



January 17, 2014

FOUNDATION INVESTIGATION REPORT

HIGHWAY 540 MUD CREEK CULVERT, SITE 49-68/C
TOWNSHIP OF BILLINGS, MANITOULIN ISLAND, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5465-09-00, WP 5466-09-01

Submitted to:

McIntosh Perry Consulting Engineers Ltd.
192 Hickson Avenue
Kingston, ON
K7K 2N9



GEOCRES NO: 41G-16

Report Number: 12-1191-0014-R06

Distribution:

- 1 e-copy - Ministry of Transportation, Ontario, North Bay, Ontario (Northeastern Region)
- 1 e-copy - Ministry of Transportation, Ontario, Downsview, Ontario (Pavement and Foundations Section)
- 1 copy - McIntosh Perry, Kingston, Ontario
- 1 e-copy - Golder Associates Ltd., Sudbury, Ontario

REPORT





Table of Contents

PART A – FOUNDATION INVESTIGATION REPORT

| | |
|--|----------|
| 1.0 INTRODUCTION..... | 1 |
| 2.0 SITE DESCRIPTION..... | 1 |
| 3.0 INVESTIGATION PROCEDURES..... | 1 |
| 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS..... | 2 |
| 4.1 Regional Geology..... | 2 |
| 4.2 Subsurface Conditions..... | 3 |
| 4.2.1 Sand and Gravel Fill..... | 3 |
| 4.2.2 Silty Organics..... | 3 |
| 4.2.3 Gravelly Silty Sand..... | 4 |
| 4.2.4 Bedrock..... | 4 |
| 4.2.5 Groundwater Conditions..... | 5 |
| 5.0 CLOSURE..... | 5 |

DRAWINGS

Drawing 1 Borehole Locations and Soil Strata

SITE PHOTOGRAPHS

APPENDICES

Appendix A Record of Boreholes and Drillholes

List of Symbols and Abbreviations
Lithological and Geotechnical Rock Description Terminology
Record of Boreholes – M1 to M4
Record of Drillholes – M1 to M4

Appendix B Laboratory Test Results

Figure B1 Grain Size Distribution – Sand and Gravel (Fill)
Figure B2 Grain Size Distribution – Gravelly Silty Sand
Figure B3 Bedrock Core



PART A

**FOUNDATION INVESTIGATION REPORT
HIGHWAY 540 MUD CREEK CULVERT, SITE 49-68/C
TOWNSHIP OF BILLINGS, MANITOULIN ISLAND, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5465-09-00, WP 5466-09-01**



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by McIntosh Perry Consulting Engineers Ltd. (McIntosh Perry) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the replacement of the east end of the existing culvert at Mud Creek (Site 49-68/C) located at STA 20+045 on Highway 540, in the Township of Billings on Manitoulin Island, Ontario. The Key Plan showing the general location of this section of Highway 540 and the location of the investigated area are shown on Drawing 1.

The purpose of this investigation is to establish the subsurface conditions at the location of the culvert by borehole drilling, in situ testing and laboratory testing on selected samples.

2.0 SITE DESCRIPTION

The Mud Creek culvert is located in the Township of Billings on Highway 540, approximately 5.8 km west of Highway 551. The land use in the area is generally rural with a few residences in the vicinity of the site.

The topography in the area of the overall project limits is generally flat. The creek banks are vegetated with grass and small trees. The creek was dry at the time of our investigation.

The existing highway grade at the culvert is at about Elevations 220.8 m with the bottom of Mud Creek located about 2.1 m below the existing highway grade. The existing structure is a 3.0 m span by 0.8 m high by 15.8 m long open footing concrete culvert under approximately 0.8 m of fill. We understand the original open footing culvert, which was constructed in 1964, was approximately 6.2 m in length. Since the original construction, the culvert has been extended about 7.7 m to the west and 1.9 m the east. The construction date of the extensions is not known. The existing inlet (west) and outlet (east) inverts are at Elevation 218.7 m and 218.8 m, respectively.

A 2010 structural inspection indicated severe scaling, delaminations and medium stained cracks. The base of the south wall of the east culvert extension was noted to be rotating inwards. Based on the 2012 inspection performed by McIntosh Perry, the north side of the east culvert extension has also rotated inward at the base of the wall.

Photographs taken at the site are included following the text of the report.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation was carried out on July 8 and 9, 2013, during which time a total of four boreholes (M1 to M4) were advanced at the culvert location. The locations of the boreholes are shown on Drawing 1.

The field investigation was carried out using a track-mounted CME-850 drill rig supplied and operated by Landcore Drilling Inc. of Sudbury, Ontario. The boreholes were advanced through the overburden using 108 mm inside diameter hollow-stem augers. Soil samples were obtained at intervals of depth of about 0.75 m, using a 50 mm outer diameter split-spoon sampler, operated by an automatic hammer on the drill rig, in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586-08a). Samples of the bedrock were obtained using



NW casing and NQ size rock core barrels in each of the boreholes. The groundwater levels in the open boreholes were observed during the drilling operations as described on the Record of Borehole sheets in Appendix A. The boreholes were backfilled with bentonite upon completion in accordance with Ontario Regulation 903 (as amended by Ontario Regulation 372).

The fieldwork was supervised throughout by members of our technical staff who: located the boreholes; arranged for the clearance of underground services; supervised the drilling, sampling operations; logged the boreholes; and examined and cared for the soil and bedrock samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Sudbury geotechnical laboratory where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. Classification testing (water contents and grain size distributions) was carried out on selected soil samples and uniaxial compressive strength (UCS) testing was carried out on specimens of the recovered bedrock core. The geotechnical laboratory testing was completed according to applicable MTO LS standards. The results of the laboratory testing are included on the Record of Borehole sheets in Appendix A and in Appendix B.

The as-drilled borehole locations and ground surface elevations were measured and surveyed by members of our technical staff, referenced to stations on the highway. The MTM NAD 83 northing and easting coordinates, ground surface elevations referenced to Geodetic datum and borehole depths at each borehole location are presented on the Record of Borehole sheets in Appendix A and are summarized below.

| Borehole | Location (m) | | Ground Surface Elevation (m) | Borehole Depth (m) |
|----------|--------------|----------|------------------------------|--------------------|
| | Northing | Easting | | |
| M1 | 5078730.0 | 326590.3 | 220.5 | 5.6 |
| M2 | 5078736.4 | 326590.3 | 220.6 | 5.5 |
| M3 | 5078730.0 | 326598.7 | 220.6 | 4.7 |
| M4 | 5078736.7 | 326605.3 | 218.8 | 3.3 |

As part of the foundation investigation, an excavator was used to expose the foundation at the northeast corner of the culvert extension. As shown in Photograph #3 following the text of the report, the wall of the culvert extension is bearing directly on the exposed bedrock.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on the Physiography of Southern Ontario (Ministry of Northern Development and Mines)¹, the site is located within limestone plains bordering with clay plains and drumlin formations.

¹ Ministry of Northern Development and Mines, 2007, Physiography of Southern Ontario, MRD228.



Based on geological mapping in the area (Ministry of Northern Development and Mines)², the bedrock in the area consists typically of sandstone, shale, dolostone and siltstone from the Amabel Formation from the Silurian Period of the Paleozoic Era.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced for this investigation, together with the results of the laboratory tests carried out on selected soil samples, are given on the attached Record of Borehole and Drillhole sheets in Appendix A. The results of the laboratory testing are provided in Appendix B. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling, observations of drilling progress and the results of SPTs. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations. The inferred soil stratigraphy based on the results of the boreholes is shown in profile on Drawing 1.

In general, the subsurface conditions encountered at the site generally consist of embankment fill overlying bedrock. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Sand and Gravel Fill

A 1.8 m to 2.1 m thick layer of brown, moist, sand and gravel fill, trace to some silt, trace clay was encountered from ground surface (between Elevation 220.6 and 220.5 m) in Boreholes M1 to M3, which were advanced from the existing highway shoulders. The augers were noted to be grinding on cobbles within the fill generally at a depth of about 0.6 m below the existing ground surface (about Elevation 220.0 m).

Standard Penetration Test (SPT) 'N'-values measured within the sand and gravel fill range from 11 blows to 38 blows per 0.3 m of penetration indicating a compact to dense relative density.

Grain size distribution tests were carried out on five samples of the sand and gravel fill and the results are shown on Figure B1 in Appendix B.

The natural water content measured on five samples of the sand and gravel fill ranges from 3 per cent to 5 per cent.

4.2.2 Silty Organics

A 0.2 m thick layer of brown, moist, silty organics, trace to some sand, trace gravel was encountered from ground surface (Elevation 218.8 m) in Borehole M4, which was advanced beyond the embankment toe of slope near the culvert inlet.

² Ministry of Northern Development and Mines, 1991. *Bedrock Geology of Ontario*, Southern Sheet, Map 2544.



4.2.3 Gravelly Silty Sand

A 0.4 m thick deposit of brown, wet gravelly silty sand, trace organics, was encountered below the sand and gravel fill in Borehole M1. The surface of this deposit was encountered at Elevation 218.7 m.

The SPT 'N'-value measured within the gravelly silty sand deposit is 14 blows per 0.3 m penetration, indicating a compact relative density.

The natural water content measured on one sample of the gravelly silty sand is 20 per cent.

A grain size distribution test was carried out on a sample of the gravelly silty sand and the results are shown on Figure B2 in Appendix B.

4.2.4 Bedrock

Bedrock was cored in Boreholes M1 to M4. The bedrock surface/refusal depths and elevations are presented below.

| Borehole No. | Depth to Bedrock (m) | Bedrock Surface Elevation (m) | Notes |
|--------------|----------------------|-------------------------------|-------------------------|
| M1 | 2.2 | 218.3 | Bedrock Cored for 3.4 m |
| M2 | 2.1 | 218.5 | Bedrock Cored for 3.4 m |
| M3 | 1.8 | 218.8 | Bedrock Cored for 2.9 m |
| M4 | 0.2 | 218.6 | Bedrock Cored for 3.1 m |

The retrieved bedrock core is described as a fine grained, fresh to slightly weathered, grey, dolomitic limestone, as presented in the Record of Drillhole sheets in Appendix A. Photographs of the retrieved bedrock core samples are shown on Figure B3 in Appendix B.

The Total Core Recovery (TCR) during bedrock coring ranged from 97 per cent to 100 per cent. The Rock Quality Designation (RQD) measured on the core samples ranges from 58 per cent to 100 per cent, indicating a rock mass of fair to excellent quality as per Table 3.10 of the Canadian Foundation Engineering Manual (CFEM, 2006).

Laboratory UCS testing was carried out on two core samples of the bedrock. The UCS values are presented below and the test results indicate the bedrock is very strong as per Table 3.5 of the CFEM (2006).

| Borehole | Elevation (m) | UCS (MPa) |
|----------|---------------|-----------|
| M2 | 217.9 | 229 |
| M3 | 216.8 | 183 |



4.2.5 Groundwater Conditions

The boreholes were noted to be dry upon completion of drilling prior to bedrock coring.

The creek was dry at the time of the investigation in July 2013. Groundwater levels in the area are subject to seasonal fluctuations and to fluctuations after precipitation events and snowmelt.

5.0 CLOSURE

The field personnel supervising the drilling program was Mr. Mathew Riopelle. This report was prepared by Mr. David Muldowney, P.Eng., and the technical aspects were reviewed by Mr. André Bom, P.Eng. Mr. Fintan Heffernan, P.Eng., Golder's Designated MTO Contact for this project, carried out a quality control review and reviewed the technical aspects of the report.



Report Signature Page

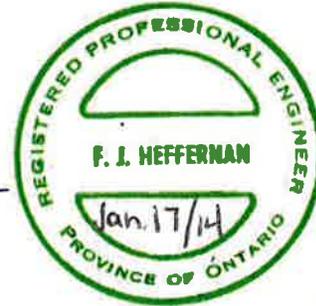
GOLDER ASSOCIATES LTD.


David Muldowney, P. Eng.
Geotechnical Engineer




André Bom, P.Eng., PMP
Geotechnical Engineer





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

DAM/AB/FJH/kp

Golder, Golder Associates and the GA globe design are trademarks of Golder Associates Corporation.

[http://capws.golder.com/sites/p211910014mtohw542and655manislandlimmins/reports/final/mud creek site 49-68/12-1191-0014-r06 rpt 14jan17 mud creek site 49-68 - fir.docx](http://capws.golder.com/sites/p211910014mtohw542and655manislandlimmins/reports/final/mud%20creek%20site%2049-68/12-1191-0014-r06_rpt_14jan17_mud_creek_site_49-68_fir.docx)

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

CONT No.
WP No. 5466-09-01

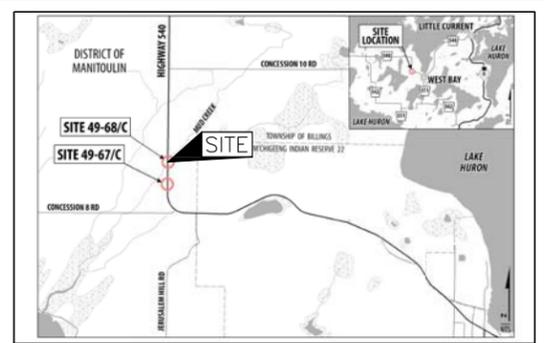


HIGHWAY 540
MUD CREEK CULVERT SITE 49-68/C
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



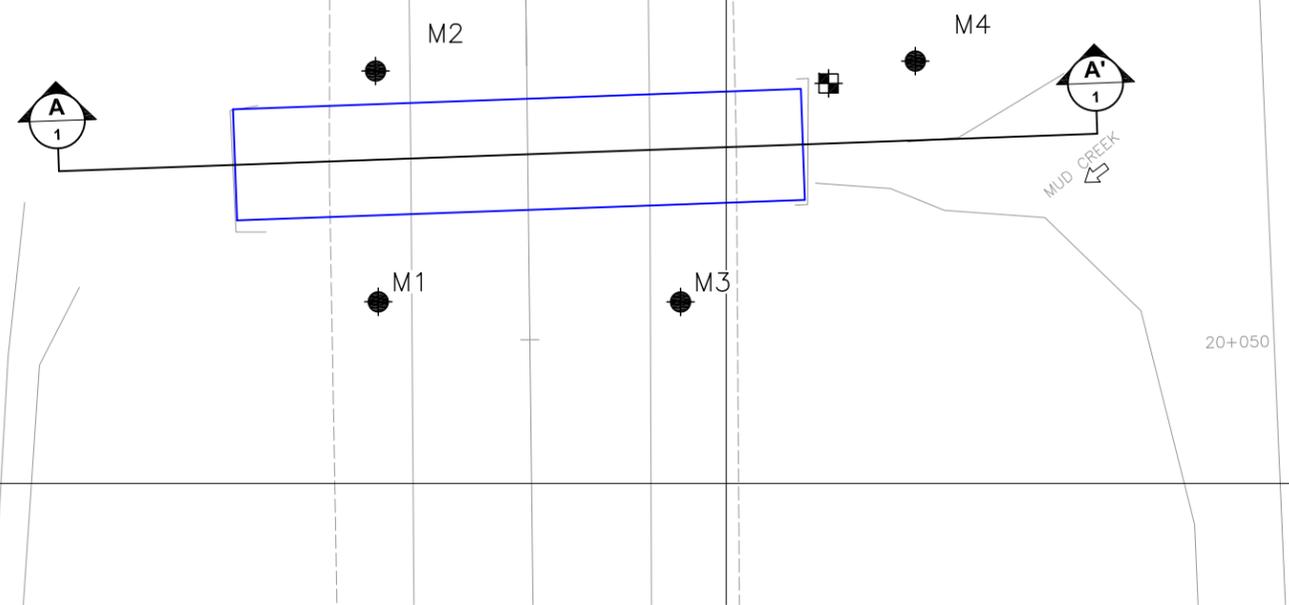
Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA



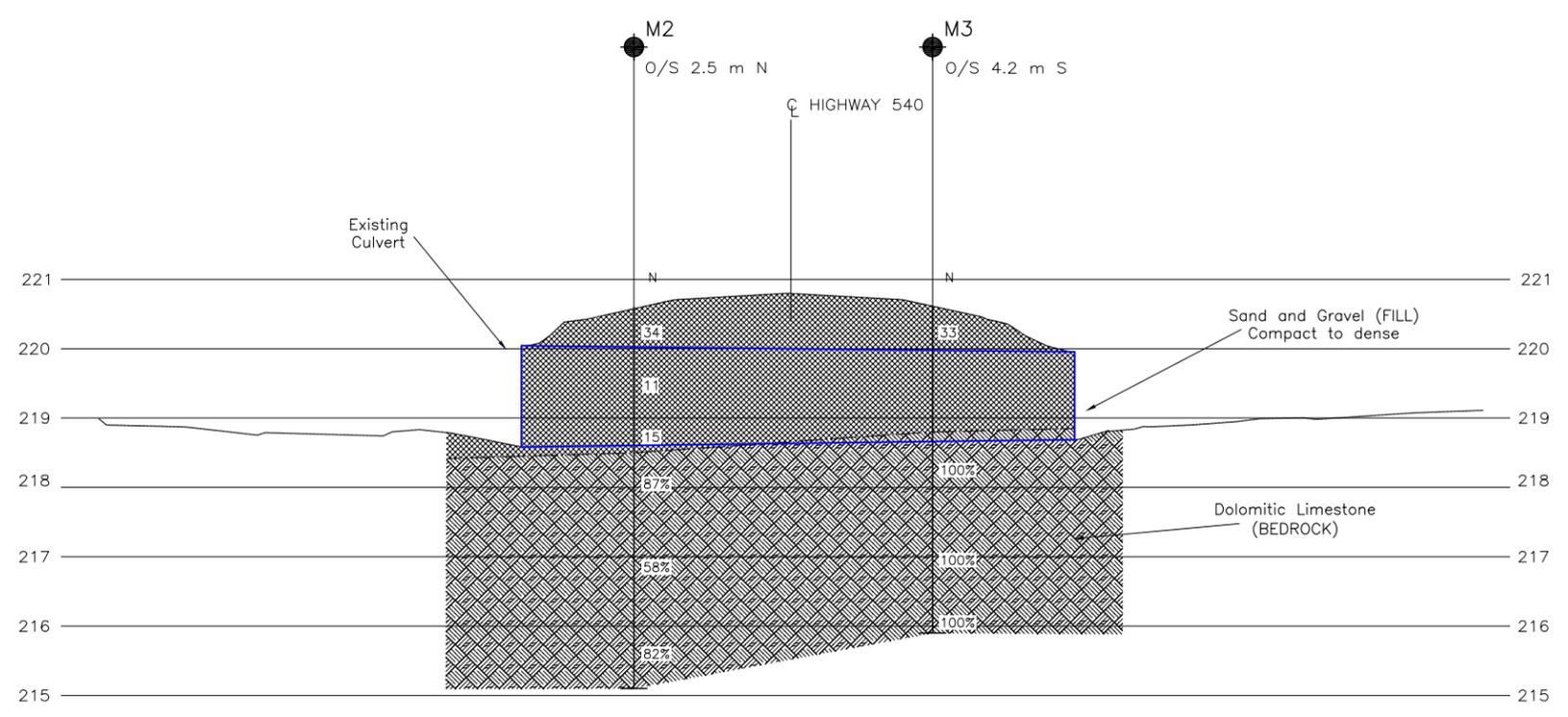
KEY PLAN



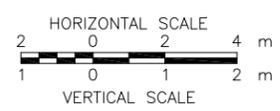
N 5078725



PLAN



CULVERT PROFILE STA. 20+045
HIGHWAY 540



LEGEND

- Borehole
- Test Pit
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)

BOREHOLE CO-ORDINATES

| No. | ELEVATION | NORTHING | EASTING |
|-----|-----------|-----------|----------|
| M1 | 220.5 | 5078730.0 | 326590.3 |
| M2 | 220.6 | 5078736.4 | 326590.3 |
| M3 | 220.6 | 5078730.0 | 326598.7 |
| M4 | 218.8 | 5078736.7 | 326605.3 |

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.

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans provided in digital format by McIntosh Perry, drawing file no. 11-684-Mud Creek Xref.dwg, received Aug 20, 2013. Cross-section file no. 11-684-Mud Creek - Typical Sections - C3D.dwg, received July 19, 2013. Key plan drawing file no. KM11684 - 49-68 and 49-67 Location Map - June 26 2012.jpg, received August 24, 2012.



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

Geocres No. 41G-16

| | | |
|-------------|--------------------------|----------------|
| HWY. 540 | PROJECT NO. 12-1191-0014 | DIST. |
| SUBM'D. DAM | CHKD. | DATE: JAN 2014 |
| DRAWN: TB | CHKD. AB | APPD. FJH |
| | | SITE: 49-68/C |
| | | DWG. 1 |



Photograph 1: Looking southeast from culvert inlet (October 2012)



**Photograph 2: Looking south at east culvert extension
(From McIntosh Perry by email Feb 25, 2013)**





Photograph 3: Looking north at exposed east culvert extension following excavation of test pit (July 2013)



Photograph 4: Looking at north wall of east extension (From McIntosh Perry by email Feb 25, 2013)





APPENDIX A

Record of Boreholes and Drillholes



LIST OF SYMBOLS

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

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

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

Notes: 1
2

$\tau = c' + \sigma' \tan \phi'$
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 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

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

(b) Cohesive Soils Consistency

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

IV. SOIL TESTS

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

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

V. MINOR SOIL CONSTITUENTS

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



LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERINGS STATE

Fresh: no visible sign of weathering

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

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

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

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

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

BEDDING THICKNESS

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

JOINT OR FOLIATION SPACING

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

GRAIN SIZE

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

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

CORE CONDITION

Total Core Recovery (TCR)

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

Solid Core Recovery (SCR)

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

Rock Quality Designation (RQD)

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

DISCONTINUITY DATA

Fracture Index

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

Dip with Respect to Core Axis

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

Description and Notes

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

Abbreviations

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

| | | |
|-----------------------------|---|-------------------------|
| PROJECT <u>12-1191-0014</u> | RECORD OF BOREHOLE No M1 | 1 OF 1 METRIC |
| W.P. <u>5466-09-01</u> | LOCATION <u>N 5078730.0; E 326590.3</u> | ORIGINATED BY <u>MR</u> |
| DIST <u>HWY 540</u> | BOREHOLE TYPE <u>108 mm ID Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring</u> | COMPILED BY <u>DAM</u> |
| DATUM <u>GEODETIC</u> | DATE <u>July 8, 2013</u> | CHECKED BY <u>AB</u> |

| ELEV DEPTH | SOIL PROFILE DESCRIPTION | STRAT PLOT | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT W _p | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---------------|---|--------------------|---------|------|------------|----------------------------|-----------------|---|----|----|-----|--|------------------------------------|-------------------------------------|-----------------------------------|--|--|
| | | | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | | | | |
| | | | | | | | 20 | 40 | 60 | 80 | 100 | | | | | | |
| 220.5 | GROUND SURFACE | | | | | | | | | | | | | | | | |
| 0.0 | Sand and gravel, some silt, trace clay (FILL) Compact to dense Brown Moist | [Hatched Pattern] | 1 | SS | 38 | | | | | | | | | | | 38 44 16 2 | |
| | Augers grinding on cobbles between 0.6 m and 0.9 m depth and between 1.4 m and 1.5 m depth. | | 2 | SS | 11 | | | | | | | | | | | 43 39 15 3 | |
| 218.7 | | | 3a | SS | 14 | | | | | | | | | | | 28 41 28 3 | |
| 218.3 | Gravelly Silty SAND, trace clay, trace organics Compact Brown Wet | [Hatched Pattern] | 3b | SS | | | | | | | | | | | | | |
| 2.2 | DOLOMITIC LIMESTONE (BEDROCK) Bedrock cored from 2.2 m depth to 5.6 m depth. For coring details see Record of Drillhole M1. | [Diagonal Pattern] | 1 | RC | REC 97% | | | | | | | | | | | RQD = 78% | |
| | | | 2 | RC | REC 100% | | | | | | | | | | | RQD = 96% | |
| | | | 3 | RC | REC 100% | | | | | | | | | | | RQD = 99% | |
| 214.9 | END OF BOREHOLE | | | | | | | | | | | | | | | | |
| 5.6 | Note: 1. Borehole dry upon completion of drilling. | | | | | | | | | | | | | | | | |

SUD_MTO_003 1211910014.5000.GPJ GAL-MASS.GDT 22/08/13 DATA INPUT:

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

PROJECT: 12-1191-0014

RECORD OF DRILLHOLE: M1

SHEET 1 OF 1

LOCATION: N 5078730.0 ; E 326590.3

DRILLING DATE: July 8, 2013

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 850

DRILLING CONTRACTOR: Landcore Drilling Ontario Inc.

| DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | COLOUR | FLUSH | RECOVERY | | R.Q.D. % | FRACT. INDEX METRES | DISCONTINUITY DATA | | | HYDRAULIC CONDUCTIVITY | | | Diametral Point Load Index (MPa) | RMC -Q' AVG. | NOTES WATER LEVELS INSTRUMENTATION | | | | |
|--------------------|---------------------------|---|--------------|-----------------|---------|--------|-------|--------------|--------------|----------|---------------------|--------------------|---------------------|------------------------------|------------------------|----|----|----------------------------------|--------------|------------------------------------|---------|-----------------|-----------------|-----------------|
| | | | | | | | | TOTAL CORE % | SOLID CORE % | | | B Angle | DIP w/ ZL CORE AXIS | Type and Surface Description | Ur | Ja | Ln | | | | k, cm/s | 10 ⁰ | 10 ¹ | 10 ² |
| | | | | | | | | % RETURN | % | | | ° | ° | | | | | | | | | | | |
| | | TOP OF ROCK | | 218.3 | | | | | | | | | | | | | | | | | | | | |
| | NW | DOLOMITIC LIMESTONE Fine grained Very strong Grey Fresh | | 2.2 | 1 | GREY | 100% | 100% | 100% | 100% | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | July 8, 2013 NG Coring | | | | 2 | GREY | 100% | 100% | 100% | 100% | | | | | | | | | | | | | | |
| 5 | | | | | 3 | GREY | 100% | 100% | 100% | 100% | | | | | | | | | | | | | | |
| 6 | | END OF DRILLHOLE | | 214.9 | | | | | | | | | | | | | | | | | | | | |
| 5.6 | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | | | | | | | | | | |

SUD-RCK 1211910014.5000.GPJ GAL-MISS.GDT 22/08/13 DATA INPUT:

DEPTH SCALE

1 : 50



LOGGED: MR

CHECKED: AB

| | | |
|---|---|-------------------------|
| PROJECT <u>12-1191-0014</u> | RECORD OF BOREHOLE No M2 | 1 OF 1 METRIC |
| W.P. <u>5466-09-01</u> | LOCATION <u>N 5078736.4; E 326590.3</u> | ORIGINATED BY <u>MR</u> |
| DIST <u> </u> HWY <u>540</u> | BOREHOLE TYPE <u>108 mm ID Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring</u> | COMPILED BY <u>DAM</u> |
| DATUM <u>GEODETIC</u> | DATE <u>July 8, 2013</u> | CHECKED BY <u>AB</u> |

| SOIL PROFILE | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT W _p | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W _L | UNIT WEIGHT γ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|--------------|--|------------|--------|------|-------------------------|-----------------|--|--------------------|----|----|-----|---------------------------------|-------------------------------|--------------------------------|------------------|---------------------------------------|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | | | "N" VALUES | SHEAR STRENGTH kPa | | | | | | | | |
| | | | | | | | 20 | 40 | 60 | 80 | 100 | | | | | |
| 220.6 | GROUND SURFACE | | | | | | | | | | | | | | | |
| 0.0 | Sand and gravel, trace to some silt (FILL) Compact to dense Brown Moist | | 1 | SS | 34 | | | | | | | | | | | |
| | Augers grinding on cobbles between 0.6 m and 0.8 m depth and between 1.2 m and 1.5 m depth. | | 2 | SS | 11 | | | | | | | | | | | 56 33 (11) |
| | | | 3 | SS | 15 | | | | | | | | | | | 39 49 (12) |
| 218.5 | DOLOMITIC LIMESTONE (BEDROCK) | | | | | | | | | | | | | | | |
| 2.1 | Bedrock cored from 2.1 m depth to 5.5 m depth. For coring details see Record of Drillhole M2. | | 1 | RC | REC 100% | | | | | | | | | | | RQD = 87% |
| | | | 2 | RC | REC 100% | | | | | | | | | | | RQD = 58% |
| | | | 3 | RC | REC 100% | | | | | | | | | | | RQD = 82% |
| 215.1 | END OF BOREHOLE | | | | | | | | | | | | | | | |
| 5.5 | Note: 1. Borehole dry upon completion of drilling. | | | | | | | | | | | | | | | |

SUD_MTO_003 1211910014.5000.GPJ GAL-MASS.GDT 22/08/13 DATA INPUT:

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

PROJECT: 12-1191-0014

RECORD OF DRILLHOLE: M3

SHEET 1 OF 1

LOCATION: N 5078730.0 ; E 326598.7

DRILLING DATE: July 9, 2013

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 850

DRILLING CONTRACTOR: Landcore Drilling Ontario Inc.

| DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | COLOUR | FLUSH | RECOVERY | | R.Q.D. % | FRACT. INDEX METRES | DISCONTINUITY DATA | | | | HYDRAULIC CONDUCTIVITY | | | Diametral Point Load Index (MPa) | RMC -Q' AVG. | NOTES WATER LEVELS INSTRUMENTATION | | | |
|--------------------|---------------------------|---|--------------|-----------------|---------|--------|-------|--------------|--------------|----------|---------------------|--------------------|----------------------|------------------------------|----|------------------------|----|---------|----------------------------------|--------------|------------------------------------|-----------------|-----------------|-----------------|
| | | | | | | | | TOTAL CORE % | SOLID CORE % | | | B Angle | DIP w.r.t. CORE AXIS | TYPE AND SURFACE DESCRIPTION | Ur | Ja | Ln | k, cm/s | | | | 10 ⁰ | 10 ¹ | 10 ² |
| | | | | | | | | 80 | 80 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 |
| | | TOP OF ROCK | | 218.8 | | | | | | | | | | | | | | | | | | | | |
| 2 | NW | DOLOMITIC LIMESTONE Fine grained Very strong Grey Fresh | | 1.8 | 1 | GREY | 100% | | | | | | | | | | | | | | | | | |
| 3 | July 9, 2013 NQ Coring | | | | 2 | GREY | 100% | | | | | | | | | | | | | | | | | |
| 4 | | | | | 3 | GREY | 100% | | | | | | | | | | | | | | | | | |
| 5 | | END OF DRILLHOLE | | 215.9 | 4.7 | | | | | | | | | | | | | | | | | | UCS = 183 MPa | |

SUD-RCK 1211910014.5000.GPJ GAL-MISS.GDT 22/08/13 DATA INPUT:

DEPTH SCALE

1 : 50



LOGGED: MR

CHECKED: AB

| | | |
|---|---|-------------------------|
| PROJECT <u>12-1191-0014</u> | RECORD OF BOREHOLE No M4 | 1 OF 1 METRIC |
| W.P. <u>5466-09-01</u> | LOCATION <u>N 5078736.7; E 326605.3</u> | ORIGINATED BY <u>MR</u> |
| DIST <u> </u> HWY <u>540</u> | BOREHOLE TYPE <u>108 mm ID Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring</u> | COMPILED BY <u>DAM</u> |
| DATUM <u>GEODETIC</u> | DATE <u>July 9, 2013</u> | CHECKED BY <u>AB</u> |

| SOIL PROFILE | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT | | | UNIT WEIGHT γ | REMARKS & GRAIN SIZE DISTRIBUTION (%) | |
|--------------|---|------------|--------|------|-------------------------|-----------------|--|--------------------|----------|----------|----------|---|-------------------|----------|----------------------|---------------------------------------|------------|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | | | "N" VALUES | SHEAR STRENGTH kPa | | | | | WATER CONTENT (%) | | | | |
| | | | | | | 20 40 60 80 100 | 20 40 60 | 20 40 60 | 20 40 60 | 20 40 60 | 20 40 60 | 20 40 60 | 20 40 60 | 20 40 60 | 20 40 60 | GR SA SI CL | |
| 218.8 | GROUND SURFACE | | | | | | | | | | | | | | | | |
| 0.0 | Silty ORGANICS, trace to some sand, trace gravel | | | | | | | | | | | | | | | | |
| 0.2 | Brown Moist DOLOMITIC LIMESTONE (BEDROCK) | | 1 | RC | REC 100% | 218 | | | | | | | | | | RQD = 84% | |
| | Bedrock cored from 0.2 m depth to 3.3 m depth. | | 2 | RC | REC 100% | 217 | | | | | | | | | | | RQD = 100% |
| | For coring details see Record of Drillhole M4. | | 3 | RC | REC 100% | 216 | | | | | | | | | | | RQD = 100% |
| 215.5 | END OF BOREHOLE | | | | | | | | | | | | | | | | |
| 3.3 | Note: 1. Borehole dry upon completion of drilling. | | | | | | | | | | | | | | | | |

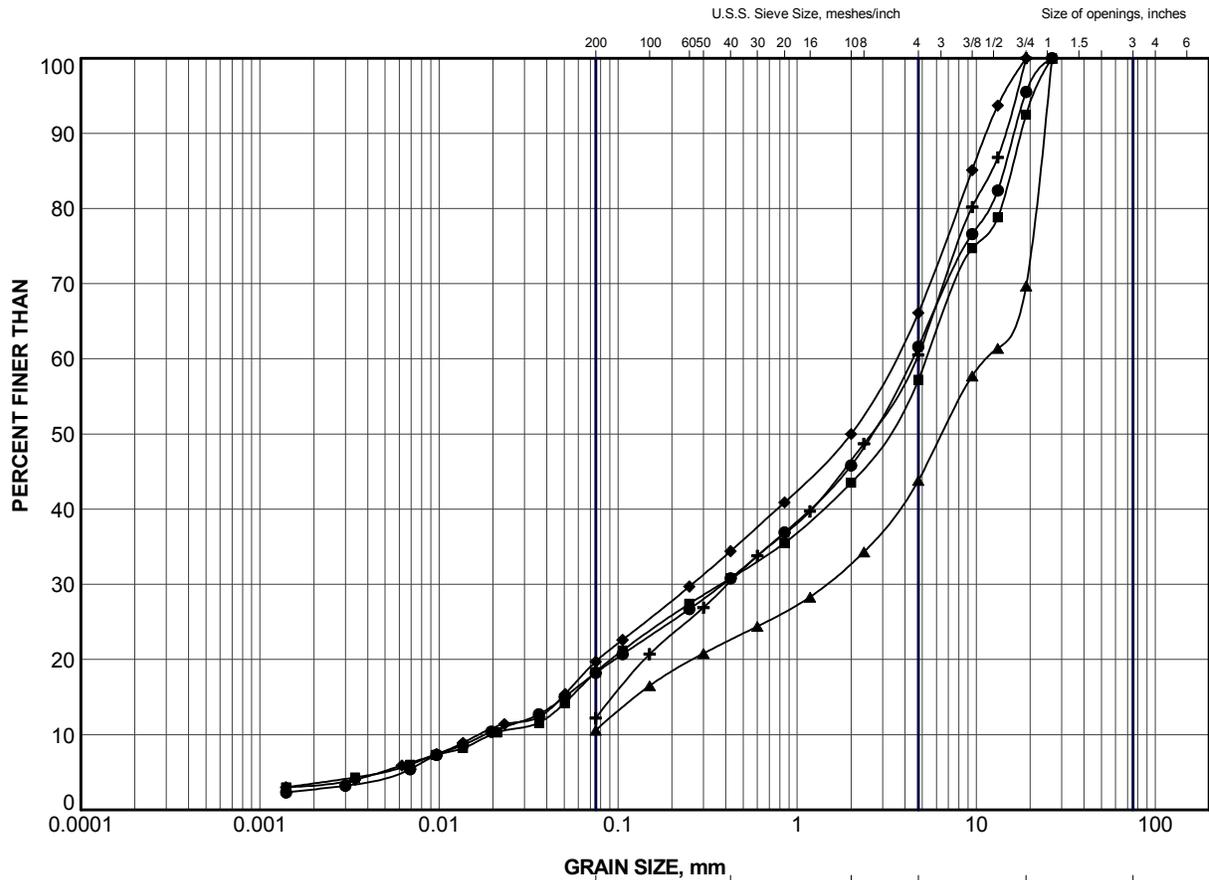
SUD_MTO_003 1211910014.5000.GPJ GAL-MASS.GDT 22/08/13 DATA INPUT:

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



APPENDIX B

Laboratory Test Results



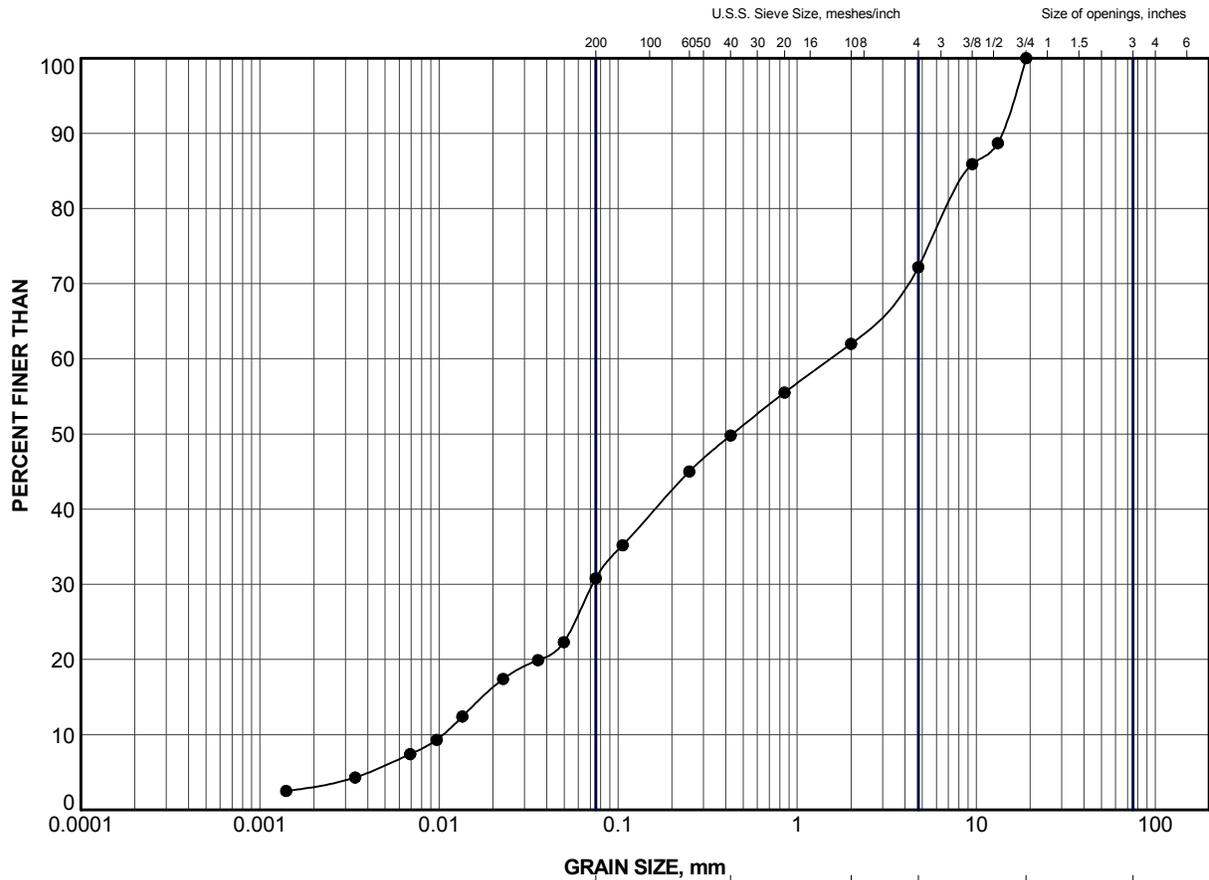
| | | | | | | |
|---------------|-----------|--------|--------|-------------|--------|-------------|
| CLAY AND SILT | fine | medium | coarse | fine | coarse | Cobble Size |
| | SAND SIZE | | | GRAVEL SIZE | | |

LEGEND

| SYMBOL | BOREHOLE | SAMPLE | ELEV (m) |
|--------|----------|--------|----------|
| ● | M1 | 1 | 220.2 |
| ■ | M1 | 2 | 219.4 |
| ▲ | M2 | 2 | 219.5 |
| + | M2 | 3 | 218.8 |
| ◆ | M3 | 1 | 220.3 |

| | | | | |
|--|-----|------------------------------|------------------|-----|
| PROJECT HIGHWAY 540 MUD CREEK CULVERT | | | | |
| TITLE GRAIN SIZE DISTRIBUTION SAND and GRAVEL (FILL) | | | | |
| PROJECT No. 12-1191-0014 | | FILE No. 1211910014.5000.GPJ | | |
| DRAWN | JJL | Aug 2013 | SCALE | N/A |
| CHECK | AB | Aug 2013 | REV. | |
| APPR | | Aug 2013 | FIGURE B1 | |





| | | | | | | |
|---------------|-----------|--------|--------|-------------|--------|-------------|
| CLAY AND SILT | fine | medium | coarse | fine | coarse | Cobble Size |
| | SAND SIZE | | | GRAVEL SIZE | | |

LEGEND

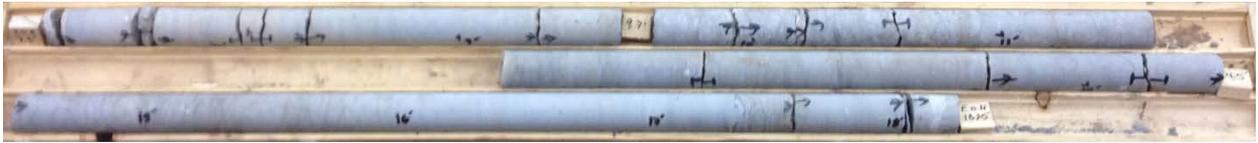
| SYMBOL | BOREHOLE | SAMPLE | ELEV (m) |
|--------|----------|--------|----------|
| ● | M1 | 3b | 218.5 |

| | | | | |
|---|-----|------------------------------|------------------|-----|
| PROJECT HIGHWAY 540 MUD CREEK CULVERT | | | | |
| TITLE GRAIN SIZE DISTRIBUTION GRAVELLY SILTY SAND | | | | |
| PROJECT No. 12-1191-0014 | | FILE No. 1211910014.5000.GPJ | | |
| DRAWN | JJL | Aug 2013 | SCALE | N/A |
| CHECK | AB | Aug 2013 | REV. | |
| APPR | | Aug 2013 | FIGURE B2 | |



SUD-MTO GSD (NEW) GLDR_LDN.GDT

Borehole M1
Elevation 218.3 m to 214.9 m



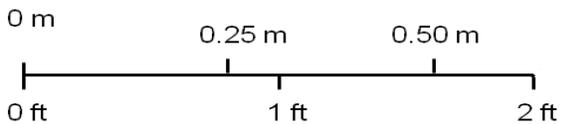
Borehole M2
Elevation 218.5 m to 215.1 m



Borehole M3
Elevation 218.8 m to 215.9 m



Borehole M4
Elevation 218.6 m to 215.5 m



| | | | |
|--------------------------|-----|------------------------------|-----------------------|
| PROJECT | | HWY 540 MUD CREEK CULVERT | |
| TITLE | | BEDROCK CORE | |
| PROJECT No. 12-1191-0014 | | FILE No. ---- | |
| DESIGN | DAM | Aug. 2013 | SCALE AS SHOWN REV. |
| CADD | -- | | |
| CHECK | AB | Aug. 2013 | |
| REVIEW | | | |



FIGURE B3

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

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

solutions@golder.com
www.golder.com

Golder Associates Ltd.
1010 Lorne Street
Sudbury, Ontario, P3C 4R9
Canada
T: +1 (705) 524 6861

