



April 27, 2015

FOUNDATION INVESTIGATION REPORT

**BORER'S CREEK CULVERT EXTENSIONS - SINGLE CELL (MTO
SITE No. 36-0302/C) AND TWIN CELL (MTO SITE No. 36-0430/C)
AND RETAINING WALLS
FUTURE HIGHWAY 5/HIGHWAY 6 INTERCHANGE
CITY OF HAMILTON
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 2112-05-00**

Submitted to:

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REPORT



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PART A

**FOUNDATION INVESTIGATION REPORT
BORER'S CREEK CULVERT EXTENSIONS AND RETAINING WALLS
FUTURE HIGHWAY 5/HIGHWAY 6 INTERCHANGE
CITY OF HAMILTON
MINISTRY OF TRANSPORTATION, ONTARIO
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by IBI Group (IBI) on behalf of the Ministry of Transportation, Ontario (MTO) to provide detail foundation engineering services for the extension of the Borer's Creek Culverts and retaining walls on the east and west side of Highway 6. The proposed work is part of the future Highway 5 and Highway 6 Interchange (IC) and associated Municipal Roads in the City of Hamilton, Ontario, which includes high fill embankments for the Highway 5 and Highway 6 re-alignments and interchange ramps, rock cut slope assessment, high mast lighting and overhead signs.

The Terms of Reference (TOR) and the scope of work for the foundation investigation are outlined in MTO's Request for Proposal, dated January 2010, which forms part of the Consultant's Assignment Number (Number 2008-E-0038) for this project. Golder's proposal for foundation engineering services associated with the Highway 5/Highway 6 Interchange structure is contained in Section 6.8 of IBI's Technical Proposal for this assignment and subsequent scope change dated December 9, 2013. The work has been carried out in accordance with Golder's Supplementary Specialty Quality Control Plan for foundation engineering services for this project, dated September 10, 2012.

This report addresses the investigation carried out for the Borer's Creek Culverts and retaining wall at both ends of the culverts. The purpose of this investigation is to establish the subsurface conditions at the proposed culverts and retaining walls, by borehole drilling, rock coring, in situ testing and laboratory testing on selected soil and rock core samples. The investigation area is shown in plan on Drawing 1.

2.0 SITE DESCRIPTION

The Borer's Creek culverts are located about 500 m north of the existing Highway 5 and Highway 6 intersection, which is located west of Waterdown and approximately 3 km north of the Highway 403/Highway 6 interchange, at Clappison's Corners in the City of Hamilton, Ontario. The existing Highway 5 alignment in this area is oriented generally in a west-east direction. The existing Highway 6 alignment is oriented generally in a north-south direction connecting with Highway 403 to the south and Highway 401 to the north of Highway 5, and it was last widened in 2005. At the location of the Borer's Creek culverts Highway 6 consists of two lanes in both the northbound and southbound directions with a centre median lane.

The existing Borer's Creek culverts are generally oriented perpendicular to Highway 6 and consist of two culvert structures: a twin cell box culvert (MTO Site No. 36-0430/C) centered at Station 20+492; and a single cell box culvert (MTO Site No. 36-0302/C) centered at Station 20+475. At the twin cell structure there is water flowing through the most northerly of the two sections and the southerly cell is used for pedestrian traffic. The single cell culvert is currently dry and it is understood that it is unused. The ends of the twin culverts and single cell culvert are about coincident with the toes of the existing highway embankment. In order to accommodate the roadway widening, the twin cell culvert is being fitted with a cantilever head wall, and the single cell culvert is being extended on both ends and will also be fitted with a cantilever head wall. A retaining wall is proposed between the twin cell box culvert and the single cell box culvert and to connect the headwalls at both ends of the culverts. Retaining walls, approximately 5 m to 7 m in length, are also proposed south of the single cell culvert and north of the twin cell culverts.

The topography at the site consists of relatively flat terrain which slopes downward further south of the intersection along Highway 6 down the Niagara Escarpment. The existing Highway 6 grade in the general area of the Borer's Creek culverts is at about Elevation 220.6 m and the ground surface at the toes of the highway



embankment is at about Elevations 218.5 m on the east side and 216.7 m on the west side of the highway. Approximately 3 m to the west of Borehole BC-1, bedrock outcrop is visible at ground surface.

3.0 INVESTIGATION PROCEDURES

The foundation investigation at the Borer's Creek culverts was carried out between October 8 and 28, 2014 during which time a total of five sampled boreholes were advanced at the locations shown of Drawing 1. In addition, Borehole OS-4, drilled in September 2013 for a proposed overhead sign at Station 20+480 and which is located in the vicinity of Borer's Creek, is also pertinent to the foundation investigation for the culverts.

The borehole investigation was carried out using a track-mounted CME 55 drill rig and a truck-mounted CME 75 drill rig, supplied and operated by DBW Drilling Ltd. of Ajax, Ontario. The boreholes were advanced through the overburden using 102 mm and 150 mm outside diameter solid stem augers. Soil samples were taken using 50 mm outer diameter split-spoon samplers driven by an automatic hammer in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586-08a – Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of the Soil). In general, split-spoon samples were obtained at ground surface and at depth intervals of about 0.75 m. Samples of the bedrock were obtained using NW casing and an NQ size rock core barrel and coring techniques.

The boreholes were advanced to auger and/or sampler refusal (i.e. inferred bedrock) and bedrock was confirmed by coring in five selected boreholes. The boreholes were advanced to depths ranging from 3.5m to 6.4 m below existing ground surface, including coring of bedrock for core lengths between about 3.0 m and 3.7 m in Boreholes BC-1, BC-3A, BC-5, BC-6A and OS-4. Photographs of the recovered rock samples are provided in Appendix B.

The groundwater conditions and water levels in the open boreholes were observed during the drilling operations. A piezometer was installed in Borehole BC-4 to permit monitoring of the ground water level at this location. The installed piezometer consists of 37 mm (1 ¼ inch) diameter PVC pipe, with a 1.5 m slotted screen sealed within a filter sand pack at a select depth within the borehole. The borehole and annulus surrounding the piezometer pipe above the screen and filter sand pack were backfilled to the ground surface with bentonite pellets. Piezometer installation details and water level readings are described on the Record of Borehole sheets presented in Appendix A. All open boreholes were backfilled with bentonite upon completion in accordance with Ontario Regulation 903, Wells (as amended).

The field work was observed by members of Golder's engineering and technical staff, who located the boreholes, arranged for the clearance of underground services, observed the drilling and sampling operations, logged the boreholes, and examined and cared for the soil and rock core samples. The soil samples were identified in the field, placed in appropriate containers, labelled and transported to our Mississauga geotechnical laboratory. The rock core samples from the bedrock were placed in core boxes, logged in the field and transported to our Mississauga geotechnical laboratory. In the laboratory the soil samples and rock core samples underwent further detailed visual examination and geotechnical soil classification testing (water content, Atterberg limits and grain size distribution and rock core unconfined compression (uniaxial) strength testing). All of the laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. The results of the laboratory testing are noted on the Record of Borehole and Drillhole sheets in Appendix A and are presented on the laboratory test sheets included in Appendix B.



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The as-drilled borehole location and ground surface elevation were surveyed by Callon Dietz, a licensed surveying company retained by Golder. The locations given in the Record of Borehole/Drillhole sheets and shown on Drawings 1 and 2 are positioned relative to MTM NAD 83 northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum.

The as-drilled borehole location of OS-4 was measured relative to the existing on-site features and the overhead signs location shown on the digital terrain model for the site, provided by IBI. The approximate ground surface elevation at Borehole OS-4 was obtained from the topographic and contour maps provided by IBI.

The borehole locations, ground surface elevations and drilled depths are summarized below.

Borehole No.	Location (MTM NAD 83)		Ground Surface Elevation (m)	Borehole Depth (m)*
	Northing	Easting		
BC-1	4797350.6	270543.7	218.0	6.0
BC-3A	4797364.8	270517.8	216.7	3.5
BC-4	4797371.1	270573.8	220.7	3.9
BC-5	4797387.0	270578.4	218.0	4.8
BC-6A	4797415.3	270555.1	218.5	5.5
OS-4	4797368.3	270547.7	220.5	6.4

*Including between 3.0 m and 3.7 m bedrock coring

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

The study area is located on the Niagara Escarpment¹, a topographic break that separates the two levels of the Niagara Peninsula, which is manifested in typically harder, resistant dolostone and limestone bedrock units forming vertical cliffs along the brow of the Escarpment, over the softer shale bedrock below. The Niagara Escarpment extends from the Niagara River to the northern tip of the Bruce Peninsula and is generally flanked by landscapes of glacial origin. Capping the Niagara Escarpment is the Lockport Formation consisting of white, grey and brown dolostone (Karrow, 1987)² at the crest underlain by the Rochester, Irondequoit, Reynales, Thorold, Grimsby and Cabot Head Formations consisting of grey to reddish brown shaley dolostone, limestone, siltstone and sandstone (Blair and McFarland, 1992)³.

Overburden within the study area is comprised primarily of glacial till, which is mapped as the Halton Till and extends as a sheet into the Hamilton area, terminating in the Waterdown Moraines east of the Niagara Escarpment between the Lake Iroquois and the Trafalgar Moraine. The Halton Till is generally considered a fine-grained diamicton with minor fine-grained lacustrine sediments incorporated within the body of the unit, likely from glacial reworking of underlying lacustrine sediments. The Halton Till also contains cobbles and

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

² Karrow, P.F. 1987. *Quaternary Geology of the Hamilton-Cambridge Area, Southern Ontario*, Ontario Geological Survey, Report 255. Ministry of Northern Development and Mines, Ontario.

³ Blair, R. and McFarland, S. 1993. *Regional Correlation of the Middle and Lower Silurian Stratigraphy of the Niagara Escarpment Area*, Proceedings of the 1992 Conference of the Canadian National Chapter, International Association of Hydrogeologists, Hamilton, Ontario, 659-696.



boulders and in some areas, “boulder pavements” (Watt, 1955)⁴ can be encountered where boulders are nested or concentrated within the till unit.

During the retreat of the last ice sheet, lakes were formed in depressions on the land surface in which were deposited sand, gravel, silt and clay materials. The last major meltwater system along the Escarpment occurred when the Waterdown Moraines were formed. Several channels among the Waterdown Moraines functioned at various times, feeding meltwaters southwest toward glacial lakes to create lacustrine and outwash sand deposits.

4.2 Subsurface Conditions

The detailed subsurface soil, bedrock, and groundwater conditions as encountered in the boreholes advanced during this investigation and the results of the laboratory tests carried out on selected soil and bedrock core samples are presented on the Record of Borehole and Drillhole sheets provided in Appendix A. The results of the in situ field tests (i.e. SPT ‘N’-values) as presented on the Record of Borehole sheets and in Section 4.0 are uncorrected. The results of the laboratory tests carried out on selected soil and rock core samples are provided in Appendix B.

The stratigraphic boundaries shown on the Record of Boreholes and on the stratigraphic profile and cross-sections on Drawing 2 are inferred from non-continuous sampling, observations of drilling progress and the results of Standard Penetration Tests (SPTs). These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Furthermore, subsurface conditions will vary between and beyond the borehole locations; however, the factual data presented in the record of Borehole and Drillhole sheets governs any interpretation of the site conditions. It should be noted that the interpreted stratigraphy shown on Drawing 2 is a simplification of the subsurface conditions.

In summary, the subsurface conditions in the area of the Borer’s Creek culverts consist of topsoil underlain by fill consisting of cohesionless and cohesive materials associated with the construction Highway 6. The fill material at some locations is underlain by a till deposit comprised of clayey silt to silty clay which in turn is underlain by dolostone bedrock. In general, the bedrock surface as encountered or inferred in the area of the Borer’s Creek culverts is fairly level to gently sloping upwards from northwest to southeast.

A detailed description of the subsurface conditions encountered in the boreholes at the proposed culvert extensions and retaining walls is provided in the following sections.

4.2.1 Topsoil

In Boreholes BC-1, BC-3A, BC-5 and BC-6A advanced at the toes of the embankment on either side of Highway 6 topsoil was encountered from ground surface. The thickness of the topsoil extends to depths between 0.1 m and 0.3 m below ground surface.

4.2.2 Asphalt

Borehole OS-4, advanced through the pavement structure of the south bound lanes of Highway 6 encountered 200 mm asphalt from the roadway surface.

⁴ Watt, A.K. 1955. *Pleistocene Geology and Groundwater Resources of the Township of North York, York County, Ontario* Department of Mines, Sixty Fourth Annual report, Volume LXIV, Part 7.



4.2.3 Fill

Fill materials were encountered in Boreholes BC-1, BC-4, BC-5, BC-6A and OS-4. In Boreholes BC-4, BC-5 and OS-4 cohesionless fill comprised of brown sand to silty sand and gravel to sand and gravel was encountered, from immediately below ground surface at Borehole BC-4, underlying the topsoil at Borehole BC-5 and beneath the asphalt in Borehole OS-4. The cohesionless fill material extends to depths between 0.7 m and 1.4 m (between Elevation 219.5 m and 217.3 m).

Underlying the topsoil in Borehole BC-1 and BC-6A, the silty sand and gravel fill in Borehole BC-4 and the sand and gravel fill in Borehole OS-4, cohesive fill consisting of sandy clayey silt to silty clay was encountered at depths between 0.1 m and 1.4 m (between Elevations 219.5 m and 217.8 m). The cohesive fill layer is between 0.6 m and 2.1 m thick and extends to depths ranging from 0.7 to 3.2 m (between Elevations 217.8 m and 215.7 m). The sandy clayey silt fill encountered in Borehole BC-1 contains cobbles and/or boulders as inferred by grinding of the augers and in Borehole BC-1 cobbles were removed from the borehole to a depth of 0.6 m below ground surface.

The SPT "N"-values measured within the cohesionless fill material range between 14 and 33 blows per 0.3 m of penetration, indicating a dense relative density. The SPT "N"-values recorded within the cohesive fill ranges from 6 blows to 33 blows per 0.3 m of penetration, suggesting that the clayey silt to silty clay fill has a firm to hard consistency.

Grain size distribution tests were carried out on two samples of the cohesive fill and the results are presented on Figure B1, in Appendix B. Atterberg limits tests carried out on two samples of the cohesive fill measured liquid limits of about 30 per cent, plastic limits of 18 per cent and 16 per cent corresponding plasticity indexes of 14 per cent and 12 per cent. The results of the Atterberg limits test are shown on a plasticity chart on Figure B2 in Appendix B and indicate that the cohesive fill material consists of clayey silt of low plasticity.

A grain size distribution test was carried out on one sample of the cohesionless fill and the result is presented on Figure B3, in Appendix B.

The water content measured on two samples of the silty sand and gravel fill is 4 per cent and 5 per cent and the water content recorded on five samples of the cohesive fill ranges from 16 per cent to 28 per cent. The organic content measured on a sample of the cohesive fill material from Borehole OS-4 is 1.5 per cent.

4.2.4 Clayey Silt to Silty Clay Till

A till deposit consisting of clayey silt to silty clay was encountered underlying the fill in Boreholes BC-4, BC-5, and BC-6A. The top of the till was encountered at a depth of 2.9 m (Elevation 217.8 m) in Borehole BC-4 and at depths of 0.7 m in Boreholes BC-5 (Elevation 217.3 m) and BC-6 (Elevation 217.8 m). The till deposit extends to depths between 1.2 m and 3.9 m (between Elevations 216.8 m and 216.6 m) and the deposit is between 0.5 m and 1.2 m thick.

The SPT "N"-values measured within the till deposit range from 21 blows to 106 blows per 0.3 m of penetration, suggesting that the clayey silt to silty clay till has a very stiff to hard consistency.

The till deposit is generally comprised of clayey silt some sand to silty clay, trace to some sand and trace gravel. Although cobbles and/or boulders were not encountered within the till deposit and grinding of the augers during drilling was not evident, the till deposits in southern Ontario typically contain such materials and they should be expected within such glacial deposits. Grain size distribution tests were carried out on two selected samples of the clayey silt to silty clay till deposit and the results are shown on Figure B4 in Appendix B.



Atterberg limits tests were carried out on three selected samples of this cohesive till deposit and measured liquid limits ranging from about 27 per cent to 37 per cent, plastic limits ranging from about 16 per cent to 17 per cent and plasticity indices ranging from about 11 per cent to 20 per cent. These results, which are plotted on a plasticity chart on Figure B5 in Appendix B, indicate that the till deposit consists of clayey silt of low plasticity to silty clay of intermediate plasticity.

The natural water content measured on three selected samples of the clayey silt to silty clay till ranges from 12 per cent to 18 per cent.

4.2.5 Dolostone Bedrock

Bedrock was encountered and core samples were recovered in Boreholes BC-1, BC-3A, BC-5, BC-6A and OS-4. The bedrock surface is inferred from split-spoon and auger refusal in Borehole BC-4. The depths to bedrock or refusal below ground surface and the corresponding bedrock surface or refusal elevation are summarized below.

Foundation Element	Borehole	Depth to Bedrock Surface / Refusal (m)	Bedrock Surface / Refusal Elevation (m)	Comments
West Extension of Single Cell Culvert	BC-1	2.3	215.7	Bedrock Cored
East Extension of Single Cell Culvert	BC-5	1.2	216.8	Bedrock Cored
North End of West Retaining Wall - Toe	BC-3A	0.3	216.4	Bedrock Cored
North End of East Retaining Wall - Toe	BC-6A	1.9	216.6	Bedrock Cored
South End of East Retaining Wall - Crest	BC-4	3.9	216.8	Auger and Split-Spoon Refusal
West Edge of Highway 6 between Single Cell and Twin Cell Culverts	OS-4	3.2	217.3	Bedrock Cored

In general, the bedrock surface as encountered or inferred in the area of the Borer's Creek Culvert is fairly level to gently sloping upwards from northwest to southeast. A bedrock outcrop is present at ground surface near Boreholes BC-1 and BC-3A.

Based on a review of the bedrock core samples, the bedrock consists of dolostone of the Lockport formation. In general, the bedrock core samples are described as slightly weathered to fresh, thinly to thickly bedded, fine to coarse grained, faintly to highly porous, medium strong to strong, grey, as presented in the Record of Drillhole sheets in Appendix A, and shown on the photographs of the recovered core samples on Figures B6 and B7 in Appendix B. The degree of weathering of the bedrock samples (i.e. fresh to slightly weathered – W1 to W2), and the strength classification of the intact rock mass based on field identification (i.e. medium strong to strong –



R3 to R4) are described in accordance with the International Society for Rock Mechanics (ISRM⁵) standard classification system.

The Total Core Recovery (TCR) and Solid Core Recovery (SCR) of samples recovered are between 85 per cent and 100 per cent and between 7 per cent and 100 per cent (but generally between 72 and 100 per cent), respectively. The Rock Quality Designation (RQD) measured on the core samples ranges from 0 per cent to 100 per cent (but generally ranges from 82 to 100 per cent), indicating a rock mass of poor to excellent quality as per Table 3.10 of CFEM (2006)⁵.

Point load strength index tests (ASTM D5731 – Standard Test Method for Determination of the Point Load Strength Index of Rock and Application to Rock Strength Classification) were carried out on eight selected samples of the bedrock core. The point load strength index values are shown on the Record of Drillhole sheets and are presented in Table B1. The axial tests carried out on four samples of the dolostone bedrock measured Is_{50} values ranging from about 1.8 MPa to 16.0 MPa. The diametral tests carried out on four samples of the dolostone bedrock measured Is_{50} values ranging from about 4.9 MPa to 18.3 MPa.

Two Unconfined Compression (UC) tests (ASTM D7012)⁶ were carried out on core samples of the dolostone bedrock obtained in BC-6A and Boreholes OS-4 and measured a compressive strength of about 119 MPa and 96 MPa, respectively. The laboratory UC test results are presented on Figures B8 and B9 and are summarized in Table B2.

Based on the laboratory UC test, in accordance with Table 3.5 in CFEM (2006)⁵, the dolostone bedrock is classified as strong (R4, 50 MPa < UCS < 100 MPa) to very strong (R5, 100 MPa < UCS < 250 MPa).

4.2.6 Groundwater Conditions

Details of the water levels observed in the open boreholes at the time of drilling are summarized on the Record of Borehole sheets, in Appendix A. The overburden samples taken in the boreholes were generally dry to moist. The water level in BC-1 was measured at a depth of 2.3 m (Elevation 215.7 m). Boreholes BC-3A, BC-4, BC-5 and BC-6A were dry upon completion of drilling and prior to rock coring operations.

The groundwater level measured in the piezometer in Borehole BC-4 on October 2, 2014 is at a depth of 3.7 m (Elevation 217.0 m).

It should be noted that the groundwater level in the area is subject to seasonal fluctuations and precipitation events, and should be expected to be higher during wet periods of the year.

⁵ International Society for Rock Mechanics Commission on Test Methods, 1985. Int. J. Rock Mech. Min. Sci. & Geomech. Abstr. Vol 22, No. 2, pp. 51-60.

⁶ ASTM D7012 – Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens

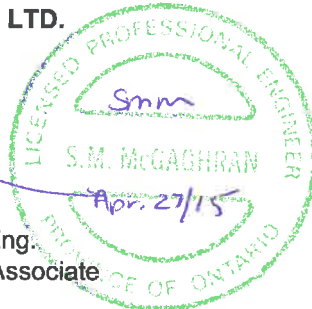


5.0 CLOSURE

Mr. Alex Szot, E.I.T., a geotechnical engineer-in-training with Golder directed the field drilling program. This report was prepared by Ms. Sandra McGaghran, P.Eng., a geotechnical engineer and Associate with Golder. Ms. Lisa Coyne, P.Eng., a Designated MTO Foundations Contact and Principal with Golder, conducted a technical and quality control review of the report.

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SMM/JMAC/LCC/sm

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15apr27 borer's creek culvert and retaining wall.docx



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ASTM International:

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

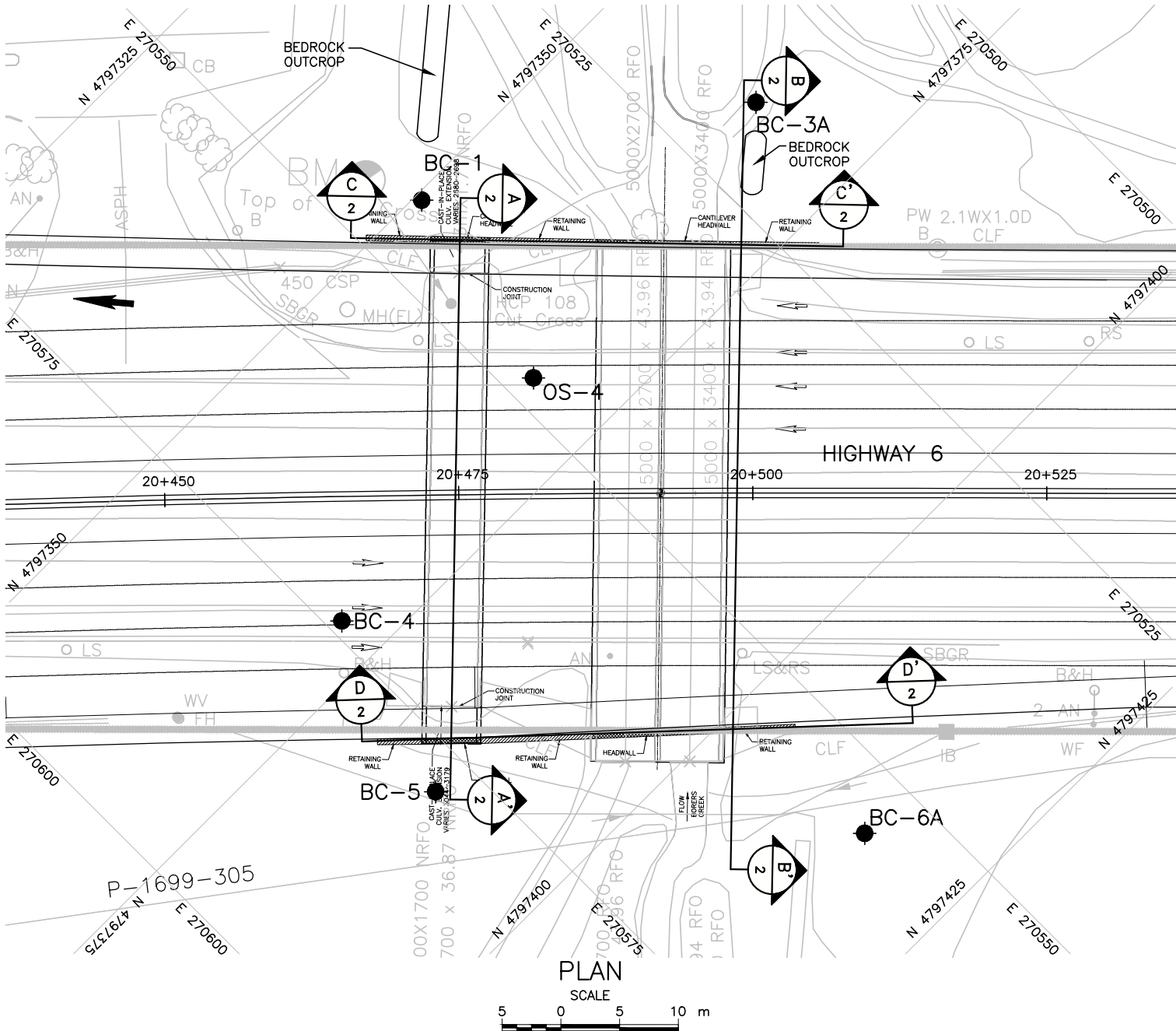
ASTM D7012 Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperatures

Ontario Water Resources Act:

Ontario Regulation 903 Wells (as amended)



DRAWINGS

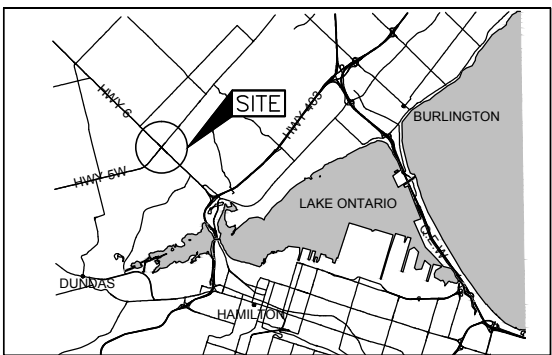


METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No. .
GWP No. 2112-05-00



HIGHWAY 5 OVER HIGHWAY 6
BORER'S CREEK CULVERT EXTENSIONS AND
RETAINING WALLS
BOREHOLE LOCATIONS



KEY PLAN
SCALE 3 0 3 6 km

LEGEND

● Borehole - Current Investigation

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
BC-1	218.0	4797350.6	270543.7
BC-3A	216.7	4797364.8	270517.8
BC-4	220.7	4797371.1	270573.8
BC-5	218.0	4797387.0	270578.4
BC-6A	218.5	4797415.3	270555.1
OS-4	220.5	4797368.0	270547.7

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 IBI, drawing file nos. 21_br_hwy5_6_culv_ga.dwg, T5&6-MPM-5lane-New STA.dwg and hwy6_5-SWM-2-New.dwg, received January 16, 2015.

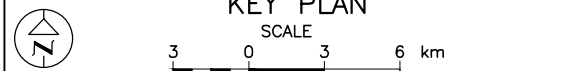
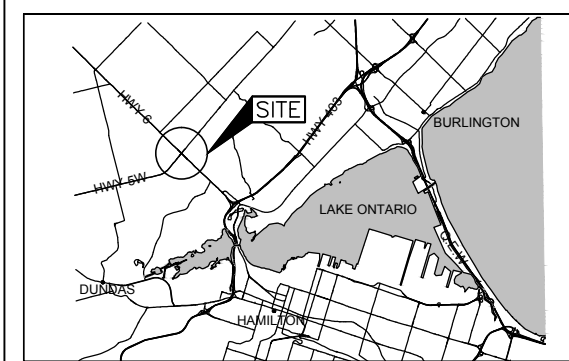


NO.	DATE	BY	REVISION
Geocres No. 30M5-311			
HWY. 5 & 6		PROJECT NO. 10-1184-0016	DIST. .
SUBM'D. AJS	CHKD. SMM	DATE: 1/28/2015	SITE: .
DRAWN: JFC	CHKD. SMM	APPD. LCC	DWG. 1

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

CONT No. _____
GWP No. 2112-05-00

HIGHWAY 5 OVER HIGHWAY 6
BORER'S CREEK CULVERT EXTENSIONS AND
RETAINING WALLS
SOIL STRATA



LEGEND

- Borehole - Current Investigation
- ⊥ Seal
- ⊥ Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)
- ≡ WL in piezometer, measured on November, 27, 2010
- ≡ WL upon completion of drilling
- R Refusal

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
BC-1	218.0	4797350.6	270543.7
BC-3A	216.7	4797364.8	270517.8
BC-4	220.7	4797371.1	270573.8
BC-5	218.0	4797387.0	270578.4
BC-6A	218.5	4797415.3	270555.1
OS-4	220.6	4797370.8	270547.7

NOTES

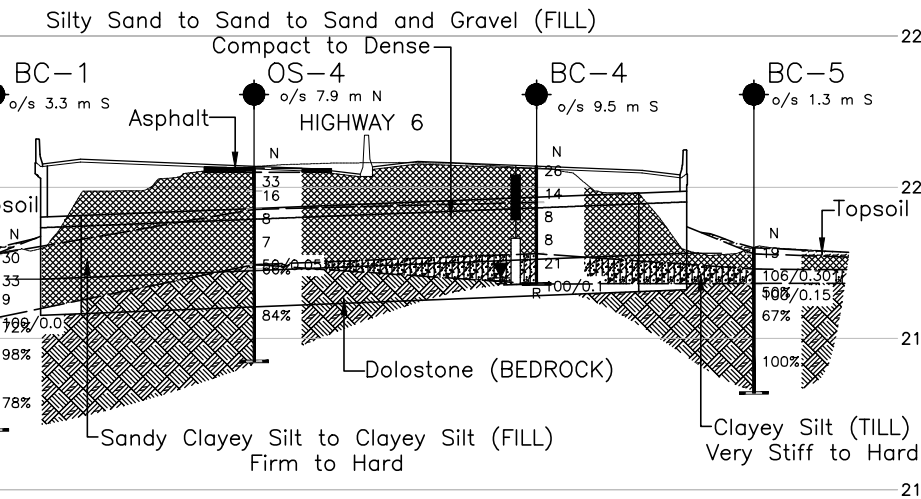
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

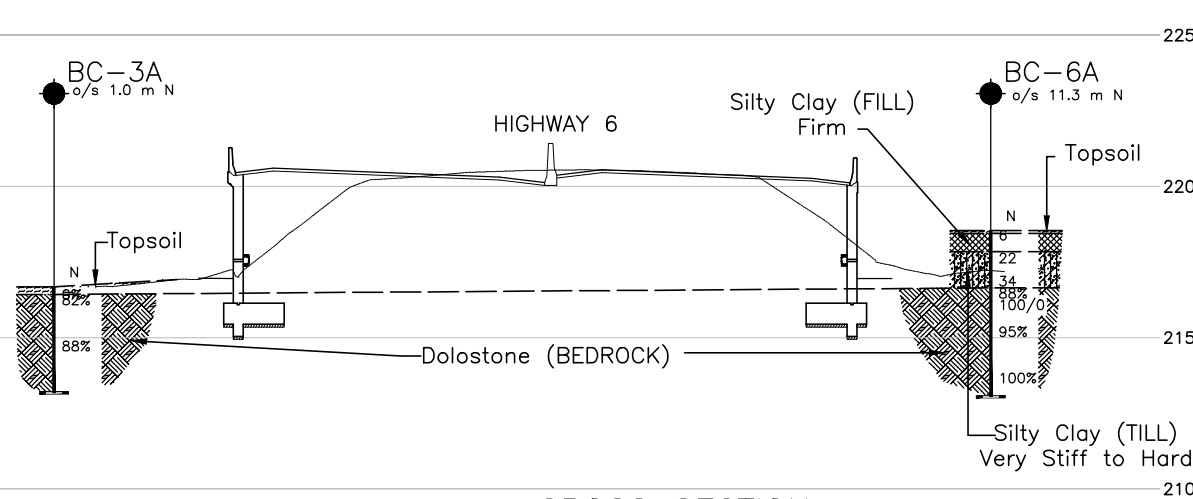
The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS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

REFERENCE

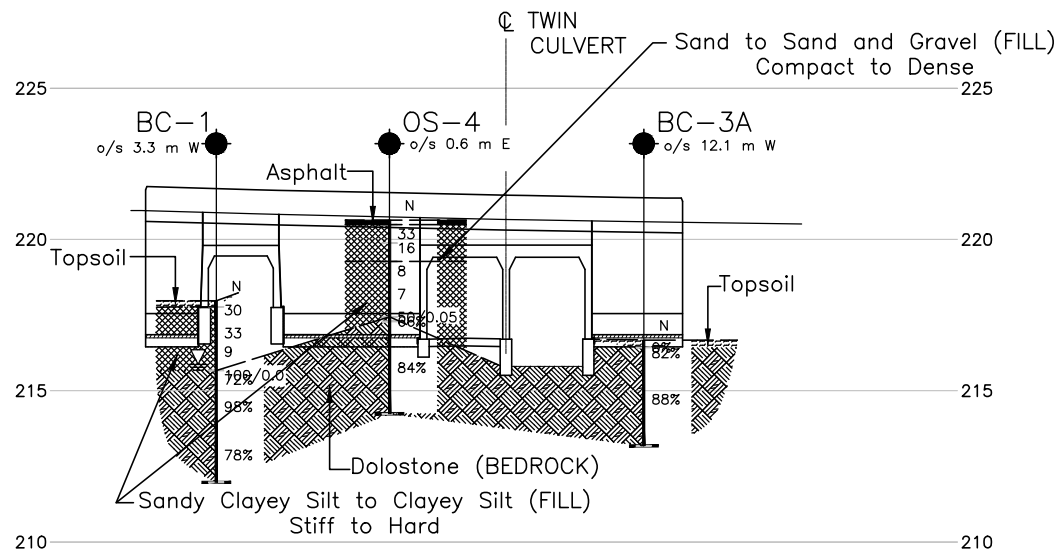
Base plans provided in digital format by IBI, drawing file nos. 21_br_hwy5_6_culv_ga.dwg, T5&6-MPM-5lane-New STA.dwg and hwy6_5-SWM-2-New.dwg, received January 16, 2015.



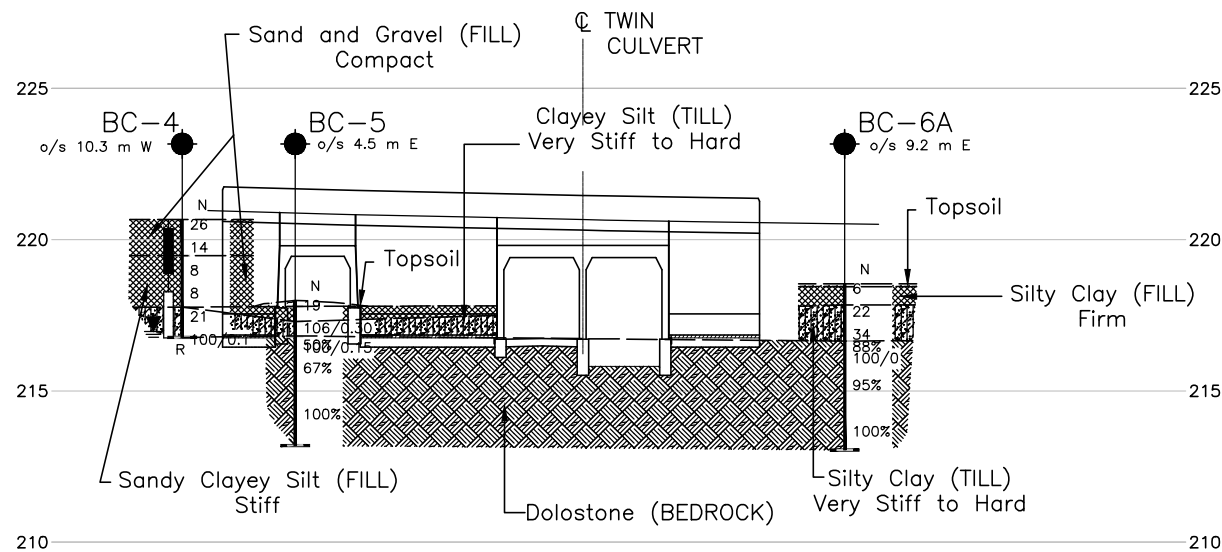
PROFILE A-A' CULVERT AT STATION 20+475 HIGHWAY 6



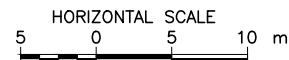
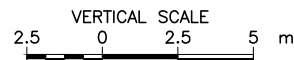
CROSS SECTION EAST AND WEST RETAINING WALL HIGHWAY 6



PROFILE C-C' WEST RETAINING WALL HIGHWAY 6



PROFILE D-D' EAST RETAINING WALL HIGHWAY 6



NO.	DATE	BY	REVISION

Geocres No. 30M5-311

HWY. 5 & 6	PROJECT NO. 10-1184-0016	DIST. .
SUBM'D. AJS	CHKD. SMM	DATE: 1/27/2015
DRAWN: JFC	CHKD. SMM	APPD. LCC
		DWG. 2



APPENDIX A

Record of Boreholes and Drillholes



LIST OF SYMBOLS

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

I. GENERAL

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

II. STRESS AND STRAIN

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

III. SOIL PROPERTIES

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

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

Notes: 1
2

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



LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Dynamic Cone Penetration Resistance; N_d :

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

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

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

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

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

(b) Cohesive Soils Consistency

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

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

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

V. MINOR SOIL CONSTITUENTS

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



LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERINGS STATE

Fresh: no visible sign of weathering

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

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

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

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

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

BEDDING THICKNESS

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

JOINT OR FOLIATION SPACING

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

GRAIN SIZE

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

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

CORE CONDITION

Total Core Recovery (TCR)

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

Solid Core Recovery (SCR)

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

Rock Quality Designation (RQD)

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

DISCONTINUITY DATA

Fracture Index

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

Dip with Respect to Core Axis

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

Description and Notes

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

Abbreviations

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

PROJECT		10-1184-0016		RECORD OF BOREHOLE No BC-1		SHEET 1 OF 1		METRIC									
G.W.P.		2112-05-00		LOCATION		N 4797350.6 ; E 270543.7		ORIGINATED BY									
DIST		Central HWY 5 & 6		BOREHOLE TYPE		102 mm O.D. Continuous Flight Solid Stem Augers		COMPILED BY									
DATUM		Geodetic		DATE		October 8, 2014		CHECKED BY									
								SMM									
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
								20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	10 20 30	10 20 30	10 20 30				
218.0	GROUND SURFACE																
0.0	TOPSOIL																
0.2	Sandy clayey silt trace to some gravel, cobbles between 0.0 m and 0.6 m depth (FILL) Stiff to hard Brown Moist - Augers grinding between 0.0 m and 2.3 m		1A	SS	30		217										
			1B	SS	33												
			2	SS	9		216										
215.7	DOLOSTONE (BEDROCK)		3	SS	9												
2.3	Bedrock cored from depths of 2.6 m to 6.0 m For bedrock coring details, refer to Record of Drillhole BC-1.		4	SS	100/0.0												
			1	RC	REC 100%		215										
			2	RC	REC 100%		214										
			3	RC	REC 85%		213										
212.0	END OF BOREHOLE						212										
6.0	NOTE: 1. Spoon bouncing and auger refusal at a depth of 2.3 m below ground surface (Elev. 215.7 m). 2. Water level in open borehole measured at a depth of 2.1 m below ground surface (Elev. 215.9 m) upon completion of drilling and prior to rock coring.																

GTA-MTO 001 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG\10-1184-0016.GPJ GAL-GTA GDT 4/20/15 DD

SHEET 1 OF 1

DATUM: Geodetic

DRILL RIG: CME-55 Track

DRILLING CONTRACTOR: DBW Drilling

CHECKED: SMM

GTA-RCK 046 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG\10-1184-0016.GPJ GAL-MISS.GDT 4/20/15 DD

PROJECT		RECORD OF BOREHOLE No BC-3A				SHEET 1 OF 1		METRIC									
G.W.P. 2112-05-00		LOCATION N 4797364.8 ; E 270517.8				ORIGINATED BY AJS											
DIST Central HWY 5 & 6		BOREHOLE TYPE 102 mm O.D. Continuous Flight Solid Stem Augers				COMPILED BY PKS											
DATUM Geodetic		DATE October 14, 2014				CHECKED BY SMM											
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									
216.7	GROUND SURFACE																
0.0	TOPSOIL		1	-	REC												
216.4			1	RC	REC 100%												RQD = 0%
0.3	DOLOSTONE (BEDROCK)																
	Bedrock cored from depths of 0.3 m to 3.5 m																
	For bedrock coring details, refer to Record of Drillhole BC-3A.																
			2	RC	REC 97%												RQD = 82%
			3	RC	REC 92%												RQD = 88%
213.2	END OF BOREHOLE																
3.5	NOTE: 1. Open borehole dry upon completion of drilling and prior to rock coring.																

GTA-MTO 001 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG\10-1184-0016.GPJ GAL-GTA.GDT 4/20/15 DD

SHEET 1 OF 1

DATUM: Geodetic

DRILLING CONTRACTOR: DBW Drilling

[illegible]

CHECKED: SMM

PROJECT		10-1184-0016		RECORD OF BOREHOLE No BC-4		SHEET 1 OF 1		METRIC				
G.W.P.		2112-05-00		LOCATION		N 4797371.1 ; E 270573.8		ORIGINATED BY				
DIST		Central HWY 5 & 6		BOREHOLE TYPE		102 mm O.D. Continuous Flight Solid Stem Augers		COMPILED BY				
DATUM		Geodetic		DATE		October 28, 2014		CHECKED BY				
								SMM				
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC NATURAL LIQUID UNIT REMARKS			
ELEV	DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	W _p W W _L	γ	GR SA SI CL
220.7	0.0	GROUND SURFACE		1	SS	26		220				
		Silty sand and gravel (FILL) Compact Brown Moist		2A	SS	14						
219.5	1.2	Sandy clayey silt, trace gravel (FILL) Stiff Grey-brown Moist		3	SS	8		219				4 25 42 29
				4A	SS	8						
217.8	2.9	CLAYEY SILT, trace to some sand, trace gravel (TILL) Very stiff Brown Moist		5	SS	21		218				0 11 60 29
				6A	SS	100/0						
216.8	3.9	END OF BOREHOLE AUGER AND SPOON REFUSAL INFERRED BEDROCK		6B				217				
NOTE: 1. Open borehole dry upon completion of drilling. 2. Water level readings in piezometer: <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div>Date</div> <div>Depth (m)</div> <div>Elev. (m)</div> </div> <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div>11/02/14</div> <div>3.7</div> <div>217.0</div> </div>												

GTA-MTO 001 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG\10-1184-0016.GPJ GAL-GTA.GDT 4/20/15 DD

PROJECT		10-1184-0016		RECORD OF BOREHOLE No BC-5		SHEET 1 OF 1		METRIC									
G.W.P.		2112-05-00		LOCATION		N 4797387.0 ; E 270578.4		ORIGINATED BY		AJS							
DIST		Central HWY 5 & 6		BOREHOLE TYPE		102 mm O.D. Continuous Flight Solid Stem Augers		COMPILED BY		PKS							
DATUM		Geodetic		DATE		October 10, 2014		CHECKED BY		SMM							
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									
218.0	GROUND SURFACE																
0.0	TOPSOIL																
0.2	Sand and gravel (FILL)		1	SS	19												
217.3	Compact Grey-brown Dry		2A	SS	106												
0.7			2B	SS	106												
216.8	CLAYEY SILT, trace sand, trace gravel (TILL)		3	SS	100/0.15												
1.2	Hard Brown Moist		1	RC	REC 100%												
	DOLOSTONE (BEDROCK)																
	Bedrock cored from depths of 1.5 m to 4.8 m																
	For bedrock coring details, refer to Record of Drillhole BC-5.		2	RC	REC 85%												
			3	RC	REC 100%												
213.2	END OF BOREHOLE																
4.8	NOTE: 1. Spoon bouncing and auger refusal at a depth of 1.4 m below ground surface (Elev. 216.6 m) 2. Open borehole dry upon completion of drilling and prior to rock coring.																

GTA-MTO 001 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG\10-1184-0016.GPJ GAL-GTA.GDT 4/20/15 DD

PROJECT: 10-1184-0016

RECORD OF DRILLHOLE: BC-5

SHEET 1 OF 1

LOCATION: N 4797387.01 ;E 270578.44

DRILLING DATE: October 10, 2014

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: CME-55 Track

DRILLING CONTRACTOR: DBW Drilling

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	PIEZOMETER																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
						FLUSH RETURN	RECOVERY		R.Q.D. %	FRACT. INDEX PER 25	DIP W/L CORE AXIS	DISCONTINUITY DATA				WEATH- ERING INDEX		Diametral Point Load Index (MPa)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
							TOTAL CORE %	SOLID CORE %				TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	W1	W2		W3	W4	W5	W6																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
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DEPTH SCALE

1 : 50



LOGGED: SP

CHECKED: SMM

GTA-RCK 046 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG\10-1184-0016.GPJ GAL-MISS.GDT 4/20/15 DD

PROJECT		10-1184-0016		RECORD OF BOREHOLE No BC-6A		SHEET 1 OF 1		METRIC									
G.W.P.		2112-05-00		LOCATION		N 4797415.3 ; E 270555.1		ORIGINATED BY									
DIST		Central HWY 5 & 6		BOREHOLE TYPE		102 mm O.D. Continuous Flight Solid Stem Augers		COMPILED BY									
DATUM		Geodetic		DATE		October 9, 2014		CHECKED BY									
								SMM									
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									
218.5	GROUND SURFACE																
0.0	TOPSOIL																
0.1	Silty clay, some sand, trace gravel, containing rootlets (FILL)		1	SS	6												
217.8	Firm																
0.7	Brown Moist		2	SS	22												
	SILTY CLAY, trace to some sand, trace gravel (TILL)																
	Very stiff to hard																
216.6	Brown Moist		3A	SS	34												
1.9	DOLOSTONE (BEDROCK)		3B														
	Bedrock cored from depths of 2.1 m to 5.5 m.		4	SS	100/0												
	For bedrock coring details, refer to Record of Drillhole BC-6A.		1	RC	REC 100%												
			2	RC	REC 100%												
			3	RC	REC 100%												
213.0	END OF BOREHOLE																
5.5	NOTE:																
	1. Spoon bouncing and auger refusal at a depth of 2.3 m below ground surface (Elev. 216.2 m)																
	2. Open borehole dry upon completion of drilling.																

GTA-MTO 001 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG\10-1184-0016.GPJ GAL-GTA.GDT 4/20/15 DD

PROJECT: 10-1184-0016

RECORD OF DRILLHOLE: BC-6A

SHEET 1 OF 1

LOCATION: N 4797415.29 ;E 270555.14

DRILLING DATE: October 9, 2014

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: CME-55 Track

DRILLING CONTRACTOR: DBW Drilling

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	PIEZOMETER																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
							RECOVERY		R.Q.D. %	FRACT. INDEX PER 25	DIP w.r.t CORE AXIS	DISCONTINUITY DATA			WEATH- ERING INDEX	Diametral Point Load Index (MPa)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
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DEPTH SCALE

1 : 50



LOGGED: SP

CHECKED: SMM

GTA-RCK 046 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG\10-1184-0016.GPJ GAL-MISS.GDT 4/20/15 DD

PROJECT		10-1184-0016		RECORD OF BOREHOLE No OS-4		SHEET 1 OF 1		METRIC									
G.W.P.		2112-05-00		LOCATION		N 4797368.3 ; E 270547.7		ORIGINATED BY									
DIST		Central HWY 5 & 6		BOREHOLE TYPE		150 mm O.D. Continuous Flight Solid Stem Augers and NQ Casing		COMPILED BY									
DATUM		Geodetic		DATE		September 3, 2013		CHECKED BY									
								SMM									
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
								20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	W _p	W	W _L	10 20 30			
220.5	GROUND SURFACE																
0.0	ASPHALT (150 mm)																
0.2	Sand, trace to some gravel, trace silt (FILL)		1	SS	33		220										
219.7	Dense Brown Moist		2	SS	16												
0.8																	
219.1	Sand and gravel, trace to some silt, trace clay (FILL)						219										
1.4	Compact Brown Moist		3	SS	8												
	Clayey silt, trace to some sand, trace gravel, trace organics, containing rootlets (FILL)		4	SS	7		218										
	Firm Mottled brown and grey Wet																
217.3			5A	SS	50/0.05												
			5B														
3.4	DOLOSTONE fragments Grey						217										
	DOLOSTONE (BEDROCK)																
	Bedrock cored from depths of 3.4 m to 6.4 m.		1	RC	REC 94%		216										
	For bedrock coring details, refer to Record of Drillhole OS-4.																
			2	RC	REC 100%		215										
214.1	END OF BOREHOLE																
6.4	NOTES:																
	1. Split spoon bouncing and auger grinding at a depth of 3.2 m (Elev. 214.3 m).																
	2. Water level in open borehole not recorded as water was introduced for bedrock coring.																

PROJECT: 10-1184-0016

RECORD OF DRILLHOLE: OS-4

SHEET 1 OF 1

LOCATION: N 4797368.33 ;E 270547.68

DRILLING DATE: September 3, 2013

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: CME-75 Truck-mounted

DRILLING CONTRACTOR: DBW Drilling

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	PIEZOMETER																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
						RECOVERY		R.Q.D. %	FRACT. INDEX PER 25	DIP w.r.t CORE AXIS	DISCONTINUITY DATA						WEATH- ERING INDEX						Diametral Point Load Index (MPa)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
						TOTAL CORE %	SOLID CORE %				TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	W1	W2	W3	W4	W5	W6																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
		Continued from Record of Borehole OS-4		217.15																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								

DEPTH SCALE

1 : 50



LOGGED: JG/AV

CHECKED: SMM

GTA-RCK 046 T:\PROJECTS\2010\10-1184-0016 (IG, HAMILTON)\LOG\10-1184-0016.GPJ GAL-MISS.GDT 4/27/15 DD



APPENDIX B

Laboratory Test Results (Soil and Rock) and Bedrock Core Photographs

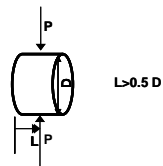
TABLE B1
POINT LOAD TEST RESULTS ON ROCK SAMPLES

Borehole Number	Run Number	Sample Depth (m)	Sample Elevation (m)	Bedrock Description	Test Type	Is (50mm) (MPa)	Approx. UCS Value ⁽¹⁾ (MPa)
BC-1	1	3.0	215.0	Dolostone	Axial	1.78	17.8
BC-1	1	3.3	214.7	Dolostone	Diametral	4.91	49.1
BC-5	2	2.7	215.3	Dolostone	Diametral	10.67	106.7
BC-5	2	2.8	215.2	Dolostone	Axial	8.20	82.0
OS-4	1	3.85	216.8	Dolostone	Diametral	17.30	173.0
OS-4	1	3.93	216.7	Dolostone	Axial	16.04	160.4
OS-4	2	4.98	215.6	Dolostone	Axial	3.46	34.6
OS-4	2	5.33	215.3	Dolostone	Diametral	18.32	183.2

⁽¹⁾ $Is_{50} \times K$ (actual value could be confirmed by UCS testing) from ISRM. This range has been given based on $K = 10$, calculated from Is_{50} Average of 8 tests on Axial Orientations and UCS Average of 2 tests conducted from core samples obtained from the boreholes advanced at the Borer's Creek. Refer to "Suggested Methods for Determining Point Load Strength", International Society for Rock Mechanics Commission on Testing Methods, Int.J.Rock. Mech. Min.Sci. and Geomechanical Abstr., Vol 22, No. 2 1985, PP 51-60.

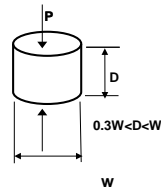
DIAMETRAL SPECIMEN SHAPE REQUIREMENTS

note: Diametral tests are perpendicular to core axis (planes of weakness)



AXIAL SPECIMEN SHAPE REQUIREMENTS

note: Axial tests are parallel to core axis



Compiled By: AJS
 Checked By: SMM
 Reviewed By: JMAC

TABLE B2
SUMMARY OF UNIAXIAL COMPRESSIVE STRENGTH TEST RESULTS
BORER'S CREEK CULVERT EXTENSIONS AND RETAINING WALLS
HIGHWAY 6, HAMILTON, ONTARIO

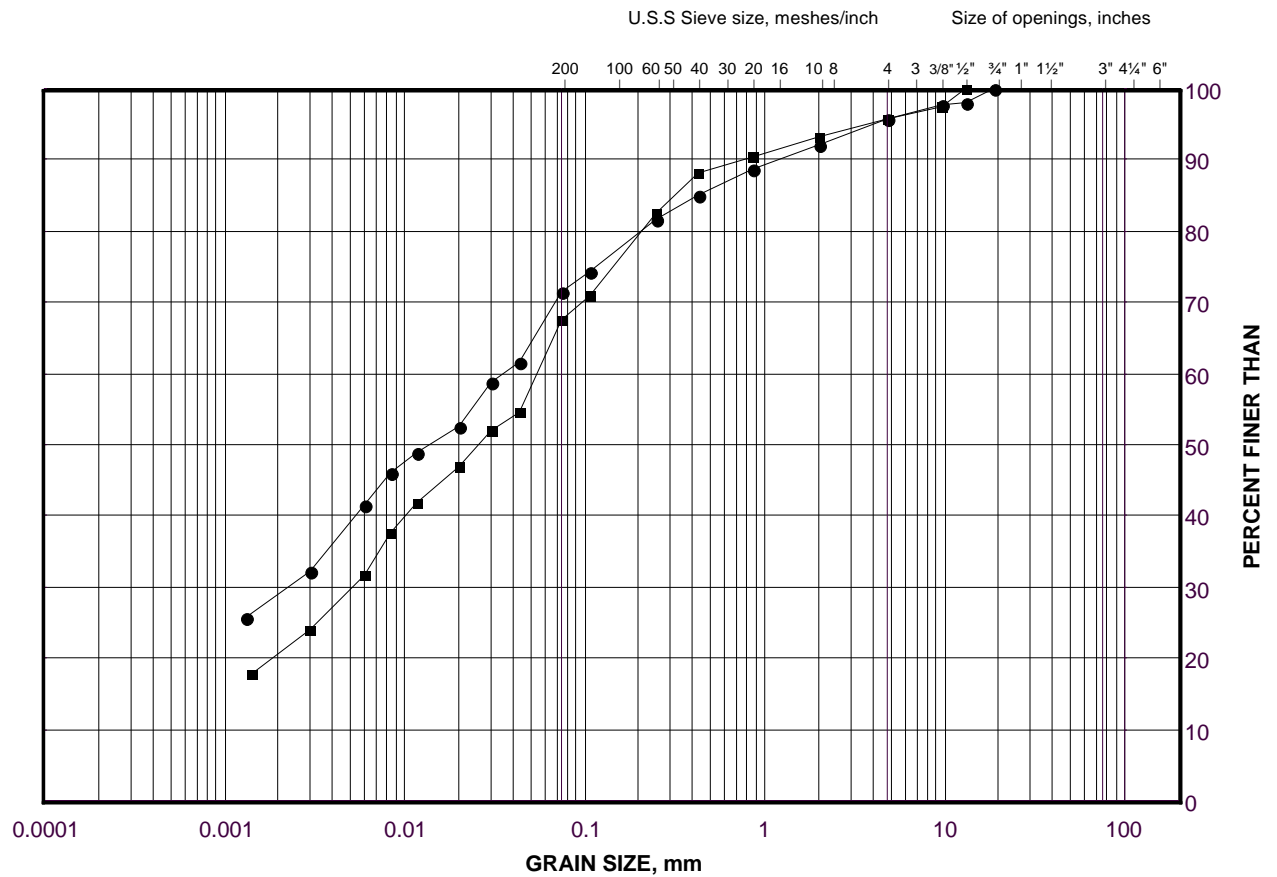
Borehole Number (Core Run)	Sample Depth (m)	Sample Elevation (m)	Rock Type	Core Diameter (mm)	Uniaxial Compressive Strength (MPa)
BC-6A (1)	2.8	215.7	Dolostone	4.74	119
OS-4 (2)	5.2	215.4	Dolostone	4.73	96

Compiled By: AJSReviewed By: SMM

GRAIN SIZE DISTRIBUTION

Sandy Clayey Silt (Fill)

FIGURE B1



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

LEGEND

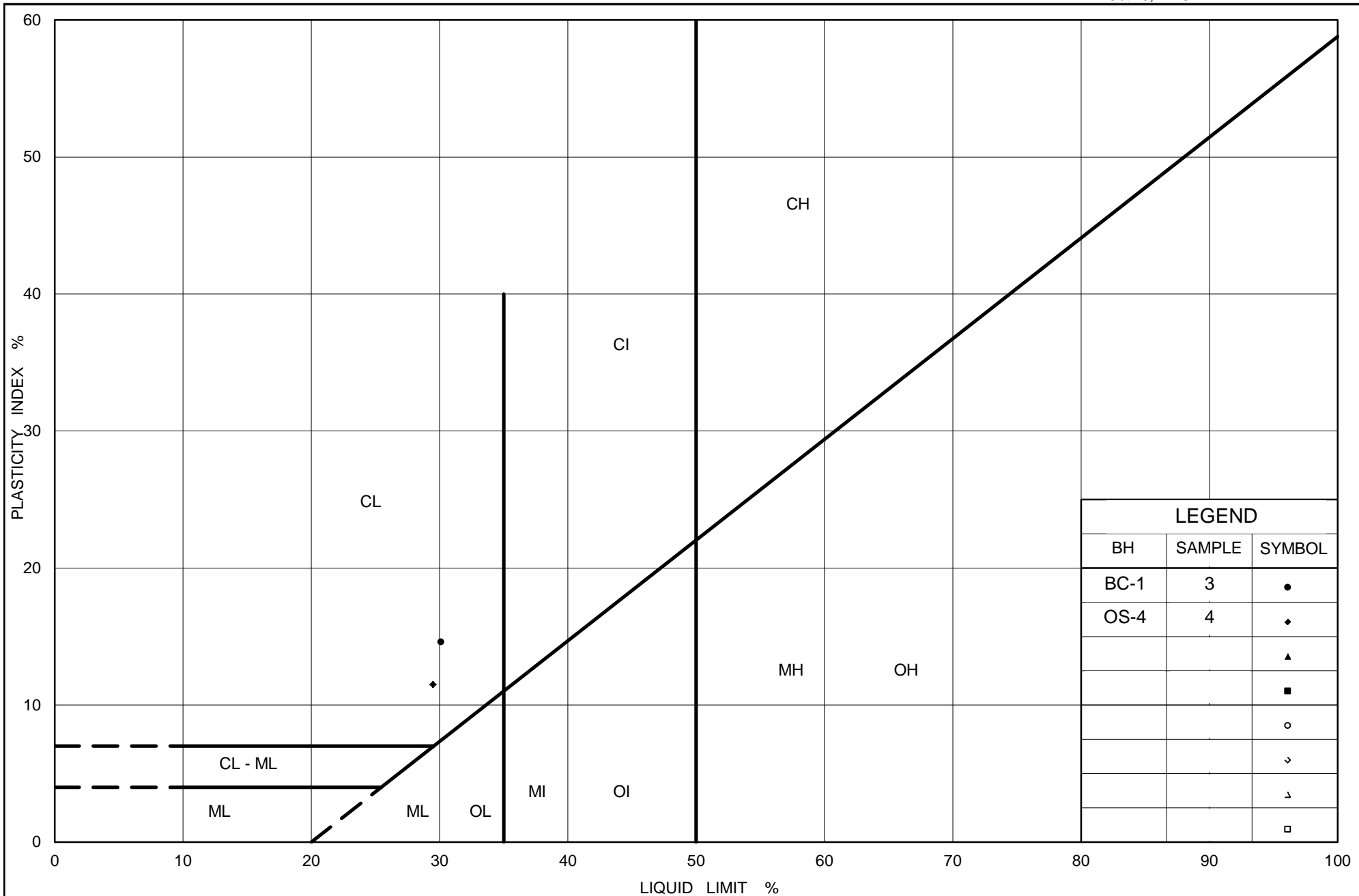
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	BC-4	3	218.8
■	BC-1	3	216.2

Project Number: 10-1184-0016

Checked By: SMM

Golder Associates

Date: 04-Feb-15



Ministry of Transportation

Ontario

PLASTICITY CHART

Sandy Clayey Silt (Fill)

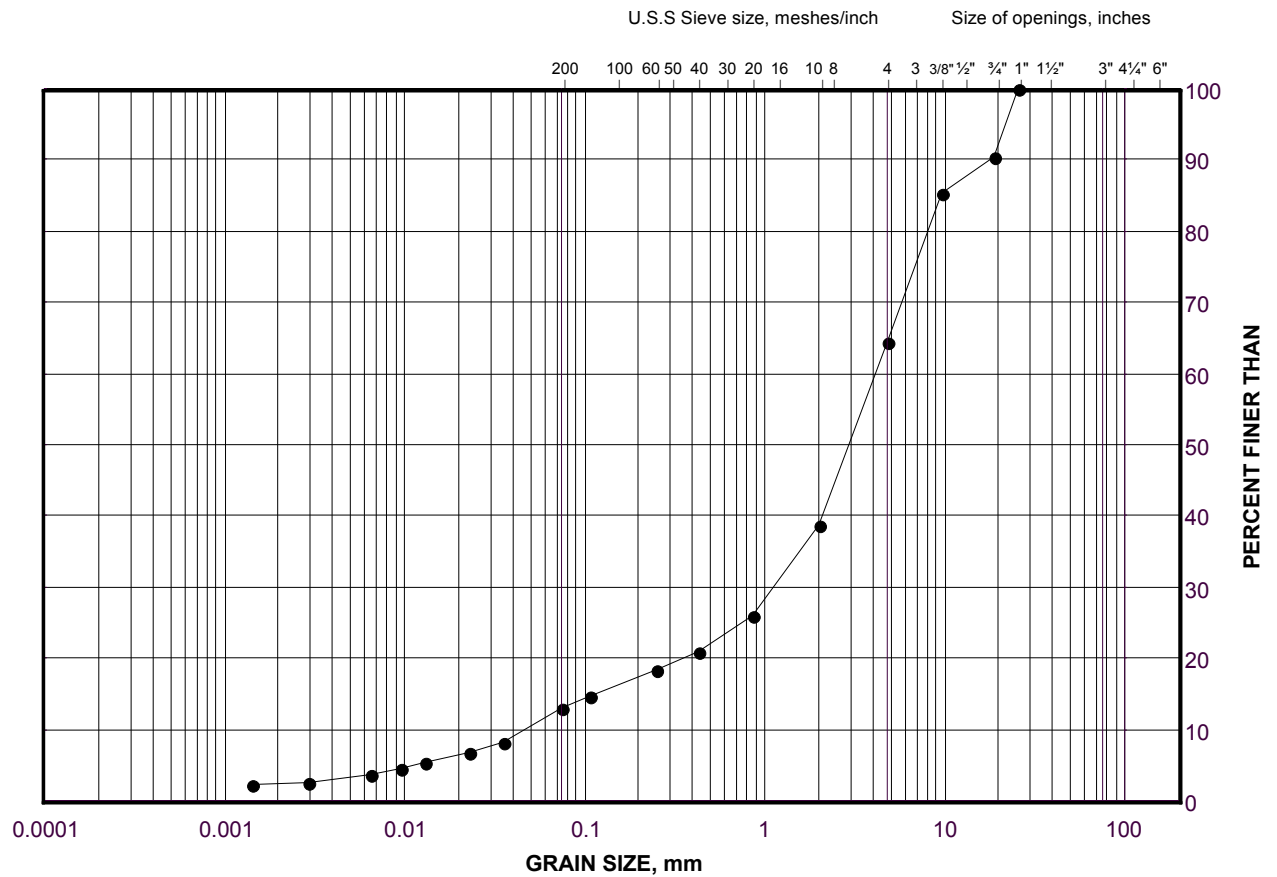
Figure No. B2

Project No. 10-1184-0016

Checked By: SMM

Sand and Gravel (Fill)

FIGURE B3



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	OS-4	2	219.6

Project Number: 10-1184-0016

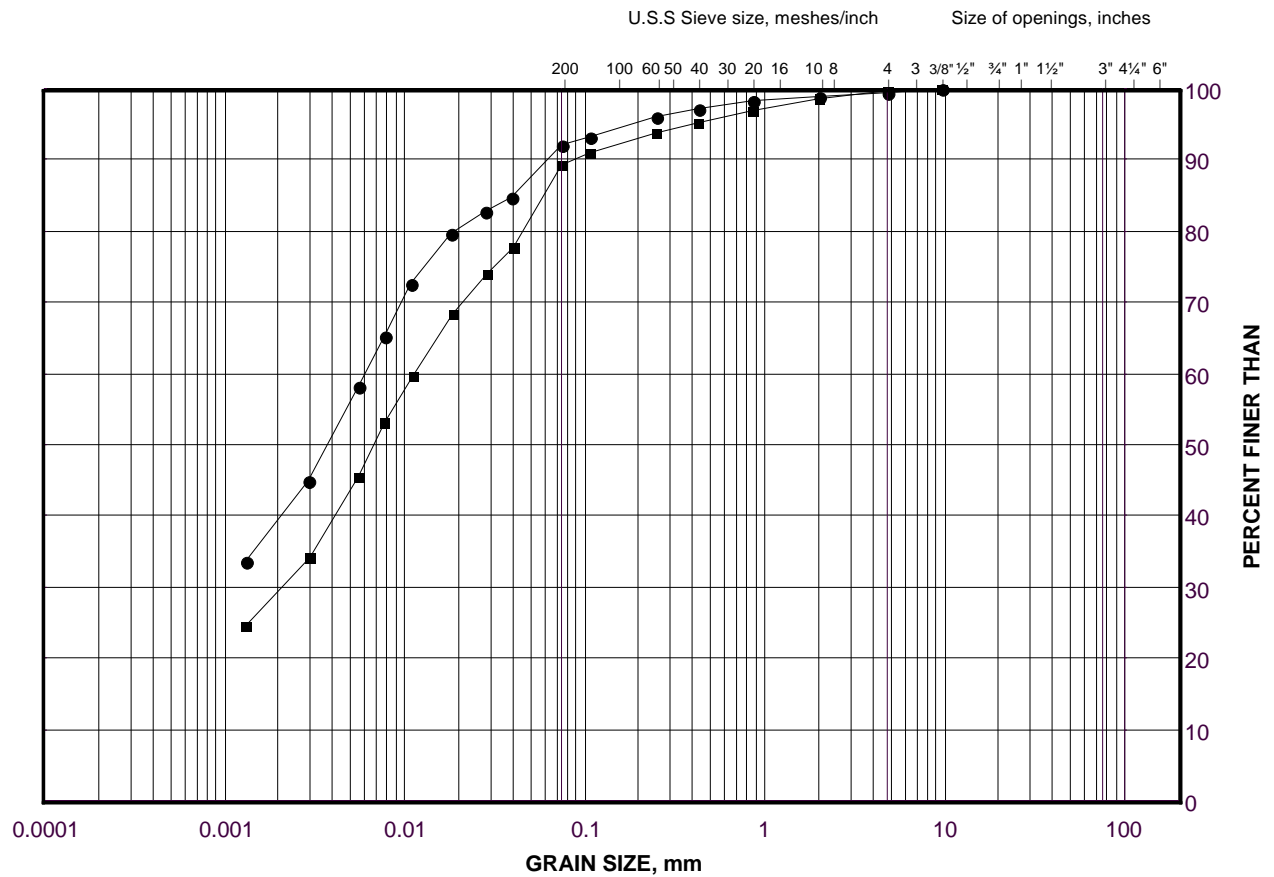
Checked By: AV

Golder Associates

Date: 31-Mar-14

Clayey Silt to Silty Clay (Till)

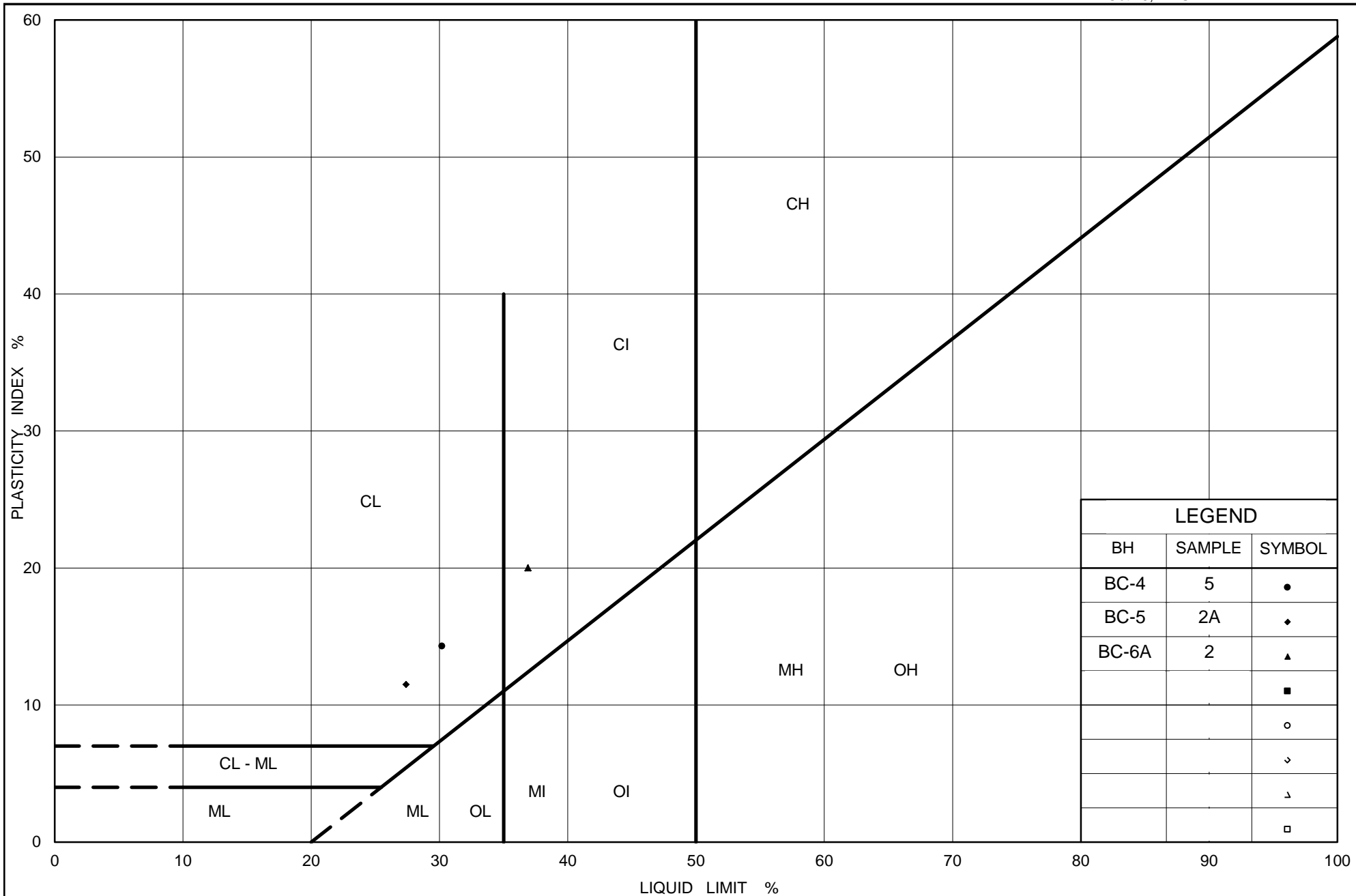
FIGURE B4



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	BC-6A	2	217.4
■	BC-4	5	217.4



Ministry of Transportation

Ontario

PLASTICITY CHART Clayey Silt to Silty Clay (Till)

Figure No. B5

Project No. 10-1184-0016

Checked By: SMM




BH BC-1: Box 1 of 1: 2.6 m to 6.0 m depth



BH BC-3A: Box 1 of 1: 0.25 m to 3.50 m depth



BH BC-5: Box 1 of 1: 1.47m to 4.80 m depth

PROJECT	BORER'S CREEK CULVERT AND RETAINING WALL CITY OF HAMILTON, MINISTRY OF TRANSPORTATION, ONTARIO GWP 2112-05-00			
TITLE	Bedrock Core Photograph – Borehole BC-1, BC-3A and BC-5			
	PROJECT No.:	10-1184-0016	FILE No.:	----
	DESIGN		SCALE	AS SHOWN
	CADD	--		REV.
	CHECK	SMM	APRIL 2015	
	REVIEW	LCC		
FIGURE B6				

UNCONFINED COMPRESSION TEST (UC)**Figure B8****ASTM D 7012-07****Sheet 1 of 2****SAMPLE IDENTIFICATION**

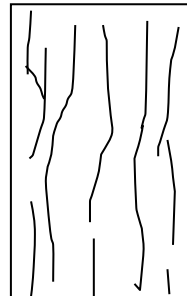
PROJECT NUMBER	10-1184-0016	SAMPLE NUMBER	-
BOREHOLE NUMBER	BC-6A	SAMPLE DEPTH, m	2.7-2.9

TEST CONDITIONS

MACHINE SPEED, mm/min	-	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST,min	>2 <15	L/D	2.24

SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	10.63	WATER CONTENT, (specimen) %	0.12
SAMPLE DIAMETER, cm	4.74	UNIT WEIGHT, kN/m ³	25.99
SAMPLE AREA, cm ²	17.62	DRY UNIT WT., kN/m ³	25.96
SAMPLE VOLUME, cm ³	187.26	SPECIFIC GRAVITY	-
WET WEIGHT, g	496.50	VOID RATIO	-
DRY WEIGHT, g	495.90		

VISUAL INSPECTION**FAILURE SKETCH****TEST RESULTS**

STRAIN AT FAILURE, %	-	COMPRESSIVE STRESS, MPa	118.7
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REMARKS:

DATE:

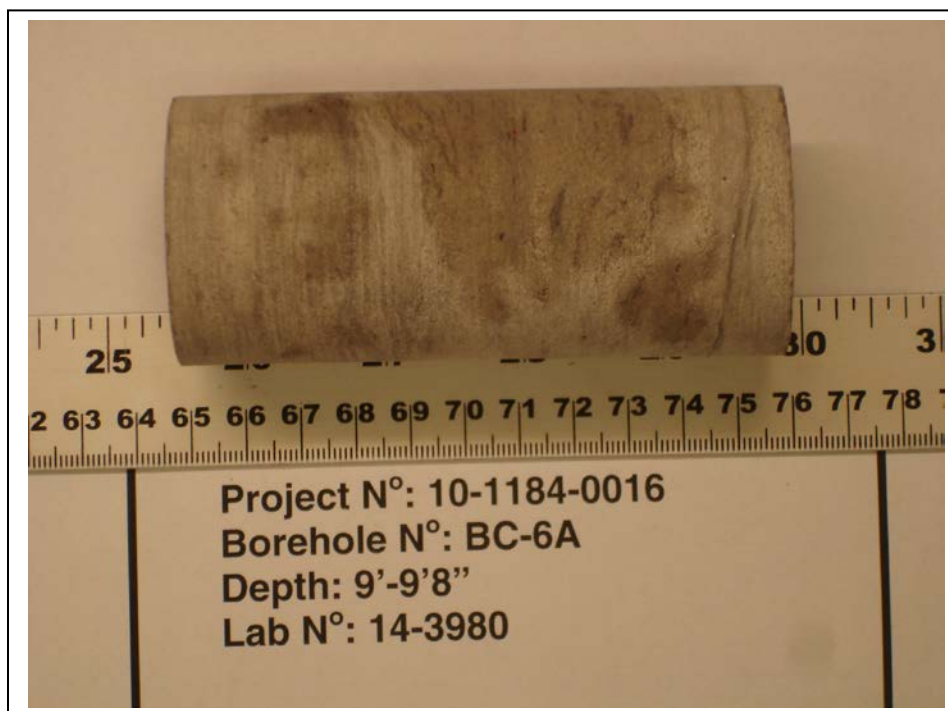
11/26/2014

Checked By:

Golder Associates

UNCONFINED COMPRESSION TEST
ASTM D7012-07

FIGURE B8
Sheet 2 of 2



BEFORE COMPRESSION



AFTER COMPRESSION

Date Nov. 25, 2014
Project 10-1184-0016

Golder Associates

Drawn Frank
Chkd. SMM

UNCONFINED COMPRESSION TEST (UC)**Figure B9****ASTM D 7012-07****Sheet 1 of 2****SAMPLE IDENTIFICATION**

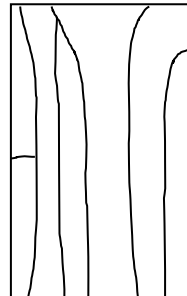
PROJECT NUMBER	10-1184-0016	SAMPLE NUMBER	2
BOREHOLE NUMBER	OS-4	SAMPLE DEPTH, m	5.19-5.30

TEST CONDITIONS

MACHINE SPEED, mm/min	-	TYPE OF SPECIMEN	Rock Core
DURATION OF TEST,min	>2 <15	L/D	2.03

SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	9.59	WATER CONTENT, (specimen) %	0.08
SAMPLE DIAMETER, cm	4.73	UNIT WEIGHT, kN/m ³	26.41
SAMPLE AREA, cm ²	17.54	DRY UNIT WT., kN/m ³	26.39
SAMPLE VOLUME, cm ³	168.23	SPECIFIC GRAVITY	-
WET WEIGHT, g	453.15	VOID RATIO	-
DRY WEIGHT, g	452.79		

VISUAL INSPECTION**FAILURE SKETCH****TEST RESULTS**

STRAIN AT FAILURE, %	-	COMPRESSIVE STRESS, MPa	96.4
----------------------	---	-------------------------	------

REMARKS:

DATE:

10/23/2013

Checked By:

Golder Associates

UNCONFINED COMPRESSION TEST
ASTM D7012-07

FIGURE B9
Sheet 2 of 2



BEFORE COMPRESSION



AFTER COMPRESSION

Date 11/4/2013
Project 10-1184-0016

Golder Associates

Drawn Frank
Chkd. SMM

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.

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North America	+ 1 800 275 3281
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