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REPORT ON

Supplementary Foundation Investigation Cataraqui River Bridge Replacement Structure Site No. 7-70 Highway 401, Kingston, Ontario G.W.P. 79-99-00

Submitted to:

Ontario Ministry of Transportation
1355 John Counter Boulevard
Kingston, Ontario
K7L 5A3

REPORT



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FOUNDATION INVESTIGATION REPORT SUPPLEMENTARY FOUNDATION INVESTIGATION CATARAQUI RIVER BRIDGE, HIGHWAY 401, KINGSTON, ONTARIO

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**FOUNDATION INVESTIGATION REPORT
SUPPLEMENTARY FOUNDATION INVESTIGATION
CATARAQUI RIVER BRIDGE, HIGHWAY 401, KINGSTON, ONTARIO**

PART A

**SUPPLEMENTARY FOUNDATION INVESTIGATION REPORT
CATARAQUI RIVER BRIDGE REPLACEMENT
HIGHWAY 401, KINGSTON, ONTARIO
G.W.P. 79-99-00**



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations associated with the detailed design of the Cataraqui River bridge replacement as part of the widening of Highway 401 between Gardiners Road and Highway 15. This report presents the results of a supplementary foundation assessment at the proposed pier locations, conducted for the replacement of the Cataraqui River bridge (Site 7-70) on Highway 401, located about 2.2 km east of Montreal Road in Kingston, Ontario.

Golder carried out a previous investigation for the Cataraqui River bridge replacement and the results of that investigation are included in the following report:

- Report prepared by Golder Associates Ltd. for MMM Group Limited (MMM) titled "*Foundation Investigation and Design, Cataraqui River Bridge Replacement, Structure Site No. 7-70, Highway 401, Kingston, Ontario, G.W.P. 79-99-00*", dated June 2015 (GEOCRES No. 31C-233).

The aforementioned report included previously collected subsurface information relevant to the current design obtained from the following sources:

- Report prepared by Foundation of Canada Engineering Corporation Ltd. (FENCO) for the MTO (then the Ontario Department of Highways) titled "*Report to Ontario Department of Highways on Soil Conditions, Cataraqui River Bridge, Kingston, Ontario*", dated April 21, 1954 (GEOCRES No. 54-F201C); and,
- Report prepared by Golder for the MTO titled "*Foundation Investigation and Design, Highway 401 Embankment Widening, Cataraqui Wetlands, Kingston, Ontario, G.W.P. 78-99-00*", dated October 2012 (GEOCRES No. 31C-203).

The terms of reference and scope of work for the foundation engineering services are outlined in MTO's Work Item Order Form for Assignment No. 7 as part of Agreement No. 4014-E-0012 received on June 10, 2016, and in Golder's Work Item Quote Form and Understanding of Scope documents submitted on June 13, 2016 and approved by MTO on June 16, 2016.



2.0 SITE DESCRIPTION

2.1 General

The site is located on Highway 401, about 2.2 km east of Montreal Road in Kingston, Ontario. The bridge was originally constructed in 1957 and consists of a three-span structure, approximately 93 m long and 28 m wide. It currently accommodates four travelled lanes (two eastbound and two westbound). Based on the available General Arrangement drawings from 1954, prepared by FENCO, the piers and abutments are supported on concrete caissons founded on bedrock between about Elevation 68 m and 73 m.

The natural ground surface within the lowland area surrounding the Cataraqui River valley is relatively flat at about Elevation 76 m. The embankments that approach the existing bridge consist of embankment fill that is up to about 9 m high at the existing bridge structure. The Highway 401 pavement grade is at approximately Elevation 84.7 m at the bridge abutments. The highway embankment side slopes are oriented at slopes ranging from about 2 horizontal to 1 vertical (2H:1V) to 3 horizontal to 1 vertical (3H:1V) in the immediate vicinity of the existing bridge. Based on visual observation during site reconnaissance visits and the drilling investigation, the existing embankment slopes are relatively well vegetated and appear to be stable.

The Cataraqui River flows south through the site and into Lake Ontario. The Cataraqui River water level was measured to range between about Elevation 74.7 m and 74.9 m in March and April 2015 and was at an average Elevation of 74.7 m in August 2016 during the current investigation field work.

2.2 Regional Geology

This area of Highway 401 lies within the southern portion of the physiographic region known as the Napanee Plain, as delineated in *The Physiography of Southern Ontario*¹.

The Napanee Plain is flat to undulating, and is characterized by relatively shallow soil deposits overlying bedrock. Geologic mapping indicates that the bedrock within the southern portion of the area consists of both granitic rock and crystalline limestone. In many areas bedrock outcrops exist at ground surface, while deeper soil deposits (on the order of 10 m) are present in the northern and southern portion of the Plain, and within and adjacent to river valleys throughout the Plain.

The overburden soils within the Napanee Plain generally consist of glacial till, although alluvium is present in river and stream valleys and, in the southern portion of the Plain, low-lying areas are typically covered with deposits of stratified clay.

In particular, the study area lies within the lowland area surrounding the Cataraqui River. In the vicinity of the bridge, the river has eroded down to the underlying pre-Cambrian bedrock. The Cataraqui River is characterized by a number of lakes joined by the river. This river flows southerly towards Kingston and is one of two major rivers in the area.

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



3.0 INVESTIGATION PROCEDURES

The subsurface investigation for the proposed bridge replacement was carried out between August 3 and 15, 2016. During that time, twelve boreholes (numbered 16-01 to 16-12, inclusive) were advanced at the locations shown on Drawings 1 and 2. The borehole records are included in Appendix A.

Boreholes 16-01 to 16-05 (inclusive) were advanced near the west pier, and 16-06 to 16-12 (inclusive) were advanced near the east pier. All boreholes were advanced using portable drilling equipment supplied and operated by OGS Inc. of Ottawa, Ontario. The boreholes were advanced to depths between about 0.9 and 6.8 m below the existing ground surface in the overburden. Boreholes 16-01, 16-02, 16-03, 16-04, 16-07, 16-09, and 16-10 were then cored about 1.5 to 2.3 m into the bedrock using BQ-size coring equipment to facilitate a sustainable drilling production rate in the strong granitic bedrock.

Continuous soil samples in the boreholes were obtained at vertical intervals of about 0.6 m, using a 50 mm outer diameter split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures.

The boreholes were backfilled with bentonite pellets mixed with native soils in the overburden, and bentonite pellets in the bedrock. The site conditions were restored following completion of work.

The field work was supervised by a member of Golder's technical staff, who located the boreholes, supervised the drilling, sampling and in situ testing operations, logged the boreholes, and examined the soil and bedrock samples. The samples were identified in the field, placed in appropriate containers, labelled, and transported to Golder's laboratory facility in Ottawa for further examination. Index and classification tests consisting of grain size distributions, Atterberg limits, organic contents and water contents were carried out on selected soil samples at the Ottawa laboratory. Unconfined compressive strength tests were carried out on selected rock core samples in Golder's Mississauga laboratory. All of the laboratory tests were carried out to MTO and/or ASTM standards as appropriate.

The borehole locations were determined based on the coordinates of the proposed pier footprints provided by MMM. The ground surface elevations and borehole locations in plan were surveyed by Golder using a Trimble R8 GPS unit. The boreholes and locations, including MTM NAD83 northing and easting coordinates and ground surface elevations referenced to Geodetic datum, are summarized in the following table and are shown on Drawings 1 and 2.

Borehole Number	Borehole Location	Northing (m)	Easting (m)	Ground Surface/River Bed Elevation (m)
16-01	West Pier	4904882.6	308944.8	74.4
16-02	West Pier	4904875.4	308947.8	74.2
16-03	West Pier	4904865.0	308949.9	73.6
16-04	West Pier	4904849.7	308950.3	73.6
16-05	West Pier	4904858.6	308950.5	73.8
16-06	East Pier	4904897.3	308985.5	74.4



**FOUNDATION INVESTIGATION REPORT
SUPPLEMENTARY FOUNDATION INVESTIGATION
CATARAQUI RIVER BRIDGE, HIGHWAY 401, KINGSTON, ONTARIO**

Borehole Number	Borehole Location	Northing (m)	Easting (m)	Ground Surface/River Bed Elevation (m)
16-07	East Pier	4904890.3	308986.1	74.5
16-08	East Pier	4904894.1	308987.8	74.9
16-09	East Pier	4904878.8	308988.5	74.9
16-10	East Pier	4904868.4	308990.2	74.9
16-11	East Pier	4904873.9	308991.1	75.2
16-12	East Pier	4904863.5	308991.4	75.3

Notes: 1) Northing and Easting coordinates shown are relative to the MTM NAD83 (Zone 9) coordinate system.
2) Ground surface/river bottom elevations shown are relative to Geodetic Datum.



4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes put down as part of the current investigation and the results of related in situ and laboratory testing are given on the Record of Borehole and Drillhole sheets contained in Appendix A. The relevant borehole logs and geotechnical test results from the previous investigations, carried out in 1954 (prior to construction of the bridge), 2009, and 2015 were reported under separate cover (Golder, 2015). The results of geotechnical laboratory testing carried out by Golder as part of the current investigation are included in Appendix B. The results of rock core testing carried out by the Colorado School of Mines are included in Appendix C.

The interpreted stratigraphic conditions along the centreline of the existing bridge and at the proposed piers and locations are shown on Drawings 1 and 2, respectively. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic sections included on Drawings 1 and 2 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

In general, the subsurface conditions at the pier locations consist of rock fill and organic sand and silt overlying very stiff to hard silty clay to clay, which is underlain by a thin deposit of glacial till consisting of silty sand at some borehole locations. The soil deposits are underlain by syenite bedrock.

A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.1.1 Surficial Fill

Rock fill was encountered at the ground surface at boreholes 16-01, 16-03, 16-05, and 16-12. The fill generally consists of a surficial layer of rock fill (cobbles and boulders) intermixed with organic silts and sands, and/or clayey silt. The rock fill extends down to depths ranging from 0.9 m to 1.8 m below the existing ground surface or river bottom. The fill also contains white shells, organic matter, and wood fragments.

The fill in boreholes 16-06 to 16-11 generally consists of silty sand to clayey silt to sandy gravel. The fill also contains cobbles, boulders, white shells, and organic matter. The fill in these boreholes extends to depths ranging from about 0.3 m to 1.4 m below the existing ground surface.

The Standard Penetration Test (SPT) “N” values measured in the fill range from ‘weight of hammer’ to greater than 50 blows per 0.3 m of penetration but were typically on the order of 1 to 8 blows per 0.3 m of penetration, indicating a generally very loose to loose relative density in the fill.

4.1.2 Organic Silt

Organic silt was encountered at the ground surface at Borehole 16-04 and 16-05, and below the fill in boreholes 16-07, 16-09, and 16-12. The organic silt contains varying amounts of sand and gravel, and extends down to depths ranging from about 0.9 m to 2.1 m below the existing ground surface. The organic silt also contains wood fragments.

The SPT “N” values measured in the organic silt range from ‘weight of hammer’ to 7 blows per 0.3 m of penetration indicating a very loose to loose relative density.

The measured water content of one sample of the organic silt was approximately 38 percent.



4.1.3 Silty Sand

A deposit of silty sand and gravel was encountered beneath the fill in Borehole 16-02. The silty sand is about 0.3 m thick and extends to about 1.3 m below the existing ground surface.

A deposit of layered silty sand, sandy silt, and silty clay was encountered beneath the rock fill in Borehole 16-05. This layered deposit is about 0.3 m thick and extends to about 2.1 m below the river bottom.

Two SPT “N” values measured in the silty sand and layered deposit are 53 and greater than 50 blows per 0.3 m of penetration indicating a very dense relative density. The higher blow counts may reflect the presence of the surface of the bedrock or glacial till rather than the state of packing of the soil matrix.

4.1.4 Silty Clay to Clay

A deposit of silty clay to clay was encountered beneath the fill and/or organic silt deposit in Boreholes 16-04, 16-06, 16-07, 16-08, and 16-11. The upper portion of the silty clay in Boreholes 16-06, 16-08, and 16-11 and the full depth of the silty clay in Borehole 16-07 has been weathered to a grey brown crust. The weathered crust extends to depths ranging from about 1.8 m to 3.4 m below the existing ground surface or river bottom. The SPT “N” values measured in the silty clay deposit range from 9 to 49 blows per 0.3 m of penetration indicating a very stiff to hard consistency.

The silty clay below the depth of weathering in Boreholes 16-06 and 16-08 and the full depth of the silty clay in Borehole 16-04 is grey in colour. In Borehole 16-11, the silty clay grades to a clayey silt containing some gravel. The silty clay to clayey silt was not fully penetrated in Boreholes 16-06 and 16-11 but was proven to a depth of about 5.5 m and 2.1 m below the existing ground surface, respectively at auger refusal at the inferred bedrock surface. The silty clay was fully penetrated in Boreholes 16-04 and 16-08 and extends to depths of about 2.6 m and 4.6 m below the existing ground surface, respectively. The measured SPT “N” values range from about 5 to 9 blows per 0.3 m of penetration, but were more typically between 8 and greater than 50 blows per 0.3 m of penetration indicate that this deposit has a generally firm to stiff consistency.

Atterberg limits tests carried out on samples of the deposit gave plasticity index values ranging from 22 to 34 percent and liquid limit values ranging from about 40 to 56 percent. These test results are presented on a plasticity chart on Figure B1 in Appendix B, indicating that the cohesive deposit consists of silty clay to clay of intermediate to high plasticity. The measured water content of the silty clay ranged from approximately 26 to 33 percent.

The results of grain size distribution testing carried out on two samples of the silty clay are included on Figure B2 in Appendix B.

4.1.5 Silty Clay, Clayey Silt, and Sandy Silt

A deposit of silty clay, clayey silt, and sandy silt was encountered below the silty clay in boreholes 16-07 and 16-08. This deposit was encountered at depths of about 2.7 and 4.6 m and has a thickness of about 0.3 and 1.8 m in boreholes 16-07 and 16-08, respectively.

SPT “N” values measured in the silty clay, clayey silt, and sandy silt range from 4 to 8 blows per 0.3 m of penetration indicating a firm consistency.

One Atterberg limits test carried out on a sample of the deposit gave a plasticity index value of about 16 percent and liquid limit value of about 32 percent; these results are presented on the plasticity chart on Figure B1 in Appendix B, indicating that the cohesive deposit consists of silty clay of low plasticity. The measured water content of one sample of the silty deposit is approximately 29 percent.



The results of grain size distribution testing carried out on one sample of the silty deposit are included on Figure B3 in Appendix B.

4.1.6 Glacial Till

A deposit of glacial till was encountered below the silty clay, silty sand, and/or fill in Boreholes 16-04, 16-05, 16-08, and 16-10. The glacial till was not fully penetrated in Boreholes 16-05 and 16-08, but was proven to a depth of about 3.0 m and 6.8 m, respectively, below the existing ground surface/river bottom. The glacial till consists of a heterogeneous mixture of cobbles, boulders, and gravel in a matrix of silty sand to sandy silt with some clay.

The measured water content of one sample of the glacial till is approximately 19 percent.

The result of a grain size distribution testing carried out on two samples of the glacial till are included on Figure B4 in Appendix B.

4.1.7 Bedrock

Refusal to split-spoon sampler advancement, inferred to represent the bedrock surface, was encountered in Boreholes 16-05, 16-06, 16-08, 16-11, and 16-12. Bedrock was encountered beneath the overburden at Boreholes 16-01 to 16-04, 16-07, 16-09, and 16-10 where it was cored for depths of between about 1.5 m to 2.3 m.

The following table summarizes the bedrock surface depths and elevations encountered at the borehole locations during the current and previous investigations. The bedrock surface elevation is variable within each proposed foundation area.

Foundation Area	Borehole Number	Existing Ground Surface/River Bottom Elevation (m)	Depth to Bedrock (m)	Bedrock Surface Elevation (m)
West Pier	16-01	74.4	1.0	73.4
	16-02	74.2	1.3	72.9
	16-03	73.6	0.9	72.7
	16-04	73.6	4.6	69.0
	16-05	73.8	3.0*	70.8*
East Pier	16-06	74.4	5.5*	68.9*
	16-07	74.5	3.0	71.6
	16-08	74.9	6.8*	68.1*
	16-09	74.9	1.1	73.8
	16-10	74.9	1.7	73.2
	16-11	75.2	2.1*	73.1*
	16-12	75.3	2.1*	73.2*

Note: * Depth and elevation to bedrock inferred from refusal to augering and split-spoon penetration.



FOUNDATION INVESTIGATION REPORT SUPPLEMENTARY FOUNDATION INVESTIGATION CATARAQUI RIVER BRIDGE, HIGHWAY 401, KINGSTON, ONTARIO

The bedrock encountered in the cored boreholes of the current investigation typically consists of pink grey diabase, syenite, to syenite gneiss, bedrock. The bedrock is generally fresh, fine to coarse grained, non-porous, and very strong.

The Rock Quality Designation (RQD) values measured on the recovered bedrock core samples typically ranged from about 565 to 100 percent, indicating fair to excellent quality rock. The discontinuities observed in the rock core were associated with the joints, veins, faults and fractures of the bedrock.

Laboratory point load testing and unconfined compressive strength testing was carried out on selected specimens of the bedrock core. The results of the testing are summarized on Figures B5 and B6 in Appendix B. The unconfined compressive strengths interpreted from the point load tests range from 137 to 302 MPa indicating a strong to very strong bedrock. The measured unconfined compressive strengths range from 37 to 124 MPa indicating a medium strong to very strong bedrock.

Selected rock core samples were sent to the Colorado School of Mines in Golden, Colorado for laboratory testing that included determination Cerchar Abrasivity Index and Shore Scleroscope Hardness. The results of the testing are included in Appendix C, and are summarized as follows:

- Cerchar Abrasivity Index = 3.1 to 3.7 (four tests);
- Shore Scleroscope Hardness Index (H_s) = 92.4 to 99.2 (four tests).

4.2 Groundwater Conditions

The water level in the Cataraqui River varies from about Elevation 74.6 to 74.9 m as shown below:

Date	River Surface Elevation (m)
March 1954	74.6
March 10, 2015	74.7
April 17, 2015	74.9
August 2016	74.7*

Note: * Average river surface elevation during investigation between August 3 and 15, 2016.

It should be noted that groundwater levels in the area are subject to fluctuations both seasonally and with precipitation events.



**FOUNDATION INVESTIGATION REPORT
SUPPLEMENTARY FOUNDATION INVESTIGATION
CATARAQUI RIVER BRIDGE, HIGHWAY 401, KINGSTON, ONTARIO**

5.0 CLOSURE

This Foundation Investigation Report was prepared by Mr. Alex Meacoe, P.Eng., and reviewed by Mr. Matt Kennedy, P.Eng., a geotechnical engineer with Golder. Mr. Fin Heffernan, P.Eng., the Designated MTO Foundations Contact for this assignment, conducted an independent review of this report.

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Matt Kennedy, P.Eng.
Geotechnical Engineer

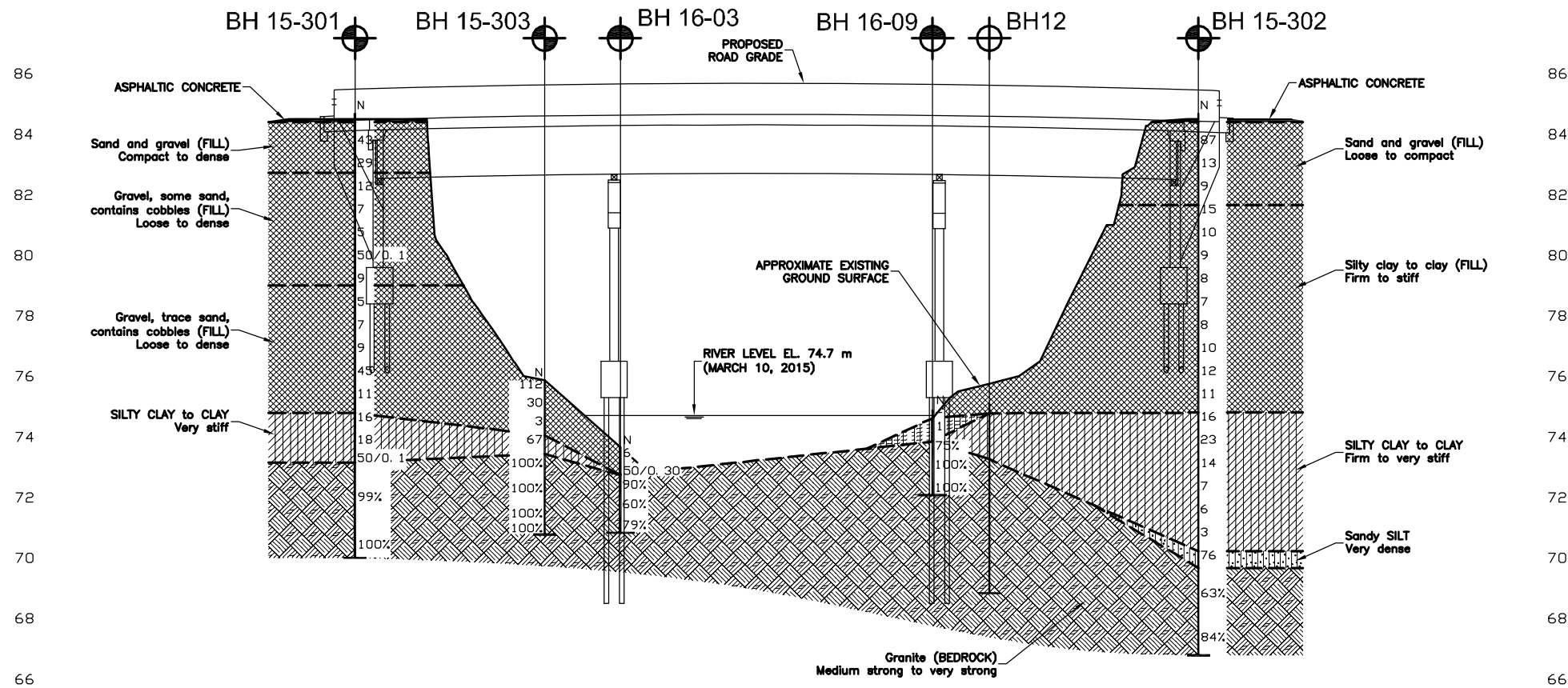
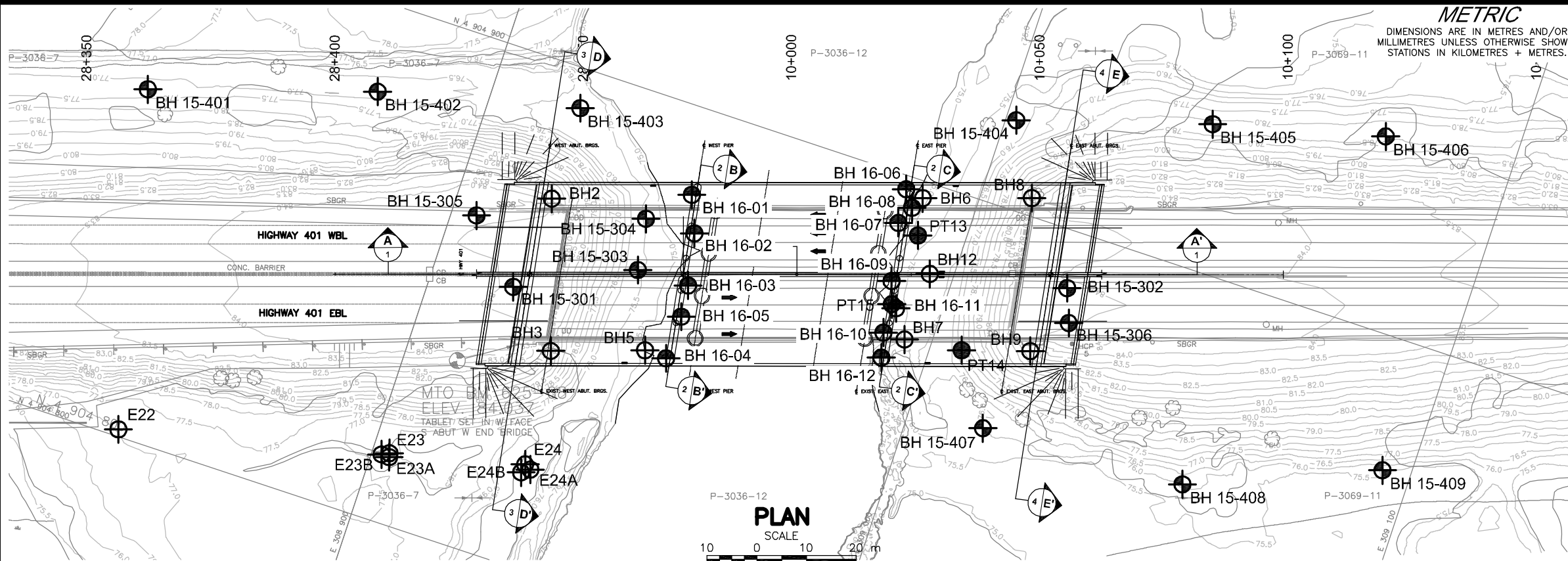


Fin Heffernan, P.Eng.
Designated MTO Foundations Contact



WAM/MJK/ob

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**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 Contract Documents.

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

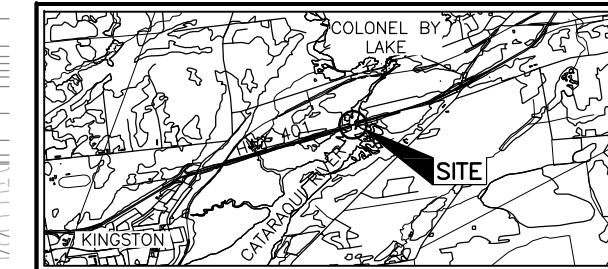
The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS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

CONT No.
WP No. 79-99-00

**CATARAQUI RIVER BRIDGE
HIGHWAY 401
BOREHOLE LOCATIONS AND SOIL STRATA**



Golder Associates Ltd.
OTTAWA ONTARIO, CANADA

**LEGEND**

- Borehole - Current Investigation
- Borehole - Previous Investigation
- Penetration Test - Previous Investigation
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL in open borehole
- WL in piezometer
- 100% Total Core Recovery (REC)
- Seal
- Piezometer

BOREHOLE CO-ORDINATES

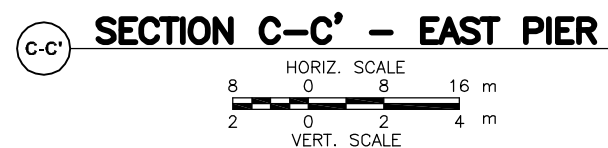
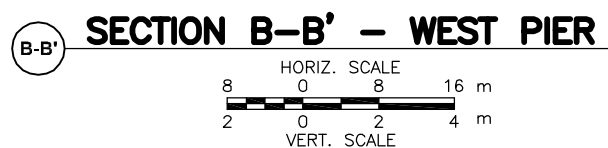
No.	ELEVATION	NORTHING	EASTING
16-01	74.4	4904882.6	308944.8
16-02	74.2	4904875.4	308947.8
16-03	73.7	4904865.1	308949.9
16-04	73.6	4904849.7	308950.3
16-05	73.8	4904858.6	308950.6
16-06	74.4	4904897.3	308985.5
16-07	74.6	4904890.3	308986.1
16-08	74.9	4904894.1	308987.8
16-09	74.9	4904878.8	308988.5
16-10	74.9	4904868.4	308990.2
16-11	75.2	4904873.9	308991.1
16-12	75.3	4904863.5	308991.4
15-301	84.7	4904853.7	308916.6
15-302	84.7	4904888.6	309022.5
15-303	75.9	4904864.8	308939.3
15-304	75.9	4904875.1	308937.6
15-305	84.5	4904865.0	308905.0
15-306	84.5	4904882.0	309025.0
BH2	76.1	4904873.0	308918.3
BH3	75.1	4904843.8	308927.8
BH5	74.6	4904849.9	308945.7
BH6	75.1	4904896.6	308989.2
BH7	75.0	4904868.4	308994.7
BH8	75.6	4904903.5	309010.0
BH9	75.9	4904874.2	309019.4
BH12	75.1	4904882.6	308995.3
PT13	75.1	4904882.6	308995.3
PT15	75.0	4904874.4	308990.0

REFERENCE

Base plans provided in digital format by MMM Group Limited, drawing file no. 3414034-XB1.dwg, received April 7, 2015.



NO.	DATE	BY	REVISION
Geocres No. 31C-253			
HWY. 401	PROJECT NO. 1413191-1070		DIST. Eastern
SUBM'D. WAM	CHKD. WAM	DATE: 10/12/2016	SITE: 7-70
DRAWN: JM	CHKD. MJK	APPD. FJH	DWG. 1



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

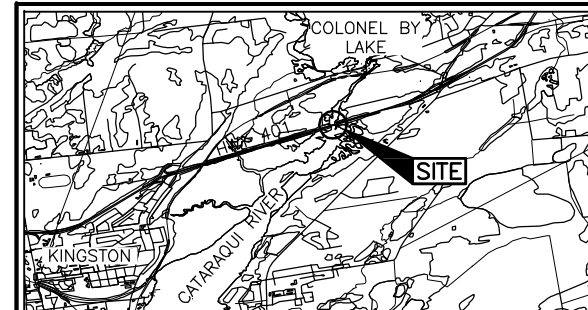
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WP No. **79-99-00**







CATARAQUI RIVER BRIDGE
HIGHWAY 401
BOREHOLE LOCATIONS AND SOIL STRATA



Golder Associates Ltd.
OTTAWA ONTARIO, CANADA



LEGEND

- | | |
|---|--|
|  | Borehole – Current 2016 Investigation |
|  | Borehole – Current 2015 Investigation |
|  | Borehole – Previous Investigation |
|  | Penetration Test – Previous Investigation |
| N | Standard Penetration Test Value |
| 16 | Blows/0.3m unless otherwise stated
(Std. Pen. Test, 475 j/blow) |
| 100% | Total Core Recovery (REC) |

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
16-01	74.4	4904882.6	308944.8
16-02	74.2	4904875.4	308947.8
16-03	73.7	4904865.1	308949.9
16-04	73.6	4904849.7	308950.3
16-05	73.8	4904858.6	308950.6
16-06	74.4	4904897.3	308985.5
16-07	74.6	4904890.3	308986.1
16-08	74.9	4904894.1	308987.8
16-09	74.9	4904878.8	308988.5
16-10	74.9	4904868.4	308990.2
16-11	75.2	4904873.9	308991.1
16-12	75.3	4904863.5	308991.4
15-301	84.7	4904853.7	308916.6
15-302	84.7	4904888.6	309022.5
15-303	75.9	4904864.8	308939.3
15-304	75.9	4904875.1	308937.6
15-305	84.5	4904865.0	308905.0
15-306	84.5	4904882.0	309025.0
BH2	76.1	4904873.0	308918.3
BH3	75.1	4904843.8	308927.8
BH5	74.6	4904849.9	308945.7
BH6	75.1	4904896.6	308989.2
BH7	75.0	4904868.4	308994.7
BH8	75.6	4904903.5	309010.0
BH9	75.9	4904874.2	309019.4
BH12	75.1	4904882.6	308995.3
PT13	75.1	4904882.6	308995.3
PT15	75.0	4904874.4	308990.0

REFERENCE

Base plans provided in digital format by MMM Group Limited, drawing file no. 3414034-XB1.dwg, received April 7, 2015.

NO.	DATE	BY	REVISION
Geocres No. 31C-253			
HWY. 401		PROJECT NO. 1413191-1070	DIST. Eastern
SUBM'D. WAM	CHKD. WAM	DATE: 10/12/2016	SITE: 7-70
DRAWN: JM	CHKD. MJK	APPD. FJH	DWG. 2





APPENDIX A

Borehole and Drillhole Records

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
DO or DP	Seamless open-ended, driven or pushed tube samplers
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split spoon sampler
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample
DT	Dual tube sample
DD	Diamond drilling

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.) split spoon sampler for a distance of 300 mm (12 in.).

Dynamic Cone Penetration Resistance (DCPT); N_d :

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive an uncased 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

Cone Penetration Test (CPT):

An electronic cone penetrometer with a 60° conical tip and a projected end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q_t), porewater pressure (u) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Cohesionless Soils

Density Index (Relative Density)	N Blows/300 mm Or Blows/ft.
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils C_u or S_u

Consistency	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 or PL	Plastic limited
w_l or LL	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
DS	Direct shear test
Gs	Specific gravity
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 test (LV-laboratory vane test)
γ	Unit weight

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

LIST OF SYMBOLS

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

I. GENERAL

π	3.1416
$\ln x$	natural logarithm of x
$\log_{10} x$ or $\log x$	logarithm of x to base 10
g	acceleration due to gravity
t	time
FOS	factor of safety
V	volume
W	weight

II. STRESS AND STRAIN

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

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) formerly (G_s)
e	void ratio
n	porosity
S	degree of saturation
*	Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (overconsolidated range)
C_s	swelling index
C_α	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	overconsolidation ratio $= \sigma'_p / \sigma'_{vo}$

(d) Shear Strength

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

Notes:

¹ $\tau = c' + \sigma' \tan \phi'$

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

LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERING STATE

Fresh: no visible sign of rock material 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 texture and structure are preserved.

BEDDING THICKNESS

<u>Description</u>	<u>Bedding Plane Spacing</u>
Very Thickly Bedded	> 2 m
Thickly Bedded	0.6 m to 2m
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	< 6 mm

JOINT OR FOLIATION SPACING

<u>Description</u>	<u>Spacing</u>
Very Wide	> 3 m
Wide	1 – 3 m
Moderately Close	0.3 – 1 m
Close	50 – 300 mm
Very Close	< 50 mm

GRAIN SIZE

<u>Term</u>	<u>Size*</u>
Very Coarse Grained	> 60 mm
Coarse Grained	2 – 60 mm
Medium Grained	60 microns – 2mm
Fine Grained	2 – 60 microns
Very Fine Grained	< 2 microns

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

CORE CONDITION

Total Core Recovery

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 varies from 0% for completely broken core 100% for core in solid sticks.

DISCONTINUITY DATA

Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including naturally occurring fractures but not including mechanically induced breaks caused by drilling.

Dip with Respect to (W.R.T.) 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 abbreviated description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature information concerning the nature of fracture surfaces and infillings are also noted.

Abbreviations

BD -	Bedding	PY -	Pyrite
FO -	Foliation/Schistosity	Ca -	Calcite
CL -	Clean	PO -	Polished
SH -	Shear Plane/Zone	K -	Slickensided
VN -	Vein	SM -	Smooth
FLT -	Fault	RO -	Ridged/Rough
CO -	Contact	ST -	Stepped
JN -	Joint	PL -	Planar
FR -	Fracture	IR -	Irregular
MB -	Mechanical Break	UN -	Undulating
BR -	Broken Rock	CU -	Curved
BL -	Blast Induced	TCA -	To Core Axis
Il -	Parallel To	STR -	Stress Induced
OR -	Orthogonal		

PROJECT <u>1413191</u>		RECORD OF BOREHOLE No 16-01		SHEET 1 OF 2		METRIC	
G.W.P. <u>79-99-00</u>		LOCATION <u>N 4904882.6 ; E 308944.8</u>		ORIGINATED BY <u>PAH</u>			
DIST <u>Eastern</u> HWY <u>401</u>		BOREHOLE TYPE <u>Rotary Drill BW Casing</u>		COMPILED BY <u>ZS</u>			
DATUM <u>Geodetic</u>		DATE <u>August 10, 2016</u>		CHECKED BY <u>WAM</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT			LIQUID LIMIT	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W _p	W	W _L			WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED														
74.7	RIVER LEVEL						74	20	40	60	80	100										
0.0	WATER							20	40	60	80	100										
74.4																						
0.3	ROCKFILL		1	RC	DD																	
74.0																						
0.8	ROCKFILL, mixed with sand and silt, contains organic matter		2	RC	DD		73															
73.4																						
1.3	Syenite (BEDROCK) Bedrock cored from depths of 1.3 m to 3.5 m For bedrock coring details refer to Record of Drillhole 16-01		1	RC	REC 100%																RQD = 100%	
			2	RC	REC 100%		72														RQD = 100%	
71.3																						
3.5	END OF BOREHOLE																					

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PROJECT: 1413191

RECORD OF DRILLHOLE: 16-01

SHEET 2 OF 2

LOCATION: N 4904882.6 ;E 308944.8

DRILLING DATE: August 10, 2016

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: Electric Core Drill

DRILLING CONTRACTOR: OGS

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY														FEATURES																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
							RECOVERY		R.Q.D. %	FRACT. INDEX PER	DIP w.r.t CORE AXIS °	DISCONTINUITY DATA		HYDRAULIC CONDUCTIVITY K, cm/sec	WEATH- ERING INDEX																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
							TOTAL CORE %	SOLID CORE %				TYPE AND SURFACE DESCRIPTION	Jr		Js	10 ⁻⁶ 10 ⁻⁵ 10 ⁻⁴ 10 ⁻³	W1 W2 W3 W4 W5 W6																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
		Continued from Record of Borehole 16-01		73.44 1.26																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										

DEPTH SCALE

1 : 50



LOGGED: PAH

CHECKED: WAM

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PROJECT 1413191			RECORD OF BOREHOLE No 16-02			SHEET 1 OF 2			METRIC								
G.W.P. 79-99-00			LOCATION N 4904875.4 ;E 308947.8			ORIGINATED BY PAH											
DIST Eastern HWY 416			BOREHOLE TYPE Rotary Drill BW Casing			COMPILED BY ZS											
DATUM Geodetic			DATE August 10-11, 2016			CHECKED BY WAM											
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									
74.7	RIVER LEVEL							20	40	60	80	100					
0.0	WATER																
74.2																	
0.5	COBBLES and BOULDERS, mixed with organic silt and sand, contains shells Loose		1	SS	1		74										
73.2			2	SS	6												
1.5	Silty SAND and GRAVEL																
72.9	Compact Grey		3	SS	REC		73										
1.8	Wet		1	RC	100%												RQD = 100%
72.6	Diabase (BEDROCK)																
2.2	Syenite (BEDROCK)																
	Bedrock cored from depths of 1.8 m to 3.4 m		2	RC	REC 100%		72										RQD = 79%
	For bedrock coring details refer to Record of Drillhole 16-02																
71.3			3	RC	REC 100%												RQD = 73%
3.4	END OF BOREHOLE																

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SHEET 2 OF 2

DATUM: Geodetic

DRILLING CONTRACTOR: OGS

[illegible]

DEPTH SCALE

1 : 50

LOGGED: PAH

CHECKED: WAM

PROJECT 1413191		RECORD OF BOREHOLE No 16-03				SHEET 1 OF 2		METRIC									
G.W.P. 79-99-00		LOCATION N 4904865.0 ; E 308949.9				ORIGINATED BY PAH											
DIST Eastern HWY 416		BOREHOLE TYPE Rotary Drill BW Casing				COMPILED BY ZS											
DATUM Geodetic		DATE August 15, 2016				CHECKED BY WAM											
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									
74.7 0.0	RIVER LEVEL WATER							20	40	60	80	100					
73.6 1.1	ROCKFILL, mixed with organic silt and sand, contains shells and wood fragments Loose Grey Wet		1	SS	6												
72.7 2.0	Diabase and Syenite Gneiss (BEDROCK) Bedrock cored from depths of 2.0 m to 3.9 m For bedrock coring details refer to Record of Drillhole 16-03		2	SS	50/0.30												
			1	RC	REC 100%												RQD = 90%
			2	RC	REC 100%												RQD = 60%
			3	RC	REC 100%												RQD = 79%
70.8 3.9	END OF BOREHOLE																

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SHEET 2 OF 2

DATUM: Geodetic

DRILLING CONTRACTOR: OGS

[illegible]

DEPTH SCALE

1 : 50

LOGGED: PAH

CHECKED: WAM

PROJECT 1413191		RECORD OF BOREHOLE No 16-04		SHEET 1 OF 2		METRIC															
G.W.P. 79-99-00		LOCATION N 4904849.7 ; E 308950.3		ORIGINATED BY PAH																	
DIST Eastern HWY 417		BOREHOLE TYPE Rotary Drill BW Casing		COMPILED BY ZS																	
DATUM Geodetic		DATE August 11-12, 2016		CHECKED BY WAM																	
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ			GR SA SI CL		
74.7 0.0	RIVER LEVEL WATER							20 40 60 80 100	20 40 60 80 100	25 50 75											
73.6 1.1	Organic SILT and SAND, contains wood fragments Very loose Grey Wet		1	SS	WH																
			2	SS	WH																
			3	SS	1																
71.6 3.1	SILTY CLAY Very stiff Grey Wet		4	SS	8																
71.0 3.7	Silty SAND, some gravel, contains cobbles and boulders (TILL) Very dense Grey Wet		5	SS	28/0.18																
			6	RC	DD																
69.0 5.7	Syenite (BEDROCK) Bedrock cored from depths of 5.7 m to 7.2 m For bedrock coring details refer to Record of Drillhole 16-04		1	RC	REC 100%																RQD = 65%
			2	RC	REC 100%																RQD = 100%
67.5 7.2	END OF BOREHOLE NOTES: 1. Bedrock core below 6.56 m was not recovered.																				

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SHEET 2 OF 2

DATUM: Geodetic

DRILLING CONTRACTOR: OGS

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CHECKED: WAM

PROJECT 1413191		RECORD OF BOREHOLE No 16-05		SHEET 1 OF 1		METRIC	
G.W.P. 79-99-00		LOCATION N 4904858.6 ; E 308950.5		ORIGINATED BY PAH			
DIST Eastern HWY 417		BOREHOLE TYPE Rotary Drill BW Casing		COMPILED BY ZS			
DATUM Geodetic		DATE August 15, 2016		CHECKED BY WAM			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL LIQUID MOISTURE LIMIT CONTENT LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL	
								○ UNCONFINED + FIELD VANE	● QUICK TRIAXIAL × REMOULDED												
74.7	RIVER LEVEL																				
0.0	WATER																				
73.8																					
0.9	ROCKFILL, mixed with organic silt and sand, contains shells and wood fragments Very loose Grey Wet		1	SS	WH																
			2	SS	WH																
			3	SS	1																
72.0																					
2.7	Layered Silty SAND, Sandy SILT and SILTY CLAY																				
71.7	Compact		4	SS	53																
3.0	Grey Wet																				
	Sandy SILT some gravel, contains cobbles and boulders (TILL)		5	RC	DD																
70.8	Very dense																				
3.9	Grey Wet		6	SS	6/0.10																
	END OF BOREHOLE SAMPLER REFUSAL																				

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PROJECT <u>1413191</u>		RECORD OF BOREHOLE No 16-06		SHEET 1 OF 1		METRIC	
G.W.P. <u>79-99-00</u>		LOCATION <u>N 4904897.3 ; E 308985.5</u>		ORIGINATED BY <u>PAH</u>			
DIST <u>Eastern</u> HWY <u>417</u>		BOREHOLE TYPE <u>Rotary Drill BW Casing</u>		COMPILED BY <u>ZS</u>			
DATUM <u>Geodetic</u>		DATE <u>August 9, 2016</u>		CHECKED BY <u>WAM</u>			

SOIL PROFILE			SAMPLES		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES
74.7	RIVER LEVEL				
0.0	WATER				
74.4					
0.3	Silty SAND, trace gravel, contains organic matter and shells (FILL/ALLUVIUM) Very loose Grey-brown Wet		1	SS	WH
73.6					
1.1	SILTY CLAY, some to trace sand (WEATHERED CRUST) Very stiff to hard Grey-brown, fissured Moist		2	SS	16
			3	SS	26
			4	SS	33
			5	SS	18
71.1			6	SS	9
3.7	SILTY CLAY Firm Grey Wet		7	SS	5
			8	SS	9/0.20
68.9	END OF BOREHOLE SAMPLER REFUSAL				
5.8					

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

PROJECT 1413191			RECORD OF BOREHOLE No 16-07			SHEET 1 OF 2			METRIC								
G.W.P. 79-99-00			LOCATION N 4904890.3 ; E 308986.1			ORIGINATED BY PAH											
DIST Eastern HWY 417			BOREHOLE TYPE Rotary Drill BW Casing			COMPILED BY ZS											
DATUM Geodetic			DATE August 8, 2016			CHECKED BY WAM											
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									
74.7	RIVER LEVEL							20	40	60	80	100					
74.0	WATER																
0.4	Gravel and cobbles (FILL)																
73.9	Silty sand to sandy silt, some clay trace gravel, contains organic matter and shells (FILL)		1	SS	WH												
0.8	Very loose																
73.6	Grey																
1.1	Wet		2	SS	7												
	Organic SILT, some sand																
	Very loose																
	Grey																
	Wet																
	SILTY CLAY (WEATHERED CRUST)		3	SS	18												
	Very stiff																
	Grey-brown, fissured																
	Moist																
			4	SS	19												
71.8	CLAYEY SILT to Sandy SILT		5	SS	9												
71.6	Compact																
3.2	Grey																
	Wet																
	Syenite Gneiss (BEDROCK)																
	Bedrock cored from depths of 3.1 m to 5.5 m		1	RC	REC 88%												RQD = 67%
	For bedrock coring details refer to Record of Drillhole 16-07																
			2	RC	REC 91%												RQD = 73%
69.2	End of Borehole																
5.5																	

PROJECT 1413191			RECORD OF BOREHOLE No 16-08			SHEET 1 OF 1			METRIC								
G.W.P. 79-99-00			LOCATION N 4904894.1 ; E 308987.8			ORIGINATED BY PAH											
DIST Eastern HWY 417			BOREHOLE TYPE Rotary Drill BW Casing			COMPILED BY ZS											
DATUM Geodetic			DATE August 3-4, 2016			CHECKED BY WAM											
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
74.9	GROUND SURFACE							20	40	60	80	100					
0.0	Sandy gravel, some silt, contains cobbles and boulders (FILL) Loose Grey Wet		1	SS	1/0.45												
74.1			2	SS	22		74										
0.8	SILTY CLAY, trace sand and gravel (WEATHERED CRUST) Very stiff to hard Grey-brown Moist		3	SS	38												
			4	SS	49												
			5	SS	21												
71.6			6	SS	6												
3.4	SILTY CLAY Firm to stiff Grey Wet		7	SS	9												
70.3			8	SS	8												
4.6	SILTY CLAY, CLAYEY SILT and Sandy SILT, trace gravel Firm Grey Wet		9	SS	7												
			10	SS	4												
68.5			11	SS	N/A												
6.4	Sandy SILT, some gravel (TILL) Loose Grey Wet																
68.1																	
6.8	END OF BOREHOLE SAMPLER REFUSAL																

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PROJECT 1413191			RECORD OF BOREHOLE No 16-09			SHEET 1 OF 2			METRIC								
G.W.P. 79-99-00			LOCATION N 4904878.8 ; E 308988.5			ORIGINATED BY PAH											
DIST Eastern HWY 417			BOREHOLE TYPE Rotary Drill BW Casing			COMPILED BY ZS											
DATUM Geodetic			DATE August 4, 2016			CHECKED BY WAM											
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									
74.9	GROUND SURFACE							20	40	60	80	100					
0.0	Sandy gravel and sandy silt, contains cobbles and organic matter (FILL)		1	GRAB	-												
74.6	Grey-brown Wet																
0.3	Organic silt, contains wood fibres (ALLUVIUM)		2	SS	1												
73.8	Very loose Grey-brown Wet																
1.1	Syenite (BEDROCK)		1	RC	REC 100%												RQD = 75%
	Bedrock cored from depths of 1.0 m to 2.8 m																
	For bedrock coring details refer to Record of Drillhole 16-09		2	RC	REC 100%												RQD = 100%
			3	RC	REC 100%												RQD = 100%
72.1	END OF BOREHOLE																
2.8																	

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PROJECT: 1413191

RECORD OF DRILLHOLE: 16-09

SHEET 2 OF 2

LOCATION: N 4904878.8 ;E 308988.5

DRILLING DATE: August 4, 2016

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: Electric Core Drill

DRILLING CONTRACTOR: OGS

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




1 : 50



LOGGED: PAH

CHECKED: WAM

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PROJECT 1413191			RECORD OF BOREHOLE No 16-10			SHEET 1 OF 2			METRIC									
G.W.P. 79-99-00			LOCATION N 4904868.4 ;E 308990.2			ORIGINATED BY PAH												
DIST Eastern HWY 417			BOREHOLE TYPE Rotary Drill BW Casing			COMPILED BY ZS												
DATUM Geodetic			DATE August 4-5, 2016			CHECKED BY WAM												
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)
74.9	GROUND SURFACE							20	40	60	80	100						
0.0	Gravel, cobbles and boulders, contains clayey silt and organic matter (FILL)		1	SS	8													
0.2	CLAYEY SILT, some sand and gravel, contains organic matter (FILL) Firm to stiff Brown Wet		2	SS	7													
73.7																		
1.2	Gravelly Silty SAND (TILL) Compact Grey Wet		3	SS	17												27 30 25 18	
73.2																		
1.7	Syenite (BEDROCK) Bedrock cored from depths of 1.7 m to 3.2 m For bedrock coring details refer to Record of Drillhole 16-10		1	RC	REC 100%												RQD = 85%	
			2	RC	REC 100%													RQD = 50%
			3	RC	REC 100%													RQD = 88%
71.7																		
3.2	END OF BOREHOLE																	

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PROJECT: 1413191

RECORD OF DRILLHOLE: 16-10

SHEET 2 OF 2

LOCATION: N 4904868.4 ; E 308990.2

DRILLING DATE: August 4-5, 2016

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: Electric Core Drill

DRILLING CONTRACTOR: OGS

DEPTH SCALE METRES	DRILLING RECORD		DESCRIPTION	SYMBOLIC LOG	ELEV.		RUN No.	FLUSH RETURN	NOTE: For abbreviations, symbols and descriptions refer to LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY														FEATURES																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
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UCS = 108.4 MPa

DEPTH SCALE


1 : 50



LOGGED: PAH

CHECKED: WAM

PROJECT <u>1413191</u>		RECORD OF BOREHOLE No 16-11		SHEET 1 OF 1		METRIC	
G.W.P. <u>79-99-00</u>		LOCATION <u>N 4904873.9 ; E 308991.1</u>		ORIGINATED BY <u>PAH</u>			
DIST <u>Eastern</u> HWY <u>417</u>		BOREHOLE TYPE <u>Rotary Drill BW Casing</u>		COMPILED BY <u>ZS</u>			
DATUM <u>Geodetic</u>		DATE <u>August 4, 2016</u>		CHECKED BY <u>WAM</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W _p	W	W _L		
75.2	GROUND SURFACE																
0.0	Clayey silt, some sand and gravel, contains organic matter (FILL)		1	SS	2												
74.8	Firm Brown Wet																
0.4	Clayey silt and silty sand, trace gravel, contains organic matter (FILL/ALLUVIUM)		2	SS	7												
	Loose Grey-brown Wet																
73.8	SILTY CLAY, some sand (WEATHERED CRUST)																
1.4	Very stiff Grey-brown, fissured Wet		3	SS	12												
73.4																	
1.8	CLAYEY SILT, some gravel		4	SS	72/0.15												
73.1	Hard Grey-brown Wet																
2.1	END OF BOREHOLE SAMPLER REFUSAL																

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PROJECT <u>1413191</u>		RECORD OF BOREHOLE No 16-12		SHEET 1 OF 1		METRIC	
G.W.P. <u>79-99-00</u>		LOCATION <u>N 4904863.5 ; E 308991.4</u>		ORIGINATED BY <u>PAH</u>			
DIST <u>Eastern</u> HWY <u>417</u>		BOREHOLE TYPE <u>Rotary Drill BW Casing</u>		COMPILED BY <u>ZS</u>			
DATUM <u>Geodetic</u>		DATE <u>August 8, 2016</u>		CHECKED BY <u>WAM</u>			

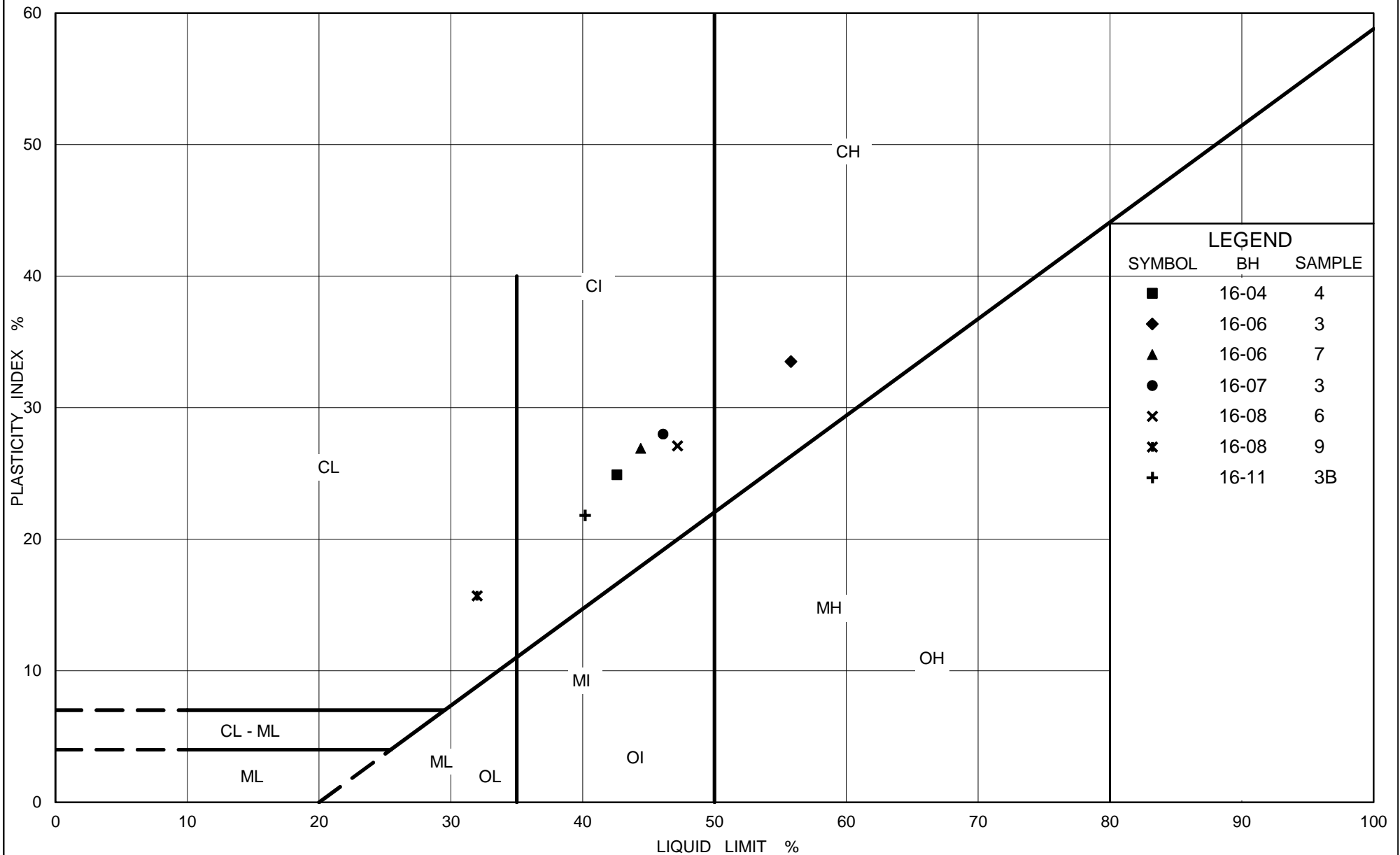
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W _p	W	W _L		
75.3	GROUND SURFACE																
0.0	ROCKFILL, mixed with sand, some gravel, contains organic matter Loose Brown Moist		1	SS	5												
74.7																	
0.6	Rockfill, mixed with clayey silt, some sand (FILL/ALLUVIUM) Loose Brown Wet		2	SS	6												
74.1																	
1.2	Organic Sandy SILT, trace gravel Very loose Grey-brown Wet		3	SS	5												
73.2																	
2.1	END OF BOREHOLE SAMPLER REFUSAL		4	SS	15/0.08												

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APPENDIX B

Laboratory Test Results – Golder Associates Ltd.



Ministry of Transportation

Ontario

PLASTICITY CHART

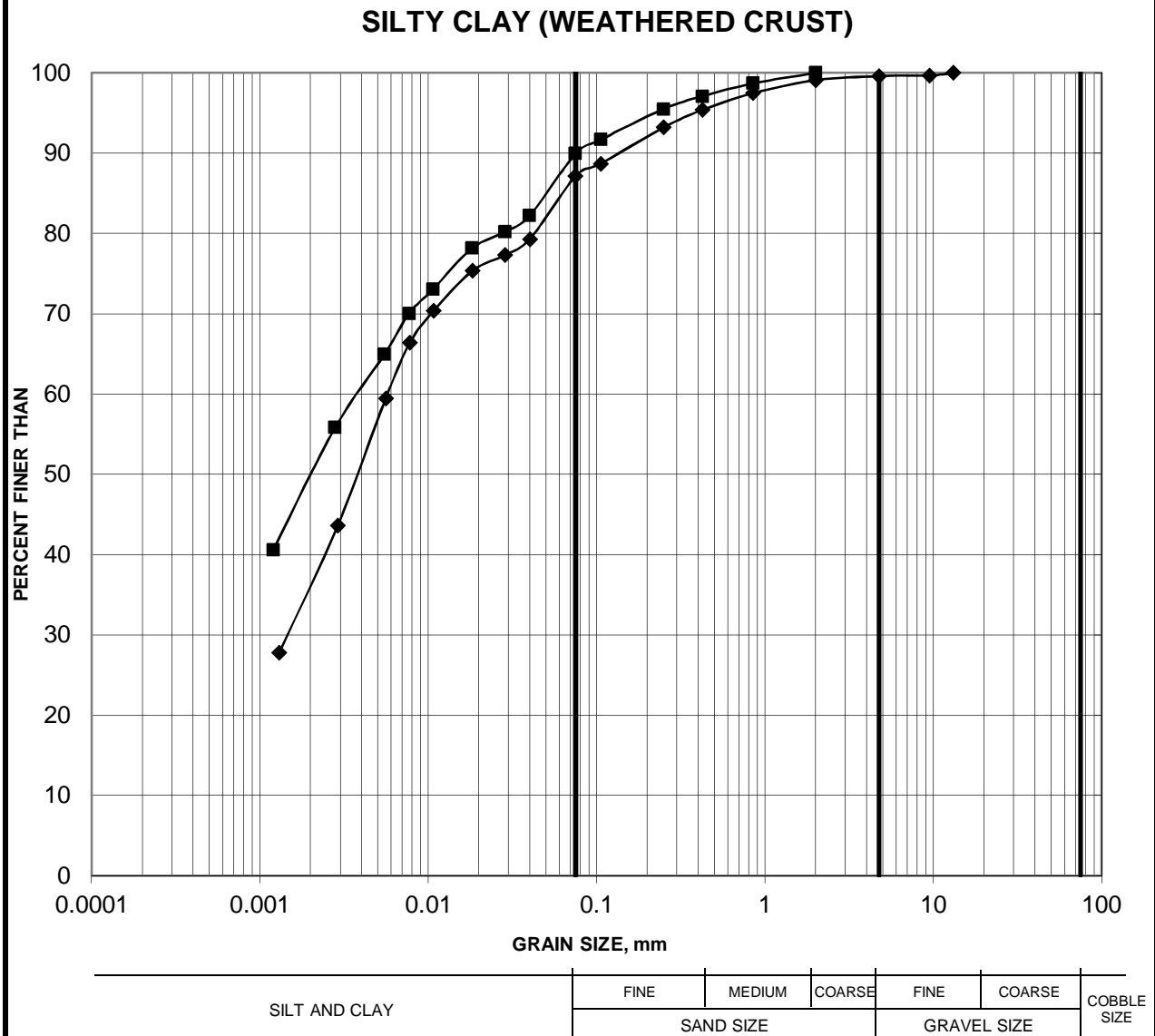
FIG No. B1

Project No. 1413191/ 1070

Compiled By : MI Checked By : CNM

GRAIN SIZE DISTRIBUTION

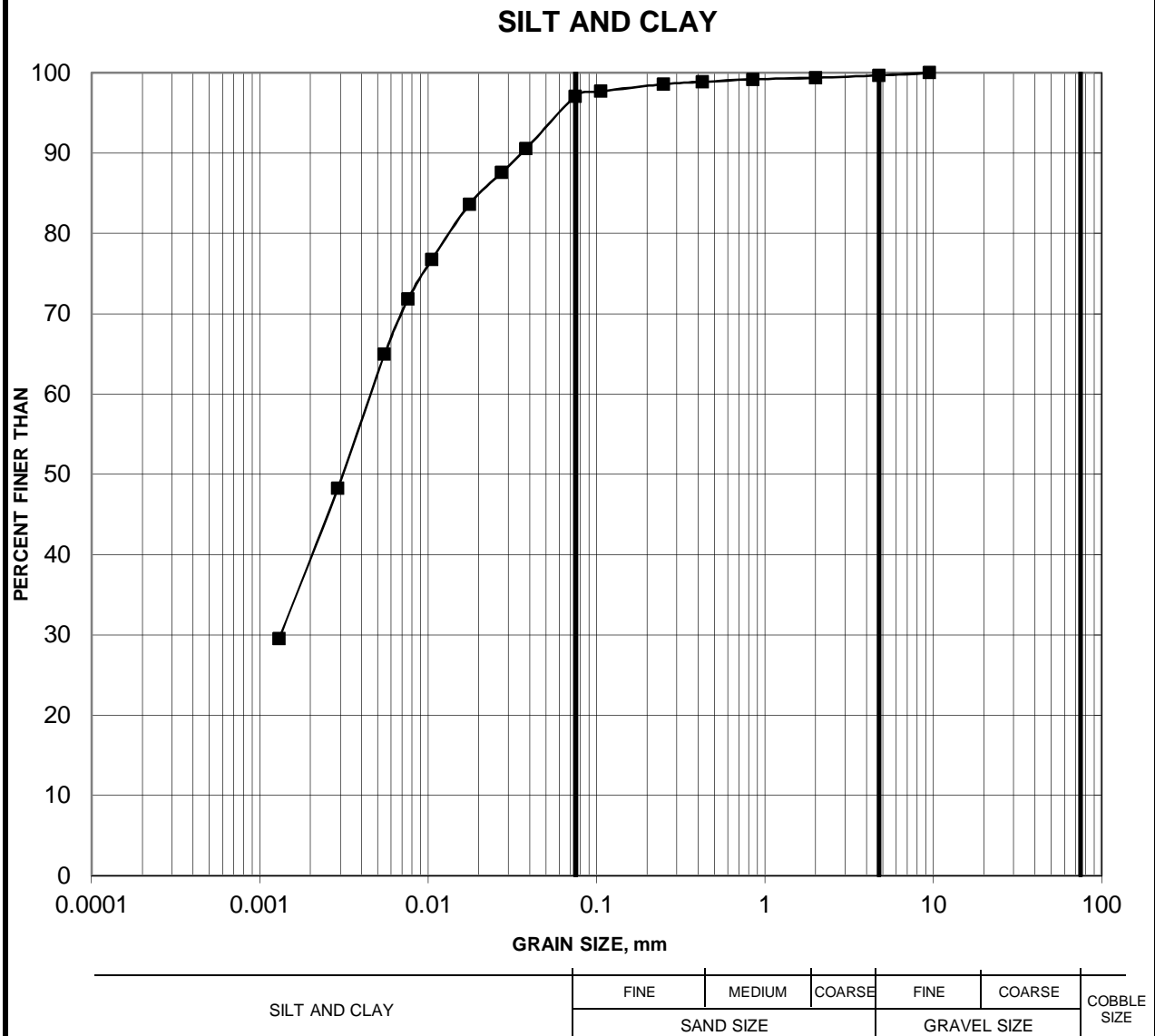
FIGURE B2



Borehole	Sample	Depth (m)
16-06	3	1.22-1.83
16-11	3B	1.37-1.83

GRAIN SIZE DISTRIBUTION

FIGURE B3

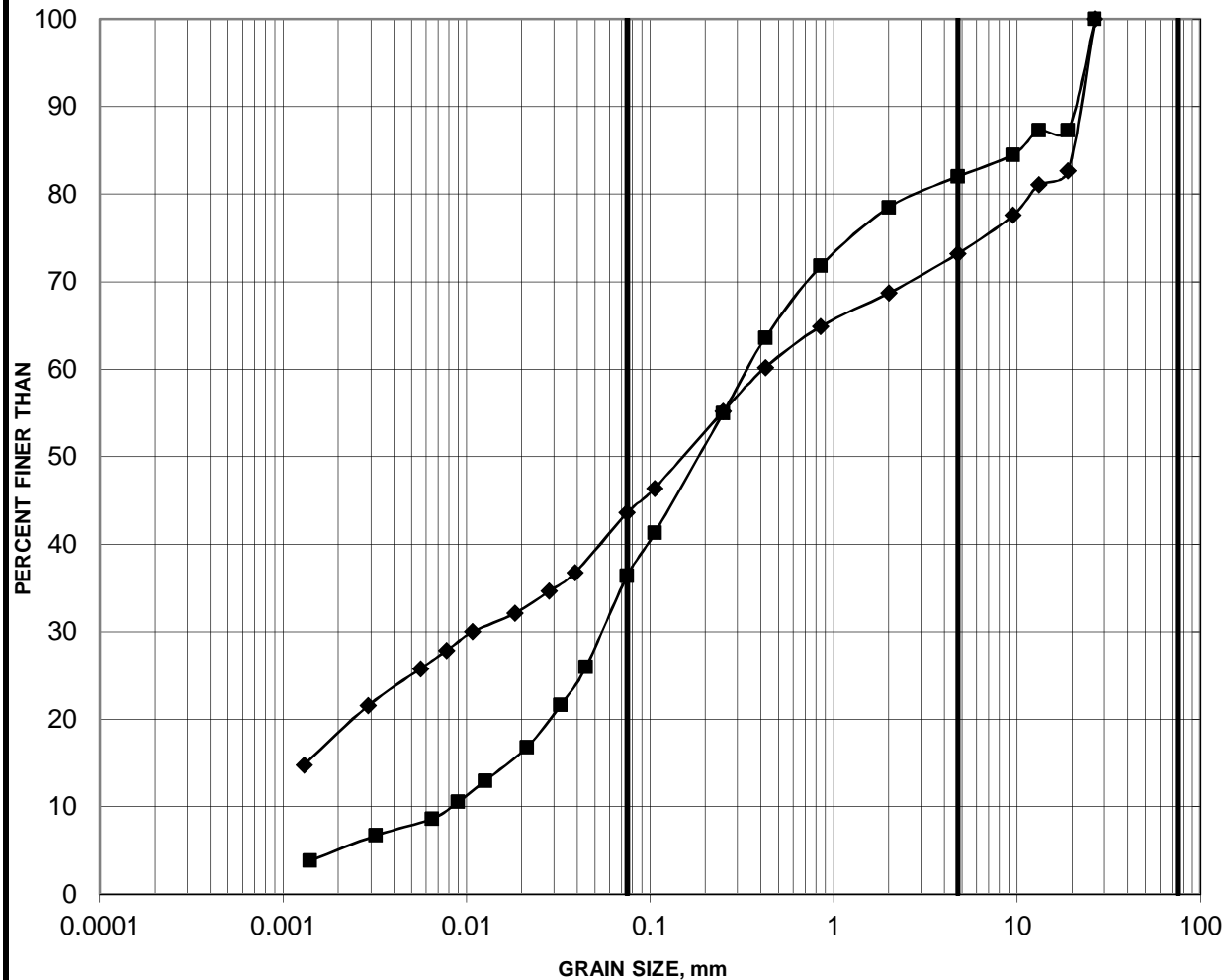


Borehole	Sample	Depth (m)
16-08	9	5.18-5.79

GRAIN SIZE DISTRIBUTION

FIGURE B4

GLACIAL TILL

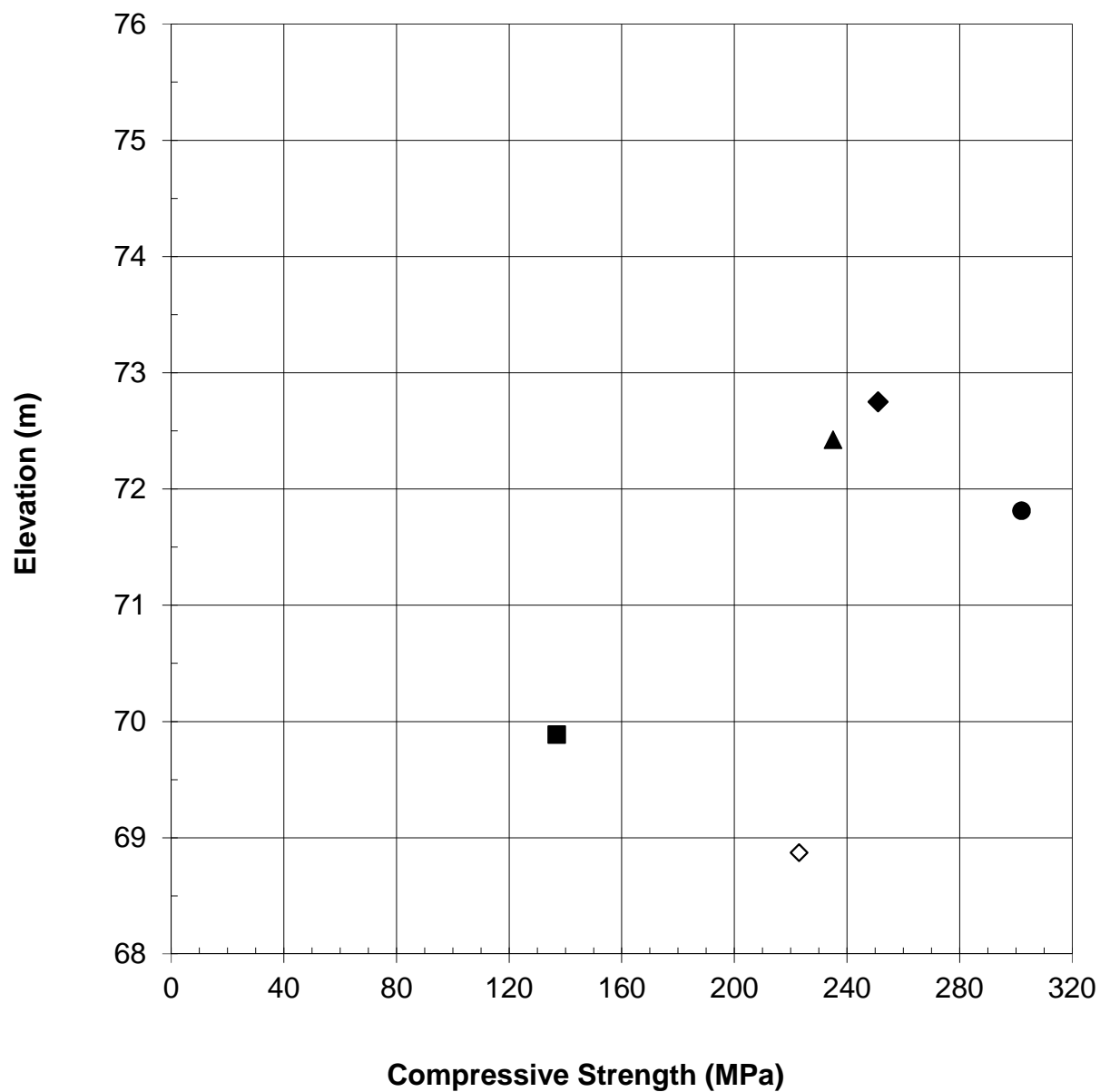


SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)
16-04	5	2.97-3.29
16-10	3	1.22-1.68

SUMMARY OF LABORATORY COMPRESSIVE STRENGTH INTERPRETED POINT LOAD TESTING

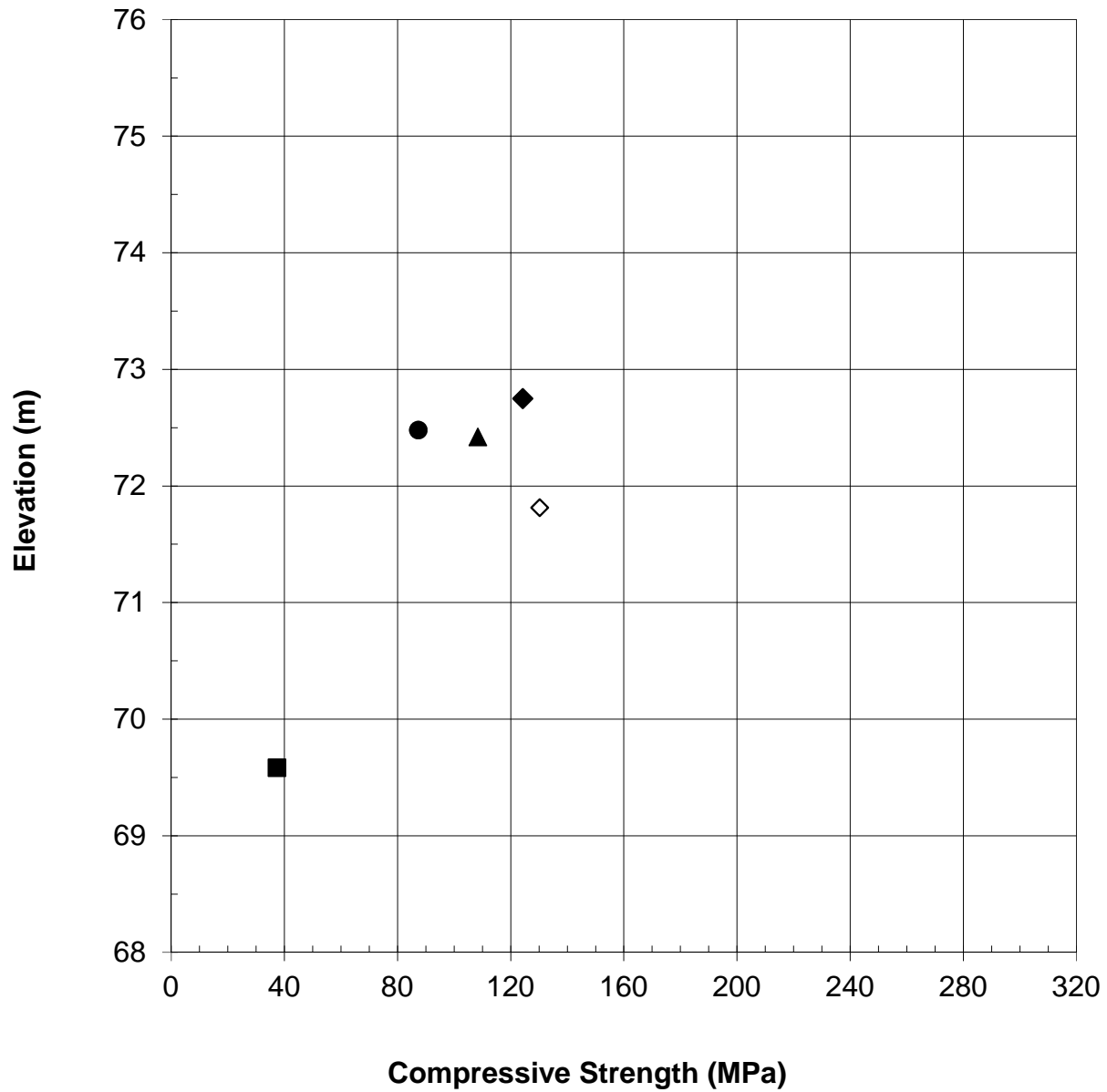
FIGURE B5



◆ 16-01 ● 16-03 ◇ 16-04 ■ 16-07 ▲ 16-09

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

FIGURE B6



◆ 16-01 ● 16-02 ◇ 16-03 ■ 16-07 ▲ 16-10



APPENDIX C

Laboratory Test Results - Colorado School of Mines

Earth Mechanics Institute

Client: Golder

Project Name: 1413191



Colorado School of Mines

Mining Engineering Department

Date: 9/9/2016	Rock Type	Cerchar Abrasivity Index
Sample ID		
BH-16-02 @ 5'1.5"-5'5"	Igneous	3.1
BH-16-03 @ 5'-5'3"	Igneous	3.1
BH-16-07 @ 10'3"-11'6"	Igneous	3.7
BH-16-10 @ 7'2"-7'8"	Igneous	3.1

Earth Mechanics Institute

Client: Golder

Project Name: 1413191



Colorado School of Mines
Mining Engineering Department

Date: 9/22/2013	Rock	Shore Scleroscope Values																				Scleroscope Rebound Hardness (H _{RS})	Notes
Sample ID	Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
Calibration Anvil	H _{RS} = 25	25	26	26	25	25	25	25	25	24	24	26	25	25	26	26	27	24	25	26	24	25.2	Calibration Constant = 0.992
BH-16-02 @ 5' 10.5" - 6' 4"	Sedimentary	95	93	88	63	95	102	83	84	96	104	92	103	43	98	78	102	99	43	54	39	97.9	Result based on highest 10 readings, indicated by BOLD
BH-16-03 @ 5' 3" - 5' 7"	Sedimentary	101	94	101	68	63	76	76	87	90	84	88	82	38	83	92	85	94	89	88	94	92.4	
BH-16-07 @ 10'3"-11'6"	Sedimentary	98	102	97	89	38	95	89	93	62	90	93	101	97	101	89	87	92	96	87	96	96.8	
BH-16-10 @ 8' 5" - 8' 10"	Sedimentary	93	105	96	34	56	34	93	97	88	48	96	87	99	90	102	102	97	106	100	94	99.2	

Pictures of Sample Before and After
Cerchar Abrasivity Index

Client Name: Golder
Project Name: 1413191
Date: 9/9/2016

Sample ID: [BH-16-02 @ 5'1.5"-5'5"](#)



Before



After

Pictures of Sample Before and After
Cerchar Abrasivity Index

Client Name: Golder
Project Name: 1413191
Date: 9/9/2016

Sample ID: [BH-16-03 @ 5'-5'3"](#)



Before



After

Pictures of Sample Before and After
Cerchar Abrasivity Index

Client Name: Golder
Project Name: 1413191
Date: 9/9/2016

Sample ID: [BH-16-07 @ 10'3"-11'6"](#)



Before

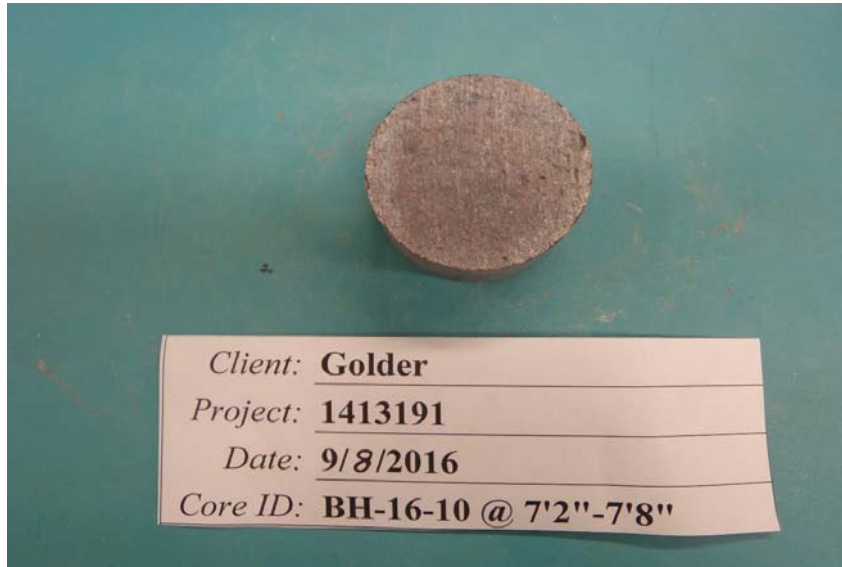


After

Pictures of Sample Before and After
Cerchar Abrasivity Index

Client Name: Golder
Project Name: 1413191
Date: 9/9/2016

Sample ID: [BH-16-10 @ 7'2"-7'8"](#)



Before



After

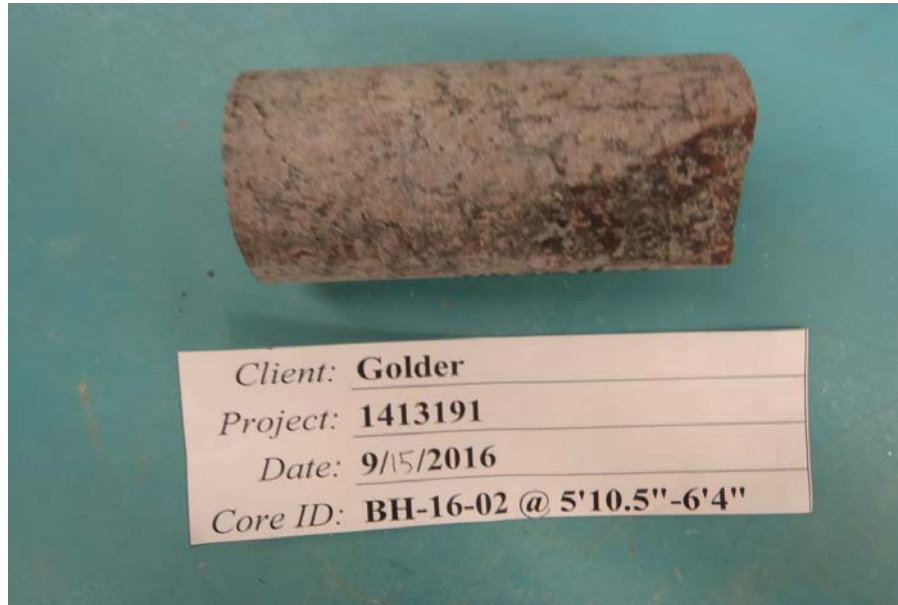
Pictures of Sample Before and After
Shore Hardness

Client Name: Golder Associates

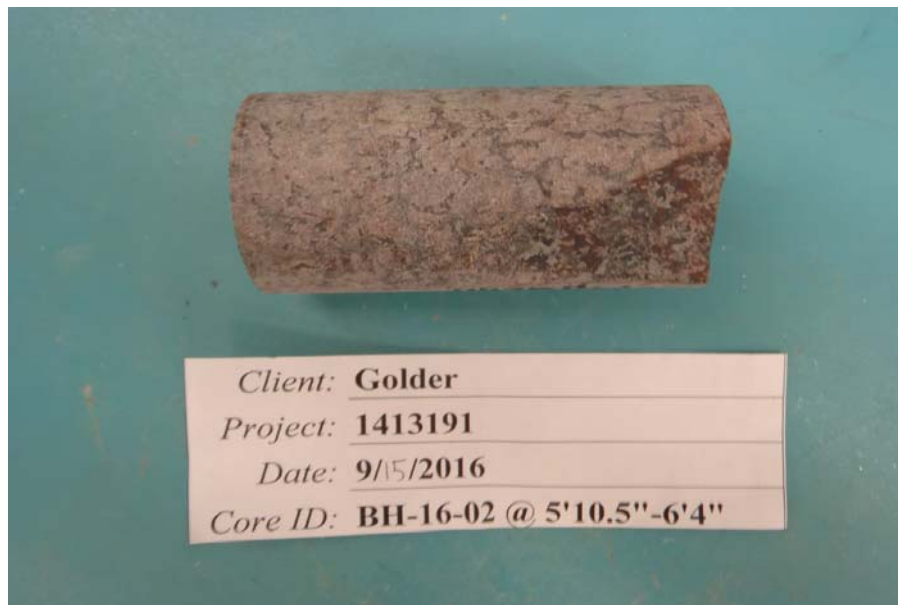
Project Name: 1413191

Date: 9/15/2016

Sample ID: BH-16-02 @ 5'10.5"-6'4"



Before



After

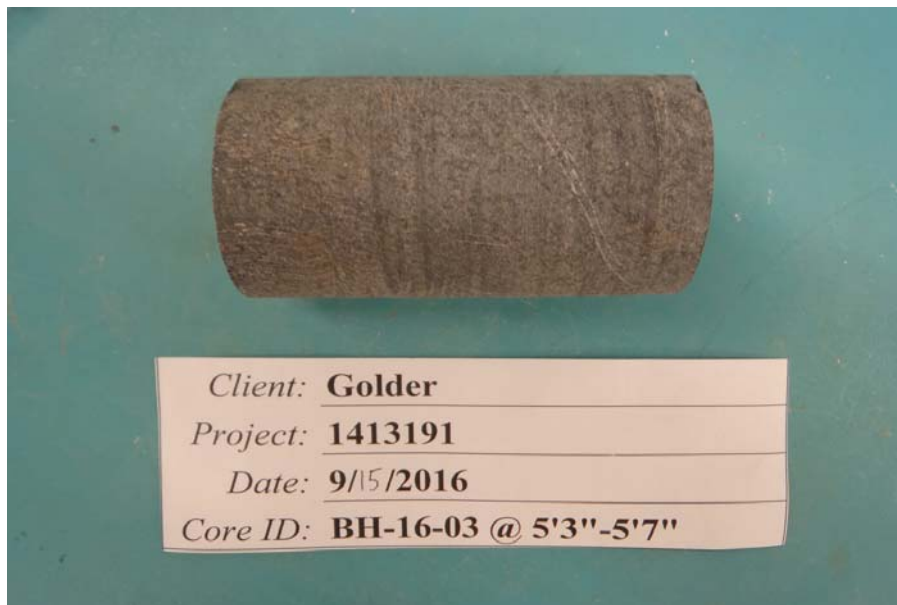
Pictures of Sample Before and After
Shore Hardness

Client Name: Golder Associates
Project Name: 1413191
Date: 9/15/2016

Sample ID: BH-16-03 @ 5'3"-5'7"



Before



After

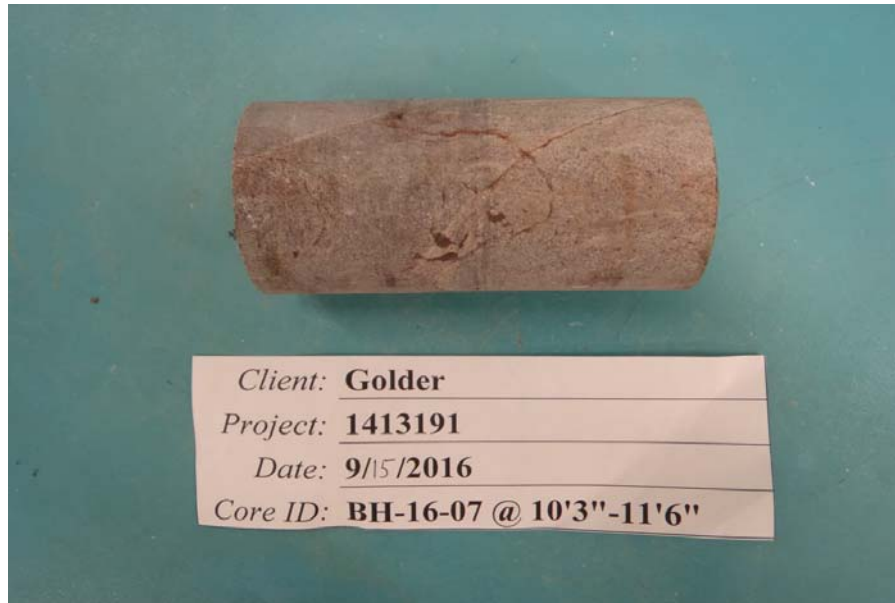
Pictures of Sample Before and After
Shore Hardness

Client Name: Golder Associates

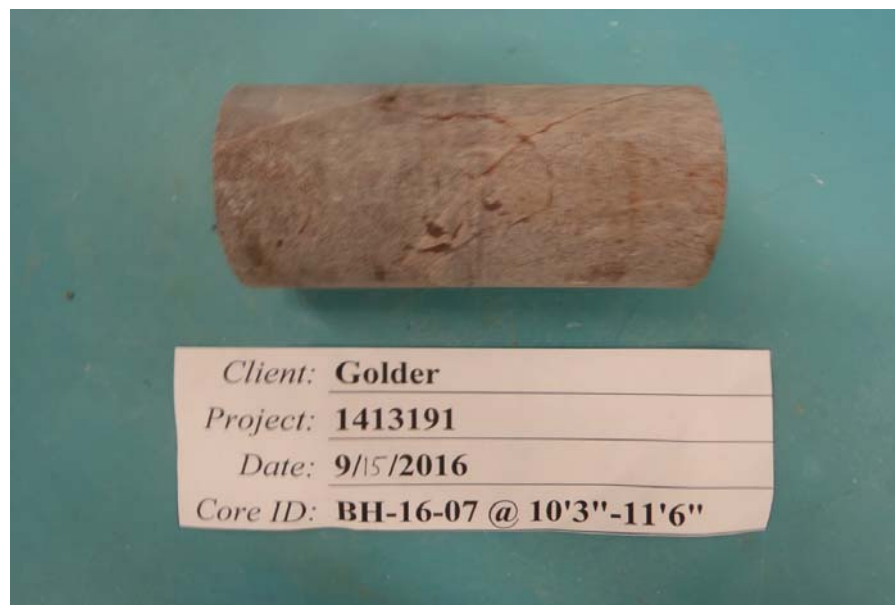
Project Name: 1413191

Date: 9/15/2016

Sample ID: BH-16-07 @ 10'3"-11'6"



Before

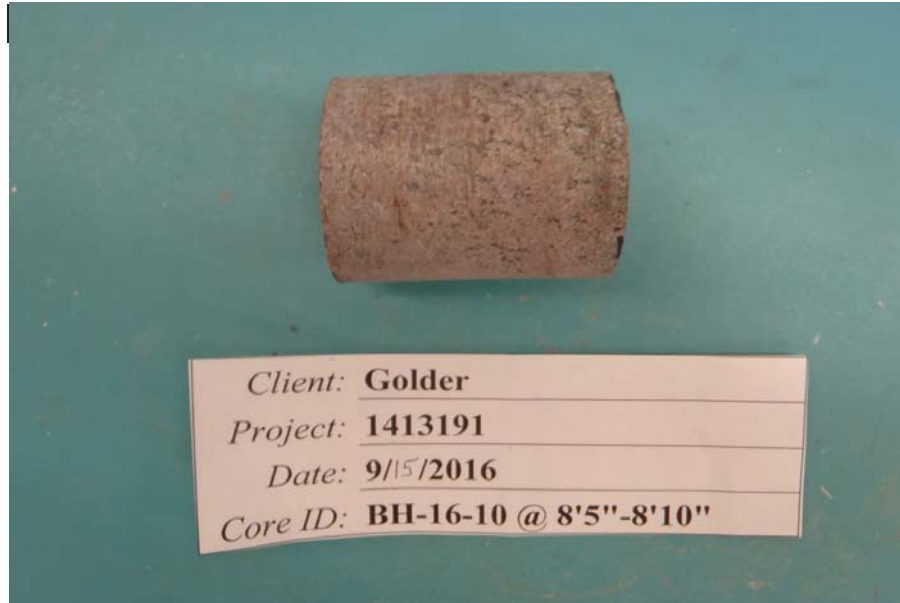


After

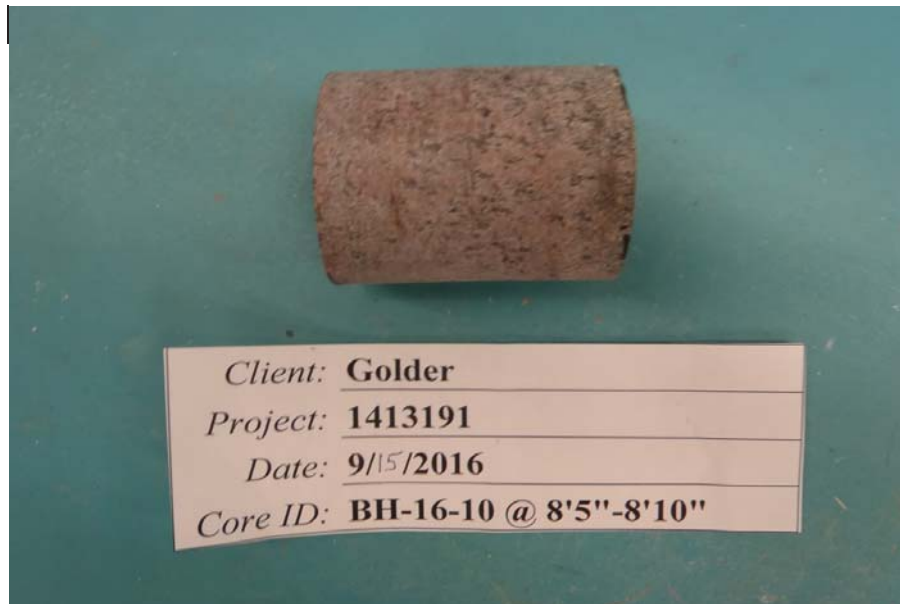
Pictures of Sample Before and After
Shore Hardness

Client Name: Golder Associates
Project Name: 1413191
Date: 9/15/2016

Sample ID: BH-16-10 @ 8'5"-8'10"



Before



After

At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. 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 now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

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