Appendix C. A grain size distribution test was carried out on one sample of the clayey silt to silt deposit recovered during the 1967 investigation and the result is presented on the borehole record included in Appendix A. Atterberg limits testing was carried out on one selected sample of the clayey silt deposit encountered during the 2018 investigation and measured a liquid limit of 21 per cent, a plastic limit of 16 per cent, and a corresponding plasticity index of 5 per cent. The result, which is plotted on a plasticity chart on Figure C-4 in Appendix C, indicates that the deposit consists of a clayey silt of low plasticity. Atterberg limits tests were also carried out on one selected sample of the clayey silt deposit encountered during the 2011 investigation and three selected sample of the clayey silt to silt deposit encountered during the 1965 investigation



and measured liquid limits ranging between about 16 per cent and 21 per cent, plastic limits ranging between about 11 per cent and 16 per cent, and plasticity indices ranging between about 4 per cent and 9 per cent, indicating that the deposit is comprised of clayey silt of low plasticity to silt of slight plasticity. The natural water content measured on selected samples of the clayey silt to silt deposits range between 11 per cent and 21 per cent.

#### 4.2.7 Silty Sand to Sand

A silty sand to sand deposit was encountered underlying the clayey silt to silt deposit in Boreholes MRU-01, 2011-3 and 37-5 at depths ranging between 7.0 m and 14.9 m, corresponding to between Elevations 155.3 m and 154.6 m. Boreholes MRU-01 and 37-5 terminated within this deposit, penetrating it for a thickness of 2.6 m and 1.1 m, corresponding to bottom Elevations 152.4 m and 154.2 m, respectively. The deposit in Borehole 2011-03 is 5.8 m thick and extended to Elevation 148.8 m.

The SPT “N”-values measured within the silty sand to sand deposit range from 15 blows per 0.3 m of penetration to 110 blows for 0.23 m of penetration, indicating a compact to very dense level of compactness.

A grain size distribution test was carried out on one selected sample of the silty sand to sand deposit encountered during the 2018 investigation, and the result is shown on Figure C-5 in Appendix C. A grain size distribution test was carried out on one sample of the silty sand to sand deposit recovered during the 2011 investigation and the result is presented on the borehole record included in Appendix A. The natural water content measured on selected samples of the silty sand to sand deposit range between 16 per cent and 19 per cent.

#### 4.2.8 Sand and Gravel

A sand and gravel deposit was encountered at a depth of 20.7 m, corresponding to Elevation 148.8 m, underlying the silty sand deposit in Borehole 2011-03. The borehole terminated within this deposit, penetrating it for a thickness of 2.5 m.

The SPT “N”-values measured within the sand and gravel deposit are 70 blows and 74 blows for 0.15 m of penetration, indicating a very dense level of compactness.

A grain size distribution test was carried out on one sample of the sand and gravel deposit encountered during the 2011 investigation and the result is presented on the borehole record included in Appendix A. The natural water content measured on one selected sample of the sand and gravel deposit is 11 per cent.

### 4.3 Groundwater Conditions

The groundwater levels in the open boreholes were measured upon completion of drilling operations during the 2018, 2011 and 1967 investigations, and in the piezometers installed in Boreholes MRU-01 and 2011-03 as summarized below.

Borehole No.	Ground Surface Elevation (m)	Depth to Groundwater (m)	Groundwater Elevation (m)	Date	Comments
MRU-01	163.7	9.2	154.5	March 20, 2018	Open borehole
		4.0	159.7	June 30, 2018	Piezometer



Borehole No.	Ground Surface Elevation (m)	Depth to Groundwater (m)	Groundwater Elevation (m)	Date	Comments
2011-03	169.5	4.9	164.6	April 8, 2011	Piezometer
		4.6	164.9	April 21, 2011	Piezometer
37-4	168.6	7.5	161.1	May 26, 1967	Open Borehole
37-5	162.3	0.3	162.0	May 30, 1967	Open Borehole

As these water levels were measured immediately after completion of drilling, they may not represent the stabilized groundwater level at the site, nor the current level in the case of the 1967 data. Based on the observed water conditions, together with soil colour transitions from brown to grey, the groundwater level is estimated to range between approximately Elevations 160 m and 165 m. The groundwater level will be subject to seasonal fluctuations and should be expected to be higher during the spring season or during and following periods of heavy precipitation.

#### 4.4 Analytical Testing Results

A soil sample was submitted to an accredited analytical laboratory for analysis of parameters used to assess the potential corrosivity of the site soil to steel and concrete. Detailed analytical test results are included in Appendix D and the test results are summarized below.

Borehole No. / Sample No.	pH	Resistivity (ohm-cm)	Electrical Conductivity (umho/cm)	Chlorides (ug/g)	Soluble Sulphates (ug/g)
MRU-01 / 4	8.07	330	3,050	1,700	<20*

\* Reportable Detection Limit



## 5.0 CLOSURE

This Foundation Investigation Report was prepared by Ms. Nikol Kochmanová, P.Eng., a geotechnical engineer with Golder. Mr. Jorge Costa, P.Eng., an MTO Foundations Designated Contact and Senior Consultant of Golder, conducted an independent technical and quality control review of the report.

### Golder Associates Ltd.



Nikol Kochmanová, Ph.D., P.Eng., PMP  
*Geotechnical Engineer*



Jorge M.A. Costa, P.Eng.  
*MTO Foundations Designated Contact, Senior Consultant*

NK/JMAC/rb

Golder and the G logo are trademarks of Golder Associates Corporation

[https://golderassociates.sharepoint.com/sites/16003g/6.deliverables/8.mccowan road/3. final/1669995 fidr08 2018dec17 hwy 401wb mccowan rd underpass.docx](https://golderassociates.sharepoint.com/sites/16003g/6.deliverables/8.mccowan%20road/3.final/1669995%20fidr08%202018dec17%20hwy%20401wb%20mccowan%20rd%20underpass.docx)



# PART B

FOUNDATION DESIGN REPORT  
MCCOWAN ROAD UNDERPASS (SITE NO. 37-217)  
HIGHWAY 401 WESTBOUND CORE AND COLLECTOR LANES, NEILSON  
ROAD TO WARDEN AVENUE, CITY OF TORONTO, ONTARIO  
MTO G.W.P. 2162-11-00



## 6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides detail foundation design recommendations for the proposed retaining wall at the north abutment of the McCowan Road underpass, to support the northward widening of Highway 401 as part of the rehabilitation and operational improvements of the Highway 401 westbound core and collector lanes, from Neilson Road to Warden Avenue in the City of Toronto, Ontario. These recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the 2018 subsurface investigation at this site, supplemented with data from the 1967 and 2011 investigations. The discussion and recommendations presented are intended to provide the designer with sufficient information to assess the feasible foundation alternatives and carry out the design of the proposed retaining wall. The foundation investigation report, discussions and recommendations are intended for the use of the Ministry of Transportation, Ontario (MTO) and their designers, and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in the Foundation Investigation Report (Part A of this report). Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project and for which special provisions may be required in the Contract Documents. Those requiring information on the aspects of construction must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling, and the like.

### 6.1 General

The existing Highway 401-McCowan Road underpass was constructed in 1970 and consists of a three-span structure, with the abutment to pier spans of 36.0 m, and a pier to pier span of 45.1 m, with a total span of about 117.1 m. The following design drawings are available for the McCowan Road underpass:

- Contract No. 70-15, WP No. 261-61, Drawing Nos. D-6299-1 to D-6299-4: "McCowan Road Underpass", prepared by Department of Highways Ontario, Bridge Division, dated December 1968.

As indicated on the design drawings, the north abutment is supported on the pile cap of 324 mm outer diameter steel tube pile foundations perched within the north approach embankment. The north row of piles at the abutment are battered away from Highway 401 at 1H:10V, and the south row of piles at the abutment are battered toward Highway 401 at 1H:3V. The design pile tip elevation is not shown on the drawings, however, based on pile lengths of 11.6 m and 11 m and a pile cut-off at about Elevation 166.1 m, the design pile tip for the north row of piles is at about Elevation 154.5 m, and for the south row of piles at about Elevation 155.1 m, both extending to found within the compact to very dense silty sand to sand deposit. The McCowan Road north approach embankment is up to approximately 6 m to 7 m high relative to the Highway 401 grade, with the abutment front slope (foreslope) inclined at approximately 2H:1V. Based on visual observations made during the recent subsurface investigation, the existing underpass structure (and in particular the north abutment and approach embankment) appears to be performing well.

The northward widening of Highway 401 at the underpass will require cutting into the north abutment foreslope, to fit a widened Highway 401 cross-section without compromising the integrity of the existing pile foundations. Based on discussions with WSP, the proposed retaining wall at the north abutment of the McCowan Road underpass is to consist of a 1.2 m high concrete toe wall.



## 6.2 General Foundation Design Context

### 6.2.1 Consequence and Site Understanding Classification

In accordance with Section 6.5 of the *Canadian Highway Bridge Design Code* CAN/CSA S6-14 (*CHBDC* (2014)) and its *Commentary*, the underpass and its foundation system may be classified as having large traffic volumes and their performance as having potential impacts on other transportation corridors, resulting in a “typical consequence level” associated with exceeding limit states design.

Based on the level of foundation investigation completed as part of the 1967, 2011 and 2018 investigations in comparison to the degree of site understanding in Section 6.5 of *CHBDC* (2014), the level of confidence for design for the proposed retaining wall at the north abutment of the McCowan Road underpass has been assessed as “typical degree of site and prediction model understanding”.

The corresponding consequence factor,  $\Psi$ , and geotechnical resistance factors,  $\phi_{gu}$  and  $\phi_{gs}$ , from Tables 6.1 and 6.2, respectively, of the *CHBDC* (2014) have been used for the assessment of the geotechnical resistance of the retaining wall foundations.

### 6.2.2 Correlation of Automatic and Manual Hammer for SPT “N” Values

The results of the 2011 and 2018 foundation investigations generally demonstrate lower Standard Penetration Test (SPT) “N”-values than encountered in Boreholes 37-4 and 37-5 from the 1967 investigation (GEOCRE No. 30M14-37). The differences are largely due to the use of an automated hammer with higher efficiency used in the 2011 and 2018 investigations as compared to a manually operated hammer (i.e., rope cathead) that was used in the 1967 investigation. The 2011 and 2018 SPT “N”-values correlate reasonably well with the 1967 data when corrected to a 60% efficiency of hammer energy transfer as indicated in CFEM (2006). The foundation options and recommendations presented below are based on the correlated “N<sub>60</sub>”-values, where applicable.

### 6.2.3 Seismic Design

#### 6.2.3.1 Seismic Site Classification

The subsurface conditions for seismic site characterization were assessed based on the results of the field investigation and laboratory testing. The corrected SPT “N”-values in the soil layers and the interpreted shear wave velocity of soils up to 30 m below founding level were used to define the seismic site classification in accordance with Table 4.1 of the *CHBDC* (2014). Based on this methodology, it is considered that a Site Class C would be applicable for the design of the retaining wall at the McCowan Road underpass.

#### 6.2.3.2 Spectral Response Values and Seismic Performance Category

In accordance with Section 4.4.3.4 of the *CHBDC* (2014) and as obtained from NRC (2017) website, the peak ground acceleration (PGA) and peak ground velocity (PGV) values and design spectral acceleration (Sa) values for Site Class C are presented below.

Seismic Hazard Values	10% Exceedance in 50 years (475-year return period)	5% Exceedance in 50 years (975-year return period)	2% Exceedance in 50 years (2,475 return period)
PGA (g)	0.041	0.072	0.136
PGV (m/s)	0.032	0.052	0.091



Seismic Hazard Values	10% Exceedance in 50 years (475-year return period)	5% Exceedance in 50 years (975-year return period)	2% Exceedance in 50 years (2,475 return period)
<b>Sa (0.2) (g)</b>	0.068	0.115	0.212
<b>Sa (0.5) (g)</b>	0.043	0.067	0.113
<b>Sa (1.0) (g)</b>	0.024	0.037	0.059
<b>Sa (2.0) (g)</b>	0.011	0.018	0.029
<b>Sa (5.0) (g)</b>	0.0025	0.0041	0.0069
<b>Sa (10.0) (g)</b>	0.0011	0.0017	0.0029

#### 6.2.4 Soil Liquefaction

Given the generally very stiff to hard consistency / very dense compactness condition of the site soils present at the site and the low seismic hazard classification for the site, it is considered that the risk of potential soil liquefaction due to a seismic event is very low.

### 6.3 Design and Constructability Considerations

The basic approach to designing an excavation support system and retaining wall at this site includes:

- Designing for the minimum requirements to satisfy load carrying capacity (lateral earth pressures, hydrostatic pressures and imposed foundation loads) and global system stability; and
- Designing to control deformations to acceptable levels.

For this site, the selection of appropriate, practical and feasible temporary and permanent retaining systems in front of the “perched” abutment pile cap at the McCowan Road underpass will depend on a number of considerations, key among them the following:

- The selected retaining structure type(s) must be constructable within the limited available headroom beneath the underside of the existing bridge deck. Based on the existing Highway 401 grade and the underside elevation of the bridge deck, it is estimated that there is a maximum of approximately 6.0 m of headroom in front of the north abutment, although this available height is reduced further by the presence of the existing abutment foreslope. It is noted that it may be possible to excavate narrow slots, oriented perpendicular to the face of the abutment wall, within the foreslope to reduce the impacts of broader excavation on the existing foundations while providing more equipment headroom for construction of certain types of walls.
- Because the existing pile cap is “perched” approximately 2.8 m above the Highway 401 grade, it will be critical to limit and control wall deflection if the retaining structure is within about 8 pile diameters of the existing foundation piles, to minimize lateral and vertical deformation of the ground behind the retaining structure that could result in movement of the bridge foundations and its superstructure. This aspect must also consider both ground and groundwater control during construction of the wall itself.



- The proposed wall alignment is approximately 5.5 m to 8.0 m away from the existing piles and the piles closest to the wall alignment are battered at 1H:3V toward the wall. Based on the proposed wall alignment, the distance between the wall and the existing piles will be greater than 8 pile diameters and as such it is anticipated that the lateral load resisted by the abutment piles will not be transferred onto the back face of the retaining wall. If the alignment of the retaining wall is shifted closer to the abutment, to within 8 pile diameters of the existing bridge piles, a portion of the lateral load being resisted by the abutment piles will be transferred onto the back face of the retaining wall; this additional loading would need to be taken into account by the structural engineer in the design of the retaining wall.
- The cost of the retaining structure relative to the risk of wall movement, ground deformation and resulting impacts on the existing abutment foundations and superstructure.

## 6.4 Assessment of Tolerable Deformations

Where temporary or permanent retaining walls and/or protection systems are required and are located within the zone of influence of the existing abutment pile caps (i.e., within about 8 pile diameters), it is recommended that the temporary system be designed to meet Performance Level 1A as set out in OPSS.PROV 539 (*Temporary Protection Systems*). This level specifies a maximum angular distortion of 1:1000 and a maximum horizontal displacement of 5 mm. Where temporary protection systems or permanent retaining structures are located outside the zone of influence, it is recommended that the system be designed to meet Performance Level 2 as set out in OPSS.PROV 539 (*Temporary Protection Systems*).

## 6.5 Foundations Options for Retaining Wall

It is understood that a retaining structure up to about 1.2 m high is required between the Highway 401 / McCowan Road N-W Ramp and the McCowan Road underpass north abutment. Behind the wall, the approach embankment/abutment foreslope is inclined at 2H:1V upwards away from the top of the wall.

Considering the composition and strength of the soils underlying the proposed retaining structure site, that is, very loose to compact silt to sandy silt, firm to hard clayey silt to silt, stiff to very stiff clayey silt till and compact sandy silt till, the following wall types and reinforced earth options are considered feasible, constructible and appropriate for this site from a geotechnical/foundations perspective; although each type of retaining wall has limitations on the practicality of construction.

- **Concrete Toe Wall:** A concrete toe wall, designed and constructed in accordance with OPSS 3120.100, is geotechnically feasible at this site, provided that it is placed on a minimum 1 m thick compacted OPSS.PROV 1010 (*Aggregates*) Granular 'A' or Granular 'B' Type II levelling pad. Temporary excavations on the order of 1.5 m deep would be required to allow for construction of the levelling pad. A temporary protection system between the toe wall and the existing abutment, and potentially along the existing edge of the N-W Ramp, depending on the proximity of the excavation to the edge of the McCowan Road N-W Ramp during construction staging, may be required to allow construction of the retaining wall. Construction of the temporary protection system would be constrained by the low clearance space to the underside of the underpass.
- **Concrete Retaining Wall on a Shallow Foundation:** A reinforced concrete retaining wall, such as a gravity wall or a cantilever wall supported on a shallow foundation (concrete strip footing), is geotechnically feasible for the proposed retaining structure at this site. Temporary excavations to allow for construction of the strip footing would be required and would require a temporary protection system between the



retaining wall and the existing abutment and, depending on the proximity of the excavation to the edge of the McCowan Road N-W Ramp during construction staging, along the existing edge of the N-W Ramp. Excavations to the recommended founding stratum (below fill and softened materials) would be about 4.5 m deep relative to the ground surface in front of the wall, and may be up to about 5.7 m deep relative to the abutment slope behind the wall. Alternatively, the strip footings can be founded (or perched) within the existing fill deposit on a compacted Granular 'A' pad that is a minimum 0.5 m thick. Construction of the temporary protection system would be constrained by the low clearance space to the underside of the underpass.

- **Reinforced Soil System (RSS) Wall:** An RSS wall is geotechnically feasible for the proposed retaining structure at this site. The excavation for this option would likely be larger than required for a concrete wall founded on a strip footing and would extend closer to the existing abutment piles due to the requirement for construction of the reinforced soil mass, the width of which is typically about 80 per cent of the wall height. As with the concrete retaining wall option, a temporary protection system would likely be required along the north side of the McCowan Road N-W Ramp and along the back face of the reinforced soil mass. Construction of the temporary protection system at the back of the reinforced soil mass would be constrained by the low clearance space to the underside of the underpass.
- **Soldier Pile and Concrete Panel Wall:** A soldier pile and concrete panel wall may be considered for the proposed retaining structure. This type of wall is advantageous in “top-down” construction applications (i.e., as part of a cut as a temporary protection system against the cut slope would not be required). This wall option would minimize the extent of excavation into the existing abutment foreslope as compared to those required for the above two options. In addition, due to the reduced depth of excavation required at the front of the wall, temporary protection systems along the McCowan Road N-W Ramp may not be required. Construction of the deep foundations (pile installation/caisson construction) would be constrained by the low clearance space to the underside of the underpass.
- **Reinforced Earth Slope:** A 1H:1V or steeper inclination reinforced earth slope could be considered if there is sufficient space and provided the wall design can resist the anticipated lateral loads from the existing abutment piles. Excavation for this wall option must still be completed within the zone of the reinforced earth slope, which width is typically about at least 80 per cent of the slope height. This option would therefore still require excavation into the existing abutment foreslope and potentially incorporation of a protection system, as with the concrete retaining wall or RSS wall options discussed above. Further, it may be challenging to establish vegetation on a steepened slope under the existing underpass structure, rendering this option less desirable from an aesthetic perspective.

The feasibility, advantages and disadvantages for the various retaining wall and reinforced earth options are summarized in Table 1 following the text of this report. From a geotechnical/foundations perspective, the use of a concrete toe wall is the preferred option based on minimization of excavation into the existing embankment foreslope, ease of construction and cost. The following sections of this report provide geotechnical recommendations for the feasible options.

## 6.6 Concrete Toe Wall

Based on discussions with WSP, a concrete toe wall is proposed for the northward widening at the McCowan Road underpass. The concrete toe wall should be founded below any topsoil, fill or softened/loosened surficial soils and should be designed and constructed in accordance with OPSD 3120.100 (*Concrete Toe Wall*), where it is noted



that a Type II or Type III wall should be founded on undisturbed soil having a bearing capacity at ultimate limits states of 300 kPa. Based on the subsurface conditions, the minimum bearing capacity will not be achieved if the toe wall is founded on the existing compact granular sand / silt and sand fill. It is recommended that the toe wall be founded on / or a minimum 1 m thick compacted OPSS.PROV 1010 (*Aggregates*) Granular 'A' or Granular 'B' Type II levelling pad that is placed on the native strata, and compacted in accordance with OPSS.PROV 501 (*Compacting*).

## 6.7 Concrete Retaining Wall on a Shallow Foundation

### 6.7.1 Founding Elevations

The strip footing for a concrete retaining wall at this site should be founded at a minimum depth of 1.2 m below the lowest surrounding grade to provide adequate protection against frost penetration as interpreted from OPSS 3090.101 (*Foundation Frost Depths for Southern Ontario*). For support of the concrete retaining wall, the strip footing should be founded below any existing fill and softened, disturbed or loose/firm soils, on the very stiff clayey silt / very stiff clayey silt till, at or below about Elevation 159 m. Alternatively, the strip footing can be founded (or perched) within the existing fill deposit at Elevation 162.0 m or higher, but below the adjacent Highway 401 road grade, on a compacted OPSS.PROV 1010 (*Aggregates*) Granular 'A' pad that is a minimum 0.5 m thick. The Granular 'A' pad should extend at about 1 m beyond the plan limits of the footing and be sloped no steeper than 1H:1V down to competent subgrade. The Granular 'A' pad should be constructed and compacted in accordance with OPSS.PROV 501 (*Compacting*).

The footing subgrade should be inspected by a Foundation Engineer following excavation, in accordance with OPSS 902 (*Excavating and Backfilling Structures*) to check that all existing fill and loose/firm soils and soils containing organics have been removed. Any softened/disturbed or otherwise deleterious areas should be further subexcavated and backfilled with OPSS.PROV 1010 (*Aggregates*) Granular 'A' or Granular 'B' Type II soils, that is placed and compacted in accordance with the requirements of OPSS.PROV 501 (*Compacting*).

The native soils at this site will be susceptible to disturbance on exposure to construction activities and/or ponded water. If the concrete for the retaining wall footing cannot be poured within 4 hours after excavation and inspection, it is recommended that a 100 mm thick concrete working slab be placed on the subgrade after its inspection and approval, to protect the integrity of the subgrade. A Non-Standard Special Provision (NSSP) to address this item is included in Appendix E, and this should be included in the Contract Documents if this wall/foundation type is adopted.

### 6.7.2 Geotechnical Resistances

A strip footing constructed on the properly prepared subgrade, or on an engineered granular pad following subexcavation to or below the elevations given in Section 6.7.1, should be designed based on the factored ultimate geotechnical resistance and factored serviceability geotechnical resistance (for 25 mm of settlement) for a 1 m to 2 m wide footing, given below:

Founding Stratum	Factored Ultimate Geotechnical Resistance (kPa)	Factored Serviceability Geotechnical Resistance (kPa) (for 25 mm of Settlement)
Very stiff clayey silt / very stiff clayey silt till	1000	350



Founding Stratum	Factored Ultimate Geotechnical Resistance (kPa)	Factored Serviceability Geotechnical Resistance (kPa) (for 25 mm of Settlement)
0.5 m (min) thick Compacted Granular 'A' Pad on existing compact gravelly sand fill at Elevation 162.0 m or higher, but below adjacent Highway 401 road grade	650	175

The geotechnical resistances and settlement are dependent on the footing size, configuration and applied load, the geotechnical resistances should, therefore, be reviewed if the selected footing width or founding elevation differ from those given above. In addition, these geotechnical resistances are provided for loads applied perpendicular to the surface of the footings; where applicable, inclination of the load should be taken into account in accordance with Section 6.10.4 of the Canadian Highway Bridge Design Code (*CHBDC 2014*) and its Commentary.

### 6.7.3 Resistance to Lateral Loads

Resistance to lateral forces / sliding resistance between the new concrete footing and the subgrade should be calculated in accordance with Section 6.10.5 of the *CHBDC* (2014). For a cast-in-place concrete footing constructed on the very stiff clayey silt, the coefficient of friction,  $\tan \phi'$ , can be taken as 0.5 and on a Granular A pad can be taken as 0.6, as interpreted from *NAVFAC* (1986). This represents an unfactored value; in accordance with the *CHBDC*, the appropriate consequence factor and degree of site understanding factor from Table 6.1 and 6.2 in the *CHBDC* (2014) are to be applied in calculating the horizontal resistance.

## 6.8 Retained Soil System (RSS) Wall

### 6.8.1 Founding Elevations

A typical RSS wall has a front facing panel system that is supported on a strip footing placed at a shallow depth below the ground surface in front of the wall. The facing footing should be placed within a 500 mm thick levelling pad comprised of OPSS.PROV 1010 Granular 'A', placed in accordance with OPSS.PROV 501 (*Compacting*), as detailed on Figure 5.2 of the *RSS Wall Design Guidelines* (MTO, September 2008).

As detailed on Figure 5.22 of MTO's *RSS Wall Design Guidelines*, it is recommended that the underside of the levelling pad be founded at a minimum depth of 1.0 m below the finished grade at the base of the RSS wall. The minimum soil cover to the base of the wall/top of the footing/levelling pad should be 0.5 m below the finished grade in front of the base of the RSS wall. Prior to placement of the levelling pad and the reinforced soil mass, the existing fill is to be proof-rolled to identify any softened/disturbed areas for sub-excavation and replacement, where applicable, with compacted OPSS.PROV 1010 (*Aggregates*) Granular 'A', placed and compacted in accordance with OPSS.PROV 501 (*Compacting*).

The RSS wall leveling pad/backfill and positioning of the front facing footing should be constructed as indicated on Figure 5.2 of the *RSS Wall Design Guidelines* (MTO, September 2008). Based on the borehole information, it is recommended that the top of the 500 mm thick Granular 'A' levelling pad, the front facing footing and the reinforced soil mass may be founded on the existing compact gravelly sand / silt and sand fill at Elevation 162.5 m or on the native loose silt and sand till / very stiff clayey silt /stiff to very stiff clayey silt till at Elevation 160.5 m. Depending on the final grade of the base of the RSS wall, the levelling pad may need to be installed below this recommended



elevation to achieve the minimum embedment depth of 1.0 m between the underside of the levelling pad and the finished grade and its thickness of 0.5 m.

### 6.8.2 Geotechnical Resistance

Assuming that the RSS wall acts as a unit and uses the full width of the reinforced soil mass (assumed to be a minimum width of 0.8 of the retained height, for a reinforced width of 1.0 m), the proprietary RSS wall design may be based on the factored ultimate geotechnical resistance and factored serviceability geotechnical resistance (25 mm of settlement) given below.

Founding Stratum	Factored Ultimate Geotechnical Resistance (kPa)	Factored Serviceability Geotechnical Resistance (kPa) (for 25 mm of Settlement)
Compact gravelly sand / silt and sand fill	325	Does not govern*
Loose silt and sand till / very stiff clayey silt /stiff to very stiff clayey silt till	600	450

\* The factored serviceability geotechnical resistance at SLS for 25 mm of settlement will be greater than the factored ultimate geotechnical resistance and does not govern.

The geotechnical resistance and settlement are dependent on the footing size, configuration and applied loads, and therefore, the geotechnical resistances should be reviewed if the selected RSS wall footprint and reinforced mass or founding elevation differ from those given above. In addition, these geotechnical resistances are provided for loads applied perpendicular to the surface of the subgrade; where applicable, inclination of the load should be taken into account in accordance with Section 6.10.4 of the *CHBDC* (2014) and its *Commentary*.

### 6.8.3 Resistance to Lateral Loads / Sliding Resistance

Resistance to lateral forces / sliding resistance between the compacted fill mass of the RSS wall and the subgrade should be calculated in accordance with Section 6.10.5 of the *CHBDC*. The coefficient of friction,  $\tan \phi'$ , between the compacted granular fills mass of the RSS wall and the properly prepared subgrade (i.e. proof-rolled existing fill or native soils) may be taken as 0.5. Similarly, the coefficient of friction,  $\tan \phi'$ , between cast-in-place concrete facing footing and underlying granular pad may be taken as 0.6, as interpreted from *NAVFAC* (1986). This represents an unfactored value; in accordance with the *CHBDC*, the appropriate consequence factor and degree of site understanding factor from Table 6.1 and 6.2 in the *CHBDC* (2014) are to be applied in calculating the horizontal resistance.

## 6.9 Soldier Pile and Concrete Panel Wall

A soldier pile and concrete panel wall system may be advantageous at this site, since it would minimize temporary excavation into the existing abutment foreslope compared to the other wall types (i.e., for construction of footings for a concrete cantilever wall, reinforced soil system wall, or a toe wall).

This wall system would consist of soldier piles socketted to sufficient depth to provide the necessary passive resistance for the maximum retained soil height. Caisson construction, including installation of the embedded H-piles, should be carried out consistent with OPSS.PROV 903 (*Deep Foundations*). The upper 1.2 m of soil in front of the soldier piles should be ignored in the calculation of the passive resistance, to account for frost effects. It is recommended that the soldier piles extend to a depth of at least the height of the wall plus the top 1.2 m (i.e., min



2.4 m long below ground surface in front of the wall), or deeper as necessary to satisfy limiting equilibrium requirements. Additional lateral support to the soldier pile and concrete panel wall system could be provided in the form of permanent soil anchors installed at strategic locations along the retaining wall in a manner to not interfere with the existing battered caissons supporting the north abutment of the underpass.

The concrete lagging panels should be installed such that the unsupported height of the existing foreslope fill does not exceed 1.2 m at any time, and the space behind the lagging should be immediately packed with granular material, which will also aid in providing for seepage drainage from behind the wall. If sufficient thickness of free-draining granular soil can not be provided behind the concrete panels to achieve adequate drainage, consideration should be given to using a drainage sheet/mat. An insulation layer could also be provided immediately behind the wall to provide protection from frost penetration, if required.

### 6.9.1 Passive Resistance for Soldier Pile Sockets

The ultimate passive lateral pressure in front of the soldier piles may be assessed using Brom's equation (1964) using the design parameters / values as follows:

- $K_p$  the coefficient of passive earth pressure, which may be taken as 3.0 in the existing fill soils and 3.3 in the native soil deposits at this site. This  $K_p$  value must be reduced by an appropriate factor that considers the allowable wall movement in accordance with Figure C6.16 of CHBDC;
- $\gamma'$  the effective unit weight of the soil in front of the soldier pile socket, which may be taken as 10 kN/m<sup>3</sup> below the groundwater level.

As noted above, the upper 1.2 m of soil in front of the soldier piles should be ignored in the calculation of the passive resistance, to account for disturbance during installation, and for frost effects as interpreted from OPSP 3090.101 (*Frost Penetration Depths for Southern Ontario*).

## 6.10 Reinforced Earth Slope

A proprietary reinforced earth slope with the face slope inclined at 1H:1V, or potentially steeper to fit the available footprint, could be considered if there is sufficient space to reinforce the slope without encroaching on or affecting the existing abutment pile cap/deep foundations supporting the abutment, and if sufficient resistance to lateral loads can be achieved. Prior to placement of the engineered reinforced fill mass, the existing fill subgrade exposed by the widening is to be proof-rolled and the slope is to be benched, as per OPSP 208.010 (*Benching of Earth Slopes*) to key/integrate the reinforced soil mass into the cut slope.

Vegetation cover should be established on the exposed slope face behind the underpass superstructure to protect against surficial erosion, as per OPSS 802 (*Topsoil*), OPSS.PROV 803 (*Sodding*) and/or OPSS.PROV 804 (*Seeding and Cover*), if and where such vegetation is compatible with the selected, proprietary reinforced earth slope system. Appropriate treatment of the steepened slope face under the superstructure will be required to reduce erosion potential on the reinforced slope face, such as by the use of granular sheeting or rip-rap/rock protection as per OPSS 511 (*Rip Rap, Rock Protection and Granular Shheeting*), or concrete facing panels.

## 6.11 Global Stability for Retaining Wall Options

The static global stability of various retaining wall types was assessed using the commercially available program SLIDE 2018, produced by Rocscience Inc., employing the Morgenstern-Price method of analysis. For all analyses, the factor of safety of numerous potential failure surfaces was computed to establish the minimum Factor of Safety (FoS). The FoS is defined as the ratio of the forces tending to resist failure to the driving forces tending to cause



failure. A target minimum factored FoS of 1.54 is adopted for the design (height and geometry) of retaining walls and retained soil under static conditions at the end of construction as per the CHBDC (2014). This FoS is considered adequate for the retaining walls at this site considering the design requirements and the field data available. In general, circular slip surfaces were analysed in the design.

The soil parameters used in the short-term (undrained) and long-term (effective stress) analyses, as given below, were estimated from empirical correlations using the results of in situ Standard Penetration Tests (SPTs) (Bowles, 1984) and geotechnical classification testing. The groundwater table was taken as being at Elevation 159.7 m in the analyses.

Soil Deposit	Bulk Unit Weight (kN/m <sup>3</sup> )	Effective Friction Angle	Undrained Shear Strength (kPa)
New Granular 'A' or Granular 'B' Type II	22	35°	-
New earth fill or SSM	20	30°	-
Existing granular fill	19	32°	-
Existing cohesive fill	20	30°	50
Firm to stiff clayey silt	20	30°	100
Very stiff to hard clayey silt	20	32°	200
Stiff to very stiff clayey silt till	21	34°	150
Compact to very dense silty sand to sand	20	32°	-
Very dense sand and gravel	20	34°	-

### 6.11.1 Concrete Cantilever Retaining Wall

The results of the static global stability analyses indicate a factor of safety greater than 1.54 is achieved for an up to 1.2 m high (exposed face) concrete retaining wall at this site for both short-term and long-term conditions.

### 6.11.2 RSS Wall

The results of the static global stability analyses indicate that a minimum factor of safety greater than 1.54 is achieved for both short- and long-term conditions for an RSS wall of up to approximately 1.2 m high (H).

The internal stability of the RSS wall is to be assessed by the proprietary product designer. Extending the reinforcement zone beyond the minimum length identified above may be required to ensure internal stability, however if a wider reinforced zone (longer reinforcing strips) is required, the suitability of such a wall for this site must be re-assessed with due consideration to negative impacts on the north abutment deep foundations (pile cap and piles).



### 6.11.3 Soldier Pile and Concrete Panel Wall

The results of the static global stability analyses indicate a minimum factor of safety greater than 1.54 is achieved for an up to 1.2 m high (exposed face) soldier pile and concrete panel retaining wall at this site for both the short-term and long-term conditions provided the soldier pile embedment length is consistent with the minimum length recommended in Section 6.9.

### 6.11.4 Reinforced Earth Slope

The results of the static global stability analysis indicate that a factor of safety greater than 1.54 is achieved against deep-seated instability for both short- and long-term conditions for a 1H:1V reinforced earth slope up to approximately 1.2 m high. This analysis assumes the reinforcing strips have a minimum width of 1.0 times the slope height (1.0H), and that the reinforced soil mass has been designed by the proprietary designer to avoid failure through/within the reinforced soil mass.

## 6.12 Lateral Earth Pressures for Design of Retaining Walls

The lateral earth pressures acting on the retaining wall will depend on the type and method of placement of the backfill materials, the nature of the soils behind the backfill, the magnitude of surcharge including loads transferred to the wall from the existing abutment piles, construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the wall. Seismic (earthquake) loading must also be taken into account in the design. The following recommendations are made concerning the design of the retaining walls:

- Free-draining granular fill meeting the specifications of OPSS.PROV 1010 (*Aggregates*) Granular 'A' or Granular 'B' Type II, should be used as backfill behind the walls or wall facing. Longitudinal drains or weep holes should be installed to provide positive drainage of the granular backfill or reinforced soil mass as may be specified by the proprietary wall designer. Compaction (including type of equipment, target densities, etc.) should be carried out in accordance with OPSS.PROV 501 (*Compaction*). Other aspects of the granular backfill requirements with respect to subdrains and frost taper should be in accordance with OPSS 3121.150 (*Walls, Retaining, Backfill, Minimum Granular Requirement*), and OPSS 3190.100 (*Walls, Retaining and Abutment, Wall Drain*).
- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the wall, in accordance with CHBDC (2014) Section 6.12.3 and Figure 6.6. Hand operated compaction equipment should be used to compact the backfill soils immediately behind the wall as per OPSS.PROV 501 (*Compaction*). Other surcharge loadings should be accounted for in the design, as required.
- For restrained walls, granular fill should be placed in a zone with the width equal to at least 1.2 m behind the back of the wall, per Figure C6.20(a) of the *Commentary* to the CHBDC (2014). For unrestrained walls, fill should be placed within the wedge-shaped zone defined by a line flatter than 1 horizontal to 1 vertical (1H:1V) extending up and back from the rear face of the footing, per Figure C6.20(b) of the *Commentary* to the CHBDC (2014).
- Where space is restricted and the walls are constructed in a top-down fashion, with a thin or absent zone of granular backfill behind the wall (i.e., soldier pile and concrete panel), it is recommended that drainage measures (e.g., pre-fabricated sheets) be incorporated on the back of the wall, before or concurrent with the panel installation, to promote drainage and minimize the risk of frost action during freezing temperatures. The wall system and facing should also incorporate subdrains and weep holes at intervals through the wall face.



### 6.12.1 Static Lateral Earth Pressures for Design

The following guidelines and recommendations are provided regarding the lateral earth pressures for static (i.e., not earthquake) loading conditions. These lateral earth pressures assume that the ground above the wall will be flat, not sloping. The coefficients of static lateral earth pressure must be adjusted to take account of the slope above the wall.

- For an unrestrained wall, the pressures are based on the granular fill in the backfill zone, and the following parameters (unfactored) may be used:

Fill Type	Unit Weight of Material	Coefficients of Static Lateral Earth Pressure	
		At-Rest, $K_o$	Active, $K_a$
Granular 'A'	22 kN/m <sup>3</sup>	0.43	0.27
Granular 'B' Type II	21 kN/m <sup>3</sup>	0.43	0.27

- For a soldier pile and concrete panel wall, or for a restrained wall, the pressures are based on the existing abutment foreslope fill, and the following parameters (unfactored) may be used assuming the presence of earth fill:

Fill Type	Unit Weight of Material	Coefficients of Static Lateral Earth Pressure	
		At-Rest, $K_o$	Active, $K_a$
Earth Fill	20 kN/m <sup>3</sup>	0.50	0.33

- If the retaining wall structure allows for lateral yielding, active earth pressures should be used in the geotechnical design. The movement required to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure for design, should be calculated in accordance with Section C6.12.1 and Table C6.6 of the *Commentary to the CHBDC* (2014).
- If the retaining wall structure does not allow lateral yielding (i.e., restrained structure where the rotational or horizontal movement is not sufficient to mobilize and active earth pressure condition), at-rest earth pressures (plus any compaction surcharge) should be assumed for geotechnical design.

### 6.12.2 Seismic Lateral Earth Pressures for Design

Seismic (earthquake) loading must also be taken into account in the design of retaining wall in accordance with Section 4.6.5 of the *CHBDC* (2014). In this regard, the following should be included in the assessment of lateral earth pressures:

- Seismic loading will result in increased lateral earth pressures acting on the retaining wall. The wall should be designed to withstand the combined lateral loading for the appropriate static pressure conditions given above, plus the earthquake induced dynamic earth pressure.
- In accordance with Sections 4.6.5 and C.4.6.5 of the *CHBDC* (2014) and its *Commentary*, for structures that allow lateral yielding, the horizontal seismic coefficient,  $k_h$ , used in the calculation of the seismic active pressure coefficient, is taken as 0.5 times the site-specific PGA. For structures that do not allow lateral yielding,  $k_h$  is



taken as equal to the site-specific PGA. For both cases the value of the vertical seismic coefficient  $k_v$  is taken as zero.

- The following seismic active pressure coefficients ( $K_{AE}$ ) may be used in design; these coefficients reflect the maximum  $K_{AE}$  obtained for each of the earthquake design periods and backfill conditions. It should be noted that these seismic earth pressure coefficients assume that the back of the wall is vertical and the ground surface behind the wall is level. Where sloping backfill is present above the top of the wall, the lateral earth pressures under seismic loading conditions should be calculated by treating the weight of the backfill located above the top of the wall as a surcharge.

Wall Type	Design Earthquake	Site PGA	Seismic Active Pressure Coefficients, $K_{AE}$		
			Granular A	Granular B Type II	Earth Fill/SSM
Yielding Wall (unrestrained)	475-Yr	0.041g	0.26	0.26	0.31
	975-Yr	0.072g	0.27	0.27	0.32
	2,475 Yr	0.136g	0.29	0.29	0.34
Non-Yielding Wall (restrained)	475-Yr	0.041g	0.27	0.27	0.33
	975-Yr	0.072g	0.29	0.29	0.35
	2,475 Yr	0.136g	0.33	0.33	0.40

- The  $K_{AE}$  value for a yielding wall is applicable provided that the wall can move up to  $250k_h$  (measured in mm), where  $k_h$  is the site-specific PGA as given above. This corresponds to displacements of 10 mm, 18 mm and 34 mm for the 475-year, 975-year and 2,475-year design earthquakes at this site.
- The earthquake-induced dynamic pressure distribution, which is to be added to the static earth pressure distribution, is a linear distribution with maximum pressure at the top of the wall and minimum pressure at its toe (i.e. an inverted triangular pressure distribution). The total pressure distribution (static plus seismic) may be determined per Section C4.6.5 of the *Commentary to CHBDC* (2014).

## 6.13 Corrosion Assessment and Protection

The results of analytical testing on one soil sample from Borehole MRU-01, advanced near the alignment of the proposed retaining wall are summarized in Section 4.4 and the analytical laboratory test report is included in Appendix D. The analytical test results were compared to CSA A23.1 Table 3 (*Additional requirements for concrete subjected to sulphate attack*) for potential sulphate attack on concrete. The sulphate concentration measured in the tested sample (<0.002%) is below the exposure class of S-3 (Moderate). Therefore, when the designer is selecting the exposure class for the structure, the effects of sulphates may not need to be considered.

The analytical test results of the soil sample were also compared to the MTO Gravity Pipe Design Guidelines (2014) for the potential attack on buried steel the pH is not considered detrimental to the steel durability. The resistivity measured in the tested soil sample (i.e., 330 ohm-cm) indicates “severe corrosiveness” potential. Based on the results of the sample tested, and given that the structure will be exposed to de-icing salt, consideration should be given by the designer to designing for a “C” type exposure class as defined by CSA A23.1 Table 1.



It is ultimately up to the structural designer to determine the appropriate exposure class and to ensure that all aspects of CSA A23.1 Section 4.1.1 “Durability Requirements” are followed.

## 6.14 Construction Considerations

### 6.14.1 Open Cut Excavation

Open-cut excavations must be carried out in accordance with the guidelines outlined in the Ontario Occupational Health and Safety Act (OHSA) for Construction Activities. The excavations for a concrete retaining wall on a strip footing, RSS wall, or reinforced earth slope construction will extend through existing fill and may encounter zones of water-bearing non-cohesive fill or groundwater that is ‘perched’ within the fill overlying the native cohesive deposits. The existing fill materials are classified as Type 3 soil, and the native soil deposits encountered in the boreholes are classified as Type 2 soil above the water table and Type 3 soils below the water table, according to the soil types defined by OHSA. If and where space permits, temporary excavations (i.e. those which are open for a relatively short time period) should be made with side slopes no steeper than 1H:1V. Where insufficient space is available, and to protect both the workers and the travelled lanes of the Highway and ramps during construction staging, it is anticipated that a temporary protection system will be required.

### 6.14.2 Temporary Excavation Support

Temporary excavation support is likely required to facilitate construction if a concrete retaining wall on a strip footing, RSS wall, or reinforced earth slope is selected for construction in order to maintain traffic on the McCowan Road N-W Ramp and to maintain the integrity of the existing north abutment foundation. The temporary excavation support systems should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*). The lateral movement of the temporary shoring system should meet performance levels discussed in Section 6.4, provided that the existing structure, as well as any adjacent utilities, can tolerate the magnitude of deformation anticipated.

It is considered that either a driven, interlocking sheetpile system or a soldier pile and timber lagging system would be suitable for the temporary excavation support at this site, based on the inferred subsurface soil conditions and groundwater conditions. An interlocking sheetpile system would contribute to both ground and, where applicable, groundwater control should seepage from groundwater perched within the non-cohesive fill occur. For a soldier pile and lagging system, it would be necessary to control seepage and also to include measures to mitigate loss of soil particles through the lagging boards in the event that soils containing perched groundwater are encountered.

High SPT “N” values (greater than 30 blows per 0.3 m of penetration), were measured within both the fill material and the native soil deposits at this site. While the installation of driven sheet piles is feasible in the less stiff/dense materials, some challenges would be encountered where harder/denser soils are present. As a result, the contractor may elect to use a soldier pile and lagging system. Both types of systems could be affected by the presence of cobbles within the glacially derived soils at the site, although a soldier pile system would have a lower risk of being negatively impacted as compared with a driven sheet pile option.

The sheet piles or soldier piles will need to extend/be socketed to a sufficient depth to provide the necessary passive resistance for the retained soil height, plus any surcharge and traffic loads behind the protection system. Lateral support to the sheet pile wall or soldier pile wall could be provided in the form of rakers or temporary anchors, if and as required.

Consideration should be given to either partial or full removal of the protection system upon completion of construction. Where possible, full removal of the protection system should be considered and is recommended at



this site to mitigate potential impediments to future rehabilitation/reconstruction work on the highway surface or north bridge abutment. An NSSP is included in Appendix E which addressed the fill removal or cut-off of the temporary protection system.

### 6.14.3 Vibration Monitoring

Residential properties are located about 400 m away from the proposed retaining wall alignment and the existing McCowan Road underpass structure foundations are located immediately adjacent to the proposed wall alignment. The use of vibratory equipment for installation of a protection system or deep foundation should be minimized where possible, and vibration monitoring of the existing bridge foundations and residences within a zone of influence of 200 m should be considered.

The monitoring program (i.e. types of instruments, frequency of monitoring and review/alert levels) for the existing bridge structure should be developed by the structural engineering team.

Vibration levels less than a maximum peak particle velocity (PPV) of 50 mm/s are generally considered applicable for buildings/structures in good condition. An NSSP for vibration monitoring is included in Appendix E.

### 6.14.4 Groundwater Control

The groundwater level measured in the standpipe piezometer installed across the interface of clayey silt deposit and underlying silty sand deposit in Borehole MRU-01 is about 4.0 m below the ground surface, corresponding to about Elevation 159.7 m.

Excavations are expected to be maintained above the groundwater level, with minimal groundwater inflow from perched groundwater above or within the non-cohesive fill and native deposits. It is anticipated that such seepage can be handled by pumping from filtered sump pumps placed at the base of the excavation and outside of the retaining wall foundation footprint. Dewatering should be carried out in accordance with OPSS.PROV 517 (*Dewatering*) as referenced in OPSS 902 (*Excavating and Backfilling Structures*) as amended by SP FOUN0003; a copy of which is provided in Appendix E. It is noted that the designer will need to fill in the data for “return period” in this SP.

In addition, surface water seepage into the excavations should be expected and will be heavier during periods of sustained precipitation and all surface water should be directed away from the excavations.

### 6.14.5 Obstructions During Installation of Temporary Protection Systems

Although not encountered during the previous and current investigations at this site, cobbles and/or boulders may be encountered within the glacially derived soils at this site, which may affect the installation of protection system elements. It is recommended that an NSSP be included in the Contract Documents to warn the Contractor of the possible presence of cobbles and/or boulders within the overburden soils; an NSSP is provided in Appendix E.

### 6.14.6 Subgrade Protection

The subgrade soils will be susceptible to disturbance from construction traffic and/or ponded water. To limit this degradation where a concrete retaining wall or RSS wall are adopted, it is recommended that a concrete working slab be placed on the subgrade within four hours after preparation, inspection and approval of the footing subgrade for the retaining wall if the footing(s) is not constructed within this time period. This requirement can be addressed with a note on the General Arrangement drawing and/or with an NSSP. A sample NSSP for the working slab is included in Appendix E.



## 7.0 CLOSURE

This Foundation Design Report was prepared by Ms. Nikol Kochmanová, P.Eng., a geotechnical engineer with Golder. Mr. Jorge Costa, P.Eng., an MTO Foundations Designated Contact and Senior Consultant of Golder, conducted an independent technical and quality control review of the report.

### Golder Associates Ltd.



Nikol Kochmanová, Ph.D., P.Eng., PMP  
*Geotechnical Engineer*



Jorge M.A. Costa, P.Eng.  
*MTO Foundations Designated Contact, Senior Consultant*

NK/JMAC/rb

Golder and the G logo are trademarks of Golder Associates Corporation

<https://golderassociates.sharepoint.com/sites/16003g/6. deliverables/8. mccowan road/3. final/1669995 fidr08 2018dec17 hwy 401wb mccowan rd underpass.docx>



## REFERENCES

Bowles, J.E., 1984. *Physical and Geotechnical Properties of Soils*, Second Edition. McGraw Hill Book Company, New York.

Broms, B. B., 1964. *Lateral Resistance of Piles in Cohesive Soils*, Journal of the Soil Mechanics and Foundation Division, American Society of Civil Engineers, Vol 89, No. SM2, March 1964, pp 27-63. 9.

Broms, B. B., 1964. *Lateral Resistance of Piles in Cohesionless Soils*, Journal of the Soil Mechanics and Foundation Division, American Society of Civil Engineers, Vol 89, No. SM3, May 1964, pp 123-157.

Canadian Geotechnical Society. 2006. *Canadian Foundation Engineering Manual (CFEM)*, 4th Edition. The Canadian Geotechnical Society, BiTech Publisher Ltd., British Columbia.

Canadian Standards Association (CSA). 2014. *Canadian Highway Bridge Design Code and Commentary on CAN/CSA-S6-14*. CSA Special Publication.

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

CSA Group. 2014. A23.1-14/A23.2-14 - Concrete materials and methods of concrete construction / Test methods and standard practices for concrete.

National Resources Canada, 2017. *Earthquake Hazard*. [http://www.earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/index\\_2015-en.php](http://www.earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/index_2015-en.php). Accessed on July 18, 2018.

Unified Facilities Criteria, U.S. Navy. 1986. *NAVFAC Design Manual 7.02. Soil Mechanics, Foundation and Earth Structures*. Alexandria, Virginia.

### ASTM International:

ASTM D1586      Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

### Commercial Software:

Slide (Version 2018) by Rocscience Inc.

### Ontario Provisional Standard Drawing:

OPSD 208.010      Benching of Earth Slopes  
 OPSD 3090.101      Foundation Frost Penetration Depths for Southern Ontario  
 OPSD 3120.100      Walls Retaining, Concrete Toe Wall  
 OPSD 3121.150      Walls, Retaining, Backfill, Minimum Granular Requirements  
 OPSD 3190.100      Walls, Retaining and Abutment, Wall Drain

### Ontario Provincial Standard Specification:

OPSS.PROV 501      Construction Specifications for Compacting  
 OPSS 511              Construction Specification for Rip-Rap, Rock Protection, and Granular Sheetting  
 OPSS.PROV 517      Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation



---

OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS 802	Construction Specification for Topsoil
OPSS.PROV 803	Construction Specification for Sodding
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS 902	Construction Specification for Excavating and Backfilling - Structures
OPSS.PROV 903	Construction Specification for Deep Foundations
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

**Special Provisions**

Dewatering Structure Excavations (Special Provision No. FOUN0003)

**Ontario Water Resources Act:**

Ontario Regulation 903 Wells (as amended)

**Ontario Occupational Health and Safety Act:**

Ontario Regulation 213/91 Construction Projects (as amended)

**Ministry of Transportation, Ontario**

*RSS Design Guidelines*, Ministry of Transportation Engineering Standards Branch, September 2008

*Gravity Pipe Design Guideline*. Drainage and Hydrology Design and Contract Standards Office, 2014.



TABLE 1 – COMPARISON OF RETAINED SOIL SYSTEMS– McCOWAN ROAD UNDERPASS WIDENING

Foundation Option (in order of preference from a Foundations perspective)	Feasibility	Advantages	Disadvantages	Constructability	Estimated Costs
Concrete Toe Wall	<ul style="list-style-type: none"><li>• Feasible provided that the lateral resistance of the concrete toe wall is adequate to satisfy the lateral earth pressures exerted by the existing abutment piles and the approach embankment fill.</li></ul>	<ul style="list-style-type: none"><li>• Conventional excavation and construction techniques and equipment.</li><li>• Potentially shallower excavation as compared with concrete retaining wall option, comparable to RSS wall</li><li>• Can use pre-cast sections to expedite the construction.</li><li>• Standard OPSD design.</li></ul>	<ul style="list-style-type: none"><li>• Excavation of the existing fill and upper layer of native material subgrade to a competent level is required to achieve the required geotechnical resistance.</li><li>• Temporary protection systems are required during construction.</li><li>• Likely will require use of small compaction equipment and therefore high level of compaction effort to achieve designer's compaction requirements of the Granular Pad.</li><li>• Potential for deformations due to settlement and frost penetration effects over the long-term - may not meet desired aesthetic requirements.</li></ul>	<ul style="list-style-type: none"><li>• Conventional construction methods.</li><li>• Can use pre-cast sections.</li></ul>	<ul style="list-style-type: none"><li>• Lower cost than concrete retaining wall and RSS wall.</li></ul>
RSS Wall	<ul style="list-style-type: none"><li>• Feasible provided sufficient space is available to accommodate construction of reinforced soil mass and/or for temporary protection systems if required.</li></ul>	<ul style="list-style-type: none"><li>• More tolerable to post-construction settlements than other more rigid retaining walls.</li><li>• Suitable founding stratum present on/below existing fill.</li><li>• Potentially shallower excavation as compared with concrete retaining wall option.</li><li>• Smaller-sized construction equipment can be used in low headroom area.</li></ul>	<ul style="list-style-type: none"><li>• Larger excavation area (approx. 1 m to 2 m) required to accommodate reinforced soil mass than for soldier pile and concrete panel wall and concrete cantilever wall.</li><li>• Excavation through the existing abutment foreslope may encroach on or may interfere with existing abutment foundations (pile cap).</li><li>• Temporary protection systems will likely be required along the McCowan Road N-W Ramp and will be required between the retaining wall and north abutment foundations to prevent loss of soil from under pile cap and front of battered piles, unless structural designers can confirm there is no adverse impact to lateral capacities of piles, and/or the wall construction is completed in segments of limited length.</li><li>• Likely will require use of small compaction equipment and therefore high level of compaction effort to achieve designer's compaction requirements of the reinforced soil mass.</li></ul>	<ul style="list-style-type: none"><li>• Specialized design and construction methods required.</li><li>• Requires concrete panels or rip-rap/granular sheeting protection on exposed portion of slope under the superstructure.</li></ul>	<ul style="list-style-type: none"><li>• Lower cost than concrete retaining wall.</li></ul>

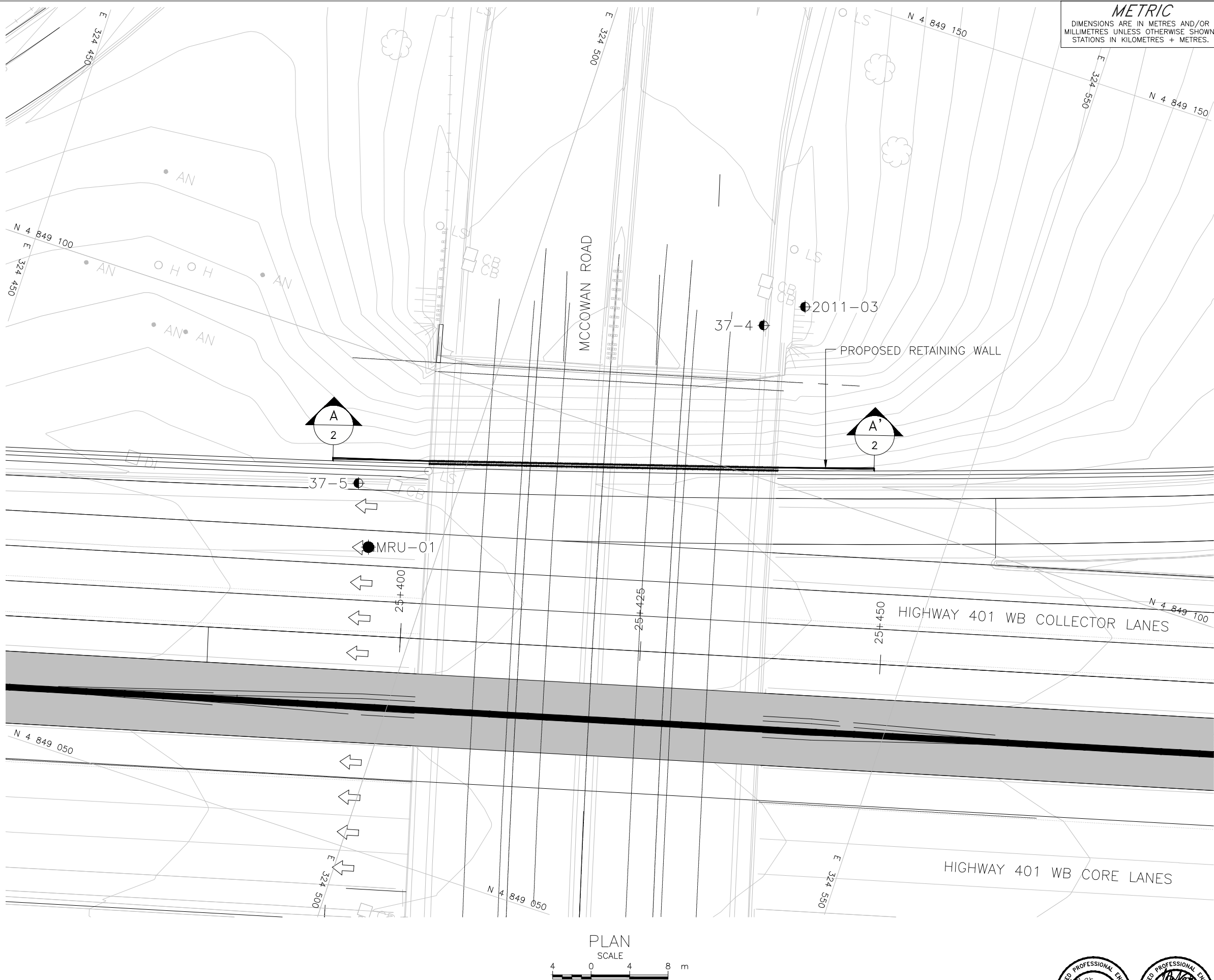


Foundation Option (in order of preference from a Foundations perspective)	Feasibility	Advantages	Disadvantages	Constructability	Estimated Costs
Reinforced Earth Slope	<ul style="list-style-type: none"><li>• Feasible provided sufficient space is available to allow construction of reinforced soil mass and/or for temporary protection systems if required.</li><li>• May require smaller excavation footprint than strip footing and RSS wall options.</li></ul>	<ul style="list-style-type: none"><li>• More tolerable of post-construction settlement than other more rigid retaining walls.</li><li>• Relative ease of construction but proprietary product required.</li><li>• Vegetated surfaces on exposed slopes beyond the superstructure could be used to improve aesthetics.</li><li>• Lowest cost alternative.</li><li>• Smaller equipment can be used in low headroom area.</li></ul>	<ul style="list-style-type: none"><li>• Large excavation area may be required to accommodate reinforced mass, similar to RSS wall, but the lower portions of excavation may not encroach towards the existing abutments as much as other wall alternatives.</li><li>• Proprietary product design; construction footprint dictated by supplier/designer.</li><li>• Special treatment of reinforced earth slope surface under superstructure required as vegetation growth is not possible under the underpass.</li><li>• Space constraints and requirements for temporary protection systems to support loads from abutment battered piles and prevent loss of soil from under pile cap may not permit reinforced earth slope construction, unless structural designers can confirm there is no adverse impact to lateral capacities of piles, and/or the wall construction is completed in segments of limited length.</li></ul>	<ul style="list-style-type: none"><li>• Relative ease of construction but proprietary product required, with specialized design of internal stability of proprietary system.</li><li>• Requires concrete panels or rip-rap/granular sheeting protection on exposed portion of slope under the superstructure as well as for the exposed front face of the reinforced slope.</li></ul>	<ul style="list-style-type: none"><li>• Lower cost than RSS wall</li></ul>
Soldier pile and concrete panel wall	<ul style="list-style-type: none"><li>• Feasible, may require permanent soil anchors.</li></ul>	<ul style="list-style-type: none"><li>• Can be constructed “top down” as excavation continues, i.e. no over excavation adjacent to abutment foundations required.</li><li>• No temporary protection system required for the highway or abutment foreslope; but requires temporary liners to mitigate potential loss of soil into the socket and loss of support on the abutment foundations (pile cap/caisson).</li><li>• Can be constructed in sections in slots cut into abutment foreslope, allowing for phased installation of caisson sockets, piles and wall lagging.</li><li>• Lowest risk of impacts to existing bridge foundations.</li></ul>	<ul style="list-style-type: none"><li>• Height restrictions below superstructure would require specialized equipment to pre-drill caisson holes and install steel H-piles in short lengths – requires splicing of pile sections.</li><li>• Would require splicing of short lengths of soldier piles to be able to fit piles under existing superstructure.</li><li>• Soldier piles would need to be installed in pre-drilled caisson holes (sockets)to penetrate the very dense zones of the native soil deposits.</li><li>• Lateral support (soil anchors) may be required - space limitations and presence of existing abutment piles will require specific knowledge of pile locations to allow for appropriate design/ use of conventional soil anchors.</li><li>• Drainage and frost protection must be incorporated behind the wall.</li><li>• Concrete facing units must be cast to meet desired aesthetic requirements.</li></ul>	<ul style="list-style-type: none"><li>• Conventional excavation but utilizing small size/specialized equipment and more time-consuming construction techniques for caisson hole advancement and soldier pile splicing and installation in low headroom.</li></ul>	<ul style="list-style-type: none"><li>• Higher costs compared to concrete retaining wall and RSS wall.</li></ul>



Foundation Option (in order of preference from a Foundations perspective)	Feasibility	Advantages	Disadvantages	Constructability	Estimated Costs
Concrete Cantilever Wall on Shallow Foundation (strip footing)	<ul style="list-style-type: none"><li>• Feasible provided sufficient space is available for footing construction and/or for temporary protection system(s) if required.</li><li>• Position wall on the footing as much as possible towards Highway 401 (“reverse configuration”) to minimize extent of excavation into abutment foreslope.</li></ul>	<ul style="list-style-type: none"><li>• Conventional excavation and construction techniques and equipment, unless temporary protection systems are required to be installed in low headroom.</li><li>• Suitable founding stratum present below existing fill deposits.</li><li>• Can be constructed in sections in slots cut into foreslope, to minimize temporary protection system requirements.</li></ul>	<ul style="list-style-type: none"><li>• Less tolerable to post-construction settlements, although this is not anticipated to be an issue at this site.</li><li>• Will require excavation to depths between about 4.5 m and 5.7 m through the existing abutment foreslope fill.</li><li>• Temporary protection systems will likely be required along the McCowan Road N-W Ramp and between the retaining wall and north abutment foundations, unless a strip approach can be adopted. Temporary protection systems will have to be installed in low headroom.</li></ul>	<ul style="list-style-type: none"><li>• Conventional excavation and construction techniques, except for temporary protection systems.</li><li>• Temporary protection system required to prevent loss of soil from under/in front of pile cap and battered piles, and design must consider loads from existing abutment piles/bottom of pile cap at about the same level as the top of the retaining wall; pile cap located about 5.5 m from retaining wall location.</li></ul>	<ul style="list-style-type: none"><li>• Higher cost relative to RSS wall</li></ul>





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

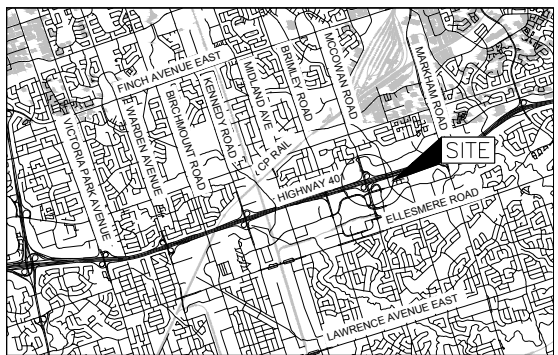
CONT No. .  
GWP No. 2162-11-00



MCCOWAN ROAD UNDERPASS  
HIGHWAY 401 WESTBOUND CORE AND COLLECTORS

SHEET

BOREHOLE LOCATIONS



KEY PLAN  
SCALE

LEGEND

- Borehole - Current Investigation
- Borehole - 1967 and 2011 Investigations (GEOCRE No. 30M14-37 and 30M14-340)

BOREHOLE CO-ORDINATES (MTM NAD 83 ZONE 10)

No.	ELEVATION	NORTHING	EASTING
37-4	168.6	4849115.2	324524.8
37-5	162.3	4849086.4	324489.9
2011-03	169.5	4849118.4	324528.3
MRU-01	163.7	4849080.4	324493.0

NOTES

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

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

REFERENCE

Base plan provided in digital format by WSP, drawings files no. H17M-01449-00\_XA01.dwg, No.H17M-01449-00\_XB01.dwg and H17M-01449-00\_XY01.dwg, received October 26, 2017.  
Design Layout provided in digital format by WSP, drawing file no. H17M-01449-00\_XN01.dwg, received November 28, 2017.  
General Arrangement provided in digital format by WSP, drawing file no. S17M-01449-00-308-001GA.dwg, received June 5, 2018.  
Existing ground provided in digital format by WSP, drawing file no. Contours Sept. 12, 2019.dwg, received September 12, 2018.

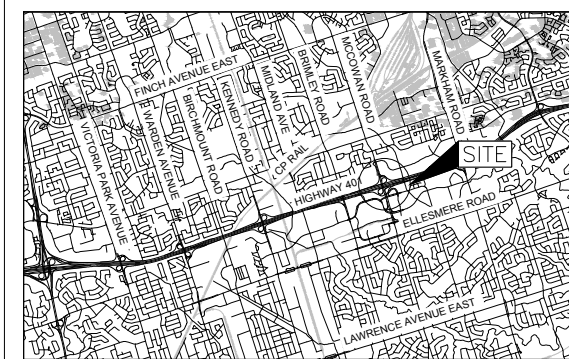


NO.	DATE	BY	REVISION
Geocres No. 30M14-483			
HWY. 401	PROJECT NO. 1669995	DIST. .	
SUBM'D. NK	CHKD. .	DATE: 12/14/2018	SITE: 37-217
DRAWN: DD	CHKD. NK	APPD. JMAC	DWG. 1



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

CONT No. GWP No. 2162-11-00	SHEET
MCCOWAN ROAD UNDERPASS HIGHWAY 401 WESTBOUND CORE AND COLLECTORS	
SOIL STRATA	



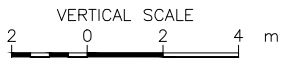
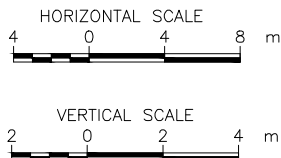
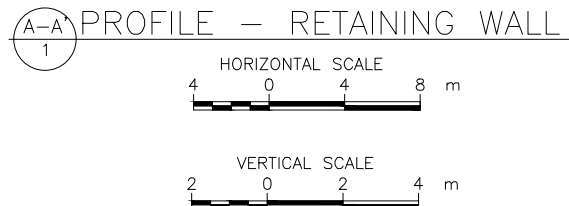
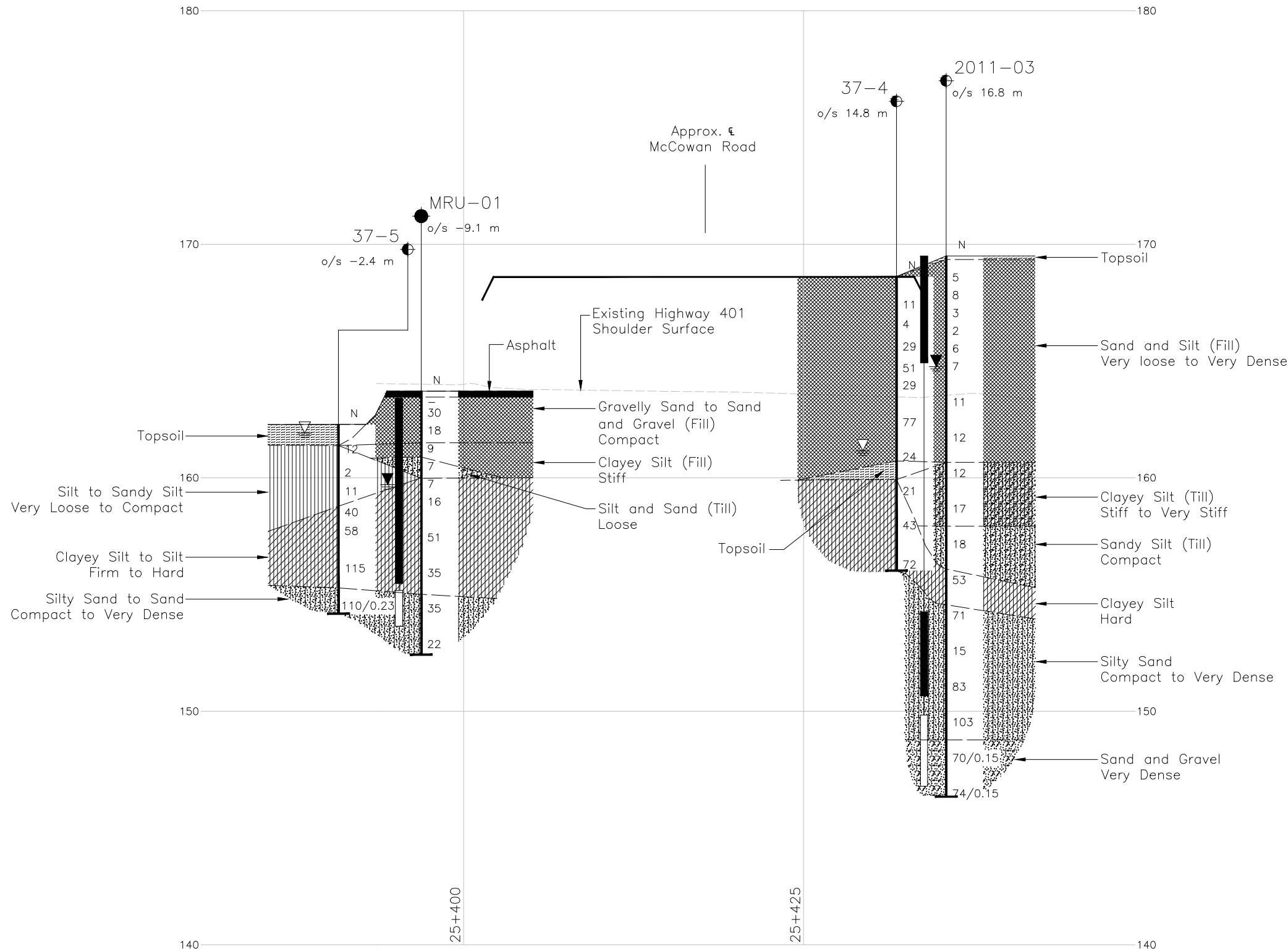
LEGEND	
	Borehole - Current Investigation
	Borehole - 1967 and 2011 Investigations (GEOCRE No. 30M14-37 and 30M14-340)
	Seal
	Piezometer
	Standard Penetration Test Value
	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
	WL in piezometer (April 21, 2011 or June 30, 2018)
	WL upon completion of drilling

BOREHOLE CO-ORDINATES (MTM NAD 83 ZONE 10)			
No.	ELEVATION	NORTHING	EASTING
37-4	168.6	4849115.2	324524.8
37-5	162.3	4849086.4	324489.9
2011-03	169.5	4849118.4	324528.3
MRU-01	163.7	4849080.4	324493.0

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

REFERENCE	
Base plan provided in digital format by WSP, drawings files no. H17M-01449-00_XA01.dwg, No.H17M-01449-00_XB01.dwg and H17M-01449-00_XY01.dwg, received October 26, 2017. Design Layout provided in digital format by WSP, drawing file no. H17M-01449-00_XN01.dwg, received November 28, 2017. General Arrangement provided in digital format by WSP, drawing file no. S17M-01449-00-308-001GA.dwg, received June 5, 2018. Existing ground provided in digital format by WSP, drawing file no. Contours Sept. 12, 2019.dwg, received September 12, 2018.	

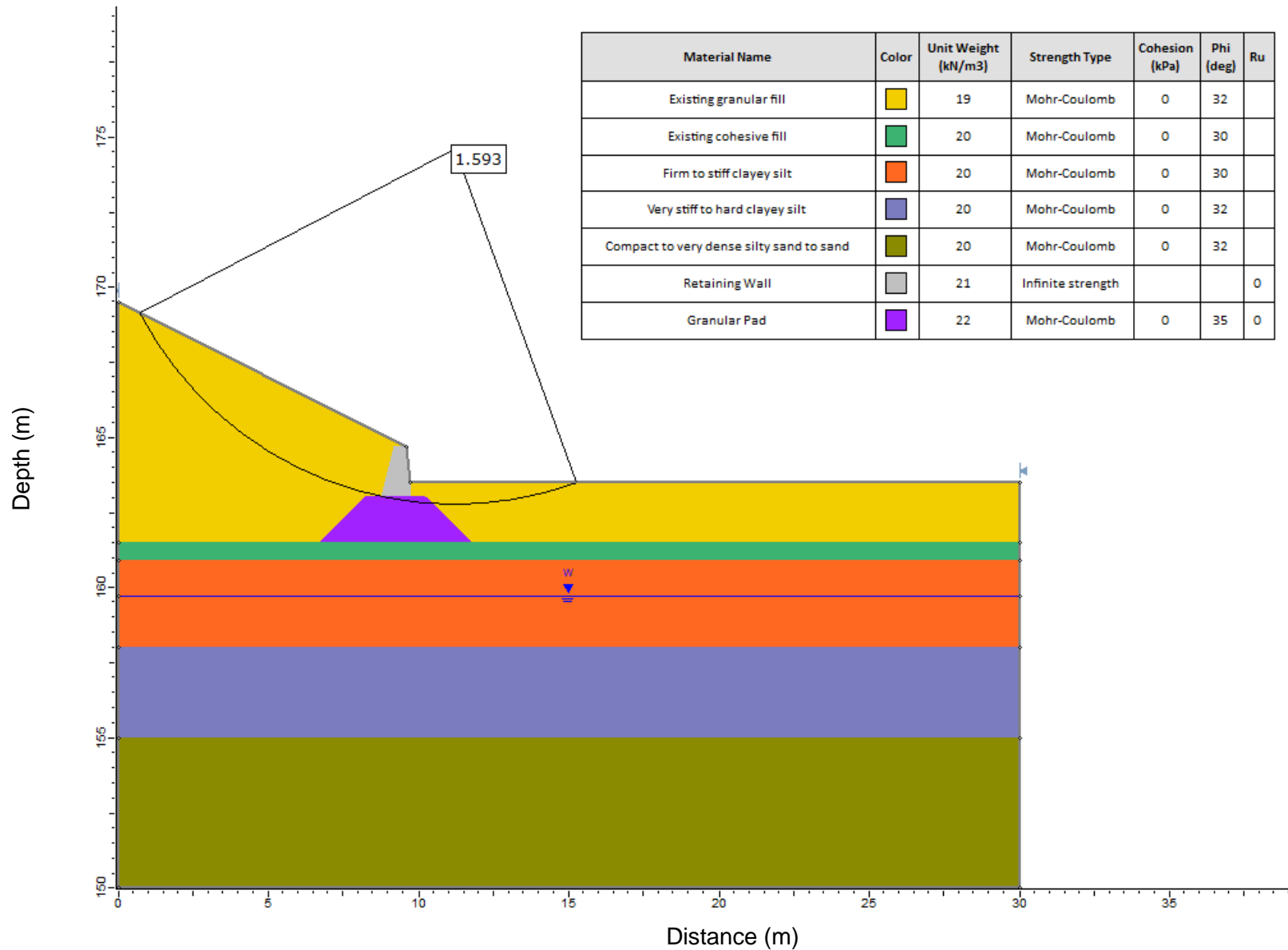
NO.	DATE	BY	REVISION
Geocres No. 30M14-483			
HWY. 401	PROJECT NO. 1669995	DIST. .	
SUBM'D. NK	CHKD. .	DATE: 12/14/2018	SITE: 37-217
DRAWN: DD	CHKD. NK	APPD. JMAC	DWG. 2





# Static Slope Stability Analysis – Proposed Retaining Wall

Figure 1





**APPENDIX A**

**Borehole Records from 1967 and  
2011 Investigations (GEOCRES  
Nos. 30M14-37 and 30M14-340)**



BH 37-4.

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS &amp; TESTING DIVISION

## RECORD OF BOREHOLE NO. 4

FOUNDATION SECTION

JOB 67-P-41

LOCATION 60,853 N; 97,537 E.

ORIGINATED BY AMS

W.P. 252-61-8

BORING DATE May 26, 1967

COMPILED BY AMS

DATUM Geodetic

BOREHOLE TYPE Cont. Flight Auger

CHECKED BY

## SOIL PROFILE

## SAMPLES

DYNAMIC PENETRATION RESISTANCE  
BLOWS / FOOTLIQUID LIMIT — WL  
PLASTIC LIMIT — WP  
WATER CONTENT — W

SHEAR STRENGTH P.S.F.

WP — WL  
10 20 30

WATER CONTENT %

BULK  
DENSITY  
Y

P.C.F.

REMARKS

ELEV.  
DEPTH

DESCRIPTION

STRAT. PLOT

NUMBER

TYPE

BLOWS / FOOT

ELEV. SCALE

553.2

GROUND LEVEL

0.0

Fine sandy silt  
with traces of  
clay and gravel.Loose to very  
dense.

1 SS 11

2 SS 4

3 SS 29

4 SS 51

5 SS 29

6 SS 77

7 SS 24

8 SS 21

9 SS 43

10 SS 72

550

540

530

520

9 4047 4

5 4447 4

528.7

Topsoil

28.5

Clayey silt to  
silt, traces of  
sand and gravel.Very stiff to  
hard/

511.7

End of Borehole



BA 37-5

FOUNDATION SECTION

CHECKED BY                     

[illegible]



PROJECT <u>09-1111-6055</u>		<b>RECORD OF BOREHOLE No 2011-03</b>		SHEET 1 OF <b>2METRIC</b>	
G.W.P. <u>07-20012</u>		LOCATION <u>N 4849118.4 ; E 324528.3</u>		ORIGINATED BY <u>SB</u>	
DIST <u>Central</u> HWY <u>401</u>		BOREHOLE TYPE <u>CME 55 Track-mount, 108 mm Inner Diameter Hollow Stem Augers</u>		COMPILED BY <u>MAS</u>	
DATUM <u>Geodetic</u>		DATE <u>April 8, 2011</u>		CHECKED BY <u>LCC</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)							
								20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>		GR	SA	SI	CL
169.5	GROUND SURFACE																			
0.0	TOPSOIL																			
0.2	SAND and SILT, trace clay, trace gravel (FILL) Very loose to compact Brown Moist																			
			1	SS	5															
			2	SS	8															
			3	SS	3															
			4	SS	2															
			5	SS	6															
			6	SS	7															
			7	SS	11															
			8	SS	12															
160.7	CLAYEY SILT with sand, trace gravel (TILL) Stiff to very stiff Grey Moist		9	SS	12															
8.8																				
			10	SS	17															
157.9	Sandy SILT, trace clay, trace gravel, containing pockets of clayey silt (TILL) Compact Grey Moist		11	SS	18															
11.6																				
			12	SS	53															
156.1	CLAYEY SILT, trace sand Hard Grey Moist																			
13.4																				
154.6																				

Continued Next Page

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

GTA-MTO 001 09-1111-6055.GPJ GAL-MISS.GDT 12/8/11 SIB



PROJECT 09-1111-6055		<b>RECORD OF BOREHOLE No 2011-03</b>				SHEET 2 OF 2 <b>METRIC</b>											
G.W.P. 07-20012		LOCATION N 4849118.4 ; E 324528.3				ORIGINATED BY SB											
DIST Central HWY 401		BOREHOLE TYPE CME 55 Track-mount, 108 mm Inner Diameter Hollow Stem Augers				COMPILED BY MAS											
DATUM Geodetic		DATE April 8, 2011				CHECKED BY LCC											
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 (%)				
								20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					10 20 30 W <sub>p</sub> W W <sub>L</sub>				
--- CONTINUED FROM PREVIOUS PAGE ---																	
14.9	Silty SAND, trace clay Very dense to compact Grey Wet		13	SS	71												
			14	SS	15												
			15	SS	83												
			16	SS	103												
148.8																	
20.7	SAND and GRAVEL, trace to some silt, trace clay Very dense Grey Wet		17	SS	70/0.15												
146.3			18	SS	74/0.15												
23.2	END OF BOREHOLE																
	NOTE:  1. Water level in piezometer at a depth of 4.9 m (Elev. 164.6 m) on completion of installation.  2. Water level in piezometer at a depth of 4.6 m (Elev. 164.9 m) on April 21, 2011.																



**APPENDIX B**

**Borehole Records from 2018  
Investigation**



## LIST OF SYMBOLS

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

### I. GENERAL

$\pi$	3.1416
$\ln x$ ,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

### II. STRESS AND STRAIN

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta \sigma$
$\varepsilon$	linear strain
$\varepsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	Poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

### III. SOIL PROPERTIES

#### (a) Index Properties

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

#### (a) Index Properties (continued)

w	water content
$w_l$ or LL	liquid limit
$w_p$ or PL	plastic limit
$I_p$ or PI	plasticity index = $(w_l - w_p)$
$w_s$	shrinkage limit
$I_L$	liquidity index = $(w - w_p) / I_p$
$I_c$	consistency index = $(w_l - w) / I_p$
$e_{max}$	void ratio in loosest state
$e_{min}$	void ratio in densest state
$I_D$	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

#### (b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

#### (c) Consolidation (one-dimensional)

$C_c$	compression index (normally consolidated range)
$C_r$	recompression index (over-consolidated range)
$C_s$	swelling index
$C_{\alpha}$	secondary compression index
$m_v$	coefficient of volume change
$C_v$	coefficient of consolidation (vertical direction)
$C_h$	coefficient of consolidation (horizontal direction)
$T_v$	time factor (vertical direction)
U	degree of consolidation
$\sigma'_p$	pre-consolidation stress
OCR	over-consolidation ratio = $\sigma'_p / \sigma'_{vo}$

#### (d) Shear Strength

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

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

Notes: 1  
2

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

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

#### (b) Cohesive Soils Consistency

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

### IV. SOIL TESTS

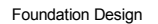
w	water content
$w_p$	plastic limit
$w_l$	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
$D_R$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

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

### V. MINOR SOIL CONSTITUENTS

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





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



**APPENDIX C**

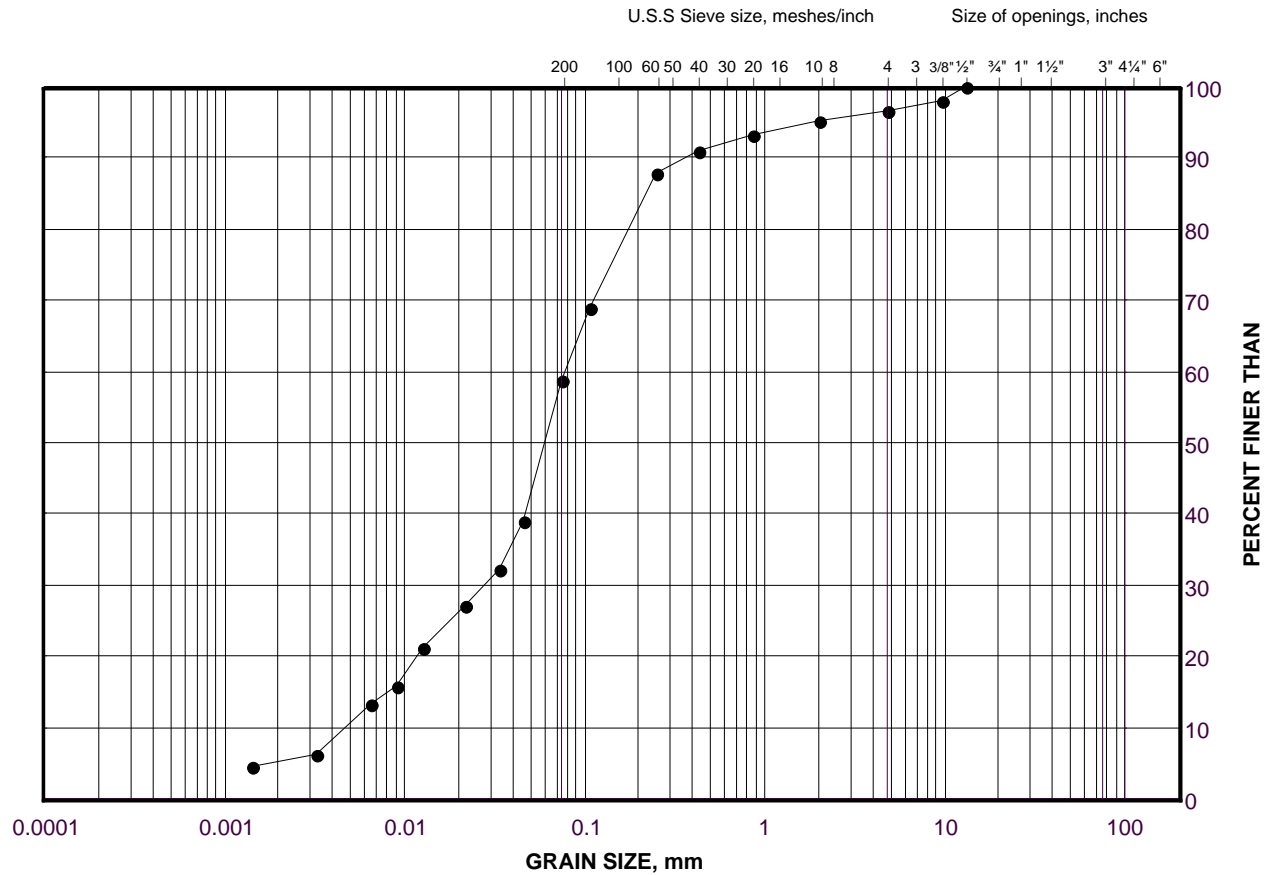
# Geotechnical Laboratory Test Results



# GRAIN SIZE DISTRIBUTION

Silt and Sand (Till)

FIGURE C-1



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

## LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	MRU-01	5	160.4

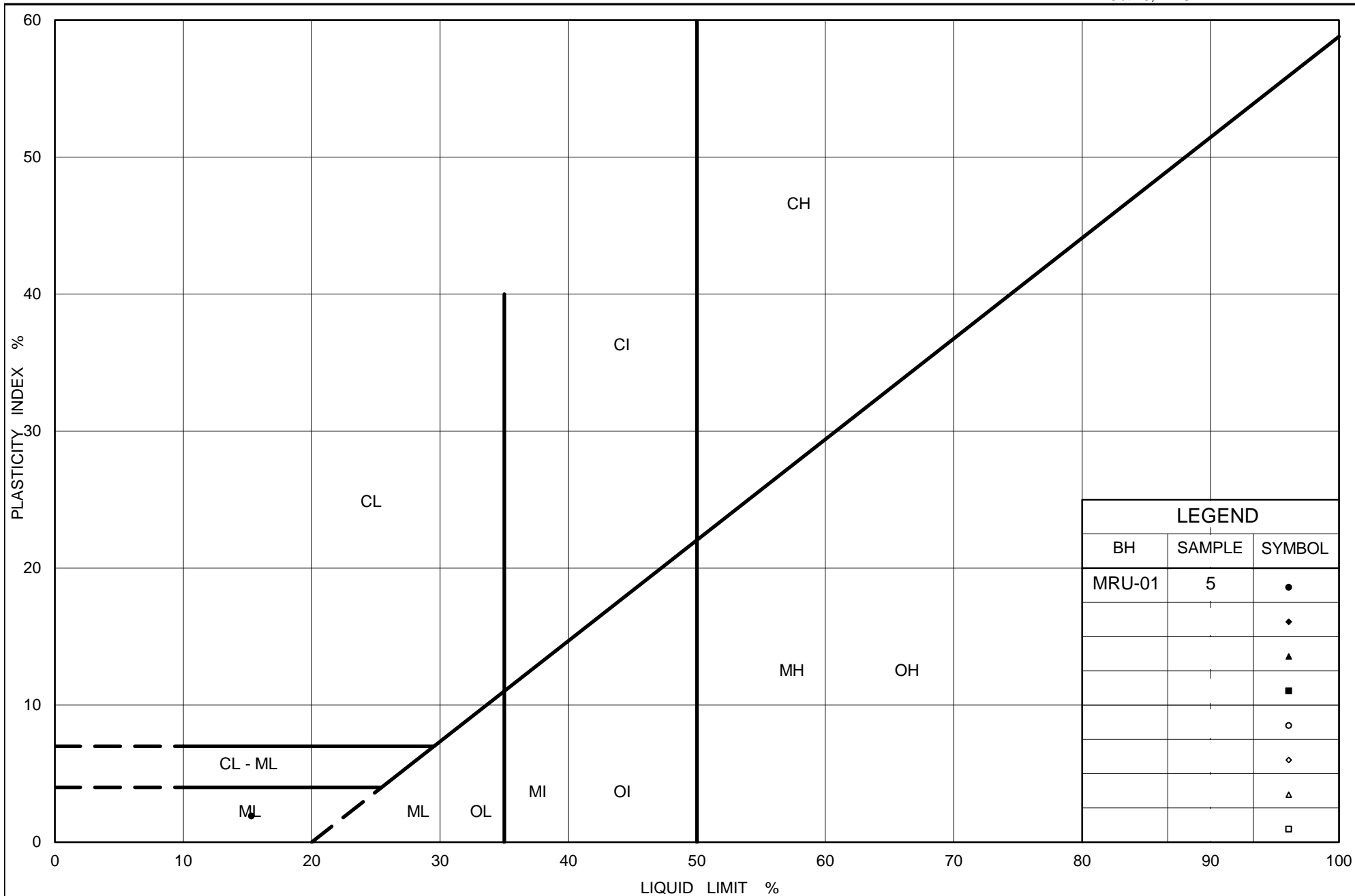
Project Number: 1669995

Checked By: NK

**Golder Associates**

Date: 09-Oct-18





Ministry of Transportation

Ontario

## PLASTICITY CHART Silt and Sand (Till)

Figure No. C-2

Project No. 1669995

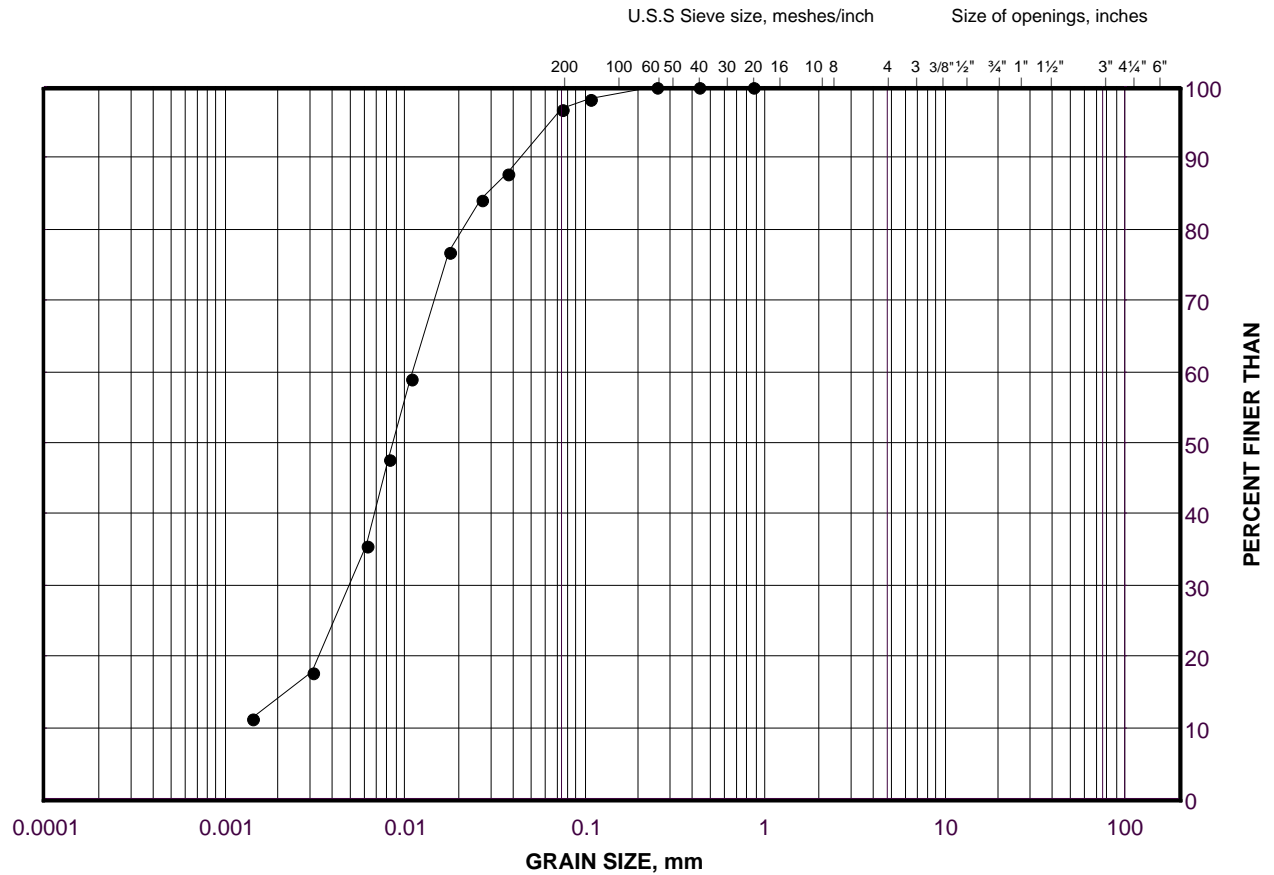
Checked By: NK



# GRAIN SIZE DISTRIBUTION

Clayey Silt

FIGURE C-3



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

## LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	MRU-01	6	159.6

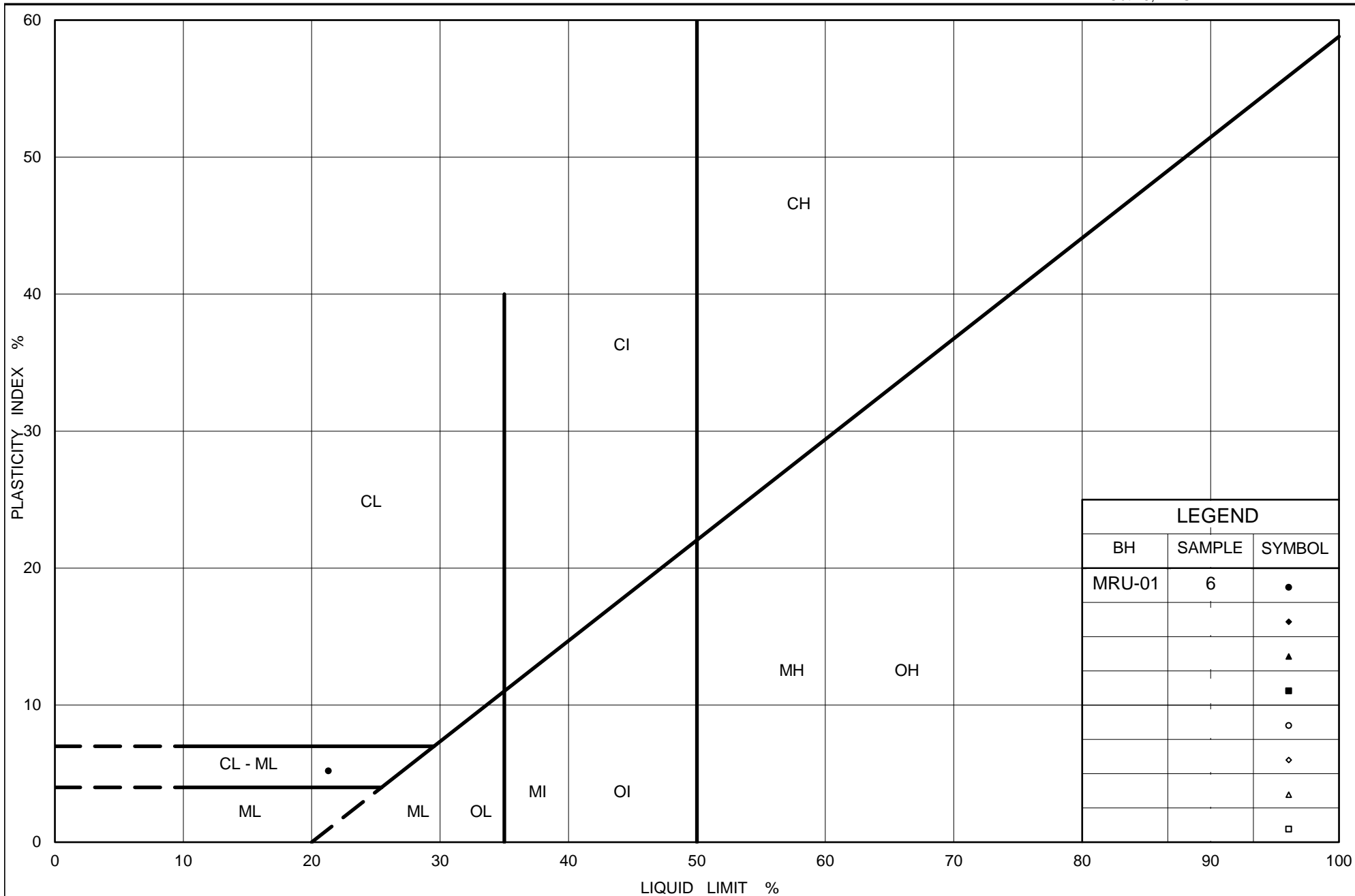
Project Number: 1669995

Checked By: NK

**Golder Associates**

Date: 09-Oct-18





Ministry of Transportation

Ontario

## PLASTICITY CHART

### Clayey Silt

Figure No. C-4

Project No. 1669995

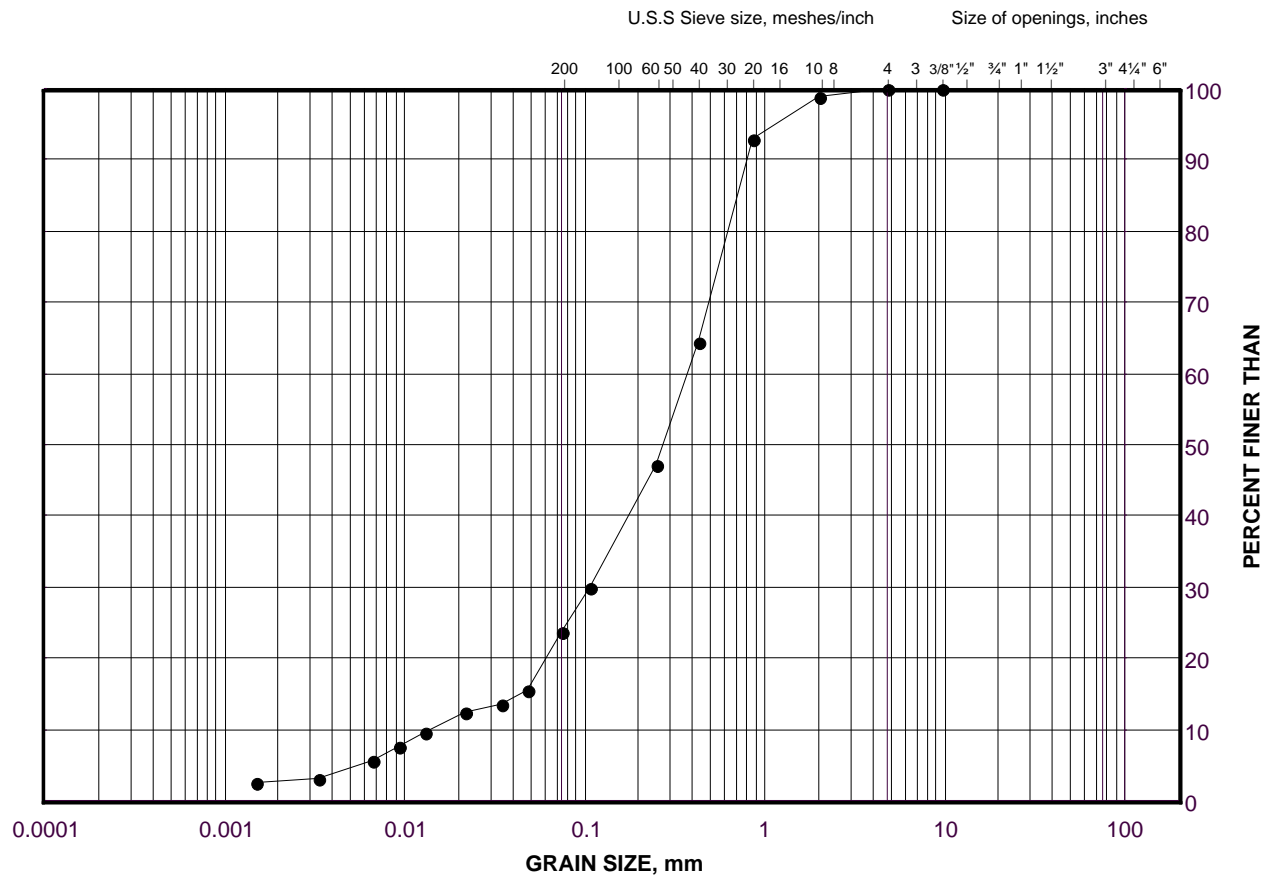
Checked By: NK



# GRAIN SIZE DISTRIBUTION

Silty Sand

FIGURE C-5



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

## LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	MRU-01	11	152.8

Project Number: 1669995

Checked By: NK

**Golder Associates**

Date: 09-Oct-18



**APPENDIX D**

# Analytical Laboratory Test Results



Your Project #: 1669995  
Site Location: 401W

**Attention: Nikol Kochmanova**

Golder Associates Ltd  
6925 Century Ave  
Suite 100  
Mississauga, ON  
CANADA L5N 7K2

Your C.O.C. #: 668025-02-01, 668025-03-01, 668025-04-01, 668025-05-01

**Report Date: 2018/06/08**  
Report #: R5226716  
Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**MAXXAM JOB #: B8D5245**

**Received: 2018/06/05, 16:46**

Sample Matrix: Soil  
# Samples Received: 31

<b>Analyses</b>	<b>Quantity</b>	<b>Date Extracted</b>	<b>Date Analyzed</b>	<b>Laboratory Method</b>	<b>Reference</b>
Chloride (20:1 extract)	31	N/A	2018/06/08	CAM SOP-00463	EPA 325.2 m
Conductivity	20	N/A	2018/06/07	CAM SOP-00414	OMOE E3530 v1 m
Conductivity	11	N/A	2018/06/08	CAM SOP-00414	OMOE E3530 v1 m
pH CaCl <sub>2</sub> EXTRACT	20	2018/06/07	2018/06/07	CAM SOP-00413	EPA 9045 D m
pH CaCl <sub>2</sub> EXTRACT	11	2018/06/08	2018/06/08	CAM SOP-00413	EPA 9045 D m
Resistivity of Soil	20	2018/06/06	2018/06/07	CAM SOP-00414	SM 23 2510 m
Resistivity of Soil	11	2018/06/06	2018/06/08	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	31	N/A	2018/06/08	CAM SOP-00464	EPA 375.4 m

**Remarks:**

Maxxam Analytics' laboratories are accredited to ISO/IEC 17025:2005 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Maxxam are based upon recognized Provincial, Federal or US method compendia such as CCME, MDDELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Maxxam's profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Maxxam in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported; unless indicated otherwise, associated sample data are not blank corrected.

Maxxam Analytics' liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Maxxam has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Maxxam, unless otherwise agreed in writing.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.

Results relate to samples tested.

This Certificate shall not be reproduced except in full, without the written approval of the laboratory.

Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

\* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.



Your Project #: 1669995  
Site Location: 401W

**Attention: Nikol Kochmanova**

Golder Associates Ltd  
6925 Century Ave  
Suite 100  
Mississauga, ON  
CANADA L5N 7K2

Your C.O.C. #: 668025-02-01, 668025-03-01, 668025-04-01, 668025-05-01

**Report Date: 2018/06/08**  
Report #: R5226716  
Version: 1 - Final

**CERTIFICATE OF ANALYSIS**

**MAXXAM JOB #: B8D5245**

**Received: 2018/06/05, 16:46**

**Encryption Key**

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Ema Gitej, Senior Project Manager

Email: EGitej@maxxam.ca

Phone# (905)817-5829

=====

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.



### RESULTS OF ANALYSES OF SOIL

<b>Maxxam ID</b>		GWL599	GWL600	GWL601		GWL601		
<b>Sampling Date</b>		2018/02/14	2018/04/09	2018/02/28		2018/02/28		
<b>COC Number</b>		668025-02-01	668025-02-01	668025-02-01		668025-02-01		
	<b>UNITS</b>	<b>BR-03 SA#14</b>	<b>RW-02 SA#9</b>	<b>MR-01 SA#10</b>	<b>QC Batch</b>	<b>MR-01 SA#10 Lab-Dup</b>	<b>RDL</b>	<b>QC Batch</b>

#### Calculated Parameters

Resistivity	ohm-cm	680	6300	1400	5567331			
-------------	--------	-----	------	------	---------	--	--	--

#### Inorganics

Soluble (20:1) Chloride (Cl)	ug/g	730	<20	390	5569372	420	20	5569372
Conductivity	umho/cm	1480	160	718	5568916	708	2	5568916
Available (CaCl2) pH	pH	8.02	8.28	8.08	5568601			
Soluble (20:1) Sulphate (SO4)	ug/g	270	68	50	5569377	51	20	5569377

RDL = Reportable Detection Limit

QC Batch = Quality Control Batch

Lab-Dup = Laboratory Initiated Duplicate

<b>Maxxam ID</b>		GWL602		GWL603		GWL604		GWL605		
<b>Sampling Date</b>		2018/04/11		2018/04/12		2018/03/19		2018/03/21		
<b>COC Number</b>		668025-02-01		668025-02-01		668025-02-01		668025-02-01		
	<b>UNITS</b>	<b>OH-7 SA#5</b>	<b>QC Batch</b>	<b>OH-4 SA#4</b>	<b>RDL</b>	<b>MRU-01 SA#4</b>	<b>RDL</b>	<b>BRU-01 SA#6</b>	<b>RDL</b>	<b>QC Batch</b>

#### Calculated Parameters

Resistivity	ohm-cm	710	5567331	1300		330		990		5567331
-------------	--------	-----	---------	------	--	-----	--	-----	--	---------

#### Inorganics

Soluble (20:1) Chloride (Cl)	ug/g	680	5569369	220	20	1700	60	620	20	5569369
Conductivity	umho/cm	1410	5570740	764	2	3050	2	1010	2	5570740
Available (CaCl2) pH	pH	7.99	5568601	8.01		8.07		8.07		5569005
Soluble (20:1) Sulphate (SO4)	ug/g	280	5569370	370	20	<20	20	<20	20	5569370

RDL = Reportable Detection Limit

QC Batch = Quality Control Batch



### RESULTS OF ANALYSES OF SOIL

<b>Maxxam ID</b>		GWL606			GWL606			GWL607	GWL608		
<b>Sampling Date</b>		2018/03/14			2018/03/14			2018/03/22	2018/04/05		
<b>COC Number</b>		668025-02-01			668025-02-01			668025-02-01	668025-02-01		
	<b>UNITS</b>	<b>CN-02 SA#23B</b>	<b>RDL</b>	<b>QC Batch</b>	<b>CN-02 SA#23B Lab-Dup</b>	<b>RDL</b>	<b>QC Batch</b>	<b>KR-01 SA#9</b>	<b>NW1-04 SA#6</b>	<b>RDL</b>	<b>QC Batch</b>

<b>Calculated Parameters</b>											
Resistivity	ohm-cm	3200		5567331				940	2000		5567331
<b>Inorganics</b>											
Soluble (20:1) Chloride (Cl)	ug/g	<20	20	5569369				580	230	20	5569372
Conductivity	umho/cm	312	2	5570740	314	2	5570740	1070	508	2	5568916
Available (CaCl2) pH	pH	8.12		5568601				8.01	8.26		5568601
Soluble (20:1) Sulphate (SO4)	ug/g	200	20	5569370				<20	<20	20	5569377
RDL = Reportable Detection Limit											
QC Batch = Quality Control Batch											
Lab-Dup = Laboratory Initiated Duplicate											

<b>Maxxam ID</b>		GWL609	GWL610	GWL611	GWL612	GWL613	GWL614		
<b>Sampling Date</b>		2018/02/25	2018/04/11	2018/02/26	2018/04/11	2018/04/06	2018/04/10		
<b>COC Number</b>		668025-03-01	668025-03-01	668025-03-01	668025-03-01	668025-03-01	668025-03-01		
	<b>UNITS</b>	<b>KR-03S SA#10</b>	<b>NW-05 SA#7B</b>	<b>MA-01 SA#11</b>	<b>NW-04 SA#4</b>	<b>NW-03S SA#7</b>	<b>NW-08 SA#7</b>	<b>RDL</b>	<b>QC Batch</b>

<b>Calculated Parameters</b>									
Resistivity	ohm-cm	2300	620	1300	1000	1600	1300		5567331
<b>Inorganics</b>									
Soluble (20:1) Chloride (Cl)	ug/g	210	820	280	510	340	350	20	5569372
Conductivity	umho/cm	437	1620	797	979	643	778	2	5568916
Available (CaCl2) pH	pH	8.21	8.11	8.09	8.16	8.08	8.13		5568601
Soluble (20:1) Sulphate (SO4)	ug/g	<20	24	310	<20	23	77	20	5569377
RDL = Reportable Detection Limit									
QC Batch = Quality Control Batch									



### RESULTS OF ANALYSES OF SOIL

<b>Maxxam ID</b>		GWL615		GWL616		GWL617		GWL618		
<b>Sampling Date</b>		2018/04/10		2018/03/25		2018/03/28		2018/03/26		
<b>COC Number</b>		668025-03-01		668025-03-01		668025-03-01		668025-03-01		
	<b>UNITS</b>	<b>NW-07 SA#5A</b>	<b>QC Batch</b>	<b>NBP1-3 SA#6</b>	<b>QC Batch</b>	<b>RW-01 SA#3</b>	<b>QC Batch</b>	<b>NW1-02 SA#3</b>	<b>RDL</b>	<b>QC Batch</b>

<b>Calculated Parameters</b>										
Resistivity	ohm-cm	610	5567331	1600	5567331	1300	5567331	2300		5567331
<b>Inorganics</b>										
Soluble (20:1) Chloride (Cl)	ug/g	810	5569372	320	5569369	370	5569372	170	20	5569372
Conductivity	umho/cm	1630	5568916	627	5568916	743	5568916	429	2	5570740
Available (CaCl2) pH	pH	8.10	5568601	8.00	5568601	8.07	5568601	8.13		5568601
Soluble (20:1) Sulphate (SO4)	ug/g	<20	5569377	<20	5569370	<20	5569377	<20	20	5569377
RDL = Reportable Detection Limit										
QC Batch = Quality Control Batch										

<b>Maxxam ID</b>		GWL618		GWL619		GWL620		GWL621		
<b>Sampling Date</b>		2018/03/26		2018/03/26		2018/04/09		2018/03/06		
<b>COC Number</b>		668025-03-01		668025-04-01		668025-04-01		668025-04-01		
	<b>UNITS</b>	<b>NW1-02 SA#3 Lab-Dup</b>	<b>QC Batch</b>	<b>NW1-01 SA#4</b>	<b>QC Batch</b>	<b>NBP1-01 SA#9</b>	<b>QC Batch</b>	<b>CN-01 SA#20A</b>	<b>RDL</b>	<b>QC Batch</b>

<b>Calculated Parameters</b>										
Resistivity	ohm-cm			4200	5567331	1200	5567331	2900		5567331
<b>Inorganics</b>										
Soluble (20:1) Chloride (Cl)	ug/g			78	5569372	460	5569369	120	20	5569372
Conductivity	umho/cm			238	5568916	835	5570740	343	2	5568916
Available (CaCl2) pH	pH	8.09	5568601	8.24	5568601	8.13	5569005	8.34		5568601
Soluble (20:1) Sulphate (SO4)	ug/g			<20	5569377	<20	5569370	92	20	5569377
RDL = Reportable Detection Limit										
QC Batch = Quality Control Batch										
Lab-Dup = Laboratory Initiated Duplicate										



### RESULTS OF ANALYSES OF SOIL

<b>Maxxam ID</b>		GWL622		GWL623		GWL624		
<b>Sampling Date</b>		2018/02/25		2018/04/12		2018/04/13		
<b>COC Number</b>		668025-04-01		668025-04-01		668025-04-01		
	<b>UNITS</b>	<b>CP-01 SA#12</b>	<b>QC Batch</b>	<b>OH-5 SA#7</b>	<b>QC Batch</b>	<b>OH-9 SA#5</b>	<b>RDL</b>	<b>QC Batch</b>

<b>Calculated Parameters</b>								
Resistivity	ohm-cm	1500	5567331	1000	5567331	1400		5567331
<b>Inorganics</b>								
Soluble (20:1) Chloride (Cl)	ug/g	340	5569369	490	5569372	330	20	5569369
Conductivity	umho/cm	649	5570740	974	5568916	733	2	5570740
Available (CaCl2) pH	pH	8.10	5569005	8.14	5568601	8.16		5569005
Soluble (20:1) Sulphate (SO4)	ug/g	<20	5569370	29	5569377	<20	20	5569370
RDL = Reportable Detection Limit								
QC Batch = Quality Control Batch								

<b>Maxxam ID</b>		GWL624			GWL625			GWL626		
<b>Sampling Date</b>		2018/04/13			2018/05/29			2018/04/12		
<b>COC Number</b>		668025-04-01			668025-04-01			668025-04-01		
	<b>UNITS</b>	<b>OH-9 SA#5</b>	<b>RDL</b>	<b>QC Batch</b>	<b>NB-02 SA#4</b>	<b>RDL</b>	<b>QC Batch</b>	<b>OH-01 SA#7</b>	<b>RDL</b>	<b>QC Batch</b>

<b>Calculated Parameters</b>										
Resistivity	ohm-cm				870		5567331	300		5567331
<b>Inorganics</b>										
Soluble (20:1) Chloride (Cl)	ug/g	330	20	5569369	670	20	5569372	1700	60	5569369
Conductivity	umho/cm				1150	2	5568916	3300	2	5570740
Available (CaCl2) pH	pH				8.24		5569005	7.47		5569005
Soluble (20:1) Sulphate (SO4)	ug/g	<20	20	5569370	62	20	5569377	250	20	5569370
RDL = Reportable Detection Limit										
QC Batch = Quality Control Batch										
Lab-Dup = Laboratory Initiated Duplicate										



### RESULTS OF ANALYSES OF SOIL

<b>Maxxam ID</b>		GWL627			GWL628			GWL629		
<b>Sampling Date</b>		2018/05/09			2018/05/07			2018/05/30		
<b>COC Number</b>		668025-04-01			668025-04-01			668025-05-01		
	<b>UNITS</b>	<b>KR-02 SA#3</b>	<b>RDL</b>	<b>QC Batch</b>	<b>MR-02 SA#7</b>	<b>RDL</b>	<b>QC Batch</b>	<b>BR-01 SA#4</b>	<b>RDL</b>	<b>QC Batch</b>
<b>Calculated Parameters</b>										
Resistivity	ohm-cm	470		5567331	760		5567331	400		5567331
<b>Inorganics</b>										
Soluble (20:1) Chloride (Cl)	ug/g	1100	40	5569369	670	20	5569372	1300	60	5569369
Conductivity	umho/cm	2140	2	5568916	1310	2	5568916	2490	2	5570740
Available (CaCl2) pH	pH	8.24		5569005	8.08		5569005	8.04		5569005
Soluble (20:1) Sulphate (SO4)	ug/g	26	20	5569370	70	20	5569377	130	20	5569370
RDL = Reportable Detection Limit										
QC Batch = Quality Control Batch										



## TEST SUMMARY

**Maxxam ID:** GWL599  
**Sample ID:** BR-03 SA#14  
**Matrix:** Soil

**Collected:** 2018/02/14  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569372	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5568916	N/A	2018/06/07	Tahir Anwar
pH CaCl2 EXTRACT	AT	5568601	2018/06/07	2018/06/07	Gnana Thomas
Resistivity of Soil		5567331	2018/06/07	2018/06/07	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569377	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL600  
**Sample ID:** RW-02 SA#9  
**Matrix:** Soil

**Collected:** 2018/04/09  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569372	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5568916	N/A	2018/06/07	Tahir Anwar
pH CaCl2 EXTRACT	AT	5568601	2018/06/07	2018/06/07	Gnana Thomas
Resistivity of Soil		5567331	2018/06/07	2018/06/07	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569377	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL601  
**Sample ID:** MR-01 SA#10  
**Matrix:** Soil

**Collected:** 2018/02/28  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569372	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5568916	N/A	2018/06/07	Tahir Anwar
pH CaCl2 EXTRACT	AT	5568601	2018/06/07	2018/06/07	Gnana Thomas
Resistivity of Soil		5567331	2018/06/07	2018/06/07	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569377	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL601 Dup  
**Sample ID:** MR-01 SA#10  
**Matrix:** Soil

**Collected:** 2018/02/28  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569372	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5568916	N/A	2018/06/07	Tahir Anwar
Sulphate (20:1 Extract)	KONE/EC	5569377	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL602  
**Sample ID:** OH-7 SA#5  
**Matrix:** Soil

**Collected:** 2018/04/11  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569369	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5570740	N/A	2018/06/08	Tahir Anwar
pH CaCl2 EXTRACT	AT	5568601	2018/06/07	2018/06/07	Gnana Thomas



## TEST SUMMARY

**Maxxam ID:** GWL602  
**Sample ID:** OH-7 SA#5  
**Matrix:** Soil

**Collected:** 2018/04/11  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Resistivity of Soil		5567331	2018/06/08	2018/06/08	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569370	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL603  
**Sample ID:** OH-4 SA#4  
**Matrix:** Soil

**Collected:** 2018/04/12  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569369	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5570740	N/A	2018/06/08	Tahir Anwar
pH CaCl2 EXTRACT	AT	5569005	2018/06/08	2018/06/08	Gnana Thomas
Resistivity of Soil		5567331	2018/06/08	2018/06/08	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569370	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL604  
**Sample ID:** MRU-01 SA#4  
**Matrix:** Soil

**Collected:** 2018/03/19  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569369	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5570740	N/A	2018/06/08	Tahir Anwar
pH CaCl2 EXTRACT	AT	5569005	2018/06/08	2018/06/08	Gnana Thomas
Resistivity of Soil		5567331	2018/06/08	2018/06/08	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569370	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL605  
**Sample ID:** BRU-01 SA#6  
**Matrix:** Soil

**Collected:** 2018/03/21  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569369	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5570740	N/A	2018/06/08	Tahir Anwar
pH CaCl2 EXTRACT	AT	5569005	2018/06/08	2018/06/08	Gnana Thomas
Resistivity of Soil		5567331	2018/06/08	2018/06/08	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569370	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL606  
**Sample ID:** CN-02 SA#23B  
**Matrix:** Soil

**Collected:** 2018/03/14  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569369	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5570740	N/A	2018/06/08	Tahir Anwar
pH CaCl2 EXTRACT	AT	5568601	2018/06/07	2018/06/07	Gnana Thomas
Resistivity of Soil		5567331	2018/06/08	2018/06/08	Automated Statchk



## TEST SUMMARY

**Maxxam ID:** GWL606  
**Sample ID:** CN-02 SA#23B  
**Matrix:** Soil

**Collected:** 2018/03/14  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Sulphate (20:1 Extract)	KONE/EC	5569370	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL606 Dup  
**Sample ID:** CN-02 SA#23B  
**Matrix:** Soil

**Collected:** 2018/03/14  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Conductivity	AT	5570740	N/A	2018/06/08	Tahir Anwar

**Maxxam ID:** GWL607  
**Sample ID:** KR-01 SA#9  
**Matrix:** Soil

**Collected:** 2018/03/22  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569372	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5568916	N/A	2018/06/07	Tahir Anwar
pH CaCl2 EXTRACT	AT	5568601	2018/06/07	2018/06/07	Gnana Thomas
Resistivity of Soil		5567331	2018/06/07	2018/06/07	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569377	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL608  
**Sample ID:** NW1-04 SA#6  
**Matrix:** Soil

**Collected:** 2018/04/05  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569372	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5568916	N/A	2018/06/07	Tahir Anwar
pH CaCl2 EXTRACT	AT	5568601	2018/06/07	2018/06/07	Gnana Thomas
Resistivity of Soil		5567331	2018/06/07	2018/06/07	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569377	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL609  
**Sample ID:** KR-03S SA#10  
**Matrix:** Soil

**Collected:** 2018/02/25  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569372	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5568916	N/A	2018/06/07	Tahir Anwar
pH CaCl2 EXTRACT	AT	5568601	2018/06/07	2018/06/07	Gnana Thomas
Resistivity of Soil		5567331	2018/06/07	2018/06/07	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569377	N/A	2018/06/08	Alina Dobreanu



## TEST SUMMARY

**Maxxam ID:** GWL610  
**Sample ID:** NW-05 SA#7B  
**Matrix:** Soil

**Collected:** 2018/04/11  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569372	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5568916	N/A	2018/06/07	Tahir Anwar
pH CaCl2 EXTRACT	AT	5568601	2018/06/07	2018/06/07	Gnana Thomas
Resistivity of Soil		5567331	2018/06/07	2018/06/07	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569377	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL611  
**Sample ID:** MA-01 SA#11  
**Matrix:** Soil

**Collected:** 2018/02/26  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569372	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5568916	N/A	2018/06/07	Tahir Anwar
pH CaCl2 EXTRACT	AT	5568601	2018/06/07	2018/06/07	Gnana Thomas
Resistivity of Soil		5567331	2018/06/07	2018/06/07	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569377	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL612  
**Sample ID:** NW-04 SA#4  
**Matrix:** Soil

**Collected:** 2018/04/11  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569372	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5568916	N/A	2018/06/07	Tahir Anwar
pH CaCl2 EXTRACT	AT	5568601	2018/06/07	2018/06/07	Gnana Thomas
Resistivity of Soil		5567331	2018/06/07	2018/06/07	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569377	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL613  
**Sample ID:** NW-03S SA#7  
**Matrix:** Soil

**Collected:** 2018/04/06  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569372	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5568916	N/A	2018/06/07	Tahir Anwar
pH CaCl2 EXTRACT	AT	5568601	2018/06/07	2018/06/07	Gnana Thomas
Resistivity of Soil		5567331	2018/06/07	2018/06/07	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569377	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL614  
**Sample ID:** NW-08 SA#7  
**Matrix:** Soil

**Collected:** 2018/04/10  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569372	N/A	2018/06/08	Deonarine Ramnarine



## TEST SUMMARY

**Maxxam ID:** GWL614  
**Sample ID:** NW-08 SA#7  
**Matrix:** Soil

**Collected:** 2018/04/10  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Conductivity	AT	5568916	N/A	2018/06/07	Tahir Anwar
pH CaCl2 EXTRACT	AT	5568601	2018/06/07	2018/06/07	Gnana Thomas
Resistivity of Soil		5567331	2018/06/07	2018/06/07	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569377	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL615  
**Sample ID:** NW-07 SA#5A  
**Matrix:** Soil

**Collected:** 2018/04/10  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569372	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5568916	N/A	2018/06/07	Tahir Anwar
pH CaCl2 EXTRACT	AT	5568601	2018/06/07	2018/06/07	Gnana Thomas
Resistivity of Soil		5567331	2018/06/07	2018/06/07	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569377	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL616  
**Sample ID:** NBP1-3 SA#6  
**Matrix:** Soil

**Collected:** 2018/03/25  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569369	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5568916	N/A	2018/06/07	Tahir Anwar
pH CaCl2 EXTRACT	AT	5568601	2018/06/07	2018/06/07	Gnana Thomas
Resistivity of Soil		5567331	2018/06/07	2018/06/07	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569370	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL617  
**Sample ID:** RW-01 SA#3  
**Matrix:** Soil

**Collected:** 2018/03/28  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569372	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5568916	N/A	2018/06/07	Tahir Anwar
pH CaCl2 EXTRACT	AT	5568601	2018/06/07	2018/06/07	Gnana Thomas
Resistivity of Soil		5567331	2018/06/07	2018/06/07	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569377	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL618  
**Sample ID:** NW1-02 SA#3  
**Matrix:** Soil

**Collected:** 2018/03/26  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569372	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5570740	N/A	2018/06/08	Tahir Anwar



## TEST SUMMARY

**Maxxam ID:** GWL618  
**Sample ID:** NW1-02 SA#3  
**Matrix:** Soil

**Collected:** 2018/03/26  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
pH CaCl2 EXTRACT	AT	5568601	2018/06/07	2018/06/07	Gnana Thomas
Resistivity of Soil		5567331	2018/06/08	2018/06/08	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569377	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL618 Dup  
**Sample ID:** NW1-02 SA#3  
**Matrix:** Soil

**Collected:** 2018/03/26  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
pH CaCl2 EXTRACT	AT	5568601	2018/06/07	2018/06/07	Gnana Thomas

**Maxxam ID:** GWL619  
**Sample ID:** NW1-01 SA#4  
**Matrix:** Soil

**Collected:** 2018/03/26  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569372	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5568916	N/A	2018/06/07	Tahir Anwar
pH CaCl2 EXTRACT	AT	5568601	2018/06/07	2018/06/07	Gnana Thomas
Resistivity of Soil		5567331	2018/06/07	2018/06/07	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569377	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL620  
**Sample ID:** NBP1-01 SA#9  
**Matrix:** Soil

**Collected:** 2018/04/09  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569369	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5570740	N/A	2018/06/08	Tahir Anwar
pH CaCl2 EXTRACT	AT	5569005	2018/06/08	2018/06/08	Gnana Thomas
Resistivity of Soil		5567331	2018/06/08	2018/06/08	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569370	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL621  
**Sample ID:** CN-01 SA#20A  
**Matrix:** Soil

**Collected:** 2018/03/06  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569372	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5568916	N/A	2018/06/07	Tahir Anwar
pH CaCl2 EXTRACT	AT	5568601	2018/06/07	2018/06/07	Gnana Thomas
Resistivity of Soil		5567331	2018/06/07	2018/06/07	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569377	N/A	2018/06/08	Alina Dobreanu



## TEST SUMMARY

**Maxxam ID:** GWL622  
**Sample ID:** CP-01 SA#12  
**Matrix:** Soil

**Collected:** 2018/02/25  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569369	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5570740	N/A	2018/06/08	Tahir Anwar
pH CaCl2 EXTRACT	AT	5569005	2018/06/08	2018/06/08	Gnana Thomas
Resistivity of Soil		5567331	2018/06/08	2018/06/08	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569370	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL623  
**Sample ID:** OH-5 SA#7  
**Matrix:** Soil

**Collected:** 2018/04/12  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569372	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5568916	N/A	2018/06/07	Tahir Anwar
pH CaCl2 EXTRACT	AT	5568601	2018/06/07	2018/06/07	Gnana Thomas
Resistivity of Soil		5567331	2018/06/07	2018/06/07	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569377	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL624  
**Sample ID:** OH-9 SA#5  
**Matrix:** Soil

**Collected:** 2018/04/13  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569369	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5570740	N/A	2018/06/08	Tahir Anwar
pH CaCl2 EXTRACT	AT	5569005	2018/06/08	2018/06/08	Gnana Thomas
Resistivity of Soil		5567331	2018/06/08	2018/06/08	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569370	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL624 Dup  
**Sample ID:** OH-9 SA#5  
**Matrix:** Soil

**Collected:** 2018/04/13  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569369	N/A	2018/06/08	Deonarine Ramnarine
Sulphate (20:1 Extract)	KONE/EC	5569370	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL625  
**Sample ID:** NB-02 SA#4  
**Matrix:** Soil

**Collected:** 2018/05/29  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569372	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5568916	N/A	2018/06/07	Tahir Anwar
pH CaCl2 EXTRACT	AT	5569005	2018/06/08	2018/06/08	Gnana Thomas
Resistivity of Soil		5567331	2018/06/07	2018/06/07	Automated Statchk



## TEST SUMMARY

**Maxxam ID:** GWL625  
**Sample ID:** NB-02 SA#4  
**Matrix:** Soil

**Collected:** 2018/05/29  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Sulphate (20:1 Extract)	KONE/EC	5569377	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL626  
**Sample ID:** OH-01 SA#7  
**Matrix:** Soil

**Collected:** 2018/04/12  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569369	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5570740	N/A	2018/06/08	Tahir Anwar
pH CaCl2 EXTRACT	AT	5569005	2018/06/08	2018/06/08	Gnana Thomas
Resistivity of Soil		5567331	2018/06/08	2018/06/08	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569370	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL627  
**Sample ID:** KR-02 SA#3  
**Matrix:** Soil

**Collected:** 2018/05/09  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569369	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5568916	N/A	2018/06/07	Tahir Anwar
pH CaCl2 EXTRACT	AT	5569005	2018/06/08	2018/06/08	Gnana Thomas
Resistivity of Soil		5567331	2018/06/07	2018/06/07	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569370	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL628  
**Sample ID:** MR-02 SA#7  
**Matrix:** Soil

**Collected:** 2018/05/07  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569372	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5568916	N/A	2018/06/07	Tahir Anwar
pH CaCl2 EXTRACT	AT	5569005	2018/06/08	2018/06/08	Gnana Thomas
Resistivity of Soil		5567331	2018/06/07	2018/06/07	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569377	N/A	2018/06/08	Alina Dobreanu

**Maxxam ID:** GWL629  
**Sample ID:** BR-01 SA#4  
**Matrix:** Soil

**Collected:** 2018/05/30  
**Shipped:**  
**Received:** 2018/06/05

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	5569369	N/A	2018/06/08	Deonarine Ramnarine
Conductivity	AT	5570740	N/A	2018/06/08	Tahir Anwar
pH CaCl2 EXTRACT	AT	5569005	2018/06/08	2018/06/08	Gnana Thomas
Resistivity of Soil		5567331	2018/06/08	2018/06/08	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	5569370	N/A	2018/06/08	Alina Dobreanu



### GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	20.0°C
-----------	--------

Most samples have been received and analyzed past the recommended hold time of 30 days as per client request.

**Results relate only to the items tested.**



## QUALITY ASSURANCE REPORT

Golder Associates Ltd  
Client Project #: 1669995  
Site Location: 401W  
Sampler Initials: AM

QC Batch	Parameter	Date	Matrix Spike		SPIKED BLANK		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
5568601	Available (CaCl <sub>2</sub> ) pH	2018/06/07			100	97 - 103			0.50	N/A
5568916	Conductivity	2018/06/07			98	90 - 110	<2	umho/cm	1.4	10
5569005	Available (CaCl <sub>2</sub> ) pH	2018/06/08			101	97 - 103			0.13	N/A
5569369	Soluble (20:1) Chloride (Cl)	2018/06/08	NC	70 - 130	108	70 - 130	<20	ug/g	0.23	35
5569370	Soluble (20:1) Sulphate (SO <sub>4</sub> )	2018/06/08	114	70 - 130	107	70 - 130	<20	ug/g	NC	35
5569372	Soluble (20:1) Chloride (Cl)	2018/06/08	NC	70 - 130	107	70 - 130	<20	ug/g	7.2	35
5569377	Soluble (20:1) Sulphate (SO <sub>4</sub> )	2018/06/08	NC	70 - 130	102	70 - 130	<20	ug/g	2.5	35
5570740	Conductivity	2018/06/08			98	90 - 110	<2	umho/cm	0.64	10

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spike amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than the native sample concentration)

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (absolute difference <= 2x RDL).



### VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

*Cristina Carriere*

---

Cristina Carriere, Scientific Service Specialist

---

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.





Maxxam Analytics International Corporation o/a Maxxam Analytics  
6740 Campbell Road, Mississauga, Ontario Canada L5N 2L8 Tel: (905) 817-5700 Toll-free 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

# CHAIN OF CUSTODY RECORD

Page 1 of 1

<b>INVOICE TO:</b>		<b>REPORT TO:</b>		<b>PROJECT INFORMATION:</b>		<b>Laboratory Use Only:</b>	
Company Name: #1326 Golder Associates Ltd		Company Name: Nikol Kochmanova		Quotation #: B80683		Maxxam Job #:	
Attention: Accounts Payable		Attention:		P.O. #:		Bottle Order #:	
Address: 6925 Century Ave Suite 100		Address:		Project: 1669995		668025	
Mississauga ON L5N 7K2				Project Name: 401W		COC #:	
Tel: (905) 567-4444 Fax: (905) 567-6561		Tel: (905) 567-6100 Ext: 1459 Fax:		Site #:		Project Manager:	
Email: AP_CustomerService@golder.com		Email: Nikol_Kochmanova@golder.com		Sampled By:		Erna Gitej	

<b>MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE MAXXAM DRINKING WATER CHAIN OF CUSTODY</b>						<b>ANALYSIS REQUESTED (PLEASE BE SPECIFIC)</b>										<b>Turnaround Time (TAT) Required:</b> Please provide advance notice for rush projects							
<b>Regulation 153 (2011)</b>						<b>Other Regulations</b>						<b>Special Instructions</b>											
<input type="checkbox"/> Table 1 <input type="checkbox"/> Res/Park <input type="checkbox"/> Medium/Fine						<input type="checkbox"/> CCME <input type="checkbox"/> Sanitary Sewer Bylaw																	
<input type="checkbox"/> Table 2 <input type="checkbox"/> Ind/Comm <input type="checkbox"/> Coarse						<input type="checkbox"/> Reg 558 <input type="checkbox"/> Storm Sewer Bylaw																	
<input type="checkbox"/> Table 3 <input type="checkbox"/> Agri/Other <input type="checkbox"/> For RSC						<input type="checkbox"/> MISA Municipality																	
<input type="checkbox"/> Table <input type="checkbox"/> PWQO						<input type="checkbox"/> Other																	
<b>Include Criteria on Certificate of Analysis (Y/N)?</b>										<b>Field Filtered (please circle):</b>										<b>Regular (Standard) TAT:</b> (will be applied if Rush TAT is not specified): Standard TAT = 5-7 Working days for most tests. Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details. <b>Job Specific Rush TAT (if applies to entire submission)</b> Date Required: Time Required: Rush Confirmation Number: (call lab for #)			
										<b>Metals / Hg / Cr VI</b>										<b># of Bottles</b>			
										<b>Corrosivity, pH, SO<sub>4</sub>, pH, Reactivity/EC - no Sulphide and Redox Potential</b>										<b>Comments</b>			
1 BR-03 SA#14 Feb 14/18 AM Soil										X										<div>05-Jun-18 16:46 Erna Gitej B8D5245 GK1 ENV-1309</div>			
2 RW-02 SA#9 Apr 9/18 AM Soil										X													
3 MR-01 SA#10 Feb 28/18 AM Soil										X													
4 OH-7 SA#5 Apr 11/18 AM Soil										X													
5 OH-4 SA#4 Apr 12/18 AM Soil										X													
6 MEU-01 SA#4 Mar 19/18 AM Soil										X													
7 BRU-d SA#6 Mar 21/18 AM Soil										X													
8 CN-02 SA#23B Mar 14/18 AM Soil										X													
9 KR-01 SA#9 Mar 22/18 AM Soil										X													
10 NWI-04 SA#6 Apr 5/18 AM Soil										X													
<b>* RELINQUISHED BY: (Signature/Print)</b> Alex M... 18/06/05 16:45										<b>RECEIVED BY: (Signature/Print)</b> ... 18/06/05 16:46										<b>Laboratory Use Only</b>			
																				<b># jars used and not submitted</b>			
																				<b>Time Sensitive</b>			
																				<b>Temperature (°C) on Reel</b>			
																				<b>Custody Seal</b>			
																				<b>Present</b>			
																				<b>Intact</b>			
																				<b>Yes</b>			
																				<b>No</b>			
																				<b>White: Maxxa Yellow: Client</b>			

\* UNLESS OTHERWISE AGREED TO IN WRITING, WORK SUBMITTED ON THIS CHAIN OF CUSTODY IS SUBJECT TO MAXXAM'S STANDARD TERMS AND CONDITIONS. SIGNING OF THIS CHAIN OF CUSTODY DOCUMENT IS ACKNOWLEDGMENT AND ACCEPTANCE OF OUR TERMS WHICH ARE AVAILABLE FOR VIEWING AT WWW.MAXXAM.CA/TERMS.

\* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

\*\* SAMPLE CONTAINER, PRESERVATION, HOLD TIME AND PACKAGE INFORMATION CAN BE VIEWED AT HTTP://MAXXAM.CA/WP-CONTENT/UPLOADS/ONTARIO-COC.PDF.

SAMPLES MUST BE KEPT COOL (< 10° C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM

NOTICE





Maxxam Analytics International Corporation o/a Maxxam Analytics  
6740 Campbell Road, Mississauga, Ontario Canada L5N 2L8 Tel: (905) 817-5700 Toll-free 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

# CHAIN OF CUSTODY RECORD

2 of 4  
Page 1/1

INVOICE TO:		REPORT TO:		PROJECT INFORMATION:		Laboratory Use Only:	
Company Name: #1326 Golder Associates Ltd	Company Name: Nikol Kochmanova	Quotation #: B80683	Maxxam Job #:	Bottle Order #:			
Attention: Accounts Payable	Attention: Nikol Kochmanova	P.O. #:					
Address: 6925 Century Ave Suite 100	Address:	Project: 1669995					
Mississauga ON L5N 7K2		Project Name: 401W					
Tel: (905) 567-4444 Fax: (905) 567-6561	Tel: (905) 567-6100 Ext: 1459 Fax:	Site #:			COC #:		Project Manager:
Email: AP_CustomerService@golder.com	Email: Nikol_Kochmanova@golder.com	Sampled By:			C#668025-03-01		Ema Gitej

MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE MAXXAM DRINKING WATER CHAIN OF CUSTODY

Regulation 153 (2011)		Other Regulations		Special Instructions	
<input type="checkbox"/> Table 1 <input type="checkbox"/> Res/Park <input type="checkbox"/> Medium/Fine	<input type="checkbox"/> CCME <input type="checkbox"/> Sanitary Sewer Bylaw				
<input type="checkbox"/> Table 2 <input type="checkbox"/> Ind/Comm <input type="checkbox"/> Coarse	<input type="checkbox"/> Reg 558 <input type="checkbox"/> Storm Sewer Bylaw				
<input type="checkbox"/> Table 3 <input type="checkbox"/> Agri/Other <input type="checkbox"/> For RSC	<input type="checkbox"/> MISA Municipality				
<input type="checkbox"/> Table	<input type="checkbox"/> PWQO				
	<input type="checkbox"/> Other				

Include Criteria on Certificate of Analysis (Y/N)?					Field Filtered (please circle): Metals / Hg / Cr / V	Corrosivity pH (CL, SO4, pH) Reactivity/EC - no Sulphide and Redox (Potential)	ANALYSIS REQUESTED (PLEASE BE SPECIFIC)										Turnaround Time (TAT) Required:	
Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix													Please provide advance notice for rush projects	
1	KR-03 SA#10	Feb 25/18	AM	SOIL		X											Regular (Standard) TAT: (will be applied if Rush TAT is not specified): Standard TAT = 5-7 Working days for most tests. Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details.	
2	NW-05 SA#7B	Apr 11/18	AM	SOIL		X											Job Specific Rush TAT (if applies to entire submission) Date Required: Time Required: Rush Confirmation Number: (call lab for #)	
3	MA-01 SA#11	Feb 26/18	AM	SOIL		X											# of Bottles	Comments
4	NW-04 SA#4	Apr 11/18	AM	SOIL		X												
5	NW-03 SA#7	Apr 6/18	AM	SOIL		X												
6	NW-02 SA#7	Apr 10/18	AM	SOIL		X												
7	NW-07 SA#5A	Apr 10/18	AM	SOIL		X												
8	NBP1-3 SA#6	Mar 25/18	AM	SOIL		X												
9	RW-01 SA#3	Mar 28/18	AM	SOIL		X												
10	NWL02 SA#3	Mar 26/18	AM	SOIL		X												

RELINQUISHED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	RECEIVED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	# jars used and not submitted	Laboratory Use Only				
See page 1			See page one				Time Sensitive	Temperature, (°C) on Reel	Custody Seal	Yes	No
									Present		
									Intact		

\* UNLESS OTHERWISE AGREED TO IN WRITING, WORK SUBMITTED ON THIS CHAIN OF CUSTODY IS SUBJECT TO MAXXAM'S STANDARD TERMS AND CONDITIONS. SIGNING OF THIS CHAIN OF CUSTODY DOCUMENT IS ACKNOWLEDGMENT AND ACCEPTANCE OF OUR TERMS WHICH ARE AVAILABLE FOR VIEWING AT WWW.MAXXAM.CA/TERMS.

\* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

\*\* SAMPLE CONTAINER, PRESERVATION, HOLD TIME AND PACKAGE INFORMATION CAN BE VIEWED AT HTTP://MAXXAM.CA/WP-CONTENT/UPLOADS/ONTARIO-COC.PDF.



SAMPLES MUST BE KEPT COOL (< 10° C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM

White: Maxxa Yellow: Client



## CHAIN OF CUSTODY RECORD

3 of 4  
Page 11

INVOICE TO:		REPORT TO:		PROJECT INFORMATION:		Laboratory Use Only:	
Company Name:	#1326 Golder Associates Ltd	Company Name:		Quotation #:	B80683	Maxxam Job #:	Bottle Order #:
Attention:	Accounts Payable	Attention:	Nikol Kochmanova	P.O. #:			
Address:	6925 Century Ave Suite 100	Address:		Project:	1669995		668025
	Mississauga ON L5N 7K2			Project Name:	401W	COC #:	Project Manager:
Tel:	(905) 567-4444 Fax: (905) 567-6561	Tel:	(905) 567-6100 Ext: 1459 Fax:	Site #:			Erna Gitej
Email:	AP_CustomerService@golder.com	Email:	Nikol_Kochmanova@golder.com	Sampled By:		C668025-04-01	

**MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE MAXXAM DRINKING WATER CHAIN OF CUSTODY**

[illegible]

* RELINQUISHED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	RECEIVED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	# jars used and not submitted	Laboratory Use Only					
							- Time Sensitive	Temperature (°C) on Receipt	Custody Seal Present [initial]	Yes	No	
See Page 1			See page one									

\* UNLESS OTHERWISE AGREED TO IN WRITING, WORK SUBMITTED ON THIS CHAIN OF CUSTODY IS SUBJECT TO MAXXAM'S STANDARD TERMS AND CONDITIONS. SIGNING OF THIS CHAIN OF CUSTODY DOCUMENT IS ACKNOWLEDGMENT AND ACCEPTANCE OF OUR TERMS WHICH ARE AVAILABLE FOR VIEWING AT [WWW.MAXXAM.CA/TERMS](http://WWW.MAXXAM.CA/TERMS).

\* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

\*\* SAMPLE CONTAINER, PRESERVATION, HOLD TIME AND PACKAGE INFORMATION CAN BE VIEWED AT [HTTP://MAXXAM.CA/WP-CONTENT/UPLOADS/ONTARIO-COC.PDF](http://MAXXAM.CA/WP-CONTENT/UPLOADS/ONTARIO-COC.PDF)

SAMPLES MUST BE KEPT COOL (  $< 10^{\circ}\text{C}$  ) FROM TIME OF SAMPLING  
UNTIL DELIVERY TO MAXXAM

White: Maxxa      Yellow: Client





Maxxam Analytics International Corporation o/a Maxxam Analytics  
6740 Campbell Road, Mississauga, Ontario Canada L5N 2L8 Tel: (905) 817-5700 Toll-free: 800-563-6266 Fax: (905) 817-5777 www.maxxam.ca

# CHAIN OF CUSTODY RECORD

404  
Page 1 of 1

<b>INVOICE TO:</b>		<b>REPORT TO:</b>		<b>PROJECT INFORMATION:</b>		<b>Laboratory Use Only:</b>	
Company Name: #1326 Golder Associates Ltd	Company Name: Nikol Kochmanova	Quotation #: B80683	Maxxam Job #:	Bottle Order #:			
Attention: Accounts Payable	Attention: Nikol Kochmanova	P.O. #:					
Address: 6925 Century Ave Suite 100	Address:	Project: 1669995					
Mississauga ON L5N 7K2		Project Name:			COC #:		Project Manager:
Tel: (905) 567-4444 Fax: (905) 567-6561	Tel: (905) 567-6100 Ext: 1459 Fax:	Site #:			C#668025-05-01		Ema Gitej
Email: AP_CustomerService@golder.com	Email: Nikol_Kochmanova@golder.com	Sampled By:					

<b>MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE MAXXAM DRINKING WATER CHAIN OF CUSTODY</b>				<b>ANALYSIS REQUESTED (PLEASE BE SPECIFIC)</b>												<b>Turnaround Time (TAT) Required:</b> Please provide advance notice for rush projects							
<b>Regulation 153 (2011)</b>				<b>Other Regulations</b>				<b>Special Instructions</b>												<b>Regular (Standard) TAT:</b> (will be applied if Rush TAT is not specified): Standard TAT = 5-7 Working days for most tests. Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details. <b>Job Specific Rush TAT (if applies to entire submission)</b> Date Required: Time Required: Rush Confirmation Number: (call lab for #)			
<input type="checkbox"/> Table 1	<input type="checkbox"/> Res/Park	<input type="checkbox"/> Medium/Fine	<input type="checkbox"/> CCME	<input type="checkbox"/> Sanitary Sewer Bylaw	<b>Field Filtered (please circle):</b> Metals / Hg / Cr VI Corrosivity: pH, SO <sub>4</sub> , pH, Resistivity/EC - no Sulphide and Redox Potential												<b># of Bottles</b>		<b>Comments</b>				
<input type="checkbox"/> Table 2	<input type="checkbox"/> Ind/Comm	<input type="checkbox"/> Coarse	<input type="checkbox"/> Reg 558	<input type="checkbox"/> Storm Sewer Bylaw																			
<input type="checkbox"/> Table 3	<input type="checkbox"/> Agri/Other	<input type="checkbox"/> For RSC	<input type="checkbox"/> MISA	<input type="checkbox"/> Municipality																			
<input type="checkbox"/> Table			<input type="checkbox"/> PWQO	<input type="checkbox"/> Other																			
<b>Include Criteria on Certificate of Analysis (Y/N)?</b>																							
Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix																			
1	BR-d SA-4	May 30/18	AM	SOIL																			
2																							
3																							
4																							
5																							
6																							
7																							
8																							
9																							
10																							
<b>* RELINQUISHED BY: (Signature/Print)</b>				<b>Date: (YY/MM/DD)</b>		<b>Time</b>		<b>RECEIVED BY: (Signature/Print)</b>				<b>Date: (YY/MM/DD)</b>		<b>Time</b>		<b># jars used and not submitted</b>		<b>Laboratory Use Only</b>					
See page 1								See page one										Time Sensitive		Temperature (°C) on Reel	Custody Seal	Yes	No
																					Intact		
<b>* UNLESS OTHERWISE AGREED TO IN WRITING, WORK SUBMITTED ON THIS CHAIN OF CUSTODY IS SUBJECT TO MAXXAM'S STANDARD TERMS AND CONDITIONS. SIGNING OF THIS CHAIN OF CUSTODY DOCUMENT IS ACKNOWLEDGMENT AND ACCEPTANCE OF OUR TERMS WHICH ARE AVAILABLE FOR VIEWING AT WWW.MAXXAM.CA/TERMS.</b>																<b>SAMPLES MUST BE KEPT COOL (&lt; 10° C) FROM TIME OF SAMPLING UNTIL DELIVERY TO MAXXAM</b>				<b>White: Maxxa Yellow: Client</b>			
<b>** IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.</b>																							
<b>** SAMPLE CONTAINER, PRESERVATION, HOLD TIME AND PACKAGE INFORMATION CAN BE VIEWED AT HTTP://MAXXAM.CA/WP-CONTENT/UPLOADS/ONTARIO-COC.PDF.</b>																							



**APPENDIX E**

# Non-Standard Special Provisions



**PROTECTION SYSTEM - Item No.**

---

Special Provision

---

**Amendment to OPSS 539, November 2014**

**593.07.02 Removal of Protection Systems**

Subsection 539.07.02 of OPSS 539 is deleted in its entirety and replaced with the following:

Protection systems shall be removed from the right-of-way unless it is specified in the Contract Documents that the protection system may be left in place.

Where piles are left in place, the top shall be removed to at least 1.2 m below the finished grade or ground level.

The method and sequence of removal shall be such that there shall be no damage to the new work, existing work and facility being protected.

All disturbed areas shall be restored to an equivalent or better condition than existing prior to the commencement of construction.



**OBSTRUCTIONS – Item No.**

---

Special Provision

---

Although not encountered during the current borehole investigation at this site, the native soils should be expected to contain cobbles and boulders. Consideration of the presence of these obstructions must be made in the selection of appropriate equipment and procedures for excavations, for installation of temporary protection systems and for installing steel H-piles in pre-drilled holes or advancing caissons, such that the design tip levels are achieved.

**Basis of Payment**

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.



## **VIBRATION MONITORING - Item No.**

---

Non-Standard Special Provision

---

### **Scope**

This special provision describes requirements for vibration monitoring during soldier pile or sheet pile installation works for the construction of the retaining wall at the McCowan Road underpass for widening of the Highway 401 Westbound lanes at McCowan Road and installation of the temporary protection systems.

### **References**

The subsurface conditions at the site are described in the following Foundation Investigation Report for GWP 2162-11-00:

McCowan Road Underpass (Site No. 37-217)  
Highway 401 Westbound Core and Collector Lanes, Neilson Road to Warden Avenue, City of Toronto, Ontario,  
Ministry of Transportation, Ontario  
G.W.P. No. 2162-11-00, GEOCREC No.

### **Definitions**

Contractor's Engineer: An Engineer with a minimum of five (5) years of experience in the field of installation of piling and vibration monitoring or alternatively has demonstrated expertise by providing satisfactory quality verification services for the work at a minimum of two (2) projects of similar scope to the contract. The Contractor's Engineer shall be retained by the Contractor to ensure general conformance with the contract documents and issue certificate(s) of conformance.

### **Submission Requirements**

The Contractor/Contractor's Engineer shall submit details of the vibration monitoring plan to the Contract Administrator for review. The submittals shall satisfy the specifications and at a minimum contain the following specific information:

- Qualifications of vibration monitoring specialist.
- Details regarding proposed instrumentation.
- Proposed location of instruments.
- Proposed frequency of readings.
- Proposed methods for adjusting piling methods if readings show vibrations exceeding tolerable levels.

### **Monitoring**

The vibration monitoring equipment shall be placed as close as possible to the works. The Contractor/Contractor's Engineer shall take readings on the existing bridge foundations and on existing residential structures located within 200 m of the works during installation of any deep foundation elements (including piles for temporary protection systems), starting with the pile furthest away for each foundation element.



The vibrations measured at the site shall not exceed 50 mm/s (peak particle velocity).

The results shall be submitted to the Contract Administrator after each pile installation, prior to continuing with the subsequent piles. As a minimum, the pile number, location, set criteria and driving/drilling log must be submitted with vibration monitoring results.

If the vibration monitoring results are acceptable, the Contractor may continue with the next pile(s) with readings taken during driving of each pile. The results of subsequent piles should be submitted to the Contract Administrator after each pile has been driven.

If the readings are not within the limits stated above, the Contractor must alter the driving procedures until the vibrations at the existing structures are within acceptable levels. The above process must be repeated for each pile.

#### **Certificate of Conformance (CoC)**

Upon completion of the work in each area of pile driving, the Contractor shall submit to the Contract Administrator a CoC sealed and signed by the Contractor's Engineer. The certificate shall state that the vibrations on the existing structure were below the limits stated above, and where the levels were exceeded, what procedures were used to reduce the vibrations to below the limits stated above.

#### **Basis of Payment**

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.

#### **END OF SECTION**



## **CONCRETE WORKING SLAB - Item No.**

---

Non-Standard Special Provision

---

### **1.0 Scope**

This Special Provision covers the requirements for the supply and placement of a concrete working slab for the base of the excavations associated with the construction of the retaining wall at the McCowan Road underpass for widening of the Highway 401 Westbound lanes at McCowan Road.

### **2.0 References**

This Special Provision refers to the following standards, specifications or publications:

Ontario Provincial Standard Specifications, Construction  
OPSS 902          Excavating and Backfilling - Structures

### **3.0 Definitions - Not Used**

### **4.0 Design and Submission Requirements - Not Used**

### **5.0 Materials**

Concrete for working slabs shall have a minimum 28 day strength of 20 MPa.

### **6.0 EQUIPMENT - Not Used**

### **7.0 CONSTRUCTION**

#### **7.01 Excavation**

Excavation for the working slab shall be according to OPSS 902.

#### **7.03 Protection of Subgrade**

The native subgrade for the retaining wall structure will be susceptible to disturbance and softening/loosening from construction traffic and ponded water. Following inspection and approval of the prepared subgrade, a concrete working slab with a minimum thickness of 100 mm shall be placed on the foundation subgrade within four hours.

The concrete shall have a compressive strength of at least 20 MPa, and be placed in accordance with OPSS.PROV 904.

#### **7.04 Dewatering**

Dewatering shall be carried out according to OPSS 902.

### **8.0 Quality Assurance - Not Used**

### **9.0 Measurement for Payment - Not Used**

### **10.0 Basis of Payment**

#### **10.01 Working Slab - Item**

Payment at the Contract price for the above tender item shall be full compensation for all labour, Equipment and Material to do the work.

**END OF SECTION**



## **DEWATERING STRUCTURE EXCAVATIONS - Item No.**

---

Special Provision No. FOUN 0003

March 8, 2018

---

### **Amendment to OPSS 902, November 2010**

#### **902.02 REFERENCES**

Section 902.02 of OPSS 902 is amended by the addition of the following:

#### **Ontario Provincial Standard Specifications, Construction**

OPSS 517      Dewatering  
OPSS 805      Temporary Erosion and Sediment Control Measures

#### **902.03 DEFINITIONS**

Section 903.03 of OPSS 902 is amended by the addition of the following:

**Automatic Transfer Switch** means as defined in OPSS 517.

**Cofferdam** means as defined in OPSS 539.

**Cut-Off Wall** means as defined in OPSS 517.

**Design Storm Return Period** means as defined in OPSS 517.

**Dewatering System** means as defined in OPSS 517.

**Groundwater Control System** means as defined in OPSS 517.

**Plug** means as defined in OPSS 517.

**Sediment** means as defined in OPSS 517.

**Sediment Control Measure** means as defined in OPSS 517.

**Temporary Flow Passage System** means as defined in OPSS 517.

**Unwatering** means as defined in OPSS 517.

**Vegetated Discharge Area** means as defined in OPSS 517.

**Waterbody** means as defined in OPSS 517.

**Watercourse** means as defined in OPSS 517.



## **902.04 DESIGN AND SUBMISSION REQUIREMENTS**

### **902.04.01 Design Requirements**

#### **902.04.01.01 Dewatering**

Clause 902.04.01.01 of OPSS 902 is deleted in its entirety and replaced with the following:

A dewatering system shall be designed to control water and the flow of water into the excavation, prevent disturbance of the foundation, permit the placing of concrete in the dry, and complete the excavating and backfilling for structures work.

When the system includes temporary flow passage system, the system shall be designed, as a minimum, for a [\* Designer Fill-In, See Notes to Designer] year design storm return period, and groundwater discharge. A longer return period shall be used when determined appropriate for the work.

The dewatering system shall be according to the design requirements specified in OPSS 517.

### **902.04.02 Submission Requirements**

Subsection 902.04.02 of OPSS 902 is deleted in its entirety and replaced with the following:

#### **902.04.02.01 Working Drawings**

Working Drawings for the dewatering system shall be according to OPSS 517.

#### **902.04.02.02 Preconstruction Survey**

When a groundwater control system by wells or a well point system will be used, a condition survey of property and structures that may be affected by the work shall be carried out. The condition survey shall include the location and condition of adjacent properties, buildings, underground structures, water wells, Utilities, and structures, within a distance of 300 metres from the groundwater control system. In addition, all water wells used as a supply of drinking water and located within this distance shall be tested for compliance with Ontario Drinking Water Quality Standards.

Water wells within the preconstruction survey distance can be located using the website <https://www.ontario.ca/environment-and-energy/map-well-records> or its successor site.

Copies of the condition survey and water quality test results shall be submitted to the Contract Administrator prior to the operation of the groundwater control system.

#### **902.04.02.03 Milestone Inspections**

Clause 902.04.02.03 of OPSS 902 is deleted in its entirety.

## **902.07 CONSTRUCTION**

Subsection 902.07.04 of OPSS 902 is deleted in its entirety and replaced with the following:



## **902.07.04                      Dewatering Structure Excavation**

### **902.07.04.01                      General**

The dewatering systems shall be constructed and operated according to the Working Drawings.

Activation and deactivation of a temporary flow passage system, if applicable, shall be according to OPSS 517.

The dewatering system shall be continuously operational to control buoyancy forces until such forces can be resisted by backfill and structure self-weight, to keep excavations stable, to avoid erosion impacts from the release of accumulated water, and to keep the work area in the condition required to complete the associated work as specified in the Contract Documents.

When a temporary flow passage system is to remain operational through a seasonal shutdown period, the Contractor shall be responsible for any maintenance or repair costs due to the system during the seasonal shutdown period.

Temporary erosion and sediment control measures, including controlling the discharge of water, shall be according to OPSS 805. Measures not specified in OPSS 805 shall be according to the Working Drawings. Temporary erosion and sediment control measures and cover material to protect exposed soils, as required by the Working Drawings, shall be installed as soon as is practical.

Stranded fish shall be managed as specified in the Contract Documents.

Unwatering shall be carried out as necessary.

Water suspected of being contaminated as indicated by visual or olfactory observations shall be reported to the Contract Administrator.

Dewatering and temporary flow passage systems shall be discontinued in a manner that does not disturb any structure, pipeline, or flow channel. Operation of the dewatering system shall be shut down according to the procedures specified in the Working Drawings, where applicable.

### **902.07.04.02                      Discharge of Water**

The discharge of water shall be according to OPSS 517.

### **902.07.04.03                      Monitoring**

Monitoring shall be according to OPSS 517.

### **902.07.04.04                      System Amendments**

Amendments to stop any displacement, damage, soil loss or erosion due to the operation of the dewatering system shall be according to OPSS 517.

### **902.07.04.05                      Removal**

Removal of dewatering system and temporary flow passage system components shall be according to OPSS 517.



NOTES TO DESIGNER:

- \* Fill in the design storm return period according to MTO Drainage Design Standard TW-1.
- \*\* Fill in the preconstruction survey distance as recommended by the foundation engineer.

WARRANT: Include with this standard tender item only on the recommendation of a foundation engineer.

CUSTODIAN: Tony Sangiuliano, MERO - Foundation Group.





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