June 29, 2017

GEOTECHNICAL AND HYDROGEOLOGICAL INVESTIGATION REPORT

Geotechnical and Hydrogeological Investigation
High-Rise Residential Apartment Buildings River Road and John Street, Niagara Fall, Ontario

Submitted to:
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REPORT

Report Number: 1668252 (2000)

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by 5507 River Development Inc. (RDI) to provide geotechnical consulting services in support of the design for the proposed high-rise residential apartment buildings (the project) to be located north of the intersection of River Road and John Street (the Site) in Niagara Falls, Ontario, at the location shown on Figure 1 Key Plan. The terms of reference for the geotechnical consulting services are included in Golder's proposal No. P1668252 dated November 9, 2016. Authorization to proceed with the investigation was received on November 10, 2016 from Mr. Mike Wang.

The purpose of the investigation was to obtain information on the general subsurface soil, rock and groundwater conditions at the Site by means of a limited number of boreholes and laboratory tests. Based on an interpretation of the factual information available for this Site, this report provides engineering comments, recommendations and parameters for the geotechnical design aspects of the project, including selected construction considerations which could influence design decisions. It should be noted that this report addresses only the geotechnical (physical) aspects of the subsurface conditions at the Site. The geo-environmental (chemical) aspects of the project, including consequences of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources, are not addressed herein. Phase I and Phase II Environmental Site Assessments (ESAs) are being carried out and submitted under separate covers.

This report provides the results of the geotechnical investigation and should be read in conjunction with the *"Important Information and Limitations of This Report"* in ***Appendix A*** which forms an integral part of this document. The reader's attention is specifically drawn to this information, as it is essential for the proper use and interpretation of this report. The factual data, interpretations and recommendations contained in this report pertain to a specific project as described in the report and are not applicable to any other project or site location. If the project is modified in concept, location or elevation, or if the project is not initiated within eighteen months of the date of the report, Golder should be given an opportunity to confirm that the recommendations in this report are still valid.

2.0 SITE AND PROJECT DESCRIPTION

The site encompasses several municipal addresses (5471, 5491 & 5507 River Road and 4339, 4407 & 4413 John Street) and is located north of the intersection of John Street and River Road in Niagara Falls, Ontario. The properties are either vacant or occupied by residential houses. The irregular shaped site is bordered on the east by River Road, Philip Street to the north and residential houses on the other sides. The site slopes upwards towards the west with elevations between 173 m and 163 m. A slope runs in the north to south direction along the portion of the site bordered by River Road. The height of the slope increases from approximately 1 m to 4 m, north to south.

At the time of preparing this report, final design information was not available for the proposed development. The drawings provided indicate that the proposed development will consist of the following:

- Tower 1 - 21 storey high-rise building with 4 levels of underground parking located at the corner of River Road and John Street;
- Tower 2 – 11 storey mid-rise building with a 4 levels of underground parking located at the corner of Philip Street and River Street; and,

- A triangular two storey structure linking Towers 1 and 2 with four levels of underground parking. At the time of writing this report, it was understood that a fifth parking level was being considered.

Based on the information provided at the time of writing this report, the finished floor elevation (FFE) of the ground floor will be 171.5 m. The drawings indicate that the P3A and P4A level will be at 9 m and 12 m below the ground floor FFE, indicating that the basement levels FFE will be at elevations of 162.5 m and 159.5 m, respectively. Parking level P4 will be lower that P4A and there is the potential for a P5 level.

3.0 INVESTIGATION PROCEDURES

The geotechnical field investigation for this assignment was carried out between November 29 and December 6, 2016, during which time four boreholes (BH16-1 to BH16-4) were advanced. The boreholes for the geotechnical investigation were drilled using standard truck-mounted CME 75 drill rig supplied and operated by DBW Drilling Ltd. of Ajax, Ontario, subcontracted to Golder. The approximate borehole locations are shown on the Borehole Location Plan, Figure 2 in ***Appendix B***.

Standard penetration testing (ASTM D1586) and sampling in the overburden soils were carried out at regular intervals of depth in BH16-1 to BH16-4 using conventional 38 mm internal diameter split spoon sampling equipment driven by an automatic hammer. Bedrock coring was carried out in the all the boreholes.

The groundwater conditions were noted in the open boreholes during and upon completion of drilling and monitoring wells were installed in all the boreholes, following the completion of drilling, to allow for groundwater measurements. Each monitoring well consists of a 50 mm diameter PVC pipe, with a slotted screen sealed at a selected depth within the borehole. A sand filter pack surrounded the screen, and above the screen the borehole and annulus surrounding the well pipe were backfilled to the surface with bentonite. The well installation details and water level readings are presented on the Record of Borehole sheets in ***Appendix C***.

The field work was observed by members of Golder’s technical staff, who located the boreholes, arranged for the clearance of underground utility services, observed the drilling, sampling and in situ testing operations, logged the boreholes, and examined and cared for the recovered soil and rock samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to Golder’s Markham geotechnical laboratory for further examination and selected laboratory testing.

Unconfined uniaxial compression tests were carried out on selected rock samples by Geomechanica Inc. located in Toronto, Ontario. The results of the geotechnical laboratory tests are included in ***Appendix D***.

A hydrogeological program was conducted in conjunction with the geotechnical program. This included:

- Installation of monitoring wells in the boreholes;
- Measurement of groundwater levels in the wells to determine depth to groundwater and determining groundwater elevations for development of a groundwater contour plan;
- Slug testing in monitoring wells to estimate the hydraulic conductivity of the bedrock; and,
- Estimation of groundwater inflow into the excavation to evaluate dewatering rates and the potential requirement for an Environmental Activity and Sector Registry (EASR).

A total of four (4) monitoring wells were installed in the boreholes at the site, between November 30 and December 7, 2016. The monitoring wells were installed in the bedrock and constructed using 50 mm diameter No. 10 slot well screen and riser pipe with sand filter and bentonite seals. The wells are protected at the surface by lockable steel casings. The survey at the top of the riser pipe and ground surface was completed using a hand held Trimble unit with an accuracy of 0.02 m.

The monitoring wells were surveyed using a Trimble GPS on January 25, 2017. The ground surface and top of pipe elevations in metres above sea level (masl) were surveyed and a summary is provided in the table below:

Table 1: Monitoring Well Survey Data

Monitoring Well	Ground Surface Elevation (masl)	Top of Pipe Elevation (masl)
MW16-1	166.85	167.72
MW16-2	169.30	170.11
MW16-3	168.78	169.65
MW16-4	171.76	171.72

Groundwater levels were measured in the monitoring wells installed in the bedrock and the results are provided in Section 4.3.7.

The groundwater levels range between 10.04 and 12.22 m below top of pipe, corresponding to a range in elevations of 157.679 to 159.960 masl. The groundwater levels were contoured for the site area using the groundwater level elevations measured on December 23, 2016. The groundwater level contour plan is shown on ***Figure 3***. The groundwater level contours ranged from 159.5 to 158.0 masl and decrease toward the Niagara River Valley. This indicated an easterly flow of groundwater across the site toward areas of discharge on the rock face of the adjacent river valley.

4.0 SITE GEOLOGY AND STRATIGRAPHY

4.1 Regional Geology

The surficial geology aspects of the general site area are presented in the following publication:

- Chapman, L.J., and Putnam, D.F., 2007, *"The Physiography of Southern Ontario"*; 4th Edition, Ontario Geological Survey.

Physiographic mapping in the area according to the above noted reference indicates that the site lies within the physiographic region of southern Ontario known as the Haldimand Clay Plain. The Haldimand Clay Plain lies between the Niagara Escarpment and Lake Erie occupying all of the Niagara Peninsula except the fruit belt below the escarpment. The underlying rocks consist of a succession of Paleozoic beds dipping slightly southward under Lake Erie. The vertical cliffs along the brow of the escarpment are formed of dolostone of the Lockport Formation and this formation underlies a narrow strip of the plain to be succeeded southward by the dolostone to the Guelph Formation.

The surficial geology mapping indicates that the site lies close to the border of regions consisting of sand plains and older alluvial deposits (clay, silt, sand and gravel).

The overburden subsurface conditions encountered during the investigation are variable and reflect the geological mapping.

4.2 Background Information

A previous geotechnical investigation was carried out at the site by AMEC Earth & Environmental. The details of this investigation were presented in a report titled, "*Geotechnical Investigation, The Residences at River Road, 5471/5491/5507 River Road, Niagara Falls, Ontario*," dated January 2006, Report No. TG53110 (AMEC 2006).

During the investigation carried in 2006, six boreholes were drilled and bedrock coring was carried out in three boreholes. An extract from AMEC 2006 is presented for reference in ***Appendix E***.

4.3 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes advanced at this site for this report are shown on the Record of Borehole sheets in ***Appendix C***. Methods of Soil Classification, Symbols and Terms used on Records of Boreholes and Test Pits are provided to assist in the interpretation of the Record of Borehole sheets. The detailed results of geotechnical laboratory testing on selected rock samples are presented in ***Appendix D***.

The Record of Borehole sheets indicate the subsurface conditions at the borehole locations only. The stratigraphic boundaries shown on the borehole records are inferred from non-continuous sampling, observations of drilling progress as well as results of Standard Penetration Tests and, therefore, represent transitions between soil types rather than exact planes of geological/stratigraphic change. The SPT "N"-values presented in the Record of Borehole sheets and discussed herein are uncorrected. Subsurface soil and underlying rock conditions will vary between and beyond the borehole locations.

The subsurface information from the boreholes generally indicates variable overburden deposits of both cohesive soils (silty clay fill, silt clay and silty clay till) and non-cohesive soils (silt, sandy silt to silty sand and sandy gravel to gravelly sand as well as silt and sand till), overlying the bedrock consisting of Dolostone of the Lockport Formation.

4.3.1 Topsoil/Fill

Topsoil was encountered in BH16-1 and BH16-4 and the thicknesses were measured at about 180 mm and 150 mm, respectively.

A deposit of silty clay fill was encountered in BH16-2 and extended to a depth of about 0.6 m (Elevation 168.7 m). A single Standard Penetration Test (SPT) carried out within the fill measured an "N"-value of 4 blows per 0.3 m penetration, suggesting a firm consistency.

4.3.2 Silty Clay

A deposit of silty clay was encountered underlying the topsoil at BH16-1 and extended to bedrock at a depth of about 3.6 m (Elevation 163.2 m). SPTs carried out within the silty clay deposit measured "N"-values ranging from 1 blow to 20 blows per 0.3 m of penetration suggesting a very soft to very stiff consistency.

4.3.3 Silty Sand to Silt

Non-cohesive deposits ranging from silty sand to silt were encountered in BH16-2 and BH16-3. In BH16-3, seams of gravelly sand to sandy gravel were encountered. SPTs carried out within the silty sand to silt deposit measured

"N"-values ranging from 4 blows per 0.3 m of penetration to 50 blows per 0.1 m of penetration indicating a loose to very dense state of compactness.

4.3.4 Silty Clay Till

A deposit of silty clay till was encountered under the topsoil at BH16-4 and extended to a depth of about 1.4 m (Elevation 170.4 m). SPTs carried out within the silty clay till deposit measured "N"-values of 11 blows and 48 blows per 0.3 m of penetration suggesting a stiff to hard consistency.

4.3.5 Silty Sand and Gravel Till

A deposit of silty sand and gravel till was encountered under the silty clay till deposit at BH16-4 and extended to bedrock a depth of about 2.4 m (Elevation 169.4 m). A single SPT carried out within the silty sand and gravel till deposit measured an "N"-value 76 blows per 0.3 m of penetration indicating a very dense state of compactness.

4.3.6 Bedrock

The bedrock consists of dolostone belonging to the Lockport Formation. Both the Goat Island and Gasport Members of the Lockport Formation are present within all four boreholes. The Goat Island Member can be generally described as slightly weathered to fresh, thinly to thickly bedded, grey, fine grained, argillaceous dolostone with vugs and nodules consisting of calcite, chert, and gypsum. The Gasport Member can be generally described as fresh, medium to thickly bedded, grey, fine to medium grained, crinoidal dolostone.

The top of bedrock was encountered in all four boreholes (BH16-1 to BH16-4) from about 1.7 m to 3.6 m below ground surface. Based on the borehole data, the top of bedrock elevations range from 169.4 m (BH16-4) at the west end of the site to 163.2 m (BH16-1) at the east end of the site.

Table 2: Table 1 - Approximate Depth and Elevation of Bedrock Surface

Borehole No.	Ground Surface Elevation (masl)	Depth to Bedrock below Existing Ground Surface (m)	Elevation of Bedrock Surface (m)	Bottom of Borehole Elevation (m)
BH16-1	166.8	3.6	163.2	149.9
BH16-2	169.3	1.7	167.7	150.2
BH16-3	168.8	2.4	166.4	149.6
BH16-4	171.8	2.4	169.4	149.8

Slightly weathered bedrock was encountered at the top of boreholes BH16-2 and BH16-4 ranging from 0.9 m to 2.9 m thick, whereas BH16-1 and BH16-3 were fresh with no visible signs of weathering at the top of bedrock. The RQD ranges from 65 to 100 per cent across all four boreholes with an average of 95 per cent. For detailed RQD values refer to the Record of Drillhole logs.

A total of ten unconfined compressive strength (UCS) laboratory tests were completed on drill core samples to assess the intact rock strength. The samples were collected from all four boreholes within both rock members in an effort to characterize the range of rock strengths at the site. The results ranged from 62.7 MPa to 218.2 MPa which can be described as strong to very strong rock. The results did not appear to vary greatly among different formations, however, one sample taken within a porous section of the Gasport Member had a significantly lower

UCS of 62.7 MPa compared to the average of 150.4 MPa. The result of the UCS laboratory tests are presented in ***Appendix D*** and summarize below:

Table 3: Summary of UCS Test Results

Sample	Depth from (m)	Depth to (m)	Bulk Density (g/cm3)	UCS (MPa)
BH16-1 Sample 1	9.79	10.04	2.77	132.1
BH16-1 Sample 2	15.61	15.80	2.74	157.3
BH16-2 Sample 1	17.00	17.17	2.75	218.2
BH16-2 Sample 2	18.15	18.38	2.71	129.0
BH16-3 Sample 1	6.82	7.05	2.67	195.7
BH16-3 Sample 2	13.77	14.02	2.46	62.7
BH16-3 Sample 3	18.75	18.96	2.70	129.7
BH16-4 Sample 1	8.82	9.06	2.75	176.3
BH16-4 Sample 2	20.26	20.47	2.74	143.5
BH16-4 Sample 3	21.52	21.83	2.70	159.3

4.3.7 Groundwater Measurements

The groundwater conditions encountered in each of the boreholes are shown in detail on the Record of Borehole sheets given in ***Appendix C***, following the text of this report. A summary of the groundwater level readings are shown below:

Table 4: Groundwater Level Measurements

Date	Groundwater Measurement (m) Depth/(Elevation)			
	BH16-1	**BH16-2**	**BH16-3**	**BH16-4**
December 5, 2016	9.1 (157.7)	-	10.7 (156.1)	-
December 6, 2016	9.2 (157.6)	11.4 (155.4)	10.9 (155.9)	-
December 7, 2016	9.2 (157.6)	11.4 (155.4)	10.8 (156.0)	11.3 (155.5)
December 19, 2016	9.2 (157.6)	11.4 (155.4)	10.9 (155.9)	11.9 (154.9)
December 21, 2016	9.3 (157.5)	11.4 (155.4)	10.9 (155.9)	11.9 (154.9)
December 23, 2016	9.1 (157.7)	11.4 (157.9)	10.8 (158.0)	11.8 (160.0)

It should be noted that the groundwater measurements reflect the groundwater conditions encountered in the boreholes at the time of the field work in December, 2016. Groundwater levels at the site are anticipated to fluctuate with seasonal variations in precipitation and snowmelt.

5.0 DISCUSSION AND GEOTECHNICAL/HYDROGEOLOGICAL RECOMMENDATIONS

This section of the report provides engineering information on and recommendations for the geotechnical design aspects of the project based on our interpretation of the borehole information, the laboratory test data and on our understanding of the project requirements. The information in this portion of the report is provided for planning and design purposes for the guidance of the design engineers and architects. Where comments are made on construction, they are provided only in order to highlight aspects of construction which could affect the design of the project. Contractors bidding on or undertaking any work at the site should examine the factual results of the investigation, satisfy themselves as to the adequacy of the information for construction and make their own interpretation of the factual data as it affects their proposed construction techniques, schedule, equipment capabilities, costs, sequencing and the like.

5.1 Foundation Design

Based on preliminary drawings and layout plans, the parking garage and condominium buildings will require excavation within the bedrock. The information provided at the time of writing this report indicates that the finished floor elevation (FFE) of the ground floor will be 171.5 m. The drawings indicate that the P3A and P4A level will be at 9 m and 12 m below the ground floor FFE, indicating the basement levels FFE will be at elevations of 162.5 m and 159.5 m, respectively. Parking level P4 will be lower that P4A and there is the potential for a P5 level. As such, it is anticipated that columns and walls can be founded on spread footings or strip footings on bedrock. If footings are required at different elevations, then the lower footings should be located outside of a line drawn at a 45 degree angle downwards from the outside edge of the upper footing.

Spread footings placed on slightly weathered to fresh bedrock may be designed for an unfactored geotechnical resistance at Ultimate Limiting States (ULS) of 40 MPa or a factored ULS of 20 MPa using a resistance factor of 0.5. It is recommended that the footings be founded on a flat lying surface to convey loads vertically to the bedrock. Any load inclination and eccentricity should be accounted for in design as it will alter the recommended ULS value. Serviceability Limiting States (SLS) do not govern the design as only minimal settlement is expected for typical spread footings (actual anticipated settlement can be assessed when the footing sizes are determined).

Resistance to sliding of the foundations founded on bedrock can be analyzed using an unfactored ULS friction angle of 30 degrees between the concrete of the footing and the underlying dolostone bedrock; the resulting coefficient of friction is 0.58.

All footing excavations should be inspected prior to placing concrete to ensure the footing base has been adequately cleaned and that the bedrock conditions exposed at the founding level are consistent with the design assumptions. Where possible the footing foundations should be excavated to provide a flat bearing surface at right angles to the axis of the load. Based on the drillhole logs and previous experience in the area the Lockport Formation is known to contain small vugs (small voids). Any vugs within the bedrock foundations should not make up more than 10% of the bearing surface area of the footing and no individual void should be greater than 20 cm in maximum dimension. If vugs or cavities are encountered in the bedrock foundations then additional probe holes will be required on a 1 m by 1 m pattern across the foundations to a depth of twice the footing width. Results of the probe drilling should be communicated to Golder in order to review the bearing capacity of the bedrock.

All exterior footings and footings in unheated areas should be provided with at least 1.2 m of cover after final grading, in order to minimize the potential for damage due to frost action.

5.2 Temporary Excavation and Support

Construction of the underground parking levels will extend to depths of 9 m to 12 m (Elevations 162.5 m to 159.5 m) below the finished ground floor level to the FFE of the basement levels and footing bases and elevator shafts are anticipated to be about 1 m to 2.5 m below the finished basement floor. The excavation for the proposed buildings will extend through the variable overburden and into the underlying bedrock described in detail in ***Section 4.0.*** The depth of the excavation into the bedrock at the borehole locations will vary from about 1 m to 5 m on the eastern side of the property and will deepen to about 10 m or more towards the western property boundary. It is anticipated that excavation into the overburden materials can be achieved with conventional hydraulic excavating equipment. However, excavation into bedrock will required blasting or mechanical excavation using mechanical rock breakers and line drilling.

5.2.1 Overburden

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA) and Regulations for Construction Projects. Depending space available unsupported open-cut excavations may be feasible at this site. Based OHSA, the overburden soils are generally classified as Type 3 soils and all excavations through these soils should be sloped no steeper than 1 horizontal to 1 vertical subject to inspection by Golder at the time of construction. It should be noted that where very soft silty clay is encountered it would be classified as Type 4 and those areas will require temporary slopes of 3 horizontal to 1 vertical or some form of approved soil support.

If space is not available for open cut excavations then some form of temporary shoring will be needed to support the excavations for the proposed buildings. In general there are three basic shoring methods that are commonly used in local practice: steel soldier piles and timber lagging, driven interlocking steel sheet piles and continuous concrete (secant pile or diaphragm) walls, each with appropriate lateral support.

The shoring method(s) selected to support the excavation must take into account the soil stratigraphy, the groundwater conditions, the methods adopted to control the groundwater, effects of weather and the ground movements associated with the shoring system stiffness and their impact on adjacent settlement sensitive structures and utilities. These shoring systems may need to be stiffened with either an external (i.e., tie-backs) or internal (i.e., rakers) shoring system to limit the size of structural members and reduce lateral ground movements.

Steel sheet pile will not be feasible due to the underlying bedrock. If temporary support is required, steel soldier pile installed in pre-augered sockets, with timber lagging may be suitable. A soldier pile and lagging wall may only be considered for excavation support provided there are not any settlement sensitive utilities or structures within the zone influence of the shoring.

The shoring system should be designed to account for horizontal/lateral earth loads, surcharge loads, groundwater pressure and the effects of weather as well as the project requirements for controlling ground displacements. Lateral pressures for design of the temporary structures will depend on the temporary structure design and the nature of the lateral support provided. The distribution of lateral pressures on a shoring system depends greatly on the methods used, the stiffness, and the degree of lateral bracing. As such, the distribution of lateral earth pressures for such a bracing system is best left to the ultimate specialist designer of the shoring who can best account for such conditions. It is a common practice for a specialist contractor to design and install the excavation support system.

5.2.2 Bedrock

Excavation in Lockport Formation dolostone bedrock can most efficiently be carried out through the use of drill and blast techniques. Since this is a residential area, before blasting is considered as an excavation method a blast impact assessment should be carried out. If blasting is allowed, then it should be carried out by an experienced specialist contractor under the design criteria specified by a specialist blasting and vibration monitoring firm. It should be noted that even with careful blasting procedures, a significant difference in elevation levels across the excavations could still result in this bedrock. In addition to the recommendations contained in this report, all blasting should be carried out in compliance with the latest version of Ontario Provincial Standard Specification (OPSS) 120. This includes, but is not limited to, providing the contract administrator with a complete blasting plan for independent review prior to the commencement of blasting and completing a pre-blast survey of all structures within 150 m of the blasting operations.

If blasting is not allowed, then the rock will need to be excavated using mechanical excavation methods which will be very slow. Line drilling of the final perimeter for mechanical excavation will be required to maintain neat excavation lines and minimize over-break or over-excavation. Large hydraulic rock breakers with sufficient percussive force to break the rock will be required if blasting is not allowed. In either case, pre and post condition surveys are recommended on structures that could be impacted by the construction activities.

It is anticipated the excavation into the bedrock will have vertical cut faces. The stability of the vertical cuts in the bedrock will depend on the presence, orientation and continuity of joints or bedding planes and whether they intersect the surface causing unstable wedges or blocks. During excavation in the bedrock, all rock faces should be scaled to remove all loose, unstable rock as the excavation progresses downward. The excavations should be progressively inspected by Golder to check for any unstable rock and to determine if the final rock faces have been supported by methods such as rock bolts, mesh, shotcrete etc. It should be anticipated that double twist wire mesh, draped over the final rock excavation walls from the top of the bedrock to approximately 2 m above the final bottom elevation will be required for all rock faces deeper than approximately 2 m.

During the winter months, groundwater inflow into the excavation will have a tendency to freeze and therefore ice can build up on the rock faces. The contractor will need to regularly inspect the rock faces for ice accumulation and any build-up of ice will need to be removed.

5.2.3 Vibration Monitoring

Excavation into bedrock will cause vibrations which will influence the surrounding structures, therefore, a vibration monitoring program should be implemented during construction to monitor and limit vibration effects on the structures within the area of influence. The method and equipment selected for the excavation by the contractor should take into consideration the vibration limits of the site.

5.3 Lateral Earth Pressure for Basement Walls in Overburden

The design of the foundation walls for the permanent basement levels should take into account the horizontal soil loads, hydrostatic pressure, as well as surcharge loads that may occur during or after construction. The permanent below-grade wall is considered to be a rigid structure (assuming that the floor diaphragm system over the multiple levels of below-grade parking will result in little lateral movement of the basement walls) and should be designed to resist at-rest lateral earth pressures calculated as follows:

$$p = K(\gamma h + q)$$

where:

p = lateral earth pressure acting depth z, kilopascals
$K = K_o$ = at rest earth pressure coefficient, use 0.5 for the foundation wall
$K = K_a$ = active pressure coefficient, use 0.33 for the foundation wall
γ = unit weight of retained soil/backfill, a value of 21 kilonewtons/cubic metre may be assumed
h = depth to point of interest in soil, metres
q = equivalent value of surcharge on the ground surface, kilopascals

The above expression assumes that the perimeter drainage system prevents the build-up of any hydrostatic pressure behind the wall. Should hydrostatic pressures be considered to build-up behind the walls, they must be included in calculating the lateral earth pressures and other measures to address possible buoyancy and waterproofing may need to be considered. The lateral earth pressures acting on the below grade walls will depend on the type and method of placement of the backfill materials, on the nature of the soils behind the shoring, on the magnitude of surcharge including construction loadings, on the freedom of lateral movement of the structure, and on the drainage conditions behind the walls. For design of the basement walls, the “at-rest” earth pressures given above may be used where the width of non-native backfill behind the wall (e.g., imported granulars) is less than 5 m wide. Surcharge pressures from the adjacent foundations and/or roads should also be included in the design as indicated.

All foundation elements in unheated areas must be provided with at least 1.2 m of earth cover for frost protection purposes. In addition, the bearing soil and fresh concrete should be protected from freezing during cold weather construction.

To avoid detrimental impacts from frost adhesion and heaving, the excavated areas behind foundation walls for the basement level or any below grade foundation elements (perimeter grade beams) should be backfilled with non-frost susceptible granular material conforming to the requirements for OPSS.MUNI 1010 Granular “B” Type I material. In areas where pavement or other hard surfacing will abut the building, differential frost heaving could occur between the granular fill immediately adjacent to the building and the more frost susceptible native materials which exist beyond the wall backfill. To reduce the severity of this differential heaving, the backfill adjacent to the wall should be placed to form a frost taper. The frost taper should be brought up to pavement subgrade level from 1.2 m below finished exterior grade at a slope of 3 horizontal to 1 vertical, or flatter, away from the wall. The backfill materials should be placed evenly in lifts not exceeding 200 mm loose thickness. The layers should be compacted to at least 95 per cent of the material’s standard proctor maximum dry density (SPMDD). Light compaction equipment should be used immediately adjacent to the wall; otherwise compaction stresses on the wall may be greater than that imposed by the backfill material. The upper 0.3 metres of backfill should consist of clayey material (where appropriate) to provide a relatively low-permeability cap and the exterior grade should also be shaped to slope away from the building.

The lateral earth pressure equation outlined above is given in an unfactored format and will need to be factored for Limit States Design purposes.

5.4 Slab-on-Grade Floor

Based on the lowest elevations for the underground parking level, it is anticipated that the lowest floor slab can be constructed as a slab-on-grade on bedrock. The final rock surface should be cleared of any loose or shattered rock and debris.

The final lift of granular fill beneath floor slabs should consist of a minimum thickness of 200 mm of OPSS Granular ‘A’ material acting as a moisture barrier, placed in maximum 200 mm loose lifts and uniformly compacted to at least 98 per cent of Standard Proctor Maximum Dry Density (SPMDD). Any filling operations should be inspected and tested by Golder. Additional Granular ‘A’ material may be needed to provide adequate pipe bedding and cover, depending on the requirements for an under-slab drainage system and also to fill in low areas. A nominally compacted 19 mm clear aggregate may be used instead of compacted Granular ‘A’.

The floor slabs should be structurally separate from the foundation walls and columns. Sawcut control joints should be provided at regular intervals and along column lines to minimize shrinkage cracking and to allow for any differential settlement of the floor slabs.

5.5 Permanent Drainage

An underfloor drainage (i.e. below the lowest garage level) and perimeter drainage system are recommended for the proposed development.

The extent of drainage measures such as a composite synthetic drainage system or equivalent, under slab drainage and sump system should be assessed during the final design stages and Golder can provide geotechnical input as required.

An under floor drainage system, connected to sumps beneath the lowest level, should be provided to collect seepage on the underside of the floor slab. The subfloor drainage system may consist of a network of filtered robust sub-drain pipes conveying collected groundwater to a sump or sumps from which the groundwater can be pumped to a municipal sewer. The drainage system would consist of interconnected perforated drain pipes (bedded on and with free draining granular soils wrapped in geotextile fabric) installed around the perimeter of the building and within the building footprint.

Drainage, such as through the use of a composite synthetic drainage system or equivalent, should be provided to the exterior walls of the underground parking levels. The composite drain must withstand the design horizontal earth pressures used for basement wall design, and should be connected to the basement level under-slab drainage system or perimeter drainage system. The drainage system collector pipes should drain to a sump for collection and discharge to a sewer.

5.6 Site Classification for Seismic Site Response

Seismic hazard is defined in the 2012 Ontario Building Code (OBC, 2012) by uniform hazard spectra (UHS) at spectral coordinates of 0.2 second, 0.5 second, 1.0 second and 2.0 seconds and a probability of exceedance of 2% in 50 years. The OBC method uses a site classification system defined by the average soil/bedrock properties (e.g. shear wave velocity, Standard Penetration Test (SPT) resistance, undrained soil shear strength, etc.) in the 30 m below the foundation level. There are 6 site classes from A to F, decreasing in ground stiffness from A, hard rock, to E, soft soil; with site class F used to denote problematic soils (e.g. sites underlain by thick peat deposits and/or liquefiable soils). The site class is then used to obtain acceleration and velocity-based site coefficients F_a and F_v, respectively, used to modify the UHS to account for the effects of site-specific soil conditions in design.

Based on the borehole information and OBC, for footings founded at the elevations discussed in ***Section 5.1*** above, **Site Class C** may be used for design. A higher site class may be available but will required vertical seismic profile (VSP) testing to be carried out.

5.7 Hydraulic Conductivity

Hydraulic conductivity tests were conducted in each of the monitoring wells, which were installed in the bedrock, on December 21, 2016. The tests were performed using slug testing methodology by quickly lowering a solid cylinder into the well and measuring the resultant rise in water levels to static conditions and subsequent fall in water levels when the slug was removed using a pressure transducer. The hydraulic conductivity of the screened bedrock was interpreted from the water level displacement data using the Bouwer-Rice formula as follows:

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{R}\right)}{2L_e}\frac{1}{t}\ln\left(\frac{H_o}{H_t}\right)$$

Where: K = hydraulic conductivity

r_c = radius of the well (standpipe)

R = radius of the sand pack

R_e = radial distance over which head is dissipated

L_e = length of the screen

H_o = drawdown at time t = 0

H_t = drawdown at time t = t

t = time since H = H_o

The slug test data was analyzed using the Aqtesolv software program. The hydraulic conductivities estimated from the results of the rising head and falling head tests are provided in the table below. The Aqtesolv analyses from these test are included in ***Appendix F***.

Table 5: Hydraulic Conductivity Test Results

Well No.	Hydraulic Conductivity (m/s)
BH16-1	9.0×10^{-6}
BH16-2	4.0×10^{-6}
BH16-3	3.0×10^{-6} to 9.0×10^{-6}
BH16-4	1.0×10^{-7} to 6.0×10^{-7}

The hydraulic conductivity estimates of the bedrock ranged from was $9x10^{-6}$ m/s to $1x10^{-7}$ m/s. The estimates of hydraulic conductivity should be considered an indicator of the hydraulic properties and not a definitive measure of the formation behaviour.

5.8 Groundwater Inflow Estimate

An estimate of the groundwater inflow into the excavation was made to evaluate potential dewatering rates and the potential requirements for an EASR for temporary construction dewatering. The methodology and results of the dewatering are discussed below.

The groundwater inflow was calculated based on the following equation for an unconfined aquifer dewatering in an excavation.

$Q = (K(H^2-h^2)/.733(Log(R_o/r_w))$

Where: Q = Discharge (m^3/day)

K = Hydraulic Conductivity (m/day)

H = Static height (m)

h = dewatering height (m)

rw = Slot radius (m)

R_o = radius of influence (m)

Based on a review of the latest site plan with sections sent by AJT to Golder on October 26, 2016 Level P4A is to be 12.0m lower than the Ground Floor elevation supplied on that drawing. A more recent site plan supplied to Golder on November 2, 2016 specifies a Finished Floor Elevation (FFE) of 171.50 masl with a minimum FFE of 170.10 masl internally. Utilizing the FFE and the 12.0m subsurface depth from the Ground Floor, it is estimated that the elevation of the P4A Level to be 159.50 masl. The groundwater elevation in the area of the parking garage ranges from 157.54 to 157.90 masl. As such the parking excavation (Level P4A) is estimated to be 2 m above the water table.

Based on the finished floor elevation (FFE) of 171.5 masl and the invert elevation of P4 at 159.5 masl (and target dewatering elevation of 158.5 masl), no dewatering would be required based on our highest measured static water level of 157.90 masl in December 2016, even assuming that water levels could fluctuate as high as 158.5 masl.

However, worst case dewatering calculations were completed, based the internal minimum FFE of 171.1 masl, a P4 invert elevation of 158.1 masl, a target dewatering elevation of 157.1 masl and a static WL of 158.5 masl, with a maximum drawdown of 1.4 m.

Using the highest measured K from the slug test analyses, 9E-6 m/s, the steady state dewatering rate for groundwater is estimated to be approximately 30 m^3/day. This estimated groundwater inflow value is less than required for an EASR application.

However, an EASR application for the project may be considered for surface water inflow water from a precipitation event which could exceed the limitation of 50 m^3/day.

6.0 ADDITIONAL CONSIDERATIONS

The construction activities could impact the existing adjacent structures, utilities and buildings. Appropriate damage assessments (pre and post-condition surveys for example) should be carried out as necessary. Information related to the type, depth and design bearing capacities of the adjacent structures, utilities and sensitivity of adjacent buried services, should be collected and incorporated into the design.

At the time of preparation of this report, only conceptual information for the proposed development was provided to us. Golder Associates should be retained to review the geotechnical aspects of the final design drawings and specifications prior to tendering and construction, to confirm that the intent of this report has been met. During construction, a sufficient degree of foundation inspections, subgrade inspections, and an adequate number of in-situ density tests and materials testing should be carried out to confirm that the conditions exposed are consistent with those encountered in the boreholes, and to monitor conformance to the pertinent project specifications. Concrete testing should be carried out of both the plastic material in the field and of set cylinder samples in a CSA certified Golder laboratory.

7.0 CLOSURE

We trust that this report provides sufficient geotechnical engineering information to facilitate the design of this project. If you have any questions regarding the contents of this report or require additional information, please do not hesitate to contact this office.

Report Signature Page

GOLDER ASSOCIATES LTD.

R Abdulla

LICENSED PROFESSIONAL ENGINEER
RA
R. ABDULLA
100126803
June 29, 2017
PROVINCE OF ONTARIO

Rafael Abdulla, M.Eng., P.Eng., PMP
Geotechnical Engineer

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Senior Geotechnical Engineer

RA/AJH/MJT/BZ/SM/ra;lah

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APPENDIX A

Important Information and Limitations of This Report

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

Standard of Care: Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder can not be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the report was prepared to be included for a specific permit application process, then upon the reasonable request of the client, Golder may authorize in writing the use of this report by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process. Any other use of this report by others is prohibited and is without responsibility to Golder. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client can not rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder can not be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Groundwater Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report. The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

Sample Disposal: Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client’s expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder’s report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder’s report.

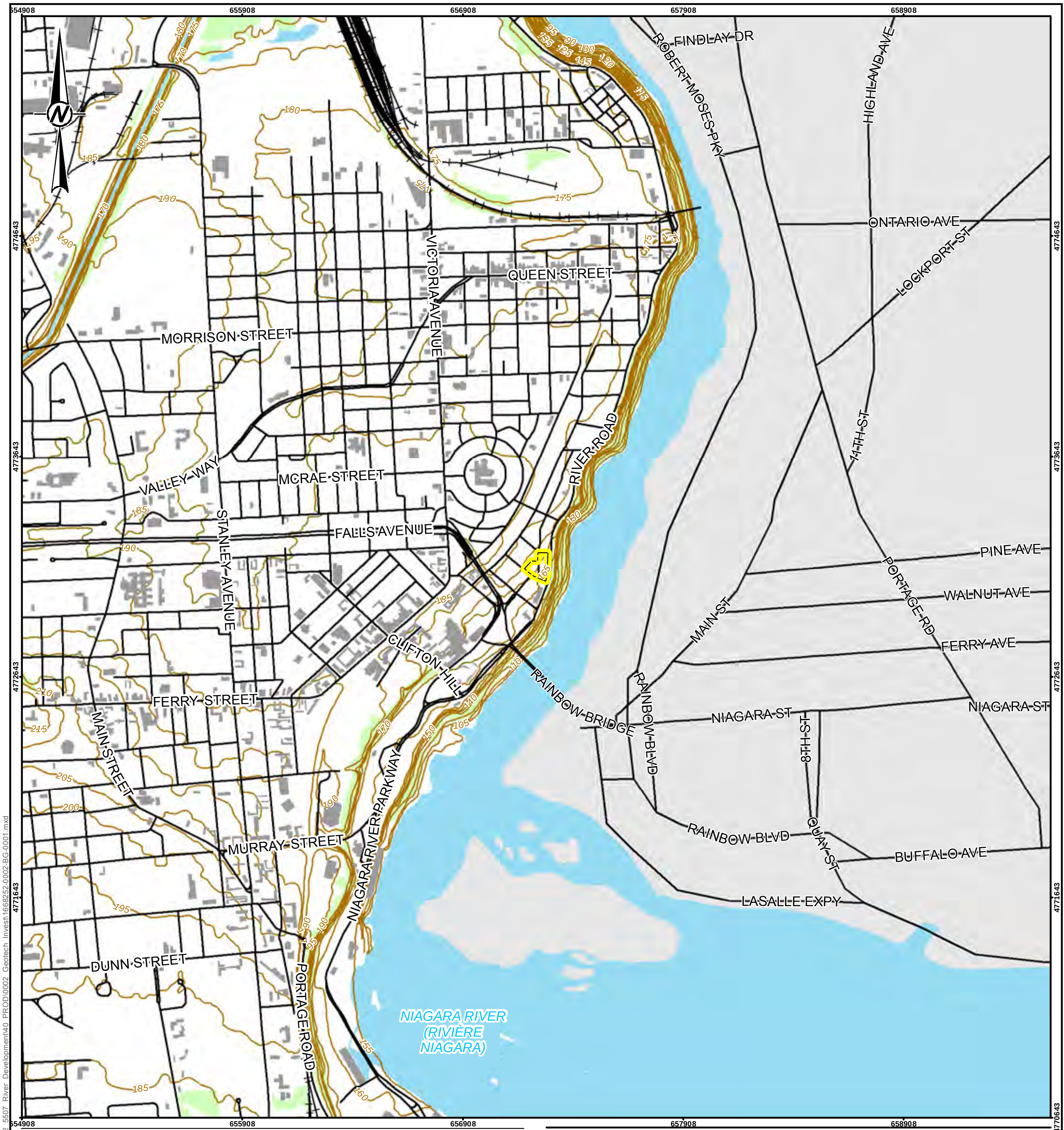
During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder’s report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder’s report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder’s responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

APPENDIX B

Figure 1 – Key Plan
Figure 2 – Borehole Location Plan
Figure 3 – Shallow Bedrock Groundwater Flow



LEGEND

— CONTOURS (M)	🟦 WATERBODY
┼ RAILWAY	🟩 WOODED AREA
— ROAD	
— WATERCOURSE	
▭ APPROXIMATE SITE BOUNDARY	
■ BUILDING	

0 500 1,000

1:25,000 METRES

REFERENCE(S)

BASE DATA - MNR LIO, OBTAINED 2016

PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2017

PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

CLIENT

5507 RIVER DEVELOPMENT INC.

PROJECT

GEOTECHNICAL INVESTIGATION
HIGH-RISE RESIDENTIAL APARTMENT BUILDINGS
RIVER ROAD AND JOHN STREET NIAGARA FALLS, ONTARIO

TITLE

KEY PLAN

CONSULTANT

Golder Associates

YYYY-MM-DD	2017-01-03
DESIGNED	JT
PREPARED	JT
REVIEWED	RA
APPROVED	MSS

PROJECT NO.	CONTROL	REV.	FIGURE
1668252			1

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NOT TO SCALE
ALL LOCATIONS ARE APPROXIMATE

LEGEND

🔴	APPROXIMATE BOREHOLE LOCATIONS OF CURRENT INVESTIGATION
🔵	APPROXIMATE LOCATIONS OF 2006 BOREHOLES BY AMEC

REFERENCE(S)

BASE PLAN PROVIDED BY KRCMAR, ENTITLED "BOUNDARY AND TOPOGRAPHIC SURVEY OF, LOTS 84, 85 AND 86, AND, PART OF LOTS 12 TO 18, INCLUSIVE, AND, PART OF LOT 83, REGISTERED PLAN 294, CITY OF NIAGARA FALLS, REGIONAL MUNICIPALITY OF NIAGARA", JOB NO. 16-179, DRAWING NAME: 16-179BT01, DATED SEPTEMBER 14, 2016.

CLIENT
5507 RIVER DEVELOPMENT INC.

CONSULTANT

Golder Associates

YYYY-MM-DD	2016-01-09
DESIGNED	
PREPARED	MK
REVIEWED	RA
APPROVED	AJH

PROJECT
GEOTECHNICAL INVESTIGATION
HIGH-RISE RESIDENTIAL APARTMENT BUILDINGS
RIVER ROAD AND JOHN STREET, NIAGARA FALLS, ONTARIO

TITLE
BOREHOLE LOCATION PLAN

PROJECT NO.	CONTROL	REV.	FIGURE
1668252		----	2

25 mm IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

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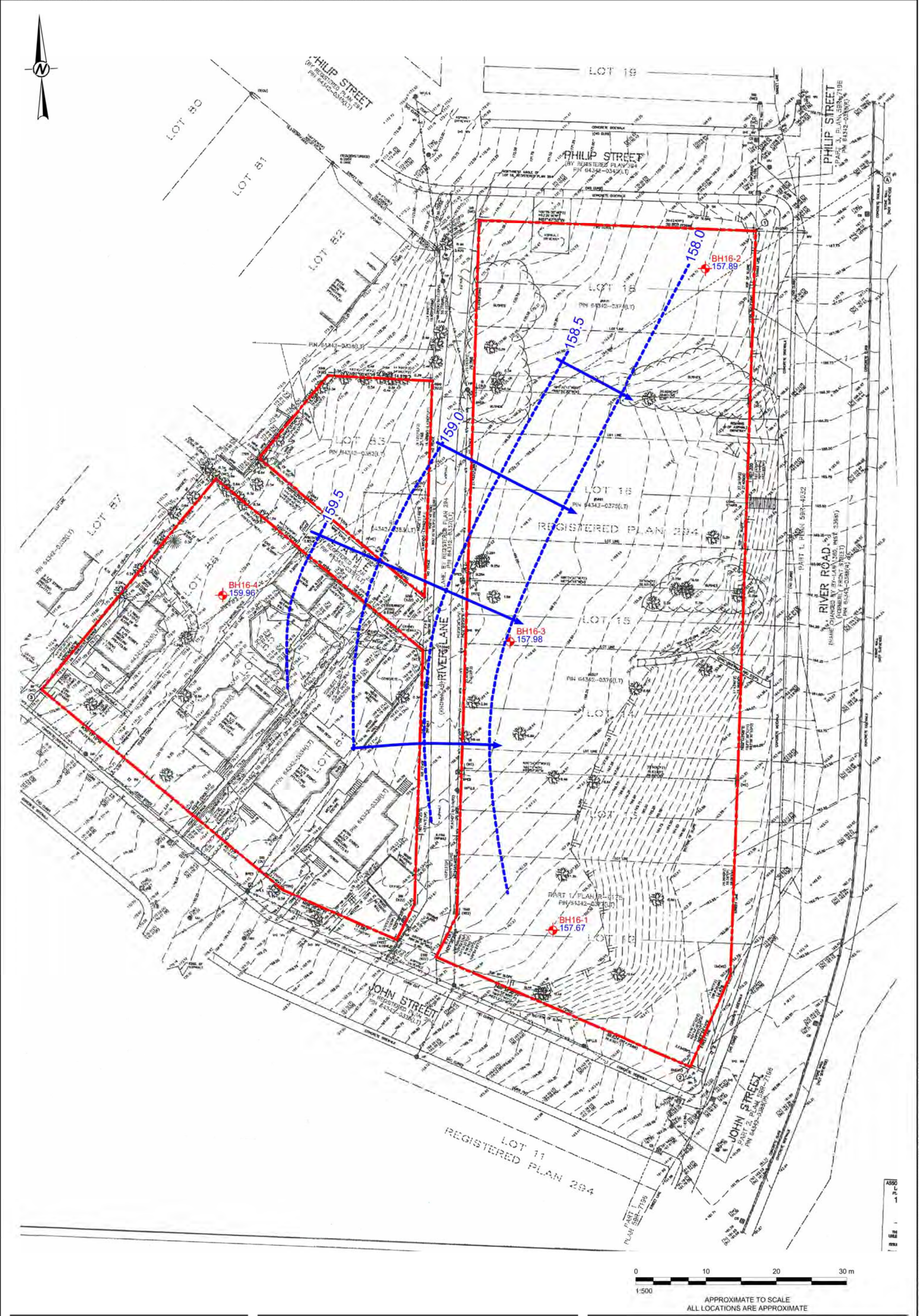

APPROXIMATE TO SCALE
ALL LOCATIONS ARE APPROXIMATE

LEGEND

🟥	PROPERTY LIMITS
⌖	BOREHOLE LOCATION
156.78	STATIC WATER LEVEL, 19 Dec 2016
▬ ▬ ▬	GROUNDWATER EQUIPOTENTIAL (masl)
→	INFERRED GROUNDWATER FLOW DIRECTION

REFERENCE(S)

Base Plan provided by KRCMAR, entitled "Boundary and Topographic Survey...", Job No. 16-179, Drawing Name: 16-179BT01, dated 14-Sep-2016

Features traced and aligned relative to Geodetic Datum UTM NAD 83 Zone 17

CLIENT
5507 RIVER DEVELOPMENT INC.

CONSULTANT
Golder Associates

YYYY-MM-DD	2016-01-09
DESIGNED	
PREPARED	JPR
REVIEWED	
APPROVED	

PROJECT
GEOTECHNICAL INVESTIGATION
HIGH-RISE RESIDENTIAL APARTMENT BUILDINGS
RIVER ROAD AND JOHN STREET, NIAGARA FALLS, ONTARIO

TITLE
SHALLOW BEDROCK GROUNDWATER FLOW

PROJECT NO.	CONTROL	REV.	FIGURE
1668252		----	3

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25 mm
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

APPENDIX C

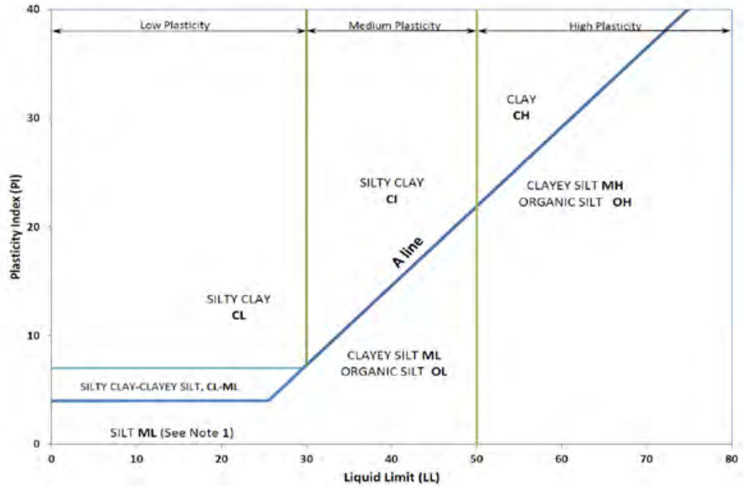
Method of Soil Classification
Symbols and Terms used on Records of Boreholes and Test Pits
List of Symbols
Record of Borehole Sheets
Boreholes BH16-1 to BH16-4

METHOD OF SOIL CLASSIFICATION

The Golder Associates Ltd. Soil Classification System is based on the Unified Soil Classification System (USCS)

Organic or Inorganic	Soil Group	Type of Soil		Gradation or Plasticity	$Cu = \frac{D_{60}}{D_{10}}$	$Cc = \frac{(D_{30})^2}{D_{10} x D_{60}}$	Organic Content	USCS Group Symbol	Group Name
INORGANIC (Organic Content ≤30% by mass)	COARSE-GRAINED SOILS (>50% by mass is larger than 0.075 mm)	GRAVELS (>50% by mass of coarse fraction is larger than 4.75 mm)	Gravels with ≤12% fines (by mass)	Poorly Graded	<4	≤1 or ≥3	≤30%	GP	GRAVEL
				Well Graded	≥4	1 to 3		GW	GRAVEL
			Gravels with >12% fines (by mass)	Below A Line	n/a			GM	SILTY GRAVEL
				Above A Line	n/a			GC	CLAYEY GRAVEL
		SANDS (≥50% by mass of coarse fraction is smaller than 4.75 mm)	Sands with ≤12% fines (by mass)	Poorly Graded	<6	≤1 or ≥3		SP	SAND
				Well Graded	≥6	1 to 3		SW	SAND
			Sands with >12% fines (by mass)	Below A Line	n/a			SM	SILTY SAND
				Above A Line	n/a			SC	CLAYEY SAND

Organic or Inorganic	Soil Group	Type of Soil	Laboratory Tests	Field Indicators					Organic Content	USCS Group Symbol	Primary Name
				Dilatancy	Dry Strength	Shine Test	Thread Diameter	Toughness (of 3 mm thread)			
INORGANIC (Organic Content ≤30% by mass)	FINE-GRAINED SOILS (≥50% by mass is smaller than 0.075 mm)	SILTS (Non-Plastic or PI and LL plot below A-Line on Plasticity Chart below)	Liquid Limit <50	Rapid	None	None	>6 mm	N/A (can't roll 3 mm thread)	<5%	ML	SILT
				Slow	None to Low	Dull	3mm to 6 mm	None to low	<5%	ML	CLAYEY SILT
				Slow to very slow	Low to medium	Dull to slight	3mm to 6 mm	Low	5% to 30%	OL	ORGANIC SILT
			Liquid Limit ≥50	Slow to very slow	Low to medium	Slight	3mm to 6 mm	Low to medium	<5%	MH	CLAYEY SILT
				None	Medium to high	Dull to slight	1 mm to 3 mm	Medium to high	5% to 30%	OH	ORGANIC SILT
		CLAYS (PI and LL plot above A-Line on Plasticity Chart below)	Liquid Limit <30	None	Low to medium	Slight to shiny	~ 3 mm	Low to medium	0% to 30% **(see Note 2)**	CL	SILTY CLAY
			Liquid Limit 30 to 50	None	Medium to high	Slight to shiny	1 mm to 3 mm	Medium		CI	SILTY CLAY
			Liquid Limit ≥50	None	High	Shiny	<1 mm	High		CH	CLAY
HIGHLY ORGANIC SOILS (Organic Content >30% by mass)		Peat and mineral soil mixtures							30% to 75%	PT	SILTY PEAT, SANDY PEAT
		Predominantly peat, may contain some mineral soil, fibrous or amorphous peat							75% to 100%		PEAT



Note 1 – Fine grained materials with PI and LL that plot in this area are named (ML) SILT with slight plasticity. Fine-grained materials which are non-plastic (i.e. a PL cannot be measured) are named SILT.

Note 2 – For soils with <5% organic content, include the descriptor "trace organics" for soils with between 5% and 30% organic content include the prefix "organic" before the Primary name.

Dual Symbol — A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC and CL-ML.

For non-cohesive soils, the dual symbols must be used when the soil has between 5% and 12% fines (i.e. to identify transitional material between "clean" and "dirty" sand or gravel.

For cohesive soils, the dual symbol must be used when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart (see Plasticity Chart at left).

Borderline Symbol — A borderline symbol is two symbols separated by a slash, for example, CL/CI, GM/SM, CL/ML.

A borderline symbol should be used to indicate that the soil has been identified as having properties that are on the transition between similar materials. In addition, a borderline symbol may be used to ~~or~~ indicate~~s~~ a range of similar soil types within a stratum.

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>300	>12
COBBLES	Not Applicable	75 to 300	3 to 12
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
SILT/CLAY	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY AND MINOR CONSTITUENTS

Percentage by Mass	Modifier
>35	Use 'and' to combine major constituents (*i.e.,* SAND and GRAVEL, SAND and CLAY)
> 12 to 35	Primary soil name prefixed with "gravelly, sandy, SILTY, CLAYEY" as applicable
> 5 to 12	some
≤ 5	trace

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.).

Cone Penetration Test (CPT)

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

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 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

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size
TP	Thin-walled, piston – note size
WS	Wash sample

SOIL TESTS

w	water content
PL , w_p	plastic limit
LL , 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, Gs)
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 (FV)	field vane (LV-laboratory vane test)
γ	unit weight

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

NON-COHESIVE (COHESIONLESS) SOILS

Compactness[2]

Term	SPT 'N' (blows/0.3m)[1]
Very Loose	0 - 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	>50

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects.
2. Definition of compactness descriptions based on SPT 'N' ranges from Terzaghi and Peck (1967) and correspond to typical average N_{60} values.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

COHESIVE SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N'[1] (blows/0.3m)
Very Soft	<12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	>200	>30

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.

Water Content

Term	Description
w < PL	Material is estimated to be drier than the Plastic Limit.
w ~ PL	Material is estimated to be close to the Plastic Limit.
w > PL	Material is estimated to be wetter than the Plastic Limit.

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

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
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_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

* 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 (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 $= \sigma'_p / \sigma'_{vo}$

(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

Notes: 1 $\tau = c' + \sigma' \tan\phi'$

2 shear strength = (compressive strength)/2

PROJECT: 1668252

LOCATION: N 4773100.00; E 657257.00

RECORD OF BOREHOLE: BH-16-1

BORING DATE: 11/29/2016

SHEET 1 OF 2

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

SHEAR STRENGTH Cu, kPa: nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-10} 10^{-8} 10^{-6} 10^{-4}

WATER CONTENT PERCENT: Wp ⊢ ○W ⊣ Wl 20 40 60 80

ADDITIONAL LAB. TESTING

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	166.80				
0	CME 75 Truck Mounted Rig 6 inch O.D. Solid Stem Auger	TOPSOIL	0.00	1A			
		(CL) SILTY CLAY, some sand, some gravel to gravelly; reddish-brown; cohesive, w<PL, very stiff to very soft	166.62 0.18	1B	SS	20	
1				2	SS	19	50 mm Diameter Monitoring Well
2				3	SS	6	
				4	SS	1	
3				5	SS	2	
	HQ Core	BEDROCK For bedrock coring details refer to RECORD OF DRILLHOLE BH-16-1 Bedrock cored between depths of 3.56 m and 16.87 m	163.24 3.56				
4							
5							Bentonite
6							
7							
8							
9							▽ Dec. 7, 2016
10							

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 50

LOGGED: SP

CHECKED: MPL

PROJECT: 1668252

LOCATION: N 4773100.00; E 657257.00

RECORD OF BOREHOLE: BH-16-1

BORING DATE: 11/29/2016

SHEET 2 OF 2

DATUM: Geodetic

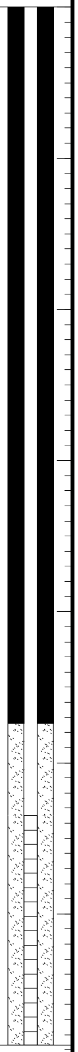
SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-10} 10^{-8} 10^{-6} 10^{-4} / WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- *CONTINUED FROM PREVIOUS PAGE* ---									
10	CME 75 Truck Mounted Rig HQ Core	BEDROCK For bedrock coring details refer to RECORD OF DRILLHOLE BH-16-1 Bedrock cored between depths of 3.56 m and 16.87 m		149.93 16.87							Bentonite Sand Sand with Screen
17		END OF BOREHOLE									

NOTES:

Date	Groundwater measurement (m bgs)
12/5/16	9.1
12/6/16	9.2
12/7/16	9.2
12/19/16	9.2
12/21/16	9.3



DEPTH SCALE

1 : 50

Golder Associates

LOGGED: SP

CHECKED: MPL

PROJECT: 1668252

RECORD OF DRILLHOLE: BH-16-1

SHEET 1 OF 2

LOCATION: N 4773100.0 ;E 657257.0

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: 11/29/2016

DRILL RIG: CME 75

DRILLING CONTRACTOR: DBW Drilling

DATUM: Geodetic

NOTE:
For abbreviations, symbols and descriptions refer to
LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	NOTES
		Top of Bedrock		163.24			
	Rotary Drill HQ Core	Fresh, thinly bedded, grey, fine grained, faintly porous, medium strong to very strong, argillaceous DOLOSTONE with calcite nodules [Lockport Formation]		3.56			
4					1		
5					2		
		Fresh, thinly to medium bedded, grey, fine to medium grained, faintly porous, medium strong to very strong, crinoidal DOLOSTONE [Lockport Formation]		160.90 5.90			
6							
7					3		
8					4		Bentonite
9							Dec. 7, 2016
10					5		
11					6		
12							
13					7		

CONTINUED NEXT PAGE

RECOVERY: TOTAL CORE % (80 60 40 20); SOLID CORE % (80 60 40 20) — R.Q.D. % (80 60 40 20) — FRACT. INDEX PER 0.25m (5 10 15 20) — DISCONTINUITY DATA: DIP w.r.t. CORE AXIS (0 30 60 90) — HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8} 10^{-6} 10^{-4} 10^{-2}) — WEATHERING INDEX (W1 W2 W3 W4 W5 W6) — FEATURES

FEATURES: ▬ Lost Core; ▨ Broken Core; ▨ Broken Core

TYPE AND SURFACE DESCRIPTION	Jr	Ja
BD,PL,RO	1.5	1
BD,PL,RO	1.5	1
BD,PL,RO	1.5	1
BD,UN,RO	3	1
BD,UN,RO,IN, BC	1	5
BD,CU,RO	3	1
JN,CU,RO,SO	3	1
BD,UN,RO	3	1
BD,UN,RO,SO	3	1
BD,PL,RO	1.5	1
BD,PL,RO	1.5	1
BD,PL,RO	1.5	1
BD,UN,RO	3	1
BD,UN,RO	3	1
BD,CU,RO	3	1
BD,UN,RO	3	1
BD,UN,RO,PC, Ca	3	3
JN,PL,RO,PC, Ca	1.5	3
BD,PL,RO	1.5	1
BD,PL,SM	1	1
JN,CU,RO	3	1
BD,PL,RO	1.5	1
JN,UN,RO,IN, Ca	1	5
JN,UN,RO,IN, Ca	1	5
JN,UN,RO	3	1

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: SP
CHECKED: MT

PROJECT: 1668252

RECORD OF DRILLHOLE: BH-16-1

SHEET 2 OF 2

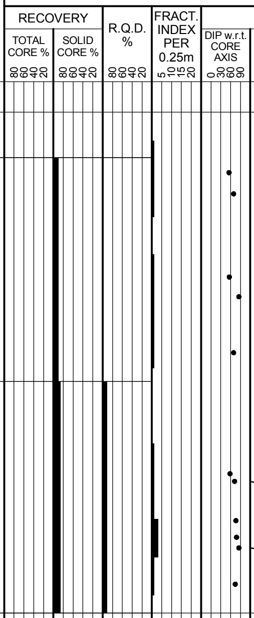
LOCATION: N 4773100.0 ;E 657257.0
INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: 11/29/2016
DRILL RIG: CME 75
DRILLING CONTRACTOR: DBW Drilling

DATUM: Geodetic

NOTE:
For abbreviations, symbols and descriptions refer to
LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

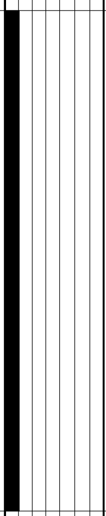
DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	FLUSH RETURN	NOTES
		--- CONTINUED FROM PREVIOUS PAGE ---					
14 15 16	Rotary Drill HQ Core	Fresh, thinly to medium bedded, grey, fine to medium grained, faintly porous, medium strong to very strong, crinoidal DOLOSTONE [Lockport Formation]		149.93	7 8 9		Bentonite Sand Sand with Screen
17		END OF DRILLHOLE		16.87			
18 19 20 21 22 23							



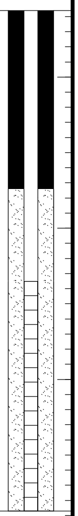
DISCONTINUITY DATA

TYPE AND SURFACE DESCRIPTION	Jr	Ja
JN,UN,RO	3	1
BD,PL,RO	1.5	1
JN,UN,RO,CC, Ca	3	3
BD,PL,RO	1.5	1
BD,PL,RO,CC, Cl	1.5	4
JN,UN,RO	3	1
BD,UN,RO	3	1
BD,UN,RO	3	1
BD,UN,RO	3	1
BD,CU,RO	3	1
BD,UN,RO	3	1

HYDRAULIC CONDUCTIVITY K, cm/sec: 10^{-8} 10^{-6} 10^{-4} 10^{-2}



FEATURES



DEPTH SCALE
1 : 50

LOGGED: SP
CHECKED: MT

PROJECT: 1668252

LOCATION: N 4773198.00; E 657288.00

RECORD OF BOREHOLE: BH-16-2

BORING DATE: 12/2/2016

SHEET 1 OF 3

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-10} 10^{-8} 10^{-6} 10^{-4} / WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		169.30							
0	CME 75 Truck Mounted Rig 6 inch O.D. Solid Stem Auger	FILL - (CL) SILTY CLAY, some sand, trace gravel; dark brown; cohesive, w<PL, firm		0.00	1	SS	4				
		(SM) gravelly SILTY SAND; reddish-brown; non-cohesive, moist, dense to very dense		168.69 0.61	2	SS	41				50 mm Diameter Monitoring Well
1					3	SS	50/ 0.13				
	HQ Core	BEDROCK For bedrock coring details refer to RECORD OF DRILLHOLE BH-16-2 Bedrock cored between depths of 1.65 m and 19.10 m		167.65 1.65							
2											
3											
4											
5											Bentonite
6											
7											
8											
9											
10											

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DEPTH SCALE

1 : 50

Golder Associates

LOGGED: SP

CHECKED: MPL

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PROJECT: 1668252

LOCATION: N 4773198.00; E 657288.00

RECORD OF BOREHOLE: BH-16-2

BORING DATE: 12/2/2016

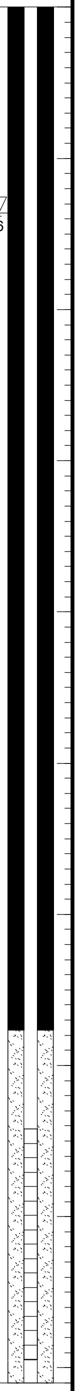
SHEET 2 OF 3

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-10} 10^{-8} 10^{-6} 10^{-4}) WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
10	CME 75 Truck Mounted Rig HQ Core	BEDROCK For bedrock coring details refer to RECORD OF DRILLHOLE BH-16-2 Bedrock cored between depths of 1.65 m and 19.10 m									
11											▽ Dec. 7, 2016
12											
13											Bentonite
14											
15											
16											
17											Sand
18											Sand with Screen
19				150.20 19.10							Sand
		END OF BOREHOLE NOTES: Date Groundwater measurement (m bgs)									
20		*CONTINUED NEXT PAGE*									



DEPTH SCALE

1 : 50

Golder Associates

LOGGED: SP

CHECKED: MPL

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PROJECT: 1668252

LOCATION: N 4773198.00; E 657288.00

RECORD OF BOREHOLE: BH-16-2

BORING DATE: 12/2/2016

SHEET 3 OF 3

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE			SAMPLES			DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-10} 10^{-8} 10^{-6} 10^{-4} WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m				
		--- CONTINUED FROM PREVIOUS PAGE ---									
20		12/6/16 11.4 12/7/16 11.4 12/19/16 11.4 12/21/16 11.4									
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: SP

CHECKED: MPL

PROJECT: 1668252

RECORD OF DRILLHOLE: BH-16-2

SHEET 1 OF 2

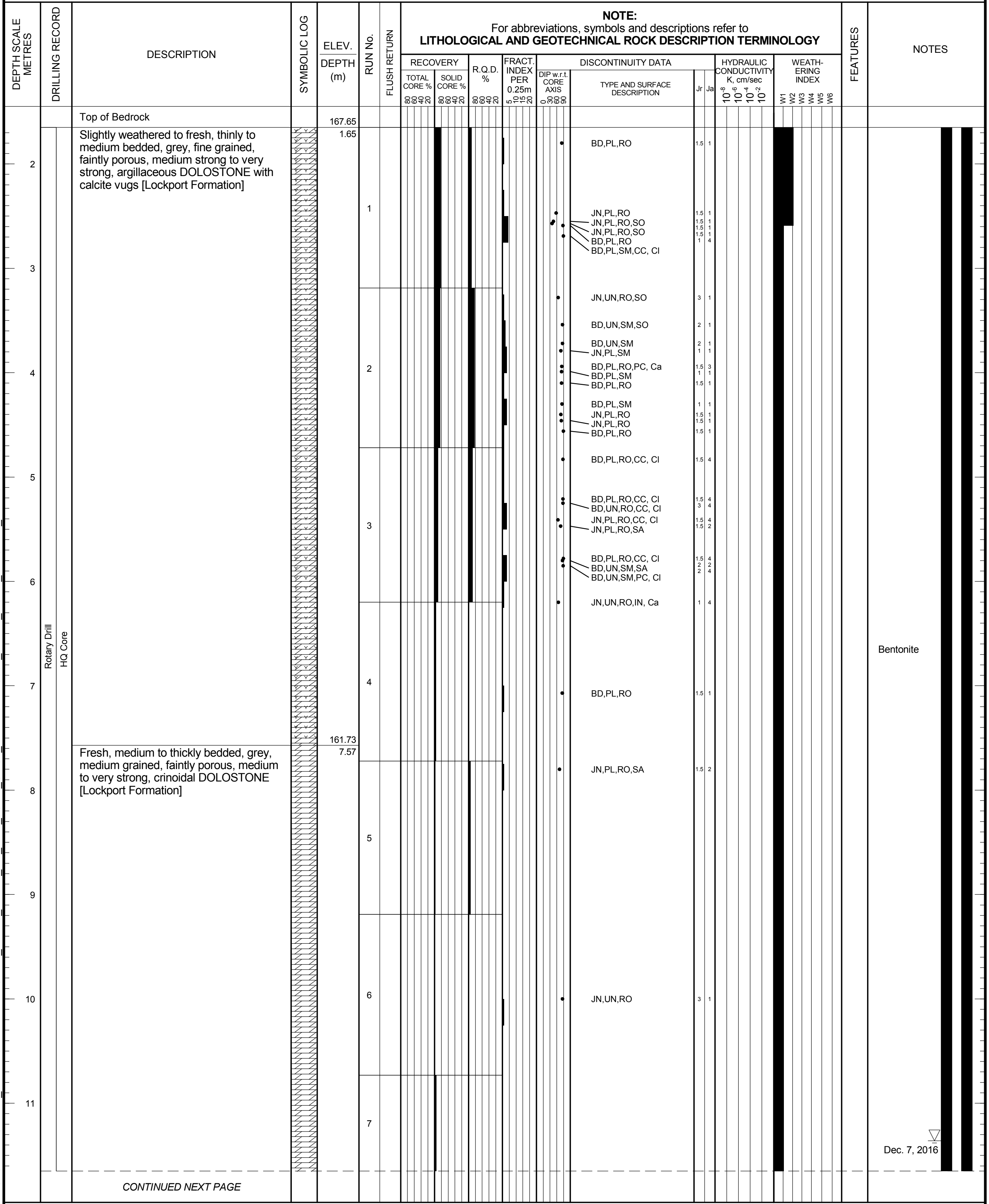
LOCATION: N 4773198.0 ;E 657288.0

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: 12/2/2016
DRILL RIG: CME 75
DRILLING CONTRACTOR: DBW Drilling

DATUM: Geodetic

NOTE:
For abbreviations, symbols and descriptions refer to
LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY



ELEV. / DEPTH (m)	DESCRIPTION
167.65	Top of Bedrock
1.65	Slightly weathered to fresh, thinly to medium bedded, grey, fine grained, faintly porous, medium strong to very strong, argillaceous DOLOSTONE with calcite vugs [Lockport Formation]
161.73 7.57	Fresh, medium to thickly bedded, grey, medium grained, faintly porous, medium to very strong, crinoidal DOLOSTONE [Lockport Formation]

DRILLING RECORD: Rotary Drill, HQ Core

RUN No.	TYPE AND SURFACE DESCRIPTION	Jr	Ja
1	BD,PL,RO	1.5	1
1	JN,PL,RO	1.5	1
1	JN,PL,RO,SO	1.5	1
1	JN,PL,RO,SO	1.5	1
1	BD,PL,RO	1.5	1
1	BD,PL,SM,CC, Cl	1	4
2	JN,UN,RO,SO	3	1
2	BD,UN,SM,SO	2	1
2	BD,UN,SM	2	1
2	JN,PL,SM	1	1
2	BD,PL,RO,PC, Ca	1.5	3
2	BD,PL,SM	1	1
2	BD,PL,RO	1.5	1
2	BD,PL,SM	1	1
2	JN,PL,RO	1.5	1
2	JN,PL,RO	1.5	1
2	BD,PL,RO	1.5	1
3	BD,PL,RO,CC, Cl	1.5	4
3	BD,PL,RO,CC, Cl	1.5	4
3	BD,UN,RO,CC, Cl	3	4
3	JN,PL,RO,CC, Cl	1.5	4
3	JN,PL,RO,SA	1.5	2
3	BD,PL,RO,CC, Cl	1.5	4
3	BD,UN,SM,SA	2	2
3	BD,UN,SM,PC, Cl	2	4
4	JN,UN,RO,IN, Ca	1	4
4	BD,PL,RO	1.5	1
5	JN,PL,RO,SA	1.5	2
6	JN,UN,RO	3	1

NOTES: Bentonite

Dec. 7, 2016

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DEPTH SCALE
1 : 50

Golder Associates

LOGGED: SP
CHECKED: MT

PROJECT: 1668252

RECORD OF DRILLHOLE: BH-16-2

SHEET 2 OF 2

LOCATION: N 4773198.0 ;E 657288.0

DRILLING DATE: 12/2/2016

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME 75

DRILLING CONTRACTOR: DBW Drilling

NOTE:
For abbreviations, symbols and descriptions refer to
LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jr	Ja	FEATURES / NOTES
		--- CONTINUED FROM PREVIOUS PAGE ---						
12	Rotary Drill HQ Core	Fresh, medium to thickly bedded, grey, medium grained, faintly porous, medium to very strong, crinoidal DOLOSTONE [Lockport Formation]		7				
13				8				Broken Core
14				9				Bentonite Broken Core
15–16				10	BD,UN,SM BD,UN,RO BD,UN,RO	2 3 3	1 1 1	Lost Core
				11				
17				12				Sand
18				13				Sand with Screen
19			150.20 19.10					Sand
		END OF DRILLHOLE						
20								
21								

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: SP

CHECKED: MT

PROJECT: 1668252

RECORD OF BOREHOLE: BH-16-3

SHEET 1 OF 3

LOCATION: N 4773144.00; E 657260.00

BORING DATE: 11/30/2016

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-10} 10^{-8} 10^{-6} 10^{-4} / WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		168.80							
0	CME 75 Truck Mounted Rig 6 inch O.D. Solid Stem Auger	(ML) SILT, some sand, some organics, trace gravel; reddish-brown; non-cohesive, moist, compact		0.00	1A 1B	SS	11				
		(SW) gravelly SAND; reddish-brown; non-cohesive, moist, compact		168.22 0.58							
1		(ML) sandy SILT, trace gravel; reddish-brown; non-cohesive, moist, dense		168.04 0.76	2A	SS	41				50 mm Diameter Monitoring Well
		(GW) sandy GRAVEL; reddish-brown; non-cohesive, moist, dense		167.66 1.14	2B						
		(ML) SILT, trace to some gravel, trace to some sand; reddish-brown; non-cohesive, moist, compact to very dense		167.48 1.32	2C						
2					3	SS	27				
					4	SS	50/ 0.08				
	HQ Core	BEDROCK For bedrock coring details refer to RECORD OF DRILLHOLE BH-16-3 Bedrock cored between depths of 2.36 m and 19.21 m		166.44 2.36							
3											
4											
5											Bentonite
6											
7											
8											
9											
10											

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: SP

CHECKED: MPL

PROJECT: 1668252

LOCATION: N 4773144.00; E 657260.00

RECORD OF BOREHOLE: BH-16-3

BORING DATE: 11/30/2016

SHEET 2 OF 3

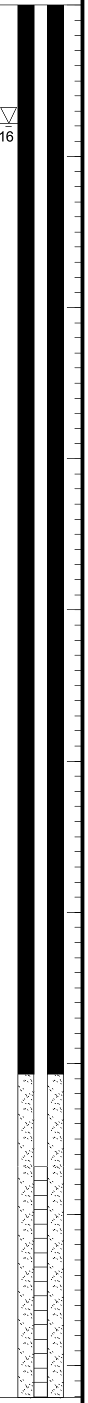
DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-10} 10^{-8} 10^{-6} 10^{-4} / WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
10	CME 75 Truck Mounted Rig HQ Core	BEDROCK For bedrock coring details refer to RECORD OF DRILLHOLE BH-16-3 Bedrock cored between depths of 2.36 m and 19.21 m		149.59 19.21							Dec. 7, 2016 Bentonite Sand Sand with Screen
		END OF BOREHOLE NOTES: Date Groundwater measurement									
20		*CONTINUED NEXT PAGE*									

Depth scale marks: 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20



DEPTH SCALE

1 : 50

Golder Associates

LOGGED: SP

CHECKED: MPL

PROJECT: 1668252

LOCATION: N 4773144.00; E 657260.00

RECORD OF BOREHOLE: BH-16-3

BORING DATE: 11/30/2016

SHEET 3 OF 3

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-10} 10^{-8} 10^{-6} 10^{-4} / WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
20		(m bgs) 12/5/16 10.7 12/6/16 10.9 12/7/16 10.8 12/14/16 10.9 12/21/16 10.9									
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: SP

CHECKED: MPL

PROJECT: 1668252

RECORD OF DRILLHOLE: BH-16-3

SHEET 1 OF 2

LOCATION: N 4773144.0 ;E 657260.0

INCLINATION: -90° AZIMUTH: ---

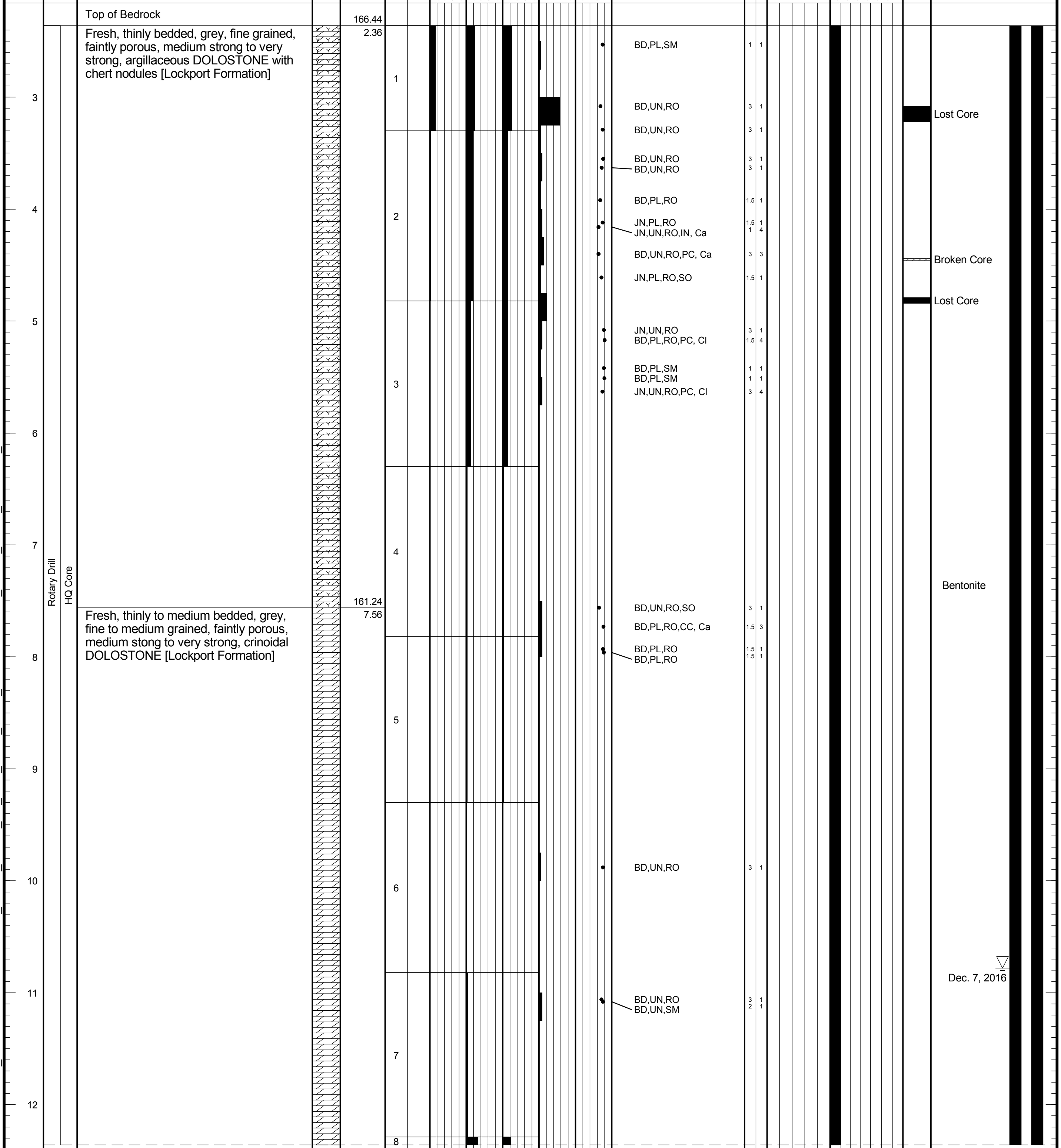
DRILLING DATE: 11/30/2016

DRILL RIG: CME 75

DRILLING CONTRACTOR: DBW Drilling

DATUM: Geodetic

NOTE:
For abbreviations, symbols and descriptions refer to
LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY



ELEV. DEPTH (m)	DESCRIPTION
	Top of Bedrock
166.44 2.36	Fresh, thinly bedded, grey, fine grained, faintly porous, medium strong to very strong, argillaceous DOLOSTONE with chert nodules [Lockport Formation]
161.24 7.56	Fresh, thinly to medium bedded, grey, fine to medium grained, faintly porous, medium stong to very strong, crinoidal DOLOSTONE [Lockport Formation]

RUN No.: 1, 2, 3, 4, 5, 6, 7, 8

TYPE AND SURFACE DESCRIPTION	Jr	Ja
BD,PL,SM	1	1
BD,UN,RO	3	1
BD,UN,RO	3	1
BD,UN,RO	3	1
BD,UN,RO	3	1
BD,PL,RO	1.5	1
JN,PL,RO	1.5	1
JN,UN,RO,IN, Ca	1	4
BD,UN,RO,PC, Ca	3	3
JN,PL,RO,SO	1.5	1
JN,UN,RO	3	1
BD,PL,RO,PC, Cl	1.5	4
BD,PL,SM	1	1
BD,PL,SM	1	1
JN,UN,RO,PC, Cl	3	4
BD,UN,RO,SO	3	1
BD,PL,RO,CC, Ca	1.5	3
BD,PL,RO	1.5	1
BD,PL,RO	1.5	1
BD,UN,RO	3	1
BD,UN,RO	3	1
BD,UN,SM	2	1

FEATURES:
- Lost Core
- Broken Core
- Lost Core

NOTES:
- Bentonite
- Dec. 7, 2016

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 50

LOGGED: SP

CHECKED: MT

PROJECT: 1668252

RECORD OF DRILLHOLE: BH-16-3

SHEET 2 OF 2

LOCATION: N 4773144.0 ;E 657260.0

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: 11/30/2016

DRILL RIG: CME 75

DRILLING CONTRACTOR: DBW Drilling

DATUM: Geodetic

NOTE:
For abbreviations, symbols and descriptions refer to
LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jr	Ja	FEATURES	NOTES
		--- CONTINUED FROM PREVIOUS PAGE ---							
	Rotary Drill HQ Core	Fresh, thinly to medium bedded, grey to brown, medium grained, moderately to highly porous, medium strong to strong, crinoidal DOLOSTONE [Lockport Formation]	156.22 12.58						
13				8	JN,UN,RO,IN, Ca JN,PL,RO,IN, Ca JN,UN,RO,PC, Ca JN,UN,RO,CC, Ca	1 1 3 3	4 4 3 3		
								▨	Broken Core
14									
				9	JN,UN,RO,IN, Ca JN,UN,RO,IN, Ca JN,PL,VRO,IN, Ca	1 1 1	4 4 4		Bentonite
15									
		Fresh, thinly to medium bedded, grey, fine to medium grained, faintly porous, medium strong to very strong, DOLOSTONE [Lockport Formation] with some SHALE laminations	153.61 15.19						
16				10	BD,PL,RO,SA	1.5	2		
17									Sand
				11	BD,PL,RO	1.5	1		
18									Sand with Screen
				12					
19			149.59						
		END OF DRILLHOLE	19.21						
20									
21									
22									

RECOVERY: TOTAL CORE % / SOLID CORE % (80 60 40 20); R.Q.D. % (80 60 40 20); FRACT. INDEX PER 0.25m (5 10 15 20); DIP w.r.t. CORE AXIS (0 30 60 90); HYDRAULIC CONDUCTIVITY K, cm/sec (10^{-8} 10^{-6} 10^{-4} 10^{-2}); WEATHERING INDEX (W1 W2 W3 W4 W5 W6); SYMBOLIC LOG; FLUSH RETURN

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: SP
CHECKED: MT

GTA-RCK 031 S:\CLIENTS\TIME_DEVELOPMENT\NIAGARA_FALLS_RIVER_RD_AND_JOHN_ST\02_DATA\GINT\5507_RIVER_ROAD_NIAGARA_FALLS.GPJ GAL-MISS.GDT 25/1/17

PROJECT: 1668252
LOCATION: N 4773149.00; E 657217.00

RECORD OF BOREHOLE: BH-16-4

BORING DATE: 12/6/2016

SHEET 1 OF 3
DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80; SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-10} 10^{-8} 10^{-6} 10^{-4}; WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE	171.80							
0	CME 75 Truck Mounted Rig 6 inch O.D. Solid Stem Auger	TOPSOIL	0.00							
		(CL) sandy SILTY CLAY, some gravel; reddish-brown (TILL); cohesive, w<PL, stiff to hard	0.15	1	SS	11				
1				2	SS	48				50 mm Diameter Monitoring Well
		(SM/GP) SILTY SAND and GRAVEL; reddish-brown (TILL); non-cohesive, dry, very dense	170.43 1.37	3	SS	76				
2										
	HQ Core	BEDROCK For bedrock coring details refer to RECORD OF DRILLHOLE BH-16-4 Bedrock cored between depths of 2.44 m and 22.01 m	169.36 2.44							
3										
4										
5										Bentonite
6										
7										
8										
9										
10										

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: AKV
CHECKED: MPL

PROJECT: 1668252

LOCATION: N 4773149.00; E 657217.00

RECORD OF BOREHOLE: BH-16-4

BORING DATE: 12/6/2016

SHEET 2 OF 3

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-10} 10^{-8} 10^{-6} 10^{-4} WATER CONTENT PERCENT Wp ├──○W──┤ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
10	CME 75 Truck Mounted Rig HQ Core	BEDROCK For bedrock coring details refer to RECORD OF DRILLHOLE BH-16-4 Bedrock cored between depths of 2.44 m and 22.01 m									
11											▽ Dec. 7, 2016
12											
13											
14											
15											Bentonite
16											
17											
18											
19											
20											Sand
		CONTINUED NEXT PAGE									

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: AKV

CHECKED: MPL

PROJECT: 1668252

LOCATION: N 4773149.00; E 657217.00

RECORD OF BOREHOLE: BH-16-4

BORING DATE: 12/6/2016

SHEET 3 OF 3

DATUM: Geodetic

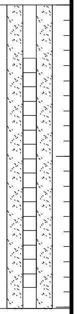
SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-10} 10^{-8} 10^{-6} 10^{-4}) WATER CONTENT PERCENT Wp ⊢ ○W ⊣ Wl (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
20	CME 75 Truck Mounted Rig HQ Core	BEDROCK For bedrock coring details refer to RECORD OF DRILLHOLE BH-16-4 Bedrock cored between depths of 2.44 m and 22.01 m									Sand
21											Sand with Screen
22				149.79 22.01							Sand
		END OF BOREHOLE									
23											
24											
25											
26											
27											
28											
29											
30											

NOTES:

Date	Groundwater measurement (m bgs)
12/7/16	11.3
12/19/16	11.9
12/21/16	11.9



DEPTH SCALE

1 : 50

Golder Associates

LOGGED: AKV

CHECKED: MPL

PROJECT: 1668252

RECORD OF DRILLHOLE: BH-16-4

SHEET 1 OF 2

LOCATION: N 4773149.0 ;E 657217.0

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: 12/6/2016

DRILL RIG: CME 75

DRILLING CONTRACTOR: DBW Drilling

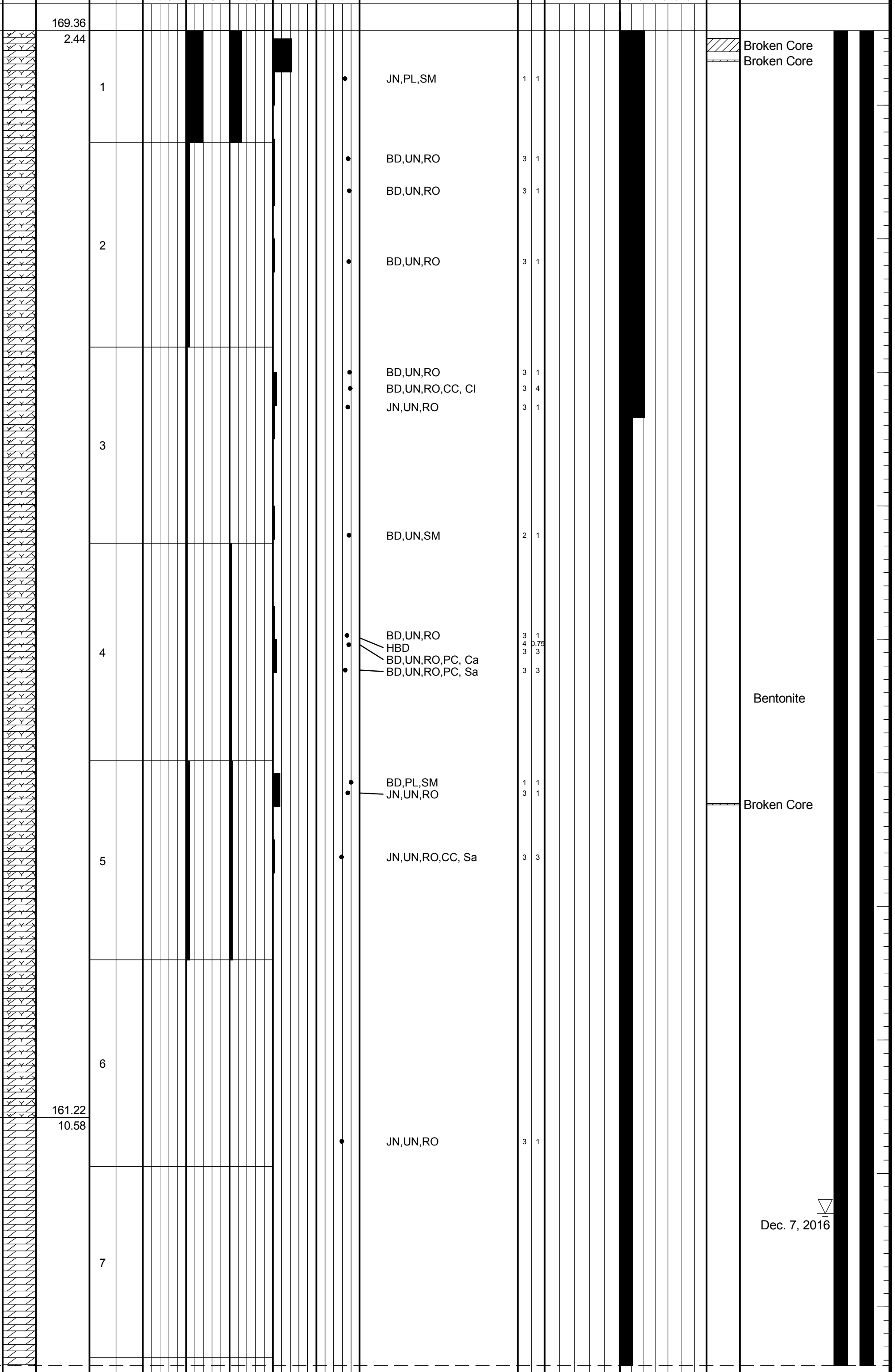
DATUM: Geodetic

NOTE: For abbreviations, symbols and descriptions refer to **LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY**

DEPTH SCALE METRES | DRILLING RECORD | DESCRIPTION | SYMBOLIC LOG | ELEV. DEPTH (m) | RUN No. | FLUSH RETURN | RECOVERY (TOTAL CORE %, SOLID CORE %) | R.Q.D. % | FRACT. INDEX PER 0.25m | DISCONTINUITY DATA (DIP w.r.t. CORE AXIS; TYPE AND SURFACE DESCRIPTION; Jr; Ja) | HYDRAULIC CONDUCTIVITY K, cm/sec | WEATHERING INDEX | FEATURES | NOTES

Drilling record: Rotary Drill, HQ Core

DESCRIPTION	ELEV. DEPTH (m)
Top of Bedrock	169.36
Slightly weathered to fresh, medium to thickly bedded, grey, fine grained, faintly porous, medium strong to very strong, argillaceous DOLOSTONE with sparse vugs, and chert and gypsum nodules [Lockport Formation]	2.44
Fresh, medium to very thickly bedded, grey, fine to medium grained, faintly porous to moderately porous, medium strong to very strong, crinoidal DOLOSTONE [Lockport Formation]	161.22 10.58



Run No.	TYPE AND SURFACE DESCRIPTION	Jr	Ja
1	JN,PL,SM	1	1
2	BD,UN,RO	3	1
2	BD,UN,RO	3	1
2	BD,UN,RO	3	1
3	BD,UN,RO	3	1
3	BD,UN,RO,CC, Cl	3	4
3	JN,UN,RO	3	1
3	BD,UN,SM	2	1
4	BD,UN,RO	3	1
4	HBD	4	0.75
4	BD,UN,RO,PC, Ca	3	3
4	BD,UN,RO,PC, Sa	3	3
5	BD,PL,SM	1	1
5	JN,UN,RO	3	1
5	JN,UN,RO,CC, Sa	3	3
6	JN,UN,RO	3	1

CONTINUED NEXT PAGE

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: AKV

CHECKED: MT

PROJECT: 1668252

RECORD OF DRILLHOLE: BH-16-4

SHEET 2 OF 2

LOCATION: N 4773149.0 ;E 657217.0

INCLINATION: -90° AZIMUTH: ---

DRILLING DATE: 12/6/2016
DRILL RIG: CME 75
DRILLING CONTRACTOR: DBW Drilling

DATUM: Geodetic

NOTE:
For abbreviations, symbols and descriptions refer to
LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

DRILLING RECORD: Rotary Drill, HQ Core

DEPTH SCALE METRES	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	Jr	Ja	NOTES
	--- CONTINUED FROM PREVIOUS PAGE ---						
	Fresh, medium to very thickly bedded, grey, fine to medium grained, faintly porous to moderately porous, medium strong to very strong, crinoidal DOLOSTONE [Lockport Formation]		8				
13			8				Broken Core
14							
			9	BD,UN,RO	3	1	
15							
16							Bentonite
	Fresh, medium to very thickly bedded, grey, fine to medium grained, moderately to highly porous, medium strong to strong, crinoidal DOLOSTONE [Lockport Formation]	155.55 16.25	10				
17							Lost Core
			11				
18	Fresh, medium to very thickly bedded, grey, fine to medium grained, faintly porous, medium strong to very strong, crinoidal DOLOSTONE [Lockport Formation]	153.80 18.00					
19			12	BD,UN,SM	2	1	
				BD,UN,RO	3	1	
20							Sand
			13				
21							Sand with Screen
							Broken Core
			14				
22	END OF DRILLHOLE	149.79 22.01					Sand

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: AKV
CHECKED: MT

APPENDIX D

Results of Geotechnical Laboratory Testing

GEOMECHANICA

Geomechanica Inc.
Suite 900 – 390 Bay St.
Toronto Ontario
Canada M5H 2Y2

December 16, 2016

Ms. Sarah Pidgen
Golder Associates Ltd.
6925 Century Avenue, Suite #100
Mississauga, Ontario
Canada L5N 7K2

Re: UCS Testing (Golder Project No. 1668252)

Dear Ms. Pidgen:

On December 9, 2016 ten (10) HQ-sized rock samples were received by Geomechanica Inc via drop off. These samples were identified as being from boreholes drilled as part of the Golder Project 1668252. A total of ten (10) uniaxial compression strength (UCS) tests (one on each sample) were completed.

Details regarding the steps of specimen preparation and testing along with the test results and photographs of specimens before and after testing are presented in the accompanying laboratory report.

Sincerely,

Giovanni Grasselli Ph.D., P. Eng.

Geomechanica Inc.
Tel: (647) 478-9767
Email: giovanni.grasselli@geomechanica.com

Rock Laboratory Testing Results

A report submitted to:

Sarah Pidgen
Golder Associates Ltd.
6925 Century Avenue, Suite #100
Mississauga, Ontario
Canada L5N 7K2

Prepared by:

Bryan Tatone, PhD
Omid Mahabadi, PhD
Giovanni Grasselli, PhD, PEng

Geomechanica Inc
#900-390 Bay St
Toronto ON
M5H 3V9 Canada
Tel: +1-647-478-9767
info@geomechanica.com

December 16, 2016
Project number: 1668252

Abstract

This document summarizes the results of Uniaxial Compressive Strength (UCS) testing of limestone samples for Golder Associates Limited. (Golder Project No. 1668252). A digital file containing all measurements taken for these tests accompanies this report.

In this document:

1 Uniaxial Compressive Strength Tests

1.1 Introduction

This section summarizes the results of rock laboratory testing of limestone samples under unconfined uniaxial compression. The tests were performed Geomechanica's laboratory using a 1.3 MN capacity Forney compression testing machine (Figure 1) under nearly constant axial strain rates of 7×10^{-6} s^{-1}. The specimen preparation and testing procedure included the following:

1. Diamond cutting of core samples to obtain cylindrical specimens with an appropriate length (length:diameter = 2:1) and nearly parallel end faces.
2. Diamond grinding of specimens to obtain flat and parallel end faces within ± 0.05 mm.
3. Placement of the specimen into the loading frame and loading to rupture while recording axial force and axial deformation to determine peak strength (UCS) and (tangent) Young's modulus (E).

Figure 1: Forney loading frame used for uniaxial compression testing.

1.2 Results

The results of UCS testing are summarized in Table 1. The corresponding stress-strain curves are presented in Figure 2. The Young's modulus values presented in Table 1 represent the tangent modulus, calculated as the slope of the best fit line through ± 300 data points on either side of the point representing 50% of the UCS.

1.3 Specimen photographs

Photographs of the specimens before and after testing are shown in Figure 3 to Figure 5.

Table 1: Summary of UCS test results.

Sample	Rock type	Depth from (m)	Depth to (m)	Bulk density (g/cm^3)	UCS (MPa)	Young's modulus, E_{50} (GPa)	Notes
SA-1-1	Limestone	9.79	10.04	2.77	132.1	63.6	[1]
SA-1-2	Limestone	15.61	15.80	2.74	157.3	58.5	
SA-2-1	Limestone	17.00	17.17	2.75	218.2	79.1	[2]
SA-2-2	Limestone	18.15	18.38	2.71	129.0	65.0	[3]
SA-3-1	Limestone	6.82	7.05	2.67	195.7	59.1	
SA-3-2	Limestone	13.77	14.02	2.46	62.7	37.6	[3, 4]
SA-3-3	Limestone	18.75	18.96	2.70	129.7	55.1	[5]
SA-4-1	Limestone	8.82	9.06	2.75	176.3	66.6	[1]
SA-4-2	Limestone	20.26	20.47	2.74	143.5	58.6	
SA-4-3	Limestone	21.52	21.83	2.70	159.3	64.5	[3]
Min				2.46	62.7	37.6	
Max				2.77	218.2	79.1	
Mean				2.70	150.4	60.8	
Standard Deviation				0.09	42.7	10.5	

[1] Failure partially along sub-horizontal shaly parting
[2] LVDTs removed prior to rupture to avoid damage
[3] Failure partially along sub-vertical healed feature
[4] Specimen had visibly high porosity
[5] Specimen length:diameter $<$ 2:1 due to core breakage during preparation

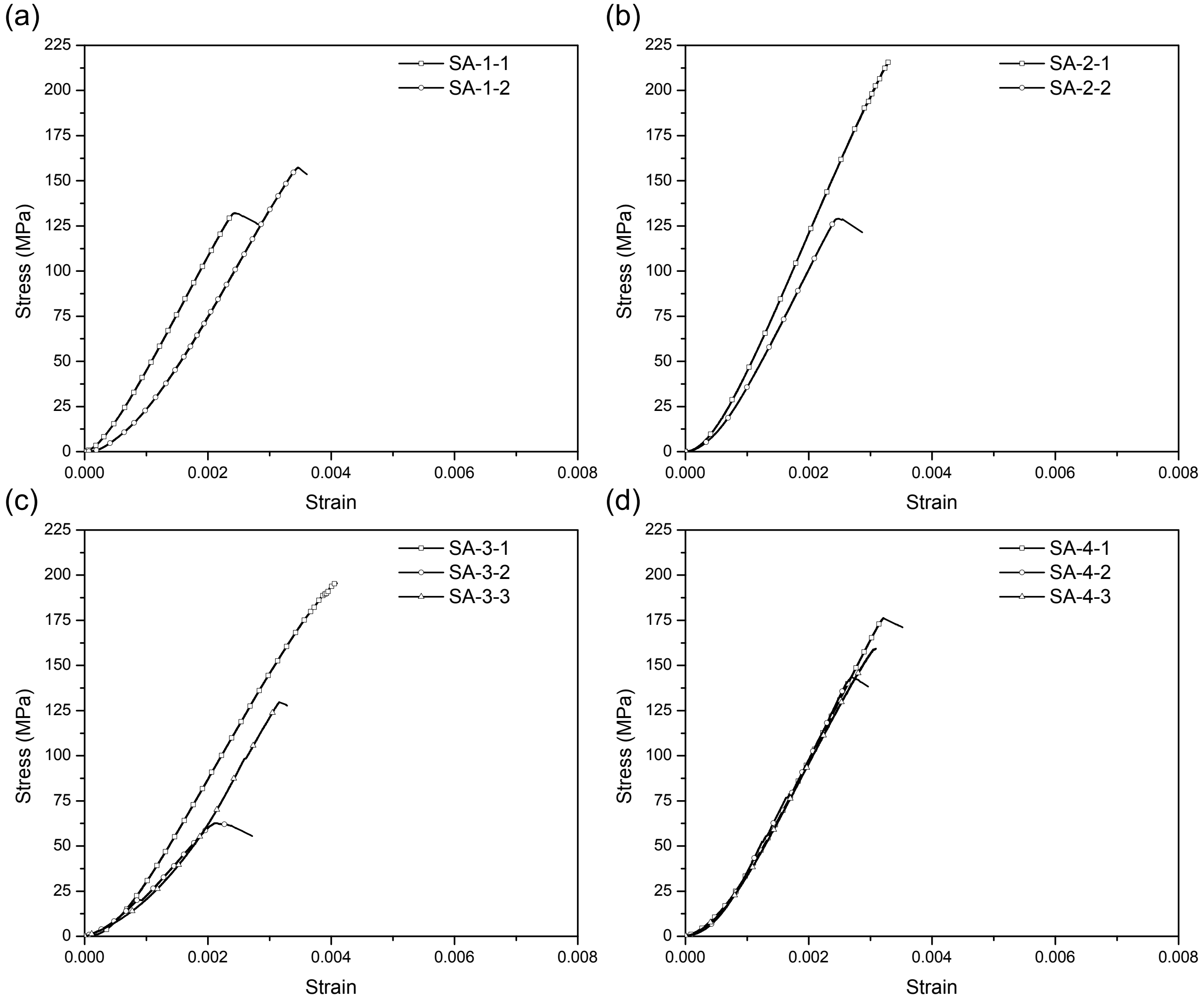


Figure 2: Measured stress-strain curves for samples from different boreholes.

Figure 3: Photographs of test specimens before testing (top) and after testing (bottom).

Figure 4: Photographs of test specimens before testing (top) and after testing (bottom).

Figure 5: Photographs of test specimens before testing (top) and after testing (bottom).

APPENDIX E

Extract from AMEC 2006

GEOTECHNICAL INVESTIGATION
‘THE RESIDENCES AT RIVER ROAD’
5471/5491/5507 RIVER ROAD
NIAGARA FALLS, ONTARIO

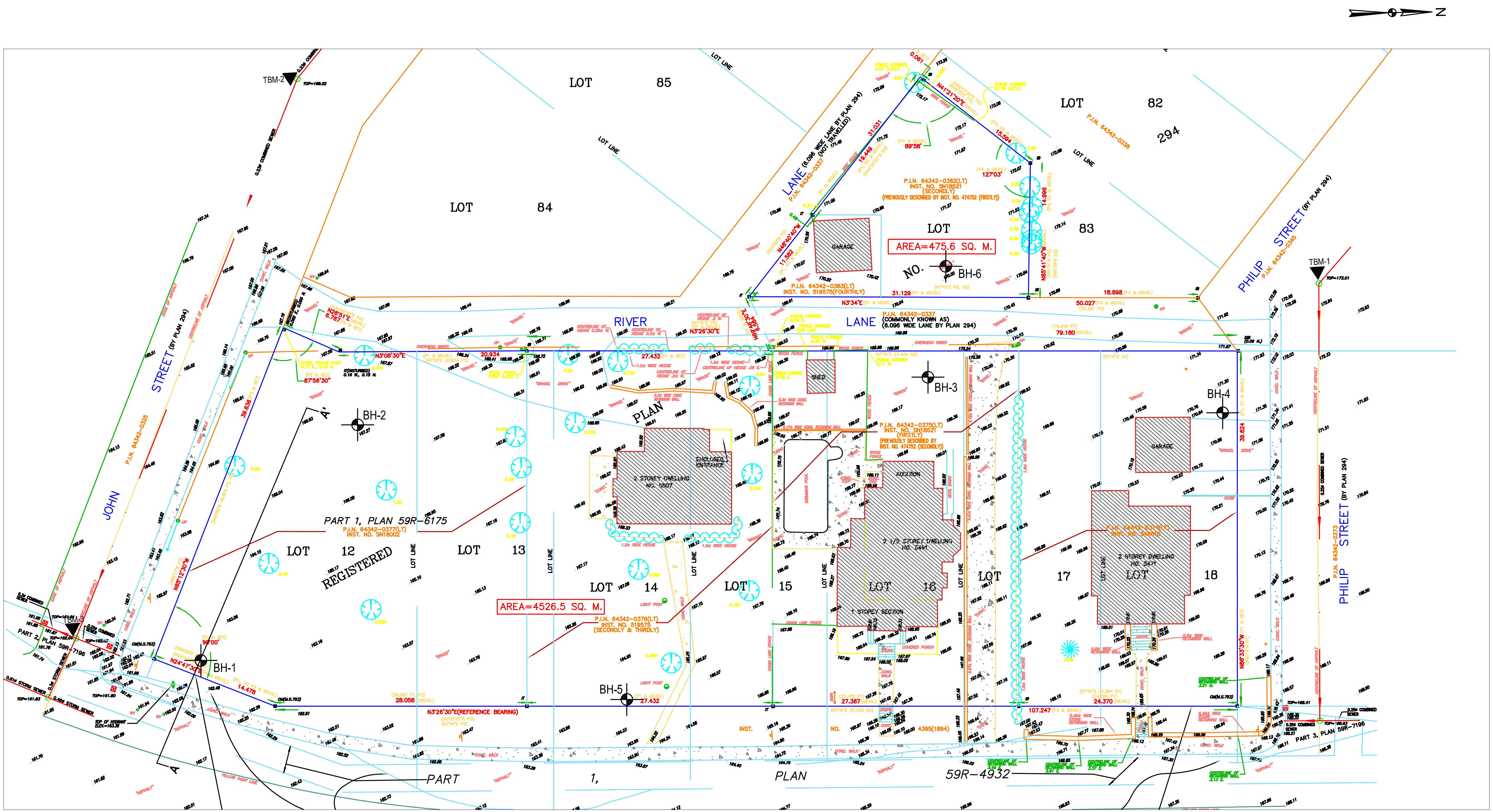
Submitted To:

Mr. J. Marc Baronette
O.R.E. Development Corporation
6755 Mississauga Road
Ontario L5N 7Y2

Submitted by:

AMEC Earth & Environmental
A Division of AMEC Americas Limited
3300 Merrittville Hwy., Unit #5
Thorold, Ontario
L2V 4Y6

January 2006
TG53110



LEGEND

BH-1 Borehole 1 (drilled on January 2006)

TBM-1 Temporary Bench Mark 1

NOTES: EXCERPT FROM DRAWING BY MATTHEWS, CAMERON, HEYWOOD - KERRY
T. HOWE SURVEYING LIMITED.
TITLE - "REGISTERED PLAN NO. 294, CITY OF NIAGARA FALLS", FILE: 05-31
DRAWN BY: AC
DECEMBER 20, 2005.

amec Earth & Environmental

O.R.E. Development Corp.
5471 - 5507 River Road
Niagara Falls, Ontario

Date: January, 2006

Approximate Scale: 1 : 500

Project No.: TG53110

Revised by: KS

Approved by: AL

Page A-3

Borehole Location Plan

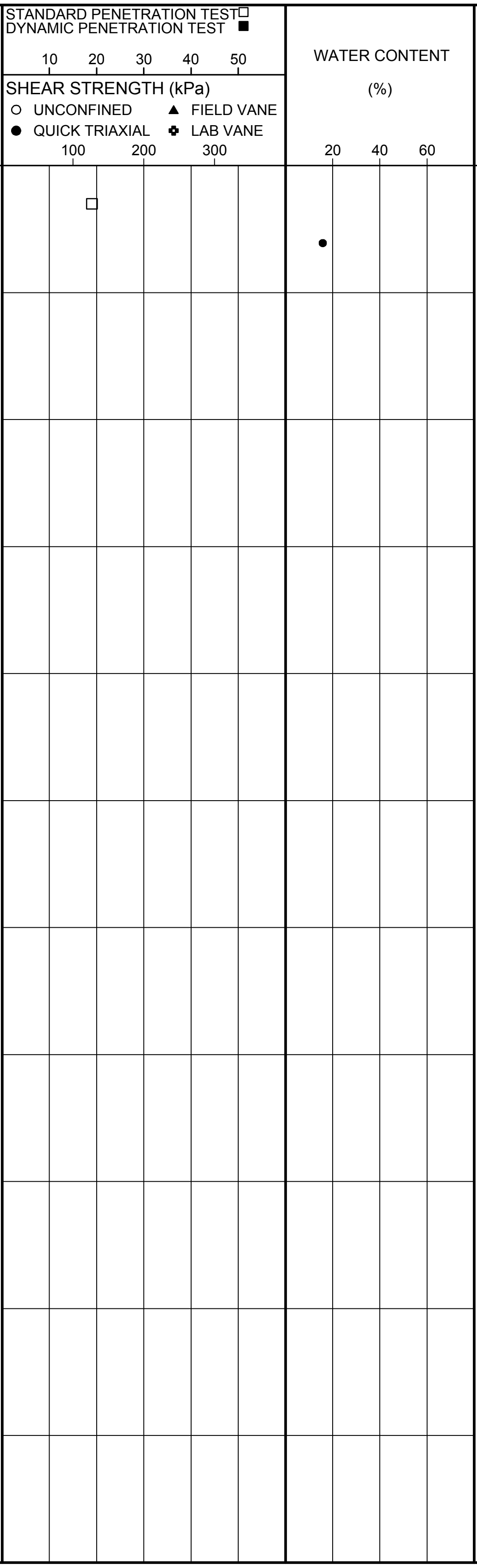
RECORD OF BOREHOLE No 1

1 OF 2

PROJECT Geotechnical Investigation - The Residence
LOCATION (see borehole location plan)
ORIGINATED BY ma
CLIENT O.R.E. Development Corp.
COMPILED BY ma
JOB NO. TG53110
DATE Jan. 5/2006
CHECKED BY al

ELEV DEPTH	SOIL PROFILE DESCRIPTION	DEPTH (m)
162.7 0.0	80 mm **TOPSOIL** over 50 mm **CRUSHED LIMESTONE** over 150 mm dark brown **SILTY SAND**, some organics, compact, moist, over brown **SAND WITH GRAVEL FILL**	
162.0 0.7	**LOCKPORT FORMATION - GOAT ISLAND MEMBER**, light blue grey, fine grained **DOLOSTONE**, medium bedded, few stylolites, 1.07 m to 1.12 m soft chert, <5% light grey chert nodules, 1.73 m to 1.83 m chert, calcite, sphalerite. Below the depth of 2.0 m, changing to Medium blue grey, fine grained, semi-crystalline, becoming medium grained with depth, medium to thick bedded, few stylolites, few fossiliferous zones, well developed calcite crystals in vugs, few shaley partings, calcite, <5% light grey chert layers	1 2 3 4 5 6 7 8 9
153.3 9.4	**LOCKPORT FORMATION - GASPORT MEMBER**, medium blue grey, fine to medium grained, semi-crystalline **DOLOSTONE**, thin to	10

SAMPLES NUMBER	TYPE	"N" VALUES	OBSERVATIONS & REMARKS
1	SS	19	TCR=Total Core Recovery; RQD=Rock Quality Designation
2	CORE		TCR = 98 %; RQD = 80% -steady grinding @ 0.6 m -good water return to 1.0 m -slow return @ 2.1 m
3	CORE		TCR = 100%; RQD = 100% -slow water return to 4 m, then no return to 4.8 m
4	CORE		TCR = 100%; RQD = 96%
5	CORE		TCR = 100%; RQD = 98% -small water return
6	CORE		TCR = 100%; RQD = 82% -splashing
7	CORE		TCR = 100%; RQD = 88% -slow water return
8	CORE		TCR = 90%; RQD = 56% -no water return



Continued Next Page

RECORD OF BOREHOLE No 1

2 OF 2

PROJECT Geotechnical Investigation - The Residence

LOCATION (see borehole location plan)

ORIGINATED BY ma

CLIENT O.R.E. Development Corp.

COMPILED BY ma

JOB NO. TG53110

DATE Jan. 5/2006

CHECKED BY al

SOIL PROFILE			SAMPLES							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	DEPTH (m)	STANDARD PENETRATION TEST ☐ DYNAMIC PENETRATION TEST ■ 10 20 30 40 50 SHEAR STRENGTH (kPa) ○ UNCONFINED ▲ FIELD VANE ● QUICK TRIAXIAL ✥ LAB VANE 100 200 300	WATER CONTENT (%) 20 40 60	OBSERVATIONS & REMARKS
	medium bedded, few small (2 - 10 mm) calcite lined vugs, few large fossiliferous zones, some shaley partings, dark grey shaley zones 9.42 m and 12.12 m, <5% chert content		9	CORE			12			TCR = 97%; RQD = 63% -no water return
			10	CORE			13			TCR = 98%; RQD = 75% -small water return below 13 m depth
							14			TCR = 98%; RQD = 73%
			11	CORE			15			
			12	CORE			16			TCR = 100%; RQD = 60%
145.6 17.1	**LOCKPORT FORMATION - DECEW MEMBER**, dark grey, fine-grained **DOLOSTONE**, medium bedded, few shaley partings, few stylolites, few gypsum nodules, 1 large (> 50 mm) at 20.07 m						17			TCR = 98%; RQD = 95%
			13	CORE			18			
			14	CORE			19			TCR = 100%; RQD = 69%
							20			
142.2 20.5	**BOREHOLE TERMINATED**									

RECORD OF BOREHOLE No 2

1 OF 1

PROJECT Geotechnical Investigation - The Residence

LOCATION (see borehole location plan)

ORIGINATED BY ma

CLIENT O.R.E. Development Corp.

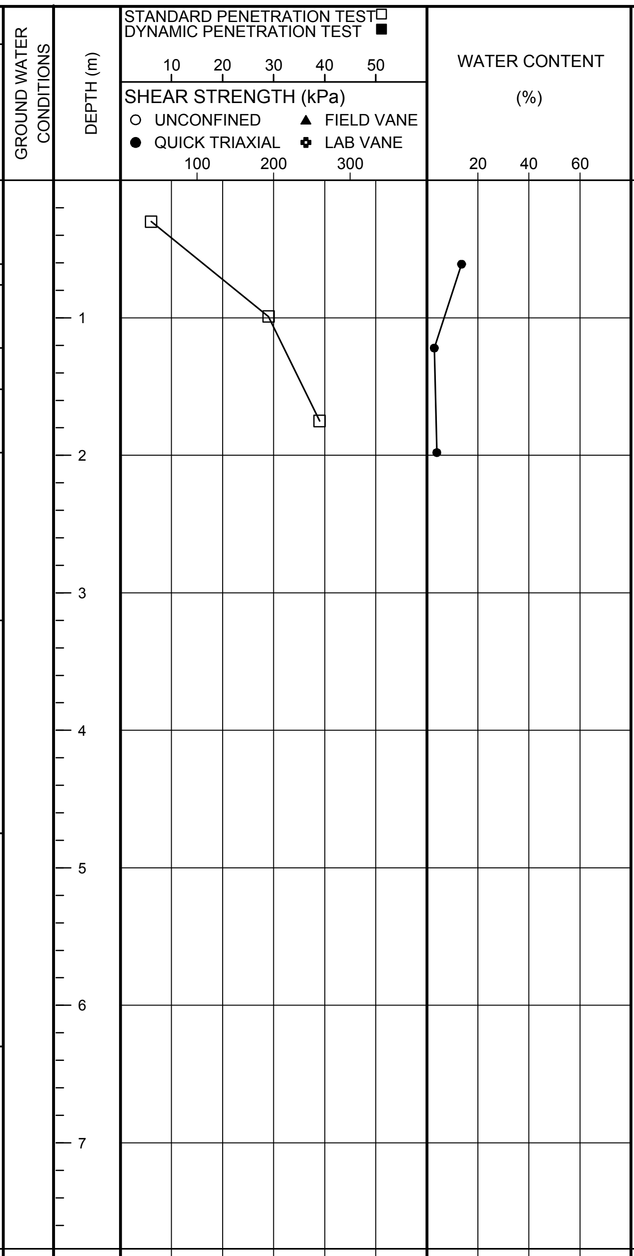
COMPILED BY ma

JOB NO. TG53110

DATE Jan. 6/2006

CHECKED BY al

SOIL PROFILE		SAMPLES			OBSERVATIONS & REMARKS
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	
167.4 0.0	Dark brown **SILTY SAND FILL**, organics, brick piece, loose, moist	1	SS	6	TCR=Total Core Recovery; RQD=Rock Quality Designation
166.8 0.6	Brown **SILTY SAND**, mottled, medium to coarse grained, some gravel, some organics, compact, (PROBABLE FILL)	2 3	SS SS	29 39	
164.7 2.7	**GRAVEL**, loose, broken rock pieces with some Sand infill				
164.2 3.2	**LOCKPORT FORMATION - ERAMOSA MEMBER**, medium grey, fine to medium grained **DOLOSTONE**, thin to medium bedded, calcite present, some alteration to sphalerite, some shaley partings, some weathered partings, <5% chert Below the depth of 7.0 m, changing to medium blue grey, medium to coarse grained, crystalline , few fine stylolites, calcite present, <5% chert	4 5 6	CORE CORE CORE		TCR = 100%; RQD = 50% TCR = 100%; RQD = 93% TCR = 100%; RQD = 100%
159.7 7.8	**BOREHOLE TERMINATED**				

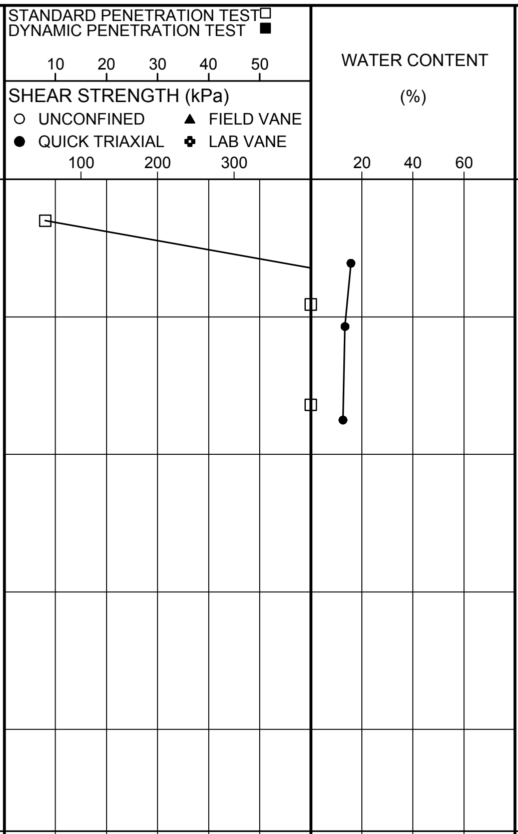


RECORD OF BOREHOLE No 3

1 OF 1

PROJECT Geotechnical Investigation - The Residence
LOCATION (see borehole location plan)
ORIGINATED BY ma
CLIENT O.R.E. Development Corp.
COMPILED BY ma
JOB NO. TG53110
DATE Jan. 6/2006
CHECKED BY al

SOIL PROFILE			SAMPLES					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	DEPTH (m)	OBSERVATIONS & REMARKS
169.9 0.0	Dark brown **SANDY SILT FILL**, organics, rootlets, some pebbles		1	SS	8			TCR=Total Core Recovery; RQD=Rock Quality Designation
169.7 0.2	Reddish brown **SILTY SAND TO SANDY SILT**, mottled, some pebbles, moist to wet, compact, (PROBABLE FILL)		2	SS	10 - 150 mm		1	
			3	SS	15 - 75 mm			
168.1 1.8	**LOCKPORT FORMATION - ERAMOSA MEMBER**, grey-brown, medium crystalline **DOLOSTONE**, medium bedded, calcite present, some alteration to sphalerite, few stylolites, vugs up to 25 mm, <5% chert		4	CORE			2 3	TCR = 100%; RQD = 100%
			5	CORE			4	TCR = 100%; RQD = 60%
165.2 4.7	**BOREHOLE TERMINATED**							

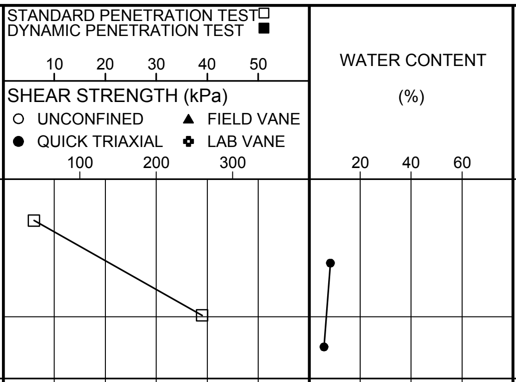


RECORD OF BOREHOLE No 4

1 OF 1

PROJECT Geotechnical Investigation - The Residence
LOCATION (see borehole location plan)
ORIGINATED BY ma
CLIENT O.R.E. Development Corp.
COMPILED BY ma
JOB NO. TG53110
DATE Jan. 9/2006
CHECKED BY al

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	"N" VALUES	GROUND WATER CONDITIONS	DEPTH (m)	OBSERVATIONS & REMARKS
171.1 0.0	Dark brown to black **SILTY SAND FILL**, organics, rootlets, burnt wood, loose	▨	1	SS	6			
170.5 0.6	Reddish brown **SILTY SAND AND GRAVEL**, mottled, some organic staining, dense, (PROBABLE FILL)		2	SS	39		1	
169.9 1.2	Reddish brown **SANDY SILT TILL**, (NATIVE), numerous pebbles, moist, compact							
169.7 1.5	**BOREHOLE TERMINATED DUE TO AUGER REFUSAL**							dry and open upon completion

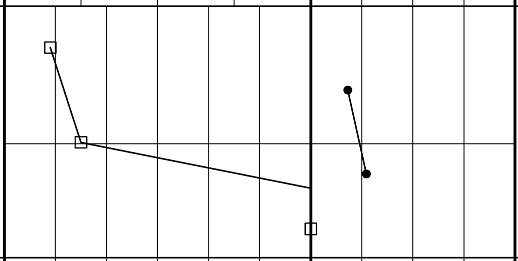


RECORD OF BOREHOLE No 5

1 OF 1

PROJECT Geotechnical Investigation - The Residence
LOCATION (see borehole location plan)
ORIGINATED BY ma
CLIENT O.R.E. Development Corp.
COMPILED BY ma
JOB NO. TG53110
DATE Jan. 9/2006
CHECKED BY al

SOIL PROFILE			SAMPLES					STANDARD PENETRATION TEST ☐ DYNAMIC PENETRATION TEST ■ 10 20 30 40 50 SHEAR STRENGTH (kPa) ○ UNCONFINED ▲ FIELD VANE ● QUICK TRIAXIAL ✚ LAB VANE 100 200 300	WATER CONTENT (%) 20 40 60	OBSERVATIONS & REMARKS
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	DEPTH (m)			
164.3 0.0	Dark brown **TOPSOIL**, peaty, organics, rootlets, moist		1	SS	9					
164.0 0.3	Brown to dark brown **GRAVELLY SAND**, some organics, moist, compact, (PROBABLE FILL)		2	SS	15		1			
			3	SS	15 - 50 mm					
162.5 1.8	**BOREHOLE TERMINATED DUE TO AUGER REFUSAL**									dry and open upon completion



A-8

RECORD OF BOREHOLE No 6

1 OF 1

PROJECT Geotechnical Investigation - The Residence
LOCATION (see borehole location plan)
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DATE Jan. 9/2006
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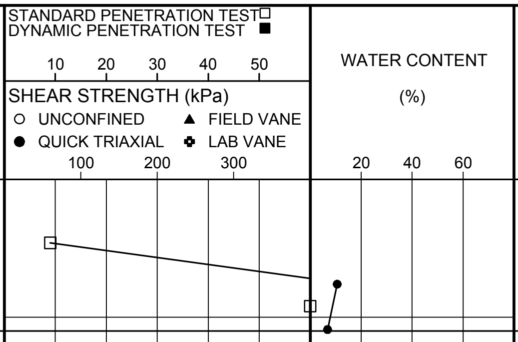
SOIL PROFILE			SAMPLES				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	DEPTH (m)
170.7							
170.5 0.0	**GRANULAR FILL**, crushed limestone						
0.2	Reddish brown **SILTY SAND**, some pebbles, (PROBABLE FILL)		1	SS	9		
170.0 0.7	Reddish brown **FINE GRAVELLY SAND/SILT**, moist, dense		2	SS	48 - 180 mm		1
169.6 1.1	**BOREHOLE TERMINATED DUE TO AUGER REFUSAL**						



OBSERVATIONS & REMARKS

dry and open upon completion

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

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