CARLETON UNIVERSITY PROPOSED RESIDENCE GEOTECHNICAL INVESTIGATION

CARLETON UNIVERSITY

GEOTECHNICAL REPORT

PROJECT NO.: 191-12948-00
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1 INTRODUCTION

1.1 CONTEXT

WSP Canada Inc. (WSP) was retained by Carleton University to conduct a Geotechnical Investigation for a proposed development at a property located within their Ottawa campus located at 1125 Colonel By Drive.

The purpose of the geotechnical investigation was to obtain subsurface information at the site by means of exploratory boreholes. This report presents the findings of the investigation and provides comments and recommendations which may affect the design and construction of the new residence.

1.2 PROJECT AND SITE DESCRIPTION

1.2.1 SITE DESCRIPTION

It is understood that Carleton University is planning to develop the Subject Site (the 'Site') with a multi-storey student residence. The Site is an irregular parcel of land with an area of approximately 1.2 hectares located immediately west of the intersection of Campus Avenue and University Drive, and is bordered to the south by the Stormont/Dundas House and to the west by the Leeds House. The Subject Site is currently occupied by landscaped areas, pedestrian pathways, roads and parking areas.

1.3 OBJECTIVES AND LIMITATIONS

The current report was prepared at the request and for the sole use of the Carleton University according to the specific terms of the mandate given to WSP. The use of this report by a third party, as well as any decision based upon this report, is under this party's sole responsibility. WSP may not be held accountable for any possible damages resulting from third party decisions based on this report.

The scope of this report is the geotechnical aspects of the project. A Phase I and Phase II environmental site assessment have been carried out by WSP and submitted under a separate cover.

Furthermore, any opinions regarding conformity with laws and regulations expressed in this report are technical in nature; the report is not and shall not, in any case, be considered as a legal opinion.

Information in this report is only valid for the boreholes locations as described.

Reference should be made to the Limitations of this Report, attached in Appendix D, which follows the text but forms an integral part of this document.

2 SITE INVESTIGATION

2.1 SCOPE OF WORK

The geotechnical scope of work for this assignment included:

- A desktop study and review of existing geotechnical information in the general area;
- Laying out the boreholes and obtaining utility locates at the project site;
- Drilling exploratory boreholes at the Site;
- In-situ soil sampling and testing, including Standard Penetration Testing (SPT), Dynamic Cone Penetration Testing (DCPT) and rock coring;
- Obtaining soil and rock samples for additional review and laboratory testing;
- Laboratory testing;
- Geotechnical analysis; and
- Preparation of this report which presents the results of the investigation and provides geotechnical recommendations related to the design and construction of the proposed development.

2.2 INVESTIGATION PROCEDURES

WSP carried out the geotechnical investigations the week of October 20th, 2019.

2.2.1 DESKTOP STUDY

Published surficial geology maps indicate the area is underlain by clay, silty clay and silt (often referred to as Champlain Sea clay or Leda Clay) as well as organic deposits (muck and peat in bogs, fens, swamps and poorly drained areas). Bedrock geology includes limestone and shale of the Ottawa Formation.

Several previous geotechnical reports and construction documents related to the general area were also provided to WSP by the University. These reports include:

McROSTIE, GENEST, ST-LOUIS (Golder), 1989 – Report on design stage for the proposed student residences at the university commons building – Carleton University. this report discussing the foundations recommendations for the Stormont Dundas residence.

John D. Patterson and Associates Limited, 2000 – Geotechnical Investigation – Proposed Student Residence. This was the geotechnical report for the Leeds residence.

Sauve Boucher Associated Inc., Student Residence – Construction plans for building plans for the Leeds residence.

2.2.2 FIELD INVESTIGATION

WSP carried out a geotechnical investigation at Carleton University the week of October 20th, 2019. The investigation consisted of drilling 12 boreholes at the Site.

The boreholes were advanced using truck and track-mounted drill rig supplied and operated by Marathon Drilling Ltd. and CCC Geotechnical Drilling (CCC), both of Ottawa, ON. The boreholes were advanced using hollow-stem augers to depths ranging from of 1.5 m to 12.6 m below the existing ground surface. With the exception of boreholes BH19-012 and BH19-013, all the boreholes were drilled to the depth of auger, DCPT or SPT sampler refusal. Soil samples retrieved during drilling were logged and visually classified in the field by a member of WSP's geotechnical staff. In-situ tests including Standard

Penetration Testing (SPT). Three boreholes were extended past the depth of auger refusal into the underlying bedrock using rock coring techniques and rock samples were retrieved during drilling. These samples were then logged and visually classified in the field by a member of WSP's geotechnical staff.

Borehole BH19-03 was eliminated from the testing program due to a potential utility conflict. Borehole BH19-011, originally scheduled to be drilled to a depth of 7.6 m below the existing ground surface was extended to the depth of auger refusal in order to gain the missing information.

The boreholes locations are shown on Drawing No. 2 in Appendix A. Carleton University has carried out a geodetic survey and has provided elevations for all the boreholes drilled at the site with the exception of borehole BH19-08.

2.2.3 LABORATORY TESTING

Upon completion of drilling and in-situ testing, soil samples were returned to WSP's laboratory for further examination, classification and testing. A laboratory testing program, which was carried out on selected representative soil samples, included the determination of natural water content, grain size distribution and chemical analyses of soil. Unconfined compressive strength (UCS) and unit weights for rock cores were conduced as well.

The results of natural water content tests are included on the relevant borehole logs in Appendix B. The results of determination of grain size distribution and UCS results are summarized on the individual borehole logs and are presented in Appendix C.

3 SUBSURFACE GEOTECHNICAL CONDITIONS

The subsurface conditions encountered within the boreholes at the site are discussed in the following sections. Detailed descriptions of the soil and groundwater conditions encountered at each of the borehole locations are included in the individual borehole logs in Appendix B.

3.1 SOIL CONDITIONS

The following provides a general description of the major soil types encountered during the current geotechnical investigation. It should be noted that the following discussion includes some simplifications for the purposes of discussing broadly similar soil strata. It should also be noted that the differences in soil types and changes between various soil strata are often gradational, as opposed to precise boundaries of geological change.

A detailed description of the soil stratigraphy encountered at each borehole location is shown on the borehole log sheets shown in **Appendix B**. Please note that the factual descriptions shown in each borehole log take precedence over the generalized (and simplified) descriptions presented below. Also, it is merit to consider the fact that boreholes findings represent the very location of these holes and not necessarily mean it represents the soil formation in the surrounding area.

3.1.1 TOPSOIL

A minor amount of topsoil and organic material was found at the ground surface in boreholes BH19-05 through BH19-010 which were advanced in grass covered areas.

3.1.2 PAVEMENT STRUCTURE

Asphaltic concrete was encountered in boreholes BH19-01, BH19-02, BH19-04 drilled on the pathway and the adjacent parking lot/access roads. The thickness of the asphalt ranged from 38 mm to 80 mm.

Boreholes BH19-011, BH19-012 and BH19-013 were drilled on Campus Drive and a layer of asphaltic concrete was encountered ranging in thickness from 30 mm to 100 mm. In boreholes BH19-011 and BH19-012 underlying the asphaltic concrete, a layer of granular road base consisting of sand with varying amounts of gravel was encounter. This layer extended to depths of 600 mm and 550 mm below the existing ground surface in boreholes BH19-011 and BH19-012, respectively. In borehole BH19-013, a layer of concrete approximately 200 m in thickness was encountered underlying the asphaltic concrete.

3.1.3 GRANULAR FILL

A layer of fill was encountered underlying the pavement structure or the topsoil in all the boreholes drilled at the site. This fill extended to depths ranging from 1.4 m to 6.9 m below the existing ground surface. The fill is variable in nature but generally consists of sand with varying amounts of gravel and of silt.

The SPT “N” values within the granular fill ranged from 5 blows per 305 mm of penetration to more than 50 blows for 75 mm of penetration indicating a loose to very dense state of packing. It should be noted that higher SPT ‘N’ values may indicate the presence of cobbles or boulders with the fill rather than the consistency of the soil matrix.

The grain size distribution of selected sample of the fill are presented in Appendix C. A summary of these grain size distributions is also presented in the table below.

Table 3.1 Results of Grain Size Analyses for Fill

Borehole No.	Sample No.	Grain Size Distribution		
		% Gravel	% Sand	% Fines
BH19-01	SS1	29	47	24
BH19-02	AS1	56	35	9
BH19-06	SS2	26	57	17
BH19-09	SS2	21	65	14
BH19-09	SS5	38	48	14

The measured water content of selected samples of the granular fill were determined to range from 3 to 11 percent.

3.1.4 SILTY CLAY

Underlying the granular fill in boreholes BH19-01 thru BH19-05, BH19-07 and BH19-08 a layer of silty clay is present. This layer of silty clay contains both gravel and organic deposits. This layer extends to depths ranging from 2.6 m to 4.6 m below the existing ground surface.

The SPT "N" values within the silty clay ranged from 1 blow to 8 blows to per 305 mm of penetration indicating a very soft to firm consistency.

The measured water content of one selected sample of the silty clay was determined to be 41 percent.

3.1.5 SAND AND GRAVEL WITH COBBLES/BOULDERS

Underlying the silty clay in boreholes BH19-01 thru BH19-05, BH19-07 and BH19-08 a layer of native sand and gravel was encountered. Based on the SPT blow counts and the fragments of rock recovered during sampling, it has been inferred that this layer also contains cobbles and or boulders. This layer extends to depths ranging from 5.3 m to 7.6 m in depth.

The SPT "N" values within the granular fill ranged from 9 blows to per 305 mm of penetration to more than 50 blows for 75 mm of penetration indicating a loose to very dense state of packing. However, as previously stated, the higher SPT 'N' values likely indicate the presence of cobbles or boulders with layer the rather than the consistency of the soil matrix.

3.1.6 GLACIAL TILL

Underlying the granular fill or native sand and gravel layer is a layer of glacial till which extended to the depth of auger/ DCPT/SPT refusal in all boreholes, save boreholes BH19-012 and BH19-013 which were terminated prior to the depth of refusal. The till is a heterogeneous mixture of clay, silt, sand and gravel with cobbles and boulders. The majority of the till would be described as silty sand, but some zones of gravel were also encountered. Cobbles and boulders are typical within this deposit and should be anticipated during construction.

The SPT "N" values within the glacial ranged from 1 blow to per 305 mm of penetration to more than 50 blows for 50 mm of penetration indicating a loose to very dense state of packing. It should be noted that the higher SPT 'N' values likely indicate the presence of cobbles or boulders with the glacial till (and are expected to be within this layer) rather than the consistency of the soil matrix.

The grain size distribution of selected sample of the glacial till are presented in Appendix C. A summary of these grain size distributions is also presented in the table below.

Table 3.2 Results of Grain Size Analyses for Glacial Till

Borehole No.	Sample No.	Grain Size Distribution		
		% Gravel	% Sand	% Fines
BH19-01	SS9	21	61	18
BH19-05	SS9	25	49	56
BH19-09	SS7	19	58	23

The measured water content of selected samples of the glacial till were determined to range from 7 and 9 percent.

3.1.7 AUGER REFUSAL AND BEDROCK

With the exception of boreholes BH19-012 and BH19-013, all boreholes were drilled to the depth of auger, DCPT, or SPT refusal. The depth of the refusal ranged from 7.6 m to 12.6 m below the existing ground surface. This refusal may represent the bedrock surface, or cobbles/boulders within the layer of glacial till.

Boreholes BH19-02, BH19-07 and BH19-08 were extended past the depth of refusal and the presence of bedrock was confirmed through coring. In boreholes BH19-02 and BH19-07 shale was encountered underlying the depth of refusal. In borehole BH19-02 this shale is highly fractured until approximately 15.4 m in depth and extended to a depth of 17.8 m. In borehole BH19-07 the shale extended to a depth of 15.4 m and contained clay seams. Underlying the shale in boreholes BH19-02 and BH19-07 and the depth of refusal in boreholes BH19-08 limestone with shale partings was encountered. This limestone was weathered to a depth of 17.0 m and 13.9 m in boreholes BH19-07 and BH19-08, respectively. The RQD values within the weathered limestone ranged from 0% to 41% indicating very poor to poor quality. Underlying the shale in borehole BH19-02 and the weathered limestone in boreholes BH19-07 and BH19-08 fresh limestone was encountered. The RQD values within the fresh limestone ranged from 95% to 100% indicating a rock quality designation of excellent.

The laboratory test results on selected core samples of the bedrock indicate bedrock compressive strengths ranging from 54 MPa to 68 MPa. The results of this testing are summarized on the individual borehole logs and are presented in the table below.

Table 3.3 Results of Intact Rock Strength

Borehole No.	Depth (m)	Unit Weight (kg/m3)	Unconfined Compressive strength (MPa)
BH19-02	16.2	2585	54
BH19-07	17.5	2615	66
BH19-08	14.1	2586	68

3.2 GROUNDWATER CONDITIONS

Standpipe piezometers were installed in boreholes BH19-04, BH19-06, and BH19-010. Groundwater levels were measured in November 2019 and were found to be at depth ranging from 4.5 m to 6.7 m below the existing ground surface in the general area. This corresponds to elevations which range from 59.5 m to 60.2 m in elevation. It should be noted that water levels vary seasonably and are expected to be higher during the spring period.

Table 3.4 Groundwater Levels

Borehole No.	Groundwater Level (m) (Elev. m)
BH19-04	4.5 (60.2)
BH19-06	6.7 (59.7)
BH19-010	5.9 (59.5)

The piezometers have been left in place and should be properly decommissioned by others during construction. It should be noted that groundwater levels can vary and are subject to seasonal fluctuations as well as fluctuations in response to major weather events.

3.3 SUMMARY

The following table provides an overview of the soil strata encountered at each of the borehole locations. Minor simplifications have been made at some locations to create these simplified soil profiles, for example the upper layer of fill also includes the pavement structure.

Table 3.5 Simplified Soil and Rock Conditions

Borehole No. (Elev. m)	Subsurface Conditions (m)					Auger Refusal (m)	Bedrock Depth (m)
	Topsoil	Granular Fill (Inc. pavement)	Silty Clay	Sand and Gravel	Glacial Till		
BH19-01 (65.5)	--	0 – 2.3	2.3 – 3.8	3.6 - 6.1	6.1 - 10.5	10.5	--
BH19-02 (65.6)	--	0 – 3.1	3.1 – 4.6	4.6 - 6.9	6.9 - 11.4	14.1*	11.4 - 18.0
BH19-04 (64.7)	--	0 – 1.4	1.4 – 2.9	2.9 - 5.9	5.9 - 7.6	7.6	--
BH19-05 (64.5)	0 - 0.2	0.2 - 2.3	2.3 – 3.1	3.1 - 5.3	5.3 - 11.3	11.3	--
BH19-06 (66.4)	0 - 0.125	0.125 - 6.1			6.1 - 11.1	11.1	--
BH19-07 (64.3)	0 - 0.15	0.15 – 2.6	2.6 – 3.1	3.1 - 5.3	5.3 - 11.8	11.8	11.8 – 18.6
BH19-08 (n/a)	0 - 0.175	0.175 – 2.3	2.3 – 2.6	2.6 - 7.6	7.6 - 10.7	10.7	10.7 - 15.5
BH19-09 (63.9)	0 - 0.2	0.2 - 4.6			4.6 - 12.6	12.6	--
BH19-010 (65.4)	0 - 0.15	0.15 – 6.9			6.9 - 12.6	12.6	--
BH19-011 (65.3)	--	0 - 3.8			3.8 - 12.6	12.6	--
BH19-012 (64.9)	--	0 - 1.5			--	--	--
BH19-013 (64.4)	--	0 - 6.1			6.1 - 8.2	--	--

* Shale bedrock was encountered at 11.4 m in depth which the auger was able to penetrate.

4 RECOMMENDATIONS

4.1 GENERAL

This section of the report provides an engineering guidance related to the geotechnical design aspects of the project based on our interpretation of the available information described herein and project requirements. Contractors bidding on or undertaking the works 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, safety, and equipment capabilities. Reference should be made to the Limitations of this Report, attached in Appendix D, which follows the text but forms an integral part of this document.

The general subsurface conditions encountered in the boreholes at Carleton University consists of fill overlying a layer of glacial till. Lying between these layers in about half of the boreholes a layer of silty clay which in turn was underlain by sand and gravel with cobbles/boulders also encountered. The glacial till extended to the depth of refusal (auger/SPT/DCPT) between 7.6 m to 12.6 m below the existing ground surface. This refusal may represent either boulders/cobbles within the glacial till or the bedrock surface. In three boreholes the presence of bedrock was confirmed through coring at depths which ranged from 10.7 m to 11.8 m below the existing ground surface.

4.2 SEISMIC SITE CLASSIFICATION

Multichannel analysis of surface waves (MASW) has been carried out on site. The aim of MASW testing is to evaluate the shear wave velocities of subsurface materials through the analysis of the dispersion properties of Rayleigh surface waves ("ground roll"). The dispersion properties are measured as a change in phase velocity with frequency. Surface wave energy will decay exponentially with depth. Lower frequency surface waves will travel deeper and thus be more influenced by deeper velocity layering than the shallow higher frequency waves. The results of the MASW are pending and will be included in a revised version of this report. The liquification analysis will be reported as well following the MASW results.

4.3 SITE GRADING AND PREPARATIONS

It is assumed that the ground floor of the new residence building will be at an elevation similar to the existing parking lots, and that there would not be any significant change to the overall site grading.

The site is underlain expected to be underlain by 3 m to 7 m of fill, some of which would have the potential to settle under the weight of any additional fill. Any raising of the grade would have the potential to cause additional settlement which may impact the performance of both new and any existing structures (such as utilities in the area). Details of any proposed grade changes should be reviewed during detailed design and WSP can provide additional guidance based on actual site grades, location of the fills, etc.

4.4 FOUNDATIONS

At this point in the design process, it is understood that consideration is being given to both deep and shallow foundations. The fill material and silty clay are not suitable for as a founding layer for foundations.

4.4.1 SHALLOW FOUNDATIONS

It is understood that a basement is proposed for the new residence and it is expected that a basement would extend to a minimum depth of 3.0 m below the existing ground level. Shallow foundations would need to extend to a minimum depth of the native sand and gravel or glacial till.

4.4.2 SPREAD FOOTINGS

For shallow strip footings founded on native undisturbed glacial till or sand and gravel (or engineered fill if over-excavation is required):

- The unfactored ultimate geotechnical bearing resistance for a footing with a minimum width of 1 m may be taken as 350 kPa. A resistance factor of 0.5 should be applied to this value for a factored ultimate bearing resistance of 175 kPa at Ultimate Limit States (ULS).
- The geotechnical resistance at Serviceability Limit State (SLS) may be taken as 150 kPa.

Provided that the subgrade is not disturbed during construction the total and differential settlements associated with the SLS resistance values are expected to be less than 25 mm and 20 mm, respectively. Considering the variation in the subsurface condition across the boreholes, the strip or spread footings may be founded on various soil conditions. This situation would cause unfavorable differential settlements.

4.4.3 RAFT FOUNDATIONS

A raft foundation founded on the native sand and gravel or glacial till could also be considered for the proposed building as the building has a basement.

The design of a raft foundations is not typically governed by overall bearing capacity (assuming the raft is stiff enough to act as a single large foundation) but by the stiffness and settlement characteristics of the raft. In determining the settlements and deflections of a raft foundation under loading the modulus of subgrade reaction is commonly used to represent the vertical stiffness of the soil below the foundation.

The modulus of vertical subgrade reaction for a foundation on soil is defined as follows:

$$\mathbf{k_{v1} = q/\delta}$$

where

k = the modulus of subgrade reaction

q = the applied bearing pressure

δ = the settlement of the foundation under the applied pressure

For the type of sand below the water table (which is present at the site below the likely founding elevation) the modulus of subgrade reaction (k_{v1}) may be assumed to be 40 MPa/m for preliminary design. There are usually an iteration process between the strucral engineer contact stresses distribution and the geotechnical modulus of subgrade reaction, until these iterations approach.

The modulus of subgrade reaction is not a fundamental soil property, but is dependent upon the loaded area of the footing, as well as the distribution of the load within that area. The value of k_{v1} is based on a 300 mm by 300 mm loaded area (which is used as a standard basis for comparison). For loaded areas larger than this the effective modulus is determined as follows:

$$kvb = kv1\left[\frac{b+0.3}{2b}\right]^2$$

The above values may be used for preliminary design to evaluate the feasibility of a raft foundation. The actual deflection and settlement of a raft foundation, however, is a complex problem depending upon the size and loading of the raft, the soil and groundwater conditions below the raft and the strength and stiffness characteristics of the raft itself. Design of a raft foundation typically requires interaction between the structural and geotechnical engineers during detailed design.

It should be noted that based on the encountered site conditions, it is likely that a raft foundation will be sitting on both glacial till and sand and gravel and these varying conditions could lead to unfavorable differential settlement. This would require the raft to be overdesigned in order to withstand any excessive differential settlements.

4.4.4 CONSTRUCTION CONSIDERATIONS

All foundation excavations should be inspected by WSP prior to placing engineered fill or concrete to confirm that the intended bearing surfaces are as anticipated during the design. Soft or disturbed soils encountered at founding levels should be over-excavated and replaced with approved, compacted, engineered fill (or the foundation placed at a lower elevation).

Loose and disturbed material should be removed from the foundation area and the subgrade should not be allowed to freeze or to pond water. The soils at the site are expected to be susceptible to disturbance and have poor trafficability, particularly where foundations are located near or below the water table. Care should be taken to avoid disturbance during construction, as this will reduce the bearing resistance of the soils and would necessitate removal and replacement of disturbed soils.

If shallow foundations are used it is recommended that an allowance be included for the installation of a mud slab to protect bearing surfaces during construction (particularly for a raft foundation).

Construction of shallow foundations (and a basement) would require excavation and disposal of soil and potentially groundwater, which may have environmental impacts that would affect disposal options and costs.

4.4.5 DEEP FOUNDATIONS

The deep fill, be it granular or silty clay, which is present to a depth of 3 m to 7 m (or deeper in some cases) is not suitable for founding large structures. The most cost-effective type of pile is likely to be driven steel pipe piles. Drilled cast-in-place concrete piles are technically feasible, and would be able to generate high capacities in the native soils and rock. However, the difficulties associated with the drilling conditions and the need to dispose of cuttings and water which may have environmental impacts will likely mean they are not the most economical choice for piles. Steel H-piles are not recommended due to the boulders or cobbles within the sand and gravel layer and within the glacial till. However, this option could still be discussed with the piling contractor.

COMPRESSIVE RESISTANCE

Steel pipe piles should be driven to rock which was encountered approximately 7.6 m to 12.2 m below the existing ground surface in the proposed development area.

Piles driven to rock typically generate high ultimate geotechnical capacities, generally equal to or in excess of the structural capacity of the steel section. For the purposes of design, the ultimate geotechnical resistance may be assumed to be equal to the ultimate structural resistance of the steel section. A resistance factor of 0.4 should be applied this value to obtain the factored geotechnical resistance of a pile driven to rock.

The pile termination criteria will be mainly dependent upon the pile driving hammer, selected pile cross section, and length of pile. It is important to make sure that piles are not overdriven as this would cause damage to the toe of the pipe piles. Piles are expected to finally sit on sound rock to achieve the required end bearing capacity.

The piles may end up sitting on shale rock, this kind of rock may require restriking the piles. This happens because of the possible softening in the top weathered shale material, pore pressure dissipation in areas containing silty Clay. Usually the restrikning of piles happens with 2 to 3 days from the pile driving. It is recommended that dynamic capacity testing (PDA testing) be conducted at the beginning of the piling operation to verify the load carrying capacity of the piles, a resistance factor of 0.5 to be applied to the results of the PDA test. The main purpose of the test is to confirm that the required geotechnical resistance is achieved. At least, 10% of the piles would require testing to confirm the proper capacity especially with the variations in the refusal depths of the drilled boreholes. Settlements for piles driven to rock are generally negligible, and the geotechnical resistance mobilized at 25 mm of settlement (SLS) would normally exceed the factored axial resistance at ULS. Geotechnical SLS considerations therefore do not generally govern the design of piles driven to rock.

UPLIFT RESISTANCE

The uplift resistance of a pile will be as a result of skin friction acting along the surface area of the embedded pile.

The unfactored shaft resistance (q_s) is equal to:

$$q_s = \beta\sigma_v' = \beta(\gamma' h)$$

where: q_s = the unfactored shaft resistance (in kPa)

β = the shaft resistance factor based on pile and soil type (use 0.6)

σ_v' = the effective stress at a given depth equal to $\gamma' h$

γ' = the effective soil unit weight at a given depth (use 18 kN/m^3 above the water table and 8.2 kN/m^3 below the water table.

h = the depth below the (final) ground surface

The above calculation can be performed for any pile shapes/sizes[1].

A resistance factor of 0.3 should be applied to this value, to obtain the factored geotechnical uplift resistance. The dead weight of the pile itself (with an appropriate structural resistance factor for dead weight) may also be added to the geotechnical resistance in calculating the total uplift resistance.

The total uplift resistance of a pile group is the lesser of the sum of the individual pile resistances as described above, or the resistance of a single "block" of soil with a perimeter equal to the perimeter of the pile group (the mass of the soil inside the "block" may be included in the calculation; use soil weights as recommended above).

WSP should review the preliminary pile design geometry and provide additional comments as appropriate.

It should be noted that the uplift resistance is highly dependant upon the installation of the piles as well as the layout of the pile groups. If the piles are used to resist significant uplift loads (and uplift governs the overall design) consideration may be given to carrying out a tension test to confirm the uplift capacity.

LATERAL RESISTANCE

The lateral resistance of long piles is typically governed by limiting the deflection which will occur under loading to some acceptable level. The geotechnical parameter most commonly used to determine lateral deflection of piles is the coefficient of horizontal subgrade reaction (k_h). For this site k_h may be assumed to be:

$$k_h = n_h \, z/d$$

Where: k_h = the modulus of subgrade reaction (kN/m^3);

z = the depth below the (final) ground surface;

d = the pile diameter/width, nh= the constant of horizontal subgrade reaction,

3.5 Mpa/m for sand layer and;

9.0 Mpa/m for Till layer

[1] When determining the surface area, the shaft friction should be assumed to act over the "boxed" area of an H-pile or similar section, not over the entire surface area of the pile.

This parameter is associated with acceptable deflections, and therefore represents an unfactored SLS value.

The value above is for a single pile. Group interaction must be considered when piles are spaced closely together. Group effects may be accounted for by reducing the coefficient of horizontal subgrade reaction (k_h) by an appropriate factor as follows:

Table 6.3 Coefficient of Horizontal Subgrade Reaction Reduction Factors

Pile Spacing in Direction of Loading (d = pile diameter)	Reduction Factor
8d	1.0
6d	0.8
4d	0.4
3d	0.25

Values for other spacings may be interpolated from the above. No reduction is required for the first row of piles (i.e. the row which bears against undisturbed soil with no piles in front). The lateral pile capacity can be improved by improving the soil matrix next to the pile cap. If the soil next to the pile cap to a certain depth is soft, it may be replaced by well compacted coarse granular material (Gran. A for instance)

NEGATIVE SKIN FRICTION

The magnitude of negative skin friction depends on the pile loading, dimensions and the final grading of the site and will need to be confirmed during detailed design based on these factors.

Negative friction need only be considered in conjunction with dead and sustained live loads (not transient loads such as wind, earthquake and transient live loads) in evaluating the structural capacity of the pile. Most of the fill layer that would cause negative skin friction will be excavated to construct the basement level. This would leave about 1.5 m of fill and clay layers. As the SPT results indicate moderate to high 'N" values, negative skin friction may not have influence on pile capacity.

CONSTRUCTION CONSIDERATIONS

The piles will be driven to bedrock (which is expected to be 7.6 m to 12.2 m below the existing ground surface) through sand and gravel as well as in the glacial till, both of which are known to contain cobbles and boulders. All piles should be fitted with appropriate driving shoes in order to protect the pile tip during driving. Battered piles should be driven with rock points to avoid sliding along the rock surface. Pipe piles should be driven closed-ended. Even with these measures, some allowance should be made for wasting of piles which become damaged or for reduced design capacities for piles which cannot be successfully driven to rock.

Appropriate piling equipment and hammers capable of generating sufficient driving energy will be required to drive the piles to rock and mobilize the full geotechnical resistance of the pile. Allowance should also be made for re-striking all piles a minimum of 2 days after initial driving to confirm that relaxation of the shale bedrock has not occurred. Based on experience driving piles in the general area it is expected that multiple re-strikes will be required. The rock quality is generally poorer near the rock surface and some penetration of the rock may occur where poor quality shale is present. This penetration is generally minimal and would typically be expected to be less than 1 m. The exception to this would be where shale bedrock was encountered as in borehole BH19-02. This layer of bedrock would be expected to be penetrable to approximately 3.0 m in depth.

The piling specifications should be reviewed by WSP prior to tender, as should the contractor's submission (i.e. shop drawings, equipment, procedures and preliminary set criteria) prior to construction. Preliminary pile driving criteria should be established prior to construction using wave equation analysis (WEAP or similar) or other approved means and confirmed through a program of dynamic testing (PDA Testing) carried out at an early stage in the piling program. Additional PDA testing should be used to confirm the pile capacities at regular intervals as the project progresses.

All piling operations should be supervised on a full-time basis by WSP to monitor pile locations, plumbness, pile set, re-striking, etc. and to confirm that the design and construction of the piles is as anticipated in preparing the recommendations included in this report

4.5 SLOPE STABILITY

At this time the final design of the building has not been provided. Assuming that the grade of the finished floor is similar to the grade of the roadways or parking lots, not slope stability issues are anticipated. This can be revisited based on the final design, if required.

4.6 SLABS-ON-GRADE

Concrete slabs-on-grade should be supported on at least 200 mm of well-graded crushed sand and gravel meeting the requirements of OPSS Granular A. All subgrades should be reviewed by WSP prior to placement of the sand and gravel base and slab-on-grade. Drainage considerations are addressed in Section 4.8.

If the slab-on-grade is placed at approximately the elevation of the existing parking lot it will be resting on generally 3 m to 7 m of fill material (and the building will be founded on piles). The fill material and the silty clay (which contains organic material) are both prone to settlement. The amount of settlement cannot be predicted with certainty; however, it is noted that the fill has been in place for a long period of time and a significant portion of the consolidation would have already occurred. If there is no additional loading on the fill it may be feasible to construct a slab-on-grade, but there would be a risk of future settlement which could result in future repair or maintenance requirements. If the uncertainty and risk of future settlement is not acceptable then a structural floor can be constructed.

As a basement level is included and the lower floor is resting on native sand and gravel or till soils then normal slab-on-grade construction would be appropriate. Drainage of the slab is discussed in Section 4.8.1.

WSP can provide additional guidance based on a review of the preliminary design, site grading and an understanding of the Universities tolerance for risk, future maintenance, etc.

4.7 LATERAL EARTH PRESSURES

The lateral earth pressure acting on below-grade walls, retaining walls, etc. may be calculated using the following expression:

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

Where P = lateral earth pressure (kPa) acting at depth h

K = earth pressure coefficient; for a wall which can tolerate some lateral movement use the coefficient of active earth pressure (Ka) equal to 0.3; for restrained walls which cannot tolerate movement use the coefficient of earth pressure at rest (Ko) equal to 0.5

γ = the density of the backfill; use 22 kN/m3 for compacted granular backfill

h = the depth to the point of interest (m)

q = the magnitude of any design surcharge at the ground surface; a minimum nominal surcharge of 12 kPa is recommended, a higher value should be used if appropriate for the building/site design

The above values assume that the wall will remain drained. If this is not the case, then the submerged unit weight should be used in the calculation and water pressures (as well as the potential for leakage) accounted for in the design of any below-grade walls and floor slabs.

Earth pressures will be higher under seismic loading conditions. In order to account for seismic earth pressures the total earth pressure during a seismic event (including both the seismic and static components) may be assumed to be:

$$\sigma_h(z) = K_a \gamma z + (K_{AE} - K_a) \gamma (H-z)$$

Where $\sigma_h(z)$ = the total earth pressure at depth z (kPa);

K_a = the active earth pressure coefficient (0.3);

γ = the unit weight of soil (22 kN/m^3 for granular fill or 19 kN/m^3 for native soil);

K_{AE} = the combined active earth pressure and seismic earth pressure coefficient (use 0.8);

H = the total height of the wall (m)

z = the depth below the top of the wall (m)

The above earth pressure values (both static and seismic) are unfactored values.

4.8 BASEMENT AND PERIMETER DRAINAGE

The earth pressure values provided above assume that below-grade walls will remain in a drained condition. In order to maintain a drained condition basement walls should be backfilled with free-draining granular backfill (Granular A or Granular B). If shoring is used to support temporary excavations, and sufficient space does not exist between the formwork and the shoring to allow for conventional backfilling and compaction, then the backfill may consist of clear stone placed using a chute or similar method. Where this clear stone could come into contact with soil it should be wrapped with a non-woven geotextile to prevent migration of fines into the stone. If basement walls are cast against a shoring wall then a suitable drainage board should be installed to ensure the wall remains in a drained condition.

In any case the backfill should be provided with a perforated rigid pipe subdrain encased in 300 mm of clear stone, which is completely wrapped with a non-woven geotextile. These drains should extend around the perimeter of the building. All drains should provide positive drainage to the sewer or a suitable sump. Typical damp-proofing should be provided for below-grade walls.

SUB-FLOOR DRAINAGE

As a basement level is included in the design a system of floor drains beneath should be included in the design. These drains can consist of similar perforated pipe sub-drains encased in 19 mm clear stone of at least 300 mm thickness completely wrapped in a non-woven geotextile. For preliminary design these drains can be assumed to be placed at 6 m centre-to-centre spacing, however this should be reviewed based on the actual building design.

If a basement level is not included in the final design (and the lowest floor is at the elevation of the existing parking lot) then the sub-drains below the floor are not required and the perimeter drains would be expected to provide adequate sub-surface drainage. The drainage system will generally be designed to fulfill the amount of groundwater table inflow that may occur in case of the increase in the ground water table during spring time (i.e. including sump pump system)

4.9 BACKFILLING AND COMPACTION

Backfill for below-grade walls, retaining walls, foundation excavations, etc. should comprise free draining Granular "A" or "B" materials. Backfill should be placed in shallow lifts, not exceeding 300 mm loose thickness, and compacted to 100% SPMDD where it is placed below the building slab-on-grade, or 98% in other areas.

To avoid damaging or laterally displacing the structures, care should be exercised when compacting fill adjacent to new structures. Where possible, backfilling should be carried out on both sides of buried structures simultaneously. Heavy equipment should be kept a minimum of 1 m away from the structure during backfilling. The 1 m width adjacent to the wall should be backfilled using hand-operated equipment unless otherwise authorized.

Excavated material from the site will be a variable mixture of fill material ranging from clay to sand and gravel. The material may be reviewed as excavated and suitable soil stockpiled for re-use, however the majority is likely not suitable as backfill around or below structures. Portions of it may be suited (from a geotechnical perspective) for use as fill below landscaped areas (where strength and settlement are not an issue).

4.10 SITE SERVICES

Water-bearing services (sewers and drains) should be placed a minimum of 2.4 m below grade to provide protection from frost. Alternatively, equivalent insulation cover may be provided in lieu of burial as per City of Ottawa specification No: F-4418 .

Details of the proposed site services are not available at this time; however, it is assumed that they will include localized shallow trenches throughout the site. Trenches in soil can be temporarily supported using sloped excavations (see Section 4.15.2) or trench boxes.

Bedding for site services should consist of a layer of Granular "A" compacted to 95% SPMDD which extends from 150 mm below the invert of the pipe to the spring line of the pipe. The use of clear stone as a bedding material is not recommended as the finer particles of the native soils and backfill may migrate into the voids of the clear stone, resulting in loss of pipe support. Cover material above the spring line should consist of Granular "A" or Granular "B" material with a maximum particle size of 25 mm. Cover material should be compacted to a minimum of 95% SPMDD (100% if below the building structure or slab-on-grade).

The discussions related to groundwater control and temporary excavations in Section 4.15.1 apply to the construction of site services as well.

4.11 CORROSION AND CEMENT TYPE

Three soil samples were submitted to Eurofins for testing related to soil corrosivity and potential exposure of concrete elements to sulphate attack. The results of the water testing are included in Appendix C and summarized in table below.

Table 4.7 Results of Soil Corrosivity Testing

Borehole/ Sample No.	Soil Type	Chloride (%)	Electrical Conductivity (mS/cm)	pH	Resistivity (ohm-cm)	Sulphate (%)
BH 19-5 SS4	Silty Clay	0.175	2.57	7.45	389	0.15
BH 19-5 SS6	Sand and Gravel	0.027	0.44	7.9	2270	0.03
BH 19-9 SS9	Glacial Till	0.039	0.54	8.11	1850	0.04

The chloride and resistivity values measured in the soil samples suggest a moderate to severe corrosive environment for buried steel elements. These values must be taken into consideration during design of below-grade steel elements.

The test results indicate a in the sand and gravel and the glacial till indicate a low soluble sulphate content and sulphate resistant Portland cement is not required. The test result in the silty clay indicates a moderate soluble sulphate content and sulphate resistant Portland cement is required

4.12 FROST PROTECTION

All footings should be protected against frost heave by providing a minimum of 1.8 m of earth cover or the thermal equivalent if insulation is used. Foundations directly on sound limestone bedrock do note require frost protection as long as the structure can tolerate minor frost movements.

In the event that foundations are to be constructed during the winter months, foundation soils are required to be protected from freezing temperatures using suitable construction techniques. Therefore, the base of all excavations should be insulated from freezing temperatures immediately upon exposure, until the time that heat can be supplied to the building interior and/or the foundations have sufficient earth cover to prevent freezing of the subgrade soils.

4.13 SLAB ON GRADE

For predictable performance of the floor slab in heated areas, under slab provision should be made for at least 150 millimetres (mm) of OPSS Granular A to form the base for the slab on grade and the subgrade material prepared as per section 4.9. The unheated areas should be provided proper insulation. Any bulk fill required below the underside of the Granular A should consist of OPSS Granular B Type II. The under-slab fill should be placed in maximum 300-millimetre thick lifts.

4.14 CONSTRUCTION CONSIDERATIONS

4.14.1 CONSTRUCTION DEWATERING

The groundwater levels were determined for three piezometers installed on the site and found to range from 4.5 m to 6.2 m below the existing surface elevation. These water levels ranged in geodetic elevation from 59.7 m to 60.2 m, within the layer of glacial till. For excavations above the water table and slightly below (less than 0.5 m) the water table, it is likely that seepage into the excavations can be managed using properly filtered sumps, ditches, etc. For deeper excavations, additional or more complex dewatering may be required, especially with the glacial till. WSP can provide additional guidance based on the size and depth of anticipated excavations, if required during detailed design.

Assuming that the new construction will be at or above the groundwater level observed in the standpipe piezometer then in this situation any groundwater inflows encountered would be expected to be low and manageable by pumping from closely spaced, properly filtered sumps. The excavation would not be expected to require a MOECC Environmental Activity and Sector Registration (EASR – which covers construction dewatering up to 400,000 l/day) or a Permit to Take Water (PTTW – which is required for dewatering in excess of 400,000 l/day). If substantially deeper excavations are required or construction is scheduled during wetter periods (such as the spring) then this assumption should be reviewed during detailed design. It should be noted that this discussion applies to groundwater flows.

The soils present at the site are expected to be sensitive to disturbance and proper control of the groundwater infiltration (by construction of sumps, use of well points, etc.) will be required to prevent excessive disturbance. Failure to adequately control groundwater inflows may result in disturbance of the subgrade and a need for over-excavation and replacement of disturbed subgrade soil.

4.14.2 TEMPORARY EXCAVATIONS

All excavations should be carried out in accordance with the most recent Occupational Health and Safety Act (OHSA). Part III of Ontario Regulation 213/91 deals with excavations.

The soils within the likely excavation depth at the proposed residence include granular fill, silty clay and native sand and gravel and glacial till. These soils can be classified as Type 3 Soil above the water table (or depth of dewatering) and Type 4 soils below the groundwater level (or depth of dewatering). These classifications must be reviewed and confirmed by a qualified person during excavation. Provided that groundwater lowering measures are used and that the groundwater level is successfully lowered below the depth of the excavation, side slopes in granular soils should be stable in the short term at 1 horizontal to 1 vertical. Flatter slopes may be required in the silty clay.

The bearing capacities provided in Section 4.4 above assume that the foundation soils will not be disturbed by construction activities. Proper de-watering and protection of the exposed subgrade will be important to the construction of the foundations. Failure to adequately control surface or groundwater may result in disturbance of the foundation subgrade and a need for over-excavation and replacement of the disturbed subgrade soils. All excavated surfaces should be kept free of frost, water, etc. during the course of construction. All excavated surfaces should be inspected by a qualified geotechnical engineer who is familiar with the findings of this investigation and the design and construction of similar structures.

EXISTING STRUCTURES

Based on the conceptual footprint provided by Carleton University, the proposed residence will be approximately 23 m from the Leeds residence and 18 m from the Stormont Dundas residence. Based on the provided reports (*Golder, 1989), (Patterson, 2000) and (Sauve Boucher Associated Inc., 2000)* deep foundation s have been used for both buildings and the foundations extend to the depth of bedrock. It is also understood that one basement level for the proposed residence is to be constructed, which typically involves an excavation of 3 to 4 metres below the existing grade. Assuming proper de-watering systems are in place, the excavation for the basement will be sloped back at a 1:1 slope and require 3 to 4 metres. If insufficient space existing for such an excavation then a shoring system will have to be in place.

If the footings for the adjacent buildings truly sit on piles which in turn are founded on bedrock then excavation and de-watering activates for the proposed residence are expected to have a minimumal impact on the surrounding foundations. If excavations deeper than the water table are carried out or excavations are deeper than 4 metres, this assumption will have to be revisited.

4.14.3 TRENCH BACKFILLING;

Based on visual and physical examination and, the onsite excavated soils from above the groundwater table will generally need to be brought to ±2% of the optimum moisture content whether by adding water or aerating. Soils excavated from below the groundwater table will be too wet to compact and will require significant aeration prior to their use as backfill material.

Unless the materials are properly pulverized and compacted in sufficiently thin lifts, post-construction settlements could occur. The backfill should be placed in maximum 200 mm thick layers at or near (±2%) their optimum moisture content, and each layer should be compacted to at last 95% SPMDD. Unsuitable materials such as organic soils, boulders, cobbles, frozen soils, etc. should not be used for backfilling. Otherwise imported selected inorganic fill will be required for backfilling at this site.

The onsite excavated soils should not be used in confined areas (e.g. around catch basins and laterals under roadways) where heavy compaction equipment cannot be operated. The use of imported granular fill together with an appropriate frost taper would be preferable in confined areas and around structures.

5 CLOSURE

The Limitations of Report, as presented in AppendixD, are an integral part of this report.

We trust that the information contained in this report is satisfactory. Should you have any questions, please do not hesitate to contact this office.

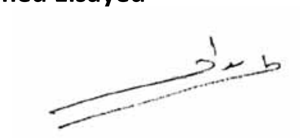
WSP Canada Inc.

Report prepared by:

Daniel Wall

Intermediate Geotechnical Engineer, P.Eng.

Mohamed Elsayed



Senior Geotechnical Engineer, M.Eng., P.Eng

APPENDIX

A

DRAWINGS

N ←

Client:	Carleton University	Title:	Site Location Plan
Project#: 191-12948-00	DWG #: 1	Project:	Geotechnical Investigation Carleton New Residence
Drawn: DW	Approved: ME		
Date: November 2019	Scale: N. T. S.		wsp
Size: Letter	Rev: 0		

LEGEND

- Unevaluated Wetlands (MNRF)
- Monitoring Well (WSP, 2019)
- Borehole (WSP, 2019)

TITLE	**BOREHOLE LOCATION PLAN**
PROJECT	**PROPOSED RESIDENCE CARLETON UNIVERSITY 1125 COLONEL By DR. OTTAWA, ONTARIO**
CLIENT	**CARLETON UNIVERSITY**

PROJECT NO	SOURCE	REVIEWED BY
191-12948-00	BING / ESRI MAPS, OTTAWA OPEN DATA, GeoOttawa, LIO, MNRF	AM
wsp	DATE: DECEMBER 2019	FIGURE: 2

Drafted By: CASC071253

\\caott1dat01.gcg.local\SPL Ottawa\Projects\191-12948-00 - Carleton University New Residence\Phase II ESA\GIS\MXD\1911294800_Figure2_BoreholeLocation_forDan.mxd

Borehole BH19-2

Client:	Carleton University			Title:	Core Photograph
Project#:	191-12948-00	DWG #:	3	Project:	Geotechnical Investigation Carleton University Proposed Residence
Drawn:	DW	Approved:	ME		
Date:	December 2019	Scale:	N. T. S.		wsp
Size:	Letter	Rev:	0		

Borehole BH19-2

Client:	Carleton University			Title:	Core Photograph
Project#:	191-12948-00	DWG #:	3	Project:	Geotechnical Investigation Carleton University Proposed Residence
Drawn:	DW	Approved:	ME		
Date:	December 2019	Scale:	N. T. S.		wsp
Size:	Letter	Rev:	0		

Borehole BH19-2

Client:	Carleton University			Title:	Core Photograph
Project#:	191-12948-00	DWG #:	3	Project:	Geotechnical Investigation Carleton University Proposed Residence
Drawn:	DW	Approved:	ME		
Date:	December 2019	Scale:	N. T. S.		wsp
Size:	Letter	Rev:	0		

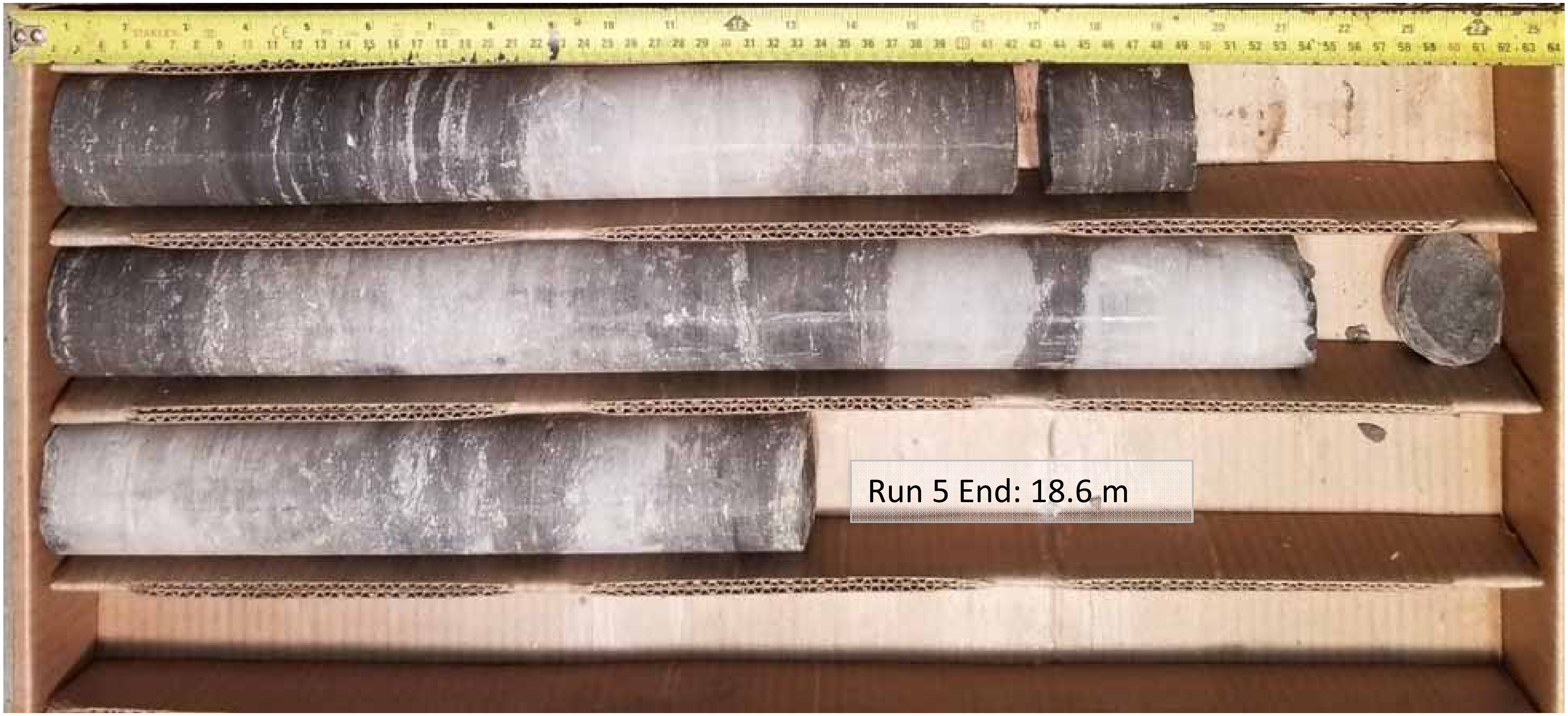
Borehole BH19-7

Client:	Carleton University			Title:	Core Photograph
Project#:	191-12948-00	DWG #:	3	Project:	Geotechnical Investigation Carleton University Proposed Residence
Drawn:	DW	Approved:	ME		
Date:	December 2019	Scale:	N. T. S.		wsp
Size:	Letter	Rev:	0		

Borehole BH19-7

Client:	Carleton University			Title:	Core Photograph
Project#:	191-12948-00	DWG #:	3	Project:	Geotechnical Investigation Carleton University Proposed Residence
Drawn:	DW	Approved:	ME		
Date:	December 2019	Scale:	N. T. S.		wsp
Size:	Letter	Rev:	0		

Run 5 Start: 17.0 m



Run 5 End: 18.6 m

Borehole BH19-7

Client:	Carleton University			Title:	Core Photograph
Project#:	191-12948-00	DWG #:	3	Project:	Geotechnical Investigation Carleton University Proposed Residence
Drawn:	DW	Approved:	ME		
Date:	December 2019	Scale:	N. T. S.		wsp
Size:	Letter	Rev:	0		

Borehole BH19-8

Client:	Carleton University			Title:	Core Photograph
Project#:	191-12948-00	DWG #:	3	Project:	Geotechnical Investigation Carleton University Proposed Residence
Drawn:	DW	Approved:	ME		
Date:	December 2019	Scale:	N. T. S.		wsp
Size:	Letter	Rev:	0		

Borehole BH19-8

Client:	Carleton University			Title:	Core Photograph
Project#:	191-12948-00	DWG #:	3	Project:	Geotechnical Investigation Carleton University Proposed Residence
Drawn:	DW	Approved:	ME		
Date:	December 2019	Scale:	N. T. S.		wsp
Size:	Letter	Rev:	0		

APPENDIX

B

BOREHOLE LOGS

LOG OF BOREHOLE 19-01

PROJECT: Carleton University New Residence
CLIENT: Carleton University
PROJECT LOCATION: Carleton University
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Hollow Stem Auger Drilling
Diameter: 203 mm
Date: Oct 23/2019

REF. NO.: 191-12948-00
ENCL NO.:

ELEV (m)	DEPTH (m)	DESCRIPTION
65.5		
65.4	0.1	**ASPHALT** - 80 mm
		SILTY SAND, some gravel, trace clay, brown, moist, loose to compact (FILL)
63.2	2.3	**SILTY CLAY**, grey, moist, stiff
61.7	3.8	**SAND AND GRAVEL**, cobbles and boulder infered, some silt, brown, moist, very dense
59.4	6.1	**SAND**, some silt to silty, some gravel to gravelly, trace clay, grey, moist (GLACIAL TILL)
		- wet below 6.8 m

SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
0	AS		29 47 (24)
1	SS	7	
2	SS	28	
3	SS	5	
4	SS	1	
5	SS	50/ 100 mm	
6	SS	50/ 150 mm	
7	SS	50/ 75 mm	
8	SS	18	
9	SS	15	21 61 (18)
10	SS	26	

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH (kPa): ○ UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE: 20 40 60 80 100
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%): 25 50 75
POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m^3)
ELEVATION: 65, 64, 63, 62, 61, 60, 59, 58

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: + 3, × 3: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

wsp

LOG OF BOREHOLE 19-01

PROJECT: Carleton University New Residence
CLIENT: Carleton University
PROJECT LOCATION: Carleton University
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Hollow Stem Auger Drilling
Diameter: 203 mm
Date: Oct 23/2019

REF. NO.: 191-12948-00
ENCL NO.:

(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	SAMPLES NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L / WATER CONTENT (%) 25 50 75	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND, some silt to silty, some gravel to gravelly, trace clay, grey, moist (GLACIAL TILL)(Continued)						57					
9			11	SS	28							
			12	SS	15		56					
10												
55.0 / 10.5	**END OF BOREHOLE** 1) Auguer refusal at 10.5 m in depth						55					

WSP SOIL LOG GEO - CARLETON UNIVERSITY NEW RESIDENCE.GPJ SPL.GDT 16/12/19

GROUNDWATER ELEVATIONS
Measurement 1st ▽ 2nd ▼ 3rd ▼ 4th ▼

GRAPH NOTES + 3, × 3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

PROJECT: Carleton University New Residence
CLIENT: Carleton University
PROJECT LOCATION: Carleton University
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Hollow Stem Auger Drilling
Diameter: 203 mm
Date: Oct 23/2019

REF. NO.: 191-12948-00
ENCL NO.:

ELEV (m) / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
65.6					
65.5 / 0.1	**ASPHALT** - 75 mm				
	SAND AND GRAVEL, trace silt, brown, moist, loose to very dense (FILL)	0	AS		AS1 was taken between 0 and 0.8 m in depth
		1	SS	50/ 125 mm	
		2	SS	9	
		3	SS	5	
62.6 / 3.1	**SILTY CLAY**, grey, moist, stiff	4	SS	3	
	- rock fragments below 3.8 m in depth	5	SS	8	
61.0 / 4.6	**SAND AND GRAVEL**, cobbles and boulder infered, some silt, brown, moist, very dense	6	SS	50/ 75 mm	
		7	SS	50/ 75 mm	
		8	SS	25	
58.8 / 6.8	**SAND**, some silt to silty, some gravel to gravelly, trace clay, grey, moist (GLACIAL TILL)	9	SS	32	

Depth scale (m): 1, 2, 3, 4, 5, 6, 7, 8
ELEVATION: 65, 64, 63, 62, 61, 60, 59, 58

Column headings: SOIL PROFILE; STRATA PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT W_L; WATER CONTENT (%) 25 50 75; POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m^3)

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES + 3, × 3: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

PROJECT: Carleton University New Residence
CLIENT: Carleton University
PROJECT LOCATION: Carleton University
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Hollow Stem Auger Drilling
Diameter: 203 mm
Date: Oct 23/2019

REF. NO.: 191-12948-00
ENCL NO.:

(m) ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND, some silt to silty, some gravel to gravelly, trace clay, grey, moist (GLACIAL TILL)(Continued)						
						57	
		10	SS	35			
9							
						56	
10							
		11	SS	46			
						55	
11							
54.2 / 11.4	**SHALE**, black, fresh						
						54	
12							
						53	
13							
						52	
14							
	Run 1: 14.1 m - 14.6 m TCR - 100% SCR - 45% RQD- 25%	1	RC				
						51	
15							
	Run 2: 14.6 m - 16.5 m TCR - 66% SCR - 17% RQD- 0%	2	RC				
						50	
16							

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH (kPa): ○ UNCONFINED + FIELD VANE & Sensitivity ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L
WATER CONTENT (%): 25 50 75
POCKET PEN. (Cu) (kPa)
NATURAL UNIT WT (kN/m^3)

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: + 3, × 3: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

WSP SOIL LOG GEO - CARLETON UNIVERSITY NEW RESIDENCE.GPJ SPL.GDT 16/12/19

PROJECT: Carleton University New Residence
CLIENT: Carleton University
PROJECT LOCATION: Carleton University
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Hollow Stem Auger Drilling
Diameter: 203 mm
Date: Oct 23/2019

REF. NO.: 191-12948-00
ENCL NO.:

ELEV (m) DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLES NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
49.4	**SHALE**, black, fresh(Continued)						
16.2	**Shale** black, fresh Run 3: 16.2 m - 17.8 m TCR - 87% SCR - 87% RQD- 87%	3	RC			49 48	
47.8 17.8	**LIMESTONE** with shale partings, fresh to slightly weathered, grey Run 4: 17.8 m - 19.3 m TCR - 100% SCR - 100% RQD- 100%	4	RC			47	
46.3 19.3	**END OF BOREHOLE** 1) Auguer refusal at 11.4 m in depth. Switch to NQ coring. 2) Coring complete at 19.3 m in depth						

Chart headers: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH (kPa): ○ UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (25, 50, 75); POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m^3)

Depth scale: 17, 18, 19

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE 19-04

PROJECT: Carleton University New Residence
CLIENT: Carleton University
PROJECT LOCATION: Carleton University
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Hollow Stem Auger Drilling
Diameter: 203 mm
Date: Oct 25/2019

REF. NO.: 191-12948-00
ENCL NO.:

ELEV (m) / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS
64.7 / 0.0	**ASPHALT** - 38 mm				
64.7 / 0.0	**SILTY GRAVELLY SAND**, light brown, damp to moist, compact (FILL)	0	AS		Bentonite
63.4 / 1.4	**SILTY CLAY**, trace sand, trace organics, grey, moist	1	SS	11	
		2	SS	4	
61.8 / 2.9	**SILT SAND AND GRAVEL**, to gravelly, cobbles and boulder infered, brown, moist, dense to very dense	3	SS	21	Cutting and Bentonite
		4	SS	59	Bentonite
		5	SS	50/ 75 mm	W. L. 60.2 m Nov 04, 2019
		6	SS	43	
58.8 / 5.9	**SAND**, some silt to silty, some gravel to gravelly, trace clay, grey, wet, compact to very dense (GLACIAL TILL)	7	SS	29	Sand Screen
		8	SS	12	
57.1 / 7.6		9	SS	50/ 75 mm	Slough
	END OF BOREHOLE 1) SPT refusal at 7.6 m in depth				

Elevation scale: 64, 63, 62, 61, 59, 58

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH (kPa): ○ UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE — 20 40 60 80 100
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L — WATER CONTENT (%) 25 50 75
POCKET PEN. (Cu) (kPa) | NATURAL UNIT WT (kN/m³) | REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: + 3, × 3: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

LOG OF BOREHOLE 19-04

PROJECT: Carleton University New Residence
CLIENT: Carleton University
PROJECT LOCATION: Carleton University
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Hollow Stem Auger Drilling
Diameter: 203 mm
Date: Oct 25/2019

REF. NO.: 191-12948-00
ENCL NO.:

SOIL PROFILE: (m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	SAMPLES: NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 25 50 75	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	2) 37.5 mm monitoring well installed at 7.5 m in depth 3) DATE WATER LEVEL Nov 4, 2019 4.5 m											

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: + 3, × 3: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

LOG OF BOREHOLE 19-05

PROJECT: Carleton University New Residence
CLIENT: Carleton University
PROJECT LOCATION: Carleton University
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Hollow Stem Auger Drilling
Diameter: 203 mm
Date: Oct 22/2019

REF. NO.: 191-12948-00
ENCL NO.:

(m) ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS / 0.3 m	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
64.5					
0.0	**TOPSOIL**				
64.3 / 0.2	**SAND and GRAVEL (to gravelly)**, dark brown, moist, very dense (FILL)	1	SS	11	
		2	SS	70	
63.0 / 1.5	**SILTY SAND**, brown, moist (FILL)	3	SS	10	
62.7 / 1.8	**SILTY SAND**, with organics, dark brown, moist (FILL)				
62.2 / 2.3	**SILTY CLAY,** mixed with organics, some sand, dark brown, moist, firm	4	SS	4	
61.5 / 3.1	**SAND and GRAVEL,** some silt to silty, brown, moist, compact to very dense	5	SS	12	25 49 (56)
		6	SS	85	
		7	SS	50/50 mm	
59.2 / 5.3	**SILT and SAND**, some gravel to gravelly, trace clay, grey, wet (GLACIAL TILL)	8	SS	17	
		9	SS	30	
		10	SS	38	
		11	SS	50/50 mm	

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION (64, 63, 62, 61, 60, 59, 58, 57); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● QUICK TRIAXIAL × LAB VANE (20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L, WATER CONTENT (%) (25 50 75); POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m^3); STRATA PLOT. Depth scale: 1, 2, 3, 4, 5, 6, 7, 8.

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: + 3, × 3: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE 19-05

PROJECT: Carleton University New Residence
CLIENT: Carleton University
PROJECT LOCATION: Carleton University
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Hollow Stem Auger Drilling
Diameter: 203 mm
Date: Oct 22/2019

REF. NO.: 191-12948-00
ENCL NO.:

(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (kPa): ○ UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (25 50 75)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SILT and SAND, some gravel to gravelly, trace clay, grey, wet (GLACIAL TILL)(Continued)						56					
9			12	SS	42							
							55					
10							54					
11												
53.2 / 11.3	**END OF BOREHOLE** 1) Auguer refusal at 11.3 m in depth											

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: + 3, × 3: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

LOG OF BOREHOLE 19-06

PROJECT: Carleton University New Residence
CLIENT: Carleton University
PROJECT LOCATION: Carleton University
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Hollow Stem Auger Drilling
Diameter: 203 mm
Date: Oct 24/2019

REF. NO.: 191-12948-00
ENCL NO.:

ELEV (m) / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
66.4						
66.3 / 0.1	**TOPSOIL** - 125 mm					
0.1	**GRAVELLY SAND,** some silt, brown, moist, loose to compact (FILL)	1	SS	22	Bentonite	
		2	SS	26		26 57 (17)
		3	SS	20		
		4	SS	14		
		5	SS	21		
		6	SS	11	Sand	
		7	SS	5	Screen	
		8	SS	17		
60.3 / 6.1	**SAND**, some silt to silty, some gravel to gravelly, trace clay, grey, wet, compact to very dense (GLACIAL TILL)	9	SS	50/75 mm	W. L. 59.7 m Nov 04, 2019	
		10	SS	50/125 mm		
		11	SS	23	Sand and Bentonite	

Elevation scale: 66, 65, 64, 63, 62, 61, 60, 59. Depth scale: 1–8.

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH (kPa): ○ UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 25 50 75
POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m^3); REMARKS AND GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: + 3, × 3: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

LOG OF BOREHOLE 19-06

PROJECT: Carleton University New Residence
CLIENT: Carleton University
PROJECT LOCATION: Carleton University
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Hollow Stem Auger Drilling
Diameter: 203 mm
Date: Oct 24/2019

REF. NO.: 191-12948-00
ENCL NO.:

ELEV (m) DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION
	SAND, some silt to silty, some gravel to gravelly, trace clay, grey, wet, compact to very dense (GLACIAL TILL)(Continued)					58
		12	SS	25	Slough	57
						56
		13	SS	50/75 mm		
55.3 / 11.1	**END OF BOREHOLE**					

1) Auguer refusal at 11.1 m in depth
2) 37.5 mm monitoring well installed at 7.9 m in depth
3) DATE — WATER LEVEL
Nov 4, 2019 — 6.7 m

Depth scale: 9, 10, 11

Column headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH (kPa): ○ UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (25, 50, 75); POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m³); REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: +3, ×3: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

LOG OF BOREHOLE 19-07

PROJECT: Carleton University New Residence	**DRILLING DATA**
CLIENT: Carleton University	Method: Hollow Stem Auger Drilling
PROJECT LOCATION: Carleton University	Diameter: 203 mm
DATUM: Geodetic	Date: Oct 27/2019
BH LOCATION: See Borehole Location Plan	

REF. NO.: 191-12948-00
ENCL NO.:

(m) ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" BLOWS / 0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH (kPa)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT W_L (WATER CONTENT %)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
64.3											
64.2 / 0.0	**TOPSOIL** - 150 mm										
0.2	**SILTY SAND** gravelly to trace gravel, brown, moist, dense to very dense (FILL)	1	SS	11		64					
		2	SS	58		63					
		3	SS	35							
62.0 / 2.3	**SILTY SAND** with organics, dark brown, moist (FILL)					62					
61.7 / 2.6	**SILTY CLAY,** with gravel, trace sand, trace organics, grey, moist	4	SS	7							
61.3 / 3.1	**SILTY SAND AND GRAVEL,** brown, moist, compact	5	SS	20		61					
60.5 / 3.8	**ROCK FRAGMENTS**	6	SS	96		60					
		7	SS	87							
59.0 / 5.3	**SAND**, some silt to silty, some gravel to gravelly, trace clay, grey, wet, compact to very dense (GLACIAL TILL)	8	SS	46		59					
		9	SS	33		58					
		10	SS	38		57					
		11	SS	23							

Dynamic cone penetration resistance plot scale: 20 40 60 80 100
Shear strength (kPa): ○ UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE; scale 20 40 60 80 100
Water content (%): 25 50 75

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GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: + 3, × 3: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

PROJECT: Carleton University New Residence
CLIENT: Carleton University
PROJECT LOCATION: Carleton University
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Hollow Stem Auger Drilling
Diameter: 203 mm
Date: Oct 27/2019

REF. NO.: 191-12948-00
ENCL NO.:

ELEV (m) / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	ELEVATION
55.9 / 8.4	**ROCK FRAGMENTS,** (Shale fragments with occasional granite fragments) (GLACIAL TILL)	12	SS	34	56
		13	SS	16	55
		14	SS	31	54
		15	SS	38	53
		16	SS	50/100 mm	
52.5 / 11.8	**Shale** with clay seams, black, fresh Run 1: 11.8 m - 12.4 m	1	CORE		52
	Run 2: 12.4 m - 13.8 m	2	CORE		51
	Run 3: 13.8 m - 15.4 m	3	CORE		50
48.9 / 15.4	**LIMESTONE** with shale partings, fresh to slightly weathered, grey Run 4: 15.4 m - 17.0 m TCR - 100% RQD - 33%				49

Depth scale (m): 9, 10, 11, 12, 13, 14, 15, 16

Other columns: GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH (kPa): ○ UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (25, 50, 75); POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m^3); REMARKS AND GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

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GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: $+^3, \times^3$: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

LOG OF BOREHOLE 19-07

PROJECT: Carleton University New Residence
CLIENT: Carleton University
PROJECT LOCATION: Carleton University
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Hollow Stem Auger Drilling
Diameter: 203 mm
Date: Oct 27/2019

REF. NO.: 191-12948-00
ENCL NO.:

(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	SAMPLE NUMBER	SAMPLE TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH (kPa)	WATER CONTENT (%)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	LIMESTONE with shale partings, fresh to slightly weathered, grey Run 4: 15.4 m - 17.0 m TCR - 100% RQD - 33%(Continued)		4	CORE			48					
17	Run 5: 17.0 m - 18.6 m TCR - 100% SCR - 100% RQD - 95%		5	CORE			47					
18							46					
45.7 18.6	End of borehole											

Legend: Dynamic cone penetration 20 40 60 80 100; Shear strength: ○ UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; Water content 25 50 75.

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE 19-08

PROJECT: Carleton University New Residence
CLIENT: Carleton University
PROJECT LOCATION: Carleton University
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Hollow Stem Auger Drilling
Diameter: 203 mm
Date: Oct 24/2019

REF. NO.: 191-12948-00
ENCL NO.:

ELEV DEPTH (m)	DESCRIPTION	NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH (kPa)	WATER CONTENT (%)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
0.0	**TOPSOIL** - 175 mm										
0.2	**SILTY SAND AND GRAVEL (to gravelly),** dark brown, moist, compact (FILL)	1	SS	15							
		2	SS	26							
		3	SS	22							
2.3	**SILTY CLAY,** moist, firm	4	SS	8							
2.6	**SILTY SAND and GRAVEL (rock fragments),** brown, wet, compact to very dense										
		5	SS	47							
		6	SS	123							
		7	SS	32							
		8	SS	29							
		9	SS	31							
		10	SS	50/150 mm							
7.6		11	SS	82							

Legend: SHEAR STRENGTH (kPa): ○ UNCONFINED; + FIELD VANE & Sensitivity; ● QUICK TRIAXIAL; × LAB VANE. PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT W_L.

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GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: $+^3, \times^3$: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

LOG OF BOREHOLE 19-08

PROJECT: Carleton University New Residence
CLIENT: Carleton University
PROJECT LOCATION: Carleton University
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Hollow Stem Auger Drilling
Diameter: 203 mm
Date: Oct 24/2019

REF. NO.: 191-12948-00
ENCL NO.:

ELEV (m) / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION / SHEAR STRENGTH (kPa)	WATER CONTENT (%)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND, some silt to silty, some gravel to gravelly, trace clay, grey, compact to very dense (GLACIAL TILL)(Continued)		12	SS	29							
			13	SS	66							
9.9	**GRAVEL SIZED ROCK FRAGMENTS,** trace to some sand, sized fragments,		14	SS	50/150 mm							
10.7	**LIMESTONE** with shale partings, fresh to slightly weathered, grey Run1: 10.7 m - 11.9 m TCR - 40% RQD - 7%		1	CORE								
	Run 2: 11.9 - 12.5 TCR - 100% RQD - 41%		2	CORE								
	Run 3: 12.5 m - 13.9 m TCR - 71% RQD - 0%		3	CORE								
	Run 4: 13.9 m - 15.5 m TCR - 95% RQD - 95%		4	CORE								
15.5	**END OF BOREHOLE** 1) Auguer refusal at 10.7 m in depth. Switch to NQ coring											

Depth scale (m): 9, 10, 11, 12, 13, 14, 15

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GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: +3, ×3: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

LOG OF BOREHOLE 19-08

PROJECT: Carleton University New Residence
CLIENT: Carleton University
PROJECT LOCATION: Carleton University
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Hollow Stem Auger Drilling
Diameter: 203 mm
Date: Oct 24/2019

REF. NO.: 191-12948-00
ENCL NO.:

SOIL PROFILE (m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	SAMPLES NUMBER	TYPE	"N" BLOWS / 0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT w LIQUID LIMIT W_L WATER CONTENT (%) 25 50 75	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	2) Borehole terminated at 15.5 m in depth											

GROUNDWATER ELEVATIONS
Measurement 1st ▽ 2nd ▼ 3rd ▼ 4th ▼

GRAPH NOTES
+ 3, × 3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE 19-09

PROJECT: Carleton University New Residence
CLIENT: Carleton University
PROJECT LOCATION: Carleton University
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Hollow Stem Auger Drilling
Diameter: 203 mm
Date: Oct 22/2019

REF. NO.: 191-12948-00
ENCL NO.:

SOIL PROFILE

ELEV (m) / DEPTH (m)	DESCRIPTION
63.9	
0.0	**TOPSOIL** - 200 mm
63.7 / 0.2	**SAND and GRAVEL (to gravelly),** with possible boulder/cobble, some gravel, some silt, brown, moist, loose to dense (FILL)
59.3 / 4.6	**SAND**, some silt to silty, some gravel to gravelly, trace clay, grey, wet, loose to very dense (GLACIAL TILL)

SAMPLES

NUMBER	TYPE	"N" BLOWS / 0.3 m	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	8	
2	SS	51	21 65 (14)
3	SS	14	
4	SS	17	
5	SS	73	38 48 (14)
6	SS	50/75 mm	
7	SS	18	19 58 (23)
8	SS	1	
9	SS	14	
10	SS	5	

ELEVATION scale: 63, 62, 61, 60, 59, 58, 57, 56
Depth scale: 1, 2, 3, 4, 5, 6, 7, 8

Column headings: STRATA PLOT; GROUND WATER CONDITIONS; ELEVATION; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH (kPa): ○ UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (25 50 75); POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m³); REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: + 3, × 3: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

PROJECT: Carleton University New Residence
CLIENT: Carleton University
PROJECT LOCATION: Carleton University
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Hollow Stem Auger Drilling
Diameter: 203 mm
Date: Oct 22/2019

REF. NO.: 191-12948-00
ENCL NO.:

(m) ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	ELEVATION
	SAND, some silt to silty, some gravel to gravelly, trace clay, grey, wet, loose to very dense (GLACIAL TILL)(Continued)				
		11	SS	17	55
9		12	SS	10	
10		13	SS	18	54
					53
11		14	SS	44	
		15	SS	63	52
12		16	SS	44	
51.3 / 12.6	**END OF BOREHOLE** 1) Auguer refusal at 12.6 m in depth				

Column headings: SOIL PROFILE; STRATA PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH (kPa): ○ UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT W_L; WATER CONTENT (%) (25, 50, 75); POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m³); REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: $+^3$, $\times^3$: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

LOG OF BOREHOLE 19-10

PROJECT: Carleton University New Residence	**DRILLING DATA**
CLIENT: Carleton University	Method: Hollow Stem Auger Drilling
PROJECT LOCATION: Carleton University	Diameter: 203 mm — REF. NO.: 191-12948-00
DATUM: Geodetic	Date: Oct 22/2019 — ENCL NO.:
BH LOCATION: See Borehole Location Plan	

ELEV (m) DEPTH	DESCRIPTION	NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS
65.4					
65.3 / 0.0	**TOPSOIL** - 150 mm				
0.2	**SAND,** some silty to silty, trace gravel to gravelly, brown, moist. compact to dense (FILL)	1	SS	11	
		2	SS	37	
		3	SS	16	Bentonite
		4	SS	33	
		5	SS	19	
61.6 / 3.8	**SAND AND GRAVEL**, some silt, trace clay, grey, wet, loose to very dense (FILL) - Metalic fragments noted at 3.8 m in depth	6	SS	50/125 mm	
		7	SS	50/100 mm	
		8	SS	25	Sand
					W. L. 59.5 m Nov 04, 2019
		9	SS	9	
58.5 / 6.9	**SAND**, some silt to silty, some gravel to gravelly, trace clay, grey, wet, loose to compact (GLACIAL TILL)	10	SS	9	
		11	SS	6	Bentonite

Column headers (not filled): STRATA PLOT; ELEVATION (65, 64, 63, 62, 61, 60, 59, 58); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH (kPa): ○ UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (25 50 75); POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m^3); REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

GRAPH NOTES: + 3, × 3: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE 19-10

PROJECT: Carleton University New Residence
CLIENT: Carleton University
PROJECT LOCATION: Carleton University
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

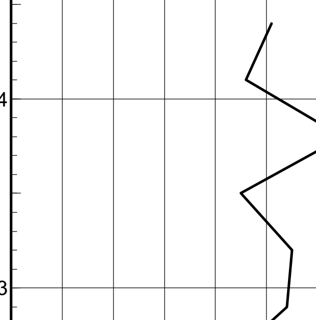
DRILLING DATA
Method: Hollow Stem Auger Drilling
Diameter: 203 mm
Date: Oct 22/2019

REF. NO.: 191-12948-00
ENCL NO.:

ELEV (m) / DEPTH	DESCRIPTION	STRATA PLOT	SAMPLE NUMBER	TYPE	"N" BLOWS / 0.3 m	GROUND WATER CONDITIONS	ELEVATION	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND, some silt to silty, some gravel to gravelly, trace clay, grey, wet, loose to compact (GLACIAL TILL)(Continued)						57	
			12	SS	19	Slough	56	
							55	
54.7 / 10.7	- Glacial TIll Inferred						54	
							53	
52.8 / 12.6	**END OF BOREHOLE**							

Depth scale (m): 9, 10, 11, 12

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH (kPa): ○ UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE: 20 40 60 80 100
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%): 25 50 75
POCKET PEN. (Cu) (kPa)
NATURAL UNIT WT (kN/m³)



END OF BOREHOLE notes:

1) Augering ended at 10.7 m due to flowing sands. Switch to DCPT.
2) DCPT Refusal at 12.6 m in depth
3) 37.5 mm monitoring well installed at 7.6 m in depth
4) DATE WATER LEVEL
Nov 4, 2019 5.9 m

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: + 3, × 3: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

LOG OF BOREHOLE 19-11

PROJECT: Carleton University New Residence
CLIENT: Carleton University
PROJECT LOCATION: Carleton University
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Hollow Stem Auger Drilling
Diameter: 203 mm
Date: Oct 25/2019

REF. NO.: 191-12948-00
ENCL NO.:

ELEV (m) / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m
65.3				
65.0 / 0.0	**ASPHALT** - 50 mm			
0.1	**SAND**, some gravel, some silt, brown, moist. loose to dense (Granular Base)	0	GRAB	
64.7 / 0.6	**SILTY SAND**, trace to some gravel, brown, moist (FILL)	1	SS	22
		2	SS	9
		3	SS	18
		4	SS	32
61.5 / 3.8	**SAND**, some silt to silty, some gravel to gravelly, trace clay, brown, moist, compact to very dense (Glacial Till)	5	SS	25
		6	SS	60
		7	SS	120
		8	SS	50/150 mm
		9	SS	40
	- heaving sand noted at 7.6 m in depth	10	SS	9

Columns: SOIL PROFILE; STRATA PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION (65, 64, 63, 62, 61, 60, 59, 58); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH (kPa): ○ UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (25, 50, 75); POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m^3); REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

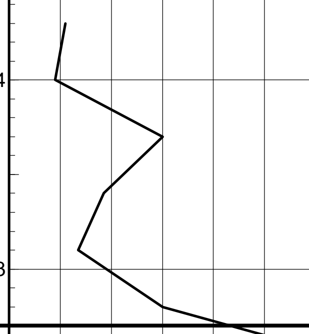
GRAPH NOTES: $+^3, \times^3$: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

PROJECT: Carleton University New Residence
CLIENT: Carleton University
PROJECT LOCATION: Carleton University
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Hollow Stem Auger Drilling
Diameter: 203 mm
Date: Oct 25/2019

REF. NO.: 191-12948-00
ENCL NO.:

SOIL PROFILE: (m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	SAMPLES: NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH (kPa): ○ UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (25 50 75)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND, some silt to silty, some gravel to gravelly, trace clay, brown, moist, compact to very dense (Glacial Till)(Continued)						57					
9							56					
10			11	SS	35		55					
54.6 / 10.7	**GLACIAL TILL INFERED**											
11							54					
12							53					
52.7 / 12.7	**END OF BOREHOLE** 1) Augering ended at 10.7 m due to flowing sands. Switch to DCPT. 2) DCPT Refusal at 12.6 m in depth											



GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: +3, ×3: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

LOG OF BOREHOLE 19-12

PROJECT: Carleton University New Residence
CLIENT: Carleton University
PROJECT LOCATION: Carleton University
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Hollow Stem Auger Drilling
Diameter: 203 mm
Date: Oct 25/2019

REF. NO.: 191-12948-00
ENCL NO.:

(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS 0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH (kPa)	WATER CONTENT (%)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
64.9												
64.9 0.0	**ASPHALT** - 30 mm											
0.0	**SAND AND GRAVEL**, trace to some silt, light brown, brown, moist (Granular Base)		1	GRAB								
64.4 0.6	**SAND**, trace gravel, light brown, moist (FILL)		2	GRAB			64					
63.4 1.5	**END OF BOREHOLE** 1) Borehole terminated at 1.5 m in depth											

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH (kPa): ○ UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 25 50 75

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: +3, ×3: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

LOG OF BOREHOLE 19-13

PROJECT: Carleton University New Residence	**DRILLING DATA**
CLIENT: Carleton University	Method: Hollow Stem Auger Drilling
PROJECT LOCATION: Carleton University	Diameter: 203 mm
DATUM: Geodetic	Date: Oct 25/2019
BH LOCATION: See Borehole Location Plan	

REF. NO.: 191-12948-00

ENCL NO.:

ELEV (m) / DEPTH	DESCRIPTION	STRATA PLOT	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
64.4 / 64.3 / 0.0	**ASPHALT - 100 mm**							
0.1 / 64.1	**CONCRETE** - 200 mm							
0.3	**SILTY SAND,** light brown, moist, dense to very dense (FILL)						64	
			1	SS	46			
							63	
			2	SS	48			
							62	
			3	SS	63			
							61	
			4	SS	38			
							60	
			5	SS	58			
							59	
58.3 / 6.1	**SAND**, some silt to silty, some gravel to gravelly, trace clay, brown, moist, compact (Glacial Till)							
			6	SS	11		58	
							57	
			7	SS	26			

Depth scale (m): 1, 2, 3, 4, 5, 6, 7, 8

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH (kPa): ○ UNCONFINED; + FIELD VANE & Sensitivity; ● QUICK TRIAXIAL; × LAB VANE — 20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT W_L

WATER CONTENT (%): 25 50 75

POCKET PEN. (Cu) (kPa)

NATURAL UNIT WT (kN/m^3)

Continued Next Page

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

GRAPH NOTES: $+^3, \times^3$: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

LOG OF BOREHOLE 19-13

PROJECT: Carleton University New Residence
CLIENT: Carleton University
PROJECT LOCATION: Carleton University
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Hollow Stem Auger Drilling
Diameter: 203 mm
Date: Oct 25/2019

REF. NO.: 191-12948-00
ENCL NO.:

(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS / 0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L / WATER CONTENT (%) 25 50 75	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
56.2												
8.2	**END OF BOREHOLE** 1) Borehole terminated at 8.2 m in depth 2) Water level upon completion of drilling was 6.9m below the existing ground surface											

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: + 3, × 3: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

Explanation of Terms Used in the Record of Boreholes

Sample Type

AS	Auger sample
BS	Block sample
CS	Chunk sample
DO	Drive open
DS	Dimension type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Spoon sample
SH	Shelby tube Sample
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

Penetration Resistance

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

WH – Samples sinks under "weight of hammer"

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

Textural Classification of Soils

Classification	Particle Size
Boulders	> 200 mm
Cobbles	75 mm - 200 mm
Gravel	4.75 mm - 75 mm
Sand	0.075 mm – 4.75 mm
Silt	0.002 mm-0.075 mm
Clay	<0.002 mm

Coarse Grain Soil Description (50% greater than 0.075 mm)

Terminology	Proportion
Trace	0-10%
Some	10-20%
Adjective (e.g. silty or sandy)	20-35%
And (e.g. sand and gravel)	> 35%

Soil Description

a) Cohesive Soils(*)

Consistency	Undrained Shear Strength (kPa)	SPT "N" Value
Very soft	<12	0-2
Soft	12-25	2-4
Firm	25-50	4-8
Stiff	50-100	8-15
Very stiff	100-200	15-30
Hard	>200	>30

(*) Hierarchy of Shear Strength prediction
1. Lab triaxial test
2. Field vane shear test
3. Lab. vane shear test
4. SPT "N" value
5. Pocket penetrometer

b) Cohesionless Soils

Density Index (Relative Density)	SPT "N" Value
Very loose	<4
Loose	4-10
Compact	10-30
Dense	30-50
Very dense	>50

Soil Tests

w	Water content
w_p	Plastic limit
w_l	Liquid limit
C	Consolidation (oedometer) test
CID	Consolidated isotropically drained triaxial test
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement
D_R	Relative density (specific gravity, Gs)
DS	Direct shear test
ENV	Environmental/ chemical analysis
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
U	Unconsolidated Undrained Triaxial Test
V	Field vane (LV-laboratory vane test)
γ	Unit weight

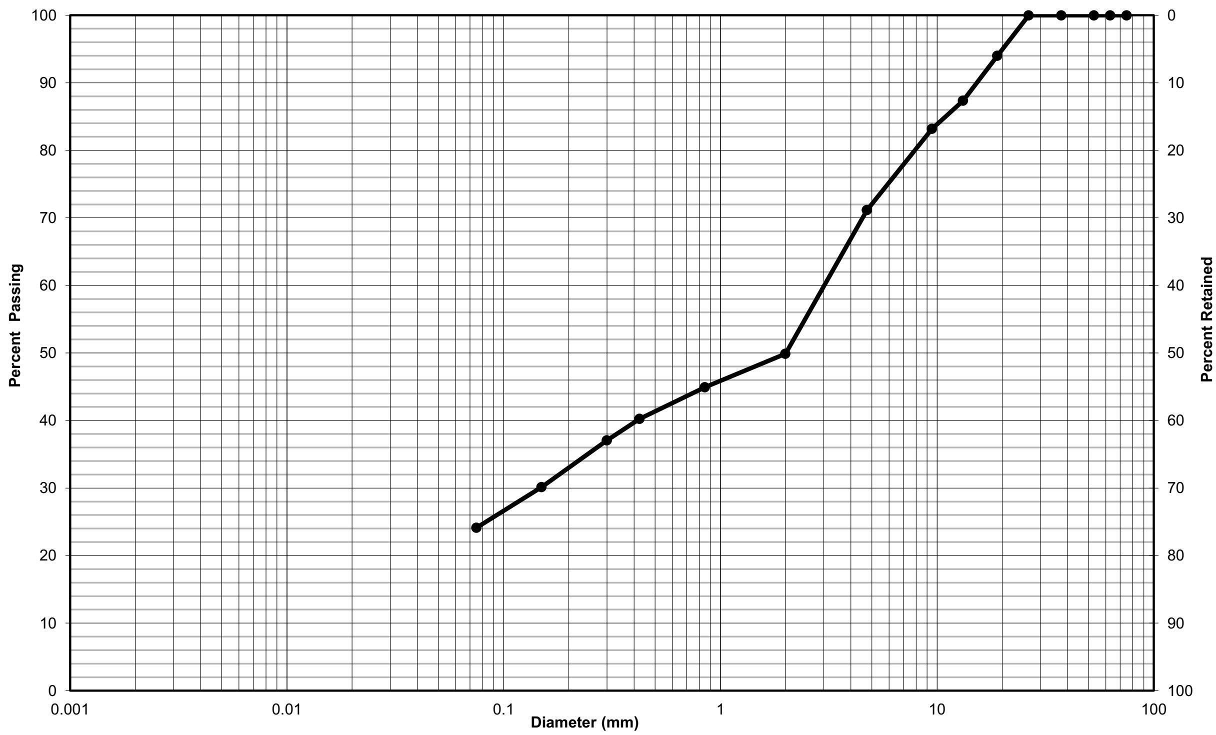
APPENDIX

C

LABORATORY TESTING RESULTS

Particle-Size Analysis of Soils
(ASTM D422)

Client:	Carleton University	**Lab no.:**	OL612-4
Project/Site:	Carleton University	**Project no.:**	191-12948-00
Borehole no.:	BH19-1	Sample no.:	SS1
Depth:	0.2-0.4m		



Clay & Silt	Sand			Gravel	
	Fine	Medium	Coarse	Fine	Coarse
Unified Soil Classification System					

	Gravel	Sand	Clay & Silt	Silt	Clay
Percent %	28.8	47.0	24.1	-	-

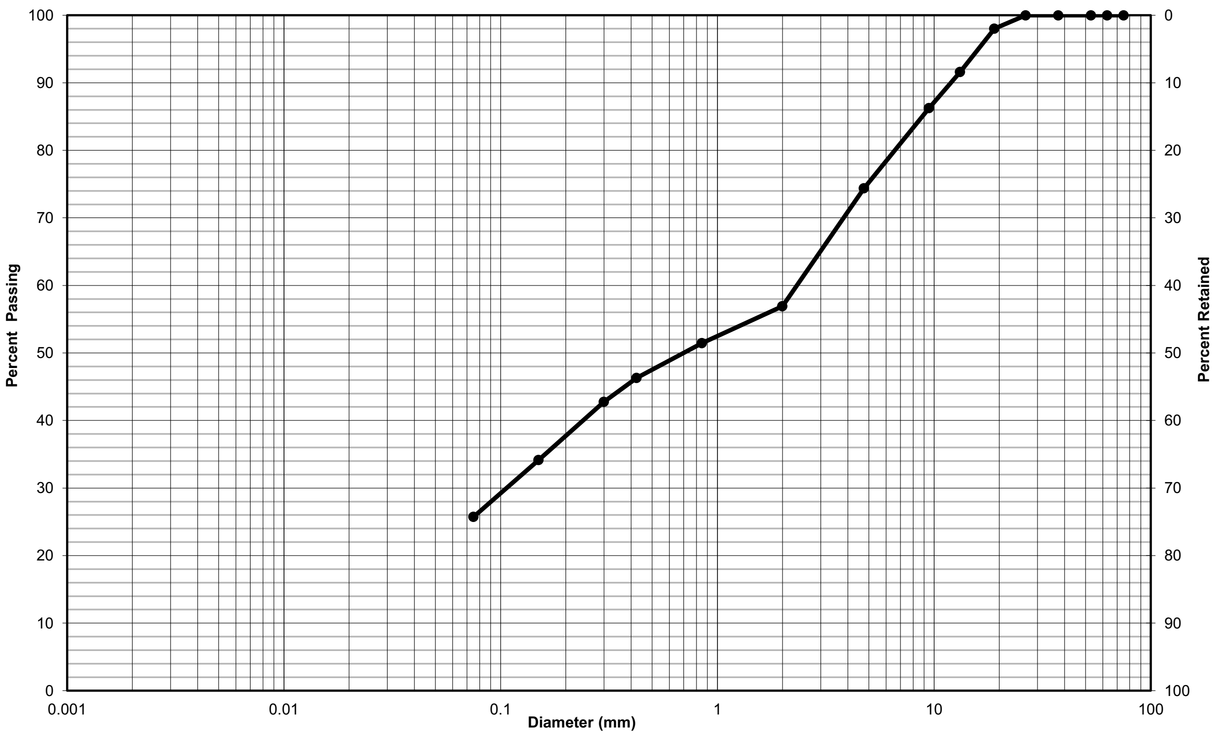
Remarks:

Performed by:	Andrey Belokurov	**Date:**	December 16, 2019
Verified by:	Rupesh Subedi	**Date:**	December 16, 2019

Particle-Size Analysis of Soils
(ASTM D422)

Client:	Carleton University	**Lab no.:**	OL612-6
Project/Site:	Carleton University	**Project no.:**	191-12948-00

Borehole no.:	BH19-5	Sample no.:	SS9
Depth:	1.9-2.0m		



Clay & Silt	Sand			Gravel	
	Fine	Medium	Coarse	Fine	Coarse
Unified Soil Classification System					

	Gravel	Sand	Clay & Silt	Silt	Clay
Percent %	25.6	48.6	25.7	-	-

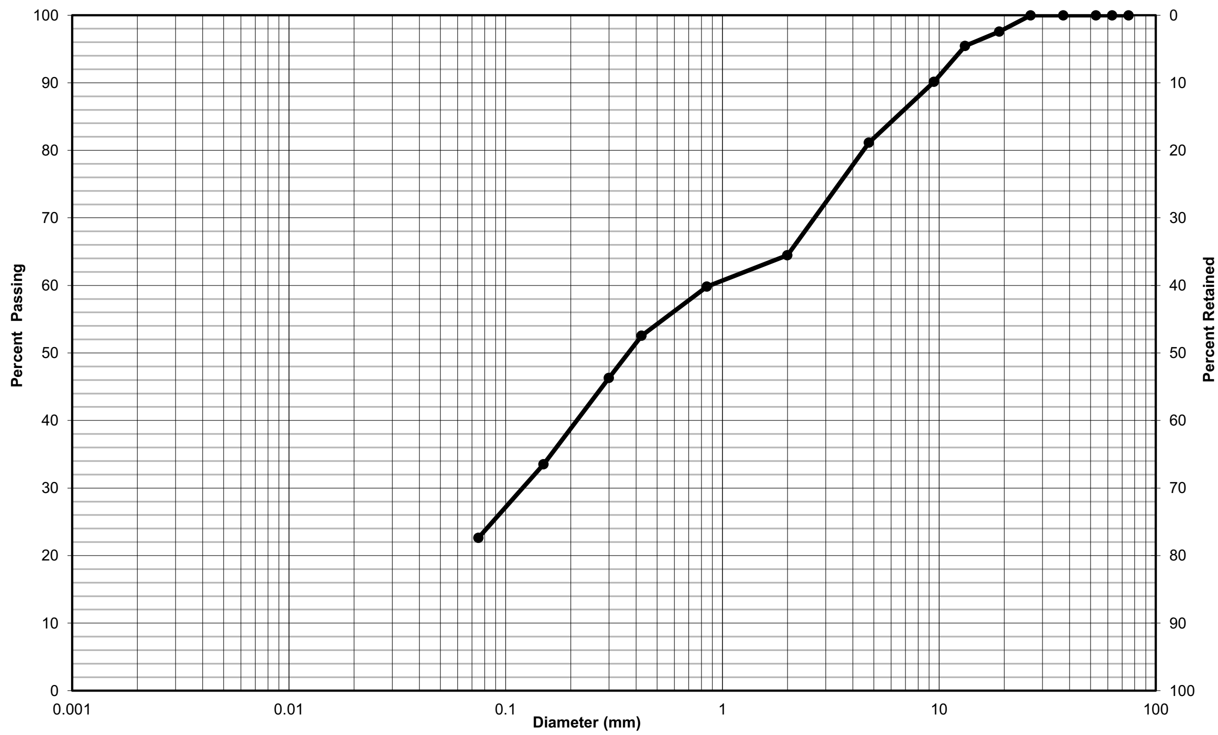
Remarks:

Performed by:	Andrey Belokurov	**Date:**	December 16, 2019
Verified by:	Rupesh Subedi	**Date:**	December 16, 2019

Particle-Size Analysis of Soils (ASTM D422)

Client:	Carleton University	**Lab no.:**	OL612-7
Project/Site:	Carleton University	**Project no.:**	191-12948-00

Borehole no.:	BH19-9	Sample no.:	SS7
Depth:	4.6-5.2m		



Clay & Silt	Sand			Gravel	
	Fine	Medium	Coarse	Fine	Coarse
Unified Soil Classification System					

Percent %	Gravel	Sand	Clay & Silt	Silt	Clay
	18.9	58.5	22.6	-	-

Remarks:

Performed by:	Andrey Belokurov	**Date:**	December 16, 2019
Verified by:	Rupesh Subedi	**Date:**	December 16, 2019

UNCONFINED COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMEN
ASTM D 7012 / D 4543

CLIENT:	Carleton University	**LAB No.:**	OL612-1
PROJECT:	Carleton University	**SAMPLE No.:**	BH19-2, Run 3
PROJECT No.:	191-12948-00	**DEPTH:**	TBD
		SAMPLING DATE:	

TESTING APPARATUS USED: **Loading device No.:** 1 **Caliper No.:** 1

	Average	
Diameter:	47.4	(mm)
Length:	104.8	(mm)
Straightness (0.5mm maximum) (S1):	<0.5	(mm)
Flatness (25µm maximum) (FP2):	<25	(µm)
Parallelism (0.25 ° maximum) (FP2)	<0.25	(°)
Perpendicularity (0.25 ° maximum) (P2)	<0.25	(°)

Mass:	478.2	(g)
Volume:	185026.8	(mm³)
Density:	2585	(kg/m³)
Moisture conditions:	as received	
Loading rate (0.5 to 1.0 MPa / sec):	0.6	(MPa/sec)
Test duration (2-15 minutes)	1:32	(minutes)
Maximum applied load:	95.72	(kN)
Compressive strength	**54.2**	(MPa)

REMARKS:

TESTED BY:	Rupesh Subedi	**DATE:**	December 13, 2019
VERIFIED BY:	Rupesh Subedi	**DATE:**	December 13, 2019

UNCONFINED COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMEN
ASTM D 7012 / D 4543

CLIENT:	Carleton University	**LAB No.:**	OL612-2
PROJECT:	Carleton University	**SAMPLE No.:**	BH19-7, Run5
PROJECT No.:	191-12948-00	**DEPTH:**	TBD
		SAMPLING DATE:	

TESTING APPARATUS USED: **Loading device No.:** 1 **Caliper No.:** 1

	Average	
Diameter:	46.4	(mm)
Length:	97.2	(mm)
Straightness (0.5mm maximum) (S1):	<0.5	(mm)
Flatness (25µm maximum) (FP2):	<25	(µm)
Parallelism (0.25 ° maximum) (FP2)	<0.25	(°)
Perpendicularity (0.25 ° maximum) (P2)	<0.25	(°)

Mass:	430.0	(g)	Volume:	164441.5	(mm³)
Density:	2615	(kg/m^3)			
Moisture conditions:	as received				
Loading rate (0.5 to 1.0 MPa / sec):	0.8	(MPa/sec)			
Test duration (2-15 minutes)	1:27	(minutes)			
Maximum applied load:	110.98	(kN)			
Compressive strength	**65.6**	(MPa)			

REMARKS:

TESTED BY:	Rupesh Subedi	**DATE:**	December 13, 2019
VERIFIED BY:	Rupesh Subedi	**DATE:**	December 13, 2019

UNCONFINED COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMEN ASTM D 7012 / D 4543

CLIENT:	Carleton University	**LAB No.:**	OL612-3
PROJECT:	Carleton University	**SAMPLE No.:**	BH19-8, Run4
PROJECT No.:	191-12948-00	**DEPTH:**	TBD
		SAMPLING DATE:	

TESTING APPARATUS USED: **Loading device No.:** 1 **Caliper No.:** 1

	Average	
Diameter:	47.3	(mm)
Length:	112.8	(mm)
Straightness (0.5mm maximum) (S1):	<0.5	(mm)
Flatness (25µm maximum) (FP2):	<25	(µm)
Parallelism (0.25 ° maximum) (FP2)	<0.25	(°)
Perpendicularity (0.25 ° maximum) (P2)	<0.25	(°)

Mass:	511.4	(g)	Volume:	197781.7	(mm^3)
Density:	2586	(kg/m^3)			
Moisture conditions:	as received				
Loading rate (0.5 to 1.0 MPa / sec):	0.5	(MPa/sec)			
Test duration (2-15 minutes)	2:23	(minutes)			
Maximum applied load:	119.87	(kN)			
Compressive strength	**68.3**	(MPa)			

REMARKS:

TESTED BY:	Rupesh Subedi	**DATE:**	December 13, 2019
VERIFIED BY:	Rupesh Subedi	**DATE:**	December 13, 2019

Certificate of Analysis

Client:	WSP Canada Inc. (SPL) 146 Colonnade Rd., Unit 17 Ottawa, ON K2E 7Y1	Report Number:	1922602
Attention:	Daniel Wall	Date Submitted:	2019-12-12
PO#:		Date Reported:	2019-12-17
Invoice to:	WSP Canada Inc.	Project:	191-12948-00
		COC #:	205897

Dear Daniel Wall:

Please find attached the analytical results for your samples. If you have any questions regarding this report, please do not hesitate to call (613-727-5692).

Report Comments:

APPROVAL: ________________________________

Addrine Thomas, Inorganics Supervisor

All analysis is completed at Eurofins Environment Testing Canada Inc. (Ottawa, Ontario) unless otherwise indicated.

Eurofins Environment Testing Canada Inc. (Ottawa, Ontario) is accredited by CALA, Canadian Association for Laboratory Accreditation to ISO/IEC 17025 for tests which appear on the scope of accreditation. The scope is available at: http://www.cala.ca/scopes/2602.pdf.

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Eurofins Environment Testing Canada Inc. (Ottawa, Ontario) is accredited by the Ontario Ministry of Agriculture, Food, and Rural Affairs for specific tests in agricultural soils.

Please note: Field data, where presented on the report, has been provided by the client and is presented for informational purposes only. Guideline values listed on this report are provided for ease of use (informational purposes) only. Eurofins recommends consulting the official provincial or federal guideline as required. Unless otherwise stated, measurement uncertainty is not taken into account when determining guideline or regulatory exceedances.

Certificate of Analysis

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Client:	WSP Canada Inc. (SPL) 146 Colonnade Rd., Unit 17 Ottawa, ON K2E 7Y1	Report Number:	1922602
Attention:	Daniel Wall	Date Submitted:	2019-12-12
PO#:		Date Reported:	2019-12-17
Invoice to:	WSP Canada Inc.	Project:	191-12948-00
		COC #:	205897

Group	Analyte	MRL	Units	Guideline	1471826	1471827	1471828
				Lab I.D.	1471826	1471827	1471828
				Sample Matrix	Soil	Soil	Soil
				Sample Type			
				Sampling Date	2019-10-23	2019-10-23	2019-10-23
				Sample I.D.	BH 19-5 SS4	BH 19-5 SS6	BH 19-9 SS9
Anions	Cl	0.002	%		0.175	0.027	0.039
	SO4	0.01	%		0.15	0.03	0.04
General Chemistry	Electrical Conductivity	0.05	mS/cm		2.57	0.44	0.54
	pH	2.00			7.45	7.90	8.11
	Resistivity	1	ohm-cm		389	2270	1850

Guideline = *** = Guideline Exceedence**

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

MRL = Method Reporting Limit, AO = Aesthetic Objective, OG = Operational Guideline, MAC = Maximum Acceptable Concentration, IMAC = Interim Maximum Acceptable Concentration, STD = Standard, PWQO = Provincial Water Quality Guideline, IPWQO = Interim Provincial Water Quality Objective, TDR = Typical Desired Range eurofins | Environment Testing

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QC Summary

Analyte	Blank	QC % Rec	QC Limits
Run No 377496 **Analysis/Extraction Date** 2019-12-16 **Analyst** OA **Method** AG SOIL			
SO4	<0.01 %	91	70-130
Run No 377523 **Analysis/Extraction Date** 2019-12-16 **Analyst** AET **Method** Ag Soil			
pH	7.11	99	90-110
Run No 377524 **Analysis/Extraction Date** 2019-12-16 **Analyst** AET **Method** Cond-Soil			
Electrical Conductivity	<0.05 mS/cm	99	90-110
Run No 377525 **Analysis/Extraction Date** 2019-12-16 **Analyst** AET **Method** Resistivity - soil			
Resistivity			
Run No 377590 **Analysis/Extraction Date** 2019-12-17 **Analyst** AET **Method** C CSA A23.2-4B			
Chloride		98	90-110

Guideline = *** = Guideline Exceedence**

Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

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APPENDIX

D

LIMITATIONS OF THIS REPORT

LIMITATIONS OF REPORT

This report is intended solely for the Client named. The material in it reflects our best judgment in light of the information available to WSP Canada Incorporated (WSP) at the time of preparation. Unless otherwise agreed in writing by WSP, it shall not be used to express or imply warranty as to the fitness of the property for a particular purpose. No portion of this report may be used as a separate entity, it is written to be read in its entirety.

The conclusions and recommendations given in this report are based on information determined at the test hole locations. The information contained herein in no way reflects on the environment aspects of the project, unless otherwise stated. Subsurface and groundwater conditions between and beyond the test holes may differ from those encountered at the test hole locations, and conditions may become apparent during construction, which could not be detected or anticipated at the time of the site investigation. The benchmark and elevations used in this report are primarily to establish relative elevation differences between the test hole locations and should not be used for other purposes, such as grading, excavating, planning, development, etc.

The design recommendations given in this report are applicable only to the project described in the text and then only if constructed substantially in accordance with the details stated in this report.

The comments made in this report on potential construction problems and possible methods are intended only for the guidance of the designer. The number of test holes may not be sufficient to determine all the factors that may affect construction methods and costs. For example, the thickness of surficial topsoil or fill layers may vary markedly and unpredictably. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusions as to how the subsurface conditions may affect their work. This work has been undertaken in accordance with normally accepted geotechnical engineering practices.

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. WSP accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

We accept no responsibility for any decisions made or actions taken as a result of this report unless we are specifically advised of and participate in such action, in which case our responsibility will be as agreed to at that time.