Soil Engineers Ltd.
CONSULTING ENGINEERS
GEOTECHNICAL • ENVIRONMENTAL • HYDROGEOLOGICAL • BUILDING SCIENCE
90 WEST BEAVER CREEK ROAD, SUITE #100, RICHMOND HILL, ONTARIO L4B 1E7 · TEL (416) 754-8515 · FAX (905) 881-8335

BARRIE	MISSISSAUGA	OSHAWA	NEWMARKET	GRAVENHURST	PETERBOROUGH	HAMILTON
TEL: (705) 721-7863	TEL: (905) 542-7605	TEL: (905) 440-2040	TEL: (905) 853-0647	TEL: (705) 684-4242	TEL: (905) 440-2040	TEL: (905) 777-7956
FAX: (705) 721-7864	FAX: (905) 542-2769	FAX: (905) 725-1315	FAX: (905) 881-8335	FAX: (705) 684-8522	FAX: (905) 725-1315	FAX: (905) 542-2769

A REPORT TO
2528233 ONTARIO INC.

A GEOTECHNICAL INVESTIGATION FOR PROPOSED 4-STOREY BUILDING WITH 1-LEVEL UNDERGROUND PARKING

1 LOCKHART ROAD

TOWN OF COLLINGWOOD

REFERENCE NO. 1812-S063

JANUARY 2019

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1.0 **INTRODUCTION**

In accordance with written authorization dated December 18, 2018, from Mr. Ryan Davidson of 2528233 Ontario Inc., a geotechnical investigation was carried out at 1 Lockhart Road, in the Town of Collingwood, for a proposed 4-Storey Building with 1-Level Underground Parking.

The purpose of the investigation was to reveal the subsurface conditions and to determine the engineering properties of the disclosed soils for the design and construction of the proposed project.

The findings and resulting geotechnical recommendations are presented in this Report.

2.0 SITE AND PROJECT DESCRIPTION

The Town of Collingwood is situated in the Simcoe Lowlands bordering the Niagara Escarpment where lacustrine deposits, outwash sands and glacial tills bedded onto undulated Black River and Trenton Group of bedrock.

The subject property is situated at the northeast corner of Lockhart Road and Hurontario Street, in the Town of Collingwood. The site area is a grass-covered open space adjacent to existing residential dwellings. The ground surface is relatively flat and level, with minor undulations.

The proposed project consists of the construction of a 4-storey building with 1-level underground parking and on-grade parking facility.

3.0 **FIELD WORK**

The field work, consisting of 1 borehole (Borehole No. 101) to a depth of 2.0 m below the prevailing ground surface, was performed on January 8, 2019, at the location shown on the Borehole Location Plan, Drawing No. 1. Six boreholes from the previous investigation at the site (Reference No. 1611-S016) are also included in the report. Refusal to augering was encountered at depths ranging from 1.7 to 2.7 m below the prevailing ground surface. A groundwater monitoring well was installed previously in Borehole 2 for groundwater monitoring purpose.

The holes were advanced at intervals to the sampling depths by a track-mounted, continuous-flight power-auger machine equipped for soil sampling. Standard Penetration Tests, using the procedures described on the enclosed "List of Abbreviations and Terms", were performed at the sampling depths. The test results are recorded as the Standard Penetration Resistance (or 'N' values) of the subsoil. The relative density of the granular strata and the consistency of the cohesive strata are inferred from the 'N' values. Split-spoon samples were recovered for soil classification and laboratory testing.

The field work was supervised and the findings were recorded by a Geotechnical Technician.

The elevation at each of the borehole locations was determined with reference to the geodetic elevations, as provided by the client.

4.0 SUBSURFACE CONDITIONS

Detailed descriptions of the encountered subsurface conditions are presented on the Borehole Logs, comprising Figures 1 to 7, inclusive. The revealed stratigraphy is plotted on the Subsurface Profile, Drawing No. 2, and the engineering properties of the disclosed soils are discussed herein.

The investigation has disclosed that beneath a veneer of topsoil and a layer of earth fill, in places, the site is underlain by strata of silty clay, sandy silt till and silty sand till. Refusal to augering was encountered at five of the boreholes, at depths ranging from 1.7 to 2.7 m; it is inferred that bedrock lies at shallow depths beneath the ground surface.

4.1 **Topsoil** (All Boreholes)

The revealed topsoil ranges from 20 to 90 cm thick. It is dark brown in colour, indicating that it contains appreciable amounts of roots and humus. These materials are unstable and compressible under loads; therefore, the topsoil is considered to be void of engineering value. Due to its humus content, it may produce volatile gases and generate an offensive odour under anaerobic conditions. Therefore, the topsoil must not be buried below any structures or deeper than 1.2 m below the finished grade, so that it will not have an adverse impact on the environmental well-being of the developed areas.

Since the topsoil is considered void of engineering value, it can only be used for general landscaping and landscape contouring purposes. A fertility analysis can be carried out to determine the suitability of the topsoil as a planting material.

4.2 **Earth Fill** (Boreholes 1, 3, 4, 5 and 6)

The earth fill extends to depths ranging from 1.0 to 2.1 m below the prevailing ground surface. Sample examination shows that the earth fill consists of silty clay, silty sand and sand, with traces of sand and gravel, and with occasional topsoil and peat layers.

The obtained 'N' values range from 5 to 14, with a median of 8 blows per 30 cm of penetration, indicating that the fill was loosely placed with nominal compaction. Its density is non-uniform and it is considered unsuitable to support structures sensitive to settlement.

The natural water content values range from 12% to 47%, with a median of 14%, indicating that the fill is in a moist to wet condition. The high water content for some of the fill samples is due to the presence of topsoil and peat.

A grain size analysis was performed on 1 representative sample of the earth fill; the result is plotted on Figure 8.

For structural use, the fill must be sorted free of any topsoil, peat, and any deleterious material and must be properly compacted.

One must be aware that the samples retrieved from boreholes 10 cm in diameter may not be truly representative of the geotechnical and environmental quality of the fill, and do not indicate whether the topsoil beneath the earth fill was completely stripped. This should be further assessed by laboratory testing and/or test pits.

4.3 Silty Clay (Borehole 6)

The silty clay was encountered below the earth fill layer and extends to the maximum investigated depth. The clay is laminated with sand and silt seams and layers, showing it is a lacustrine deposit.

The obtained ‘N’ value of 50 blows per 15 cm of penetration indicates that the consistency of the clay is hard.

The natural water content of the silty clay sample is 8%, indicating that the clay is in a moist condition.

Based on the above findings, the following engineering properties are deduced:

- High frost susceptibility and high soil-adfreezing potential.
- Low water erodibility.
- Low permeability, with an estimated coefficient of permeability of 10^{-7} cm/sec, an estimated percolation rate of over 80 min/cm, and runoff coefficients of:

Slope	
0% - 2%	0.15
2% - 6%	0.20
6% +	0.28

- A cohesive-frictional soil, its shear strength is derived from consistency and augmented by the internal friction of the silt. Its shear strength is moisture dependent.

- The clay will be prone to sloughing if it is exposed for prolonged periods in steep cuts. This would generally be initiated by infiltrating precipitation or groundwater seeping out from the silt and fine sand layers.
- A very poor pavement-supportive material, with an estimated California Bearing Ratio (CBR) value of 3% or less.
- Moderately high corrosivity to buried metal, with an estimated electrical resistivity of 3500 ohm·cm.

4.4 **Sandy Silt Till** and **Silty Sand Till** (Boreholes 1, 2, 3, 4, 5 and 101)

The tills were encountered below either the topsoil or earth fill layers, and extend to the maximum investigated depth at all above boreholes. The tills consist of a random mixture of soil particle sizes ranging from clay to gravel, with the silt or sand being the predominant fraction. The tills contain rock fragments. The till is weathered to a depth of 0.7 m at Borehole 2.

Hard resistance to augering was encountered in places, showing that cobbles, boulders and rock fragments are present in the tills. Occasional wet sand and silt seams and layers were found in the till mantle.

The obtained 'N' values range from 19 blows per 30 cm to no penetration, with a median of 70 blows per 15 cm, from which the relative density of the tills is inferred as compact to very dense, being generally very dense.

The natural water content values range from 6% to 20%, with a median of 8%, showing that the tills are in a moist to wet, generally moist condition.

Grain size analyses were performed on 3 representative samples of the tills; the gradations are plotted on Figures 9 and 10.

The deduced engineering properties pertaining to the project are given below:

- High frost susceptibility, and moderate water erodibility.
- Relatively low permeability, with an estimated coefficient of permeability of 10^{-4} to 10^{-6} cm/sec, an average percolation rate of about 20 to 50 min/cm, and runoff coefficients of:

Slope	
0% - 2%	0.07 to 0.15
2% - 6%	0.12 to 0.20
6% +	0.18 to 0.28

- A frictional-cohesive soil, its shear strength is density dependent and is augmented by cementation and cohesion.
- It will slough slowly if submerged in an unconfined state, or from an open-face cut under seepage conditions, particularly in the zone where wet sand and silt layers are prevalent.
- A fair pavement-supportive material, with an estimated CBR value of 8%.
- Moderately low corrosivity to buried metal, with an estimated electrical resistivity of 5000 ohm·cm.

4.5 Interpretation of Refusal to Augering

Refusal to augering was encountered in Boreholes 1, 2, 3, 4 and 101, at depths ranging from 1.7 to 2.7 m below the prevailing ground surface. It is inferred that shallow bedrock occurs at these levels. The type or quality of bedrock, however, was not proven by rock coring, which is beyond the scope of the investigation.

4.6 Compaction Characteristics of the Revealed Soils

The obtainable degree of compaction is primarily dependent on the soil moisture and, to a lesser extent, on the type of compactor used and the effort applied.

As a general guide, the typical water content values of the revealed soils for Standard Proctor compaction are presented in Table 1.

Table 1 - Estimated Water Content for Compaction

Soil Type	**Determined Natural Water Content (%)**	**Water Content (%) for Standard Proctor Compaction**	
		100% (optimum)	**Range for 95% or +**
Earth Fill	12 to 47 (median 14)	11 to 16	6 to 21
Silty Clay	8	16	12 to 21
Sandy Silt Till and Silty Sand Till	6 to 20 (median 8)	10 to 12	6 to 16

According to the above findings, the sandy silt till, silty sand till and portion of the earth fill are generally suitable for a 95% or + Standard Proctor compaction. However, the silty clay is too dry and will require addition of water prior to structural compaction; whereas part of the earth fill is too wet and will require aeration or mixing with drier soil prior to structural compaction. The earth fill must be sorted free of topsoil, peat, and any other deleterious materials, prior to its use as structural backfill.

The silty clay fill, silty clay and tills should be compacted using a heavy-weight, kneading-type roller. The sand fill can be compacted by a smooth roller with or without vibration, depending on the water content of the soil being compacted. The lifts for compaction should be limited to 20 cm, or to a suitable thickness as assessed by test strips performed by the equipment which will be used at the time of construction.

When compacting the silty clay or tills on the dry side of the optimum, the compactive energy will frequently bridge over the chunks in the soil and be transmitted laterally into the soil mantle. Therefore, the lifts of these soils must be limited to 20 cm or less (before compaction). It is difficult to monitor the lifts of backfill placed in deep trenches; therefore, it is preferable that the compaction of backfill at depths over 1.0 m below the road subgrade be carried out on the wet side of the optimum. This would allow a wider latitude of lift thickness. Wetting of the till will be necessary to achieve this requirement.

If the compaction of the soils is carried out with the water content within the range for 95% Standard Proctor dry density but on the wet side of the optimum, the surface of the compacted soil mantle will roll under the dynamic compactive load. This is unsuitable for road construction since each component of the pavement structure is to be placed under dynamic conditions which will induce the rolling action of the subgrade surface and cause structural failure of the new pavement. The foundations or bedding of the sewer and slab-on-grade, on the other hand, will be placed on a subgrade which will not be subjected to impact loads. Therefore, the structurally compacted soil mantle with the water content on the wet side or dry side of the optimum will provide an adequate subgrade for the construction.

The presence of boulders and rock fragments in the backfill will prevent transmission of the compactive energy into the underlying material to be compacted. If an appreciable amount of boulders over 15 cm in size is mixed with the material, it must either be sorted or must not be used for structural backfill.

5.0 GROUNDWATER CONDITIONS

Groundwater seepage encountered during augering was recorded on the field logs. The boreholes were checked for the presence of groundwater or the occurrence of cave-in upon completion of the field work. The data are plotted on the Borehole Logs and listed in Table 2.

Table 2 - Groundwater Levels

Borehole No.	Borehole Depth (m)	Measured Groundwater/Cave-In* Level On Completion	
		Depth (m)	**Elevation (m)**
1	1.7	1.2	187.34
2	1.8	Dry	-
3	2.7	1.4	187.28
4	2.4	1.4	187.39
5	1.7	Dry	-
6	1.8	Dry	-
101	2.0	1.2	187.7

Groundwater was detected at depths of 1.2 m and 1.4 m at four of the boreholes; the other boreholes remained dry upon completion of field work. The groundwater level will fluctuate with the seasons.

The groundwater yield from the silty clay and tills, due to their low to relatively low permeability, will be small and limited in quantity.

6.0 DISCUSSION AND RECOMMENDATIONS

The investigation has disclosed that beneath a veneer of topsoil, and a layer of earth fill, in places, the site is underlain by strata of hard silty clay, and compact to very dense, generally very dense sandy silt till and silty sand till. Refusal to augering was encountered at 5 borehole locations, at depths ranging from 1.7 to 2.7 m, and it is inferred that bedrock lies at shallow depths beneath the ground surface.

Groundwater was detected at depths of 1.2 m and 1.4 m at four of the boreholes; the other boreholes remained dry upon completion of field work. The groundwater level will fluctuate with the seasons.

The groundwater yield from the silty clay and tills, due to their low to relatively low permeability, will be small and limited in quantity.

The geotechnical findings which warrant special consideration are presented below:

1. The topsoil is highly compressible and must be removed as it is unsuitable for engineering applications. Due to the high humus content, the topsoil and topsoil fill will generate volatile gases under anaerobic conditions. For the environmental as well as the geotechnical well-being of the future development, the topsoil should not be buried within the building envelope, or deeper than a depth of 1.2 m below the exterior finished grade.
2. The earth fill in its present condition is not capable of sustaining foundation loads or any structure sensitive to settlement. It can be upgraded to structural status by sorting it free of topsoil, peat, and any other deleterious material prior to proper compaction.

3. The sound natural soils and the underlying bedrock are suitable for normal spread and strip footing construction. All of the footing subgrade must be inspected by a geotechnical engineer, or a geotechnical technician under the supervision of a geotechnical engineer, to ensure that the revealed conditions are compatible with the foundation requirements. Test pits will be required at the building location to confirm the bedrock subgrade at the time of construction.
4. Perimeter subdrains and dampproofing of the foundation walls will be required for basement construction. The subdrains must be shielded by a fabric filter to prevent blockage by silting.
5. For slab-on-grade construction, any soft or loose soils should be subexcavated, aerated and properly recompacted in layers prior to the placement of the slab. Any new material for raising the grade should consist of organic-free soil compacted to at least 98% of its maximum Standard Proctor dry density. The slab should be constructed on a granular base, 20 cm thick, consisting of 20-mm Crusher-Run Limestone, or equivalent, compacted to its maximum Standard Proctor dry density.
6. A Class 'B' bedding, consisting of compacted 20-mm Crusher-Run Limestone, is recommended for the construction of the underground services. The sewer joints should be leak-proof, or wrapped with an appropriate waterproof membrane, to prevent subgrade migration. Lean concrete can be used for subgrade stabilization. In areas where more extensive dewatering is required for sewer construction, a Class 'A' bedding can also be considered.
7. The in-situ soils are highly frost susceptible, with high soil-adfreezing potential. Special measures must be incorporated into the building construction to prevent serious damage due to soil adfreezing.

8. Excavation into the tills containing boulders and rock fragments may require extra effort and the use of a heavy-duty backhoe. Boulders larger than 15 cm in size are not suitable for structural backfill.
9. Excavation into the bedrock will require the use of a pneumatic hammer. Due to the proximity of the adjacent residences and other structures, any rock blasting must be conducted in a controlled manner by specialized personnel.

The recommendations appropriate for the project described in Section 2.0 are presented herein. One must be aware that the subsurface conditions may vary between boreholes. Should this become apparent during construction, a geotechnical engineer must be consulted to determine whether the following recommendations require revision.

6.1 Foundations

Based on the borehole findings, the recommended soil pressures and suitable founding levels are presented in Table 3.

Table 3 - Founding Levels

Borehole No.	**Recommended Maximum Allowable Soil Pressure (SLS)/ Factored Ultimate Soil Bearing Pressure (ULS) and Suitable Founding Level**			
	400 kPa (SLS) 640 kPa (ULS)		**800 kPa (SLS) 1280 kPa (ULS)**	
	Depth (m)	**El. (m)**	**Depth (m)**	**El. (m)**
1	-	-	1.6 or +	186.94 or -
2	-	-	1.2 or +	187.40 or -
3	-	-	2.4 or +	186.28 or -
4	-	-	1.6 or +	187.19 or -
5	-	-	1.6 or +	187.54 or -
6	-	-	1.6 or +	187.44 or -
101	1.6 or +	187.30	-	-

The recommended soil pressures (SLS) incorporate a safety factor of 3. The total and differential settlements of the footings are estimated to be 25 mm and 15 mm, respectively.

The footings exposed to weathering must have 1.2 m of earth cover for frost protection.

When the proposed footings are founded on sound bedrock, a Bearing Pressure of 3500 kPa (SLS/ULS) is recommended for the design of the strip and spread footings. Test pits will be required at the time of construction to confirm the depth of the bedrock.

For footings founded on sound bedrock, the soil cover for frost protection can be eliminated. The settlement of footings founded on bedrock will be negligible.

Perimeter subdrains and dampproofing of the foundation walls are required for basement construction; due to the occurrence of shallow groundwater, it is recommended that the basement floor level should remain at least 0.5 m above the highest level of groundwater fluctuation. To provide a dry floor, subdrains consisting of filter-wrapped weepers must be installed beneath the floor slab and connected to a positive outlet. A vapour barrier must be placed in the granular base of the floor above the crown of the subdrain.

Where the basement is considered to be placed below the groundwater regime, waterproofing will be required. The basement must be designed to resist the hydrostatic pressure and uplift; this will be costly and difficult to construct.

The footings must meet the requirements specified in the latest Ontario Building Code. As a guide, the structure should be designed to resist an earthquake force using Site Classification 'C' (soft rock).

Due to the presence of topsoil, earth fill and peat, the footing subgrade must be inspected by either a geotechnical engineer, or a geotechnical consultant under the supervision of a geotechnical engineer, to ensure that the subgrade conditions are compatible with the foundation design requirements.

As noted, the in-situ soils are high in frost heave and soil-adfreezing potential. If these soils are to be used for the foundation backfill, the foundation walls should be shielded by a polyethylene slip-membrane for protection against soil adfreezing.

6.2 Slab-On-Grade

In preparation of the subgrade, the topsoil, peat and earth fill must be completely removed. The subgrade for slab-on-grade construction should consist of sound natural soils or properly-compacted inorganic earth fill. The subgrade should be inspected and proof-rolled. Any weathered, soft or loose soil detected must be subexcavated and replaced with inorganic earth fill or granular fill, compacted to at least 98% or + of its maximum Standard Proctor dry density.

The slab should be constructed on a granular base, 20 cm thick, consisting of 20-mm Crusher-Run Limestone, or equivalent, compacted to its maximum Standard Proctor dry density.

A Modulus of Subgrade Reaction of 25 MPa/m and 50 MPa/m can be used for the design of the floor slab on soil and bedrock, respectively.

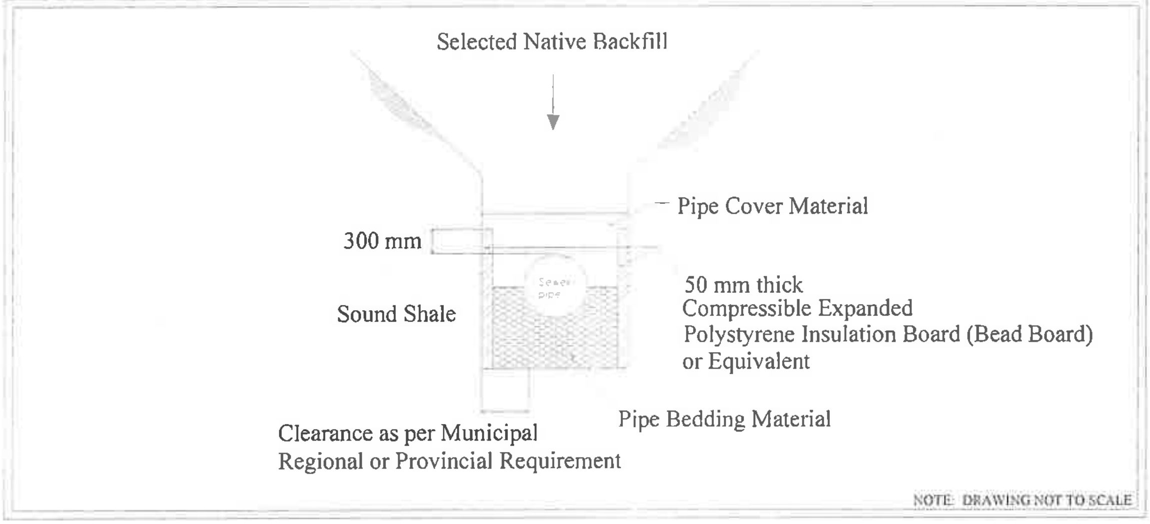
The exterior grading must be such that water is directed away from the building envelope.

6.3 Underground Services

A Class 'B' bedding, consisting of compacted 20-mm Crusher-Run Limestone, is recommended for the construction of the underground services. The sewer joints should be leak-proof, or wrapped with an appropriate waterproof membrane, to prevent subgrade migration. If subgrade stabilization is required, lean concrete can be used. In areas where more extensive dewatering is required for construction, a Class 'A' bedding should be considered.

Where the pipe is to be placed in sound bedrock, the trench sides should be sloped rather than vertical. The side slopes shall be no steeper than 2 vertical:1 horizontal. Alternatively, depending on the rock type, a larger trench can be excavated and the rock face can be lined with 50-mm Styrofoam, or equivalent. This will act as a cushioning layer to reduce the residual stress exerted on the buried structure. The bedding material should have a minimum thickness of 20 cm. Backfill between the pipes and the lined rock face should consist of fine sand with medium compaction. The recommended scheme is illustrated in Diagram 1.

Diagram 1 - Sewer Installation in Sound Bedrock



The above requirement is only necessary where the bedrock consists of sound shale.

The silty clay has moderately high corrosivity to buried metal. As a guide, an electrical resistivity of 3500 ohm·cm should be used to determine the mode of protection for the water main against soil corrosion. This, however, should be confirmed by testing the soil along the water main alignment at the time of sewer construction.

6.4 Backfilling in Trenches and Excavated Areas

The on-site inorganic soils are suitable for trench backfill. In the zone within 1.0 m below the pavement subgrade, the backfill should be compacted to at least 98% of its maximum Standard Proctor dry density with the moisture content 2% to 3% drier than the optimum. In the lower zone, a 95% or + Standard Proctor compaction is considered to be adequate; however, the material must be compacted on the wet side of the optimum.

The excavated bedrock is not suitable for trench backfill unless it is crushed to meet OPSS Granular 'A' or 'B' specifications.

In normal project construction practice, the problem areas of settlement largely occur adjacent to foundation walls, columns, manholes, catch basins and services crossings. In areas which are inaccessible to a heavy compactor, the interface of the native soils and sand backfill will have to be flooded for a period of at least 1 day.

The narrow trenches for services crossings should be cut at 1 vertical:2 horizontal so that the backfill in the trenches can be effectively compacted. Otherwise, soil arching in the trenches will prevent achievement of the proper compaction. In this case, imported sand fill, which can be appropriately compacted by using a smaller vibratory compactor, must be used. The areas at the interface of the native soil and the sand backfill should preferably be flooded for at least 1 day.

One must be aware of the possible consequences during trench backfilling and exercise caution as described below:

- When construction is carried out in freezing winter weather, allowance should be made for these following conditions. Despite stringent backfill monitoring, frozen soil layers may inadvertently be mixed with the structural trench backfill. Should the in situ soil have a water content on the dry side of the optimum, it would be impossible to wet the soil due to the freezing condition, rendering difficulties in obtaining uniform and proper compaction. Furthermore, the freezing condition will prevent flooding of the backfill when it is required, such as when the trench box is removed, or when backfill consists of limestone mixture. The above will invariably cause backfill settlement that may become evident within 1 to several years, depending on the depth of the trench which has been backfilled.
- In areas where the underground services construction is carried out during the winter months, prolonged exposure of the trench walls will result in frost heave within the soil mantle of the walls. This may result in some settlement as the frost recedes, and repair costs will be incurred prior to the final surfacing of the new pavement.
- To backfill a deep trench, one must be aware that future settlement is to be expected, unless the side of the cut is flattened to at least 1 vertical: 1.5 + horizontal, and the lifts of the fill and its moisture content are stringently controlled; i.e., lifts should be no more than 20 cm (or less if the backfilling conditions dictate) and uniformly compacted to achieve at least 95% of the maximum Standard Proctor dry density, with the moisture content on the wet side of the optimum.
- It is often difficult to achieve uniform compaction of the backfill in the lower vertical section of a trench which is an open cut or is stabilized by a trench box, particularly in the sector close to the trench walls or the sides of the box. These sectors must be backfilled with sand. In a trench stabilized

by a trench box, the void left after the removal of the box will be filled by the backfill. It is necessary to backfill this sector with sand, and the compacted backfill must be flooded for 1 day, prior to the placement of the backfill above this sector, i.e., in the upper sloped trench section. This measure is necessary in order to prevent consolidation of inadvertent voids and loose backfill which will compromise the compaction of the backfill in the upper section. In areas where groundwater movement is expected in the sand fill mantle, anti-seepage collars should be provided.

6.5 Pavement Design

According to the borehole findings, the recommended structure of the on-grade pavement design is presented in Table 4.

Table 4 - Pavement Design

Course	Thickness (mm)	OPS Specifications
Asphalt Surface	40	HL-3
Asphalt Binder	50	HL-8
Granular Base	150	Granular 'A' or equivalent
Granular Sub-base Light-Duty Parking Driveway or Fire Route	 300 400	Granular 'B' or equivalent

In preparation of the subgrade, the subgrade surface should be proof-rolled and any soft subgrade, organics and deleterious materials within 1.0 m below the underside of the granular sub-base should be subexcavated and replaced by properly compacted organic-free earth fill.

All the granular bases should be compacted to their maximum Standard Proctor dry density.

Earth fill to raise the grade for pavement construction should consist of organic-free soil uniformly compacted to 95% or + of its maximum Standard Proctor dry density.

The subgrade in the zone within 1.0 m below the underside of the granular sub-base should be compacted to at least 98% of its maximum Standard Proctor dry density,

with a moisture content 2% to 3% drier than its optimum. If the pavement is to be placed on the existing earth fill, the fill must be surface-compacted, and any serious topsoil inclusions and/or deleterious materials at the subgrade surface must be removed.

Along the perimeter where surface runoff may drain onto the pavement or water may seep into the granular bases, a swale or an intercept subdrain system should be installed. Subdrains, consisting of filter-wrapped weepers, should also be installed 0.3 m below the granular sub-base, and they should be connected to the catch basins and storm manholes in the paved areas and backfilled with free-draining granular material.

6.6 **Sidewalks, Interlocking Stone Pavement and Landscaping**

Interlocking stone pavement and the sidewalks in areas which are sensitive to frost-induced ground movement, such as entrances, must be constructed on a free-draining, non-frost-susceptible granular material such as Granular 'B'. It must extend to 1.4 m below the slab or pavement surface and be provided with positive drainage such as weeper subdrains connected to manholes or catch basins. Alternatively, the sidewalks and the interlocking stone pavement should be properly insulated with 70-mm Styrofoam, or equivalent.

6.7 Soil Parameters

The recommended soil parameters for the project design are given in Table 5.

Table 5 - Soil Parameters

Unit Weight and Bulk Factor			
	Unit Weight (kN/m^3)	**Estimated Bulk Factor**	
	Bulk	**Loose**	**Compacted**
Earth Fill and weathered Soil	21.0	1.20	1.00
Silty Clay	20.5	1.30	1.05
Sound Tills	22.0	1.33	1.03
Lateral Earth Pressure Coefficients			
	Active K_a	**At Rest K_o**	**Passive K_p**
Earth Fill and weathered Soil	0.40	0.50	2.50
Silty Clay	0.35	0.45	2.86
Sound Tills	0.30	0.40	3.33

6.8 Excavation

Excavation should be carried out in accordance with Ontario Regulation 213/91.

Any excavation in excess of 1.2 m should be sloped at 1 vertical:1 horizontal for stability.

Excavation into the very dense tills containing boulders and rock fragments will require extra effort and a properly equipped backhoe. Boulders larger than 15 cm in size are not suitable for structural backfill.

Excavation into the bedrock will require the use of a pneumatic hammer. Due to the proximity of the adjacent residence and other structures, any rock blasting must be conducted in a controlled manner by specialized personnel.

Where rock blasting or construction with vibration is to be performed at the site, pre- and post-construction surveys are to be conducted to document the existing condition of the adjacent structures in order to settle any claims for damage that may be caused by the blasting/construction vibration.

For excavation purposes, the types of soils are classified in Table 6.

Table 6 - Classification of Soils for Excavation

Material	Type
Bedrock	1
Sound Tills and weathered Bedrock	2
Earth Fill, Silty Clay and weathered Soil	3

During excavation, groundwater seepage derived from infiltrated precipitation may be encountered at shallow depths. The yield of groundwater from the silty clay and tills will be small and limited. It can be controlled by pumping from sumps.

Prospective contractors must be asked to assess the in situ subsurface conditions for soil cuts by digging test pits to at least 0.5 m below the intended bottom of excavation. These test pits should be allowed to remain open for a period of at least 4 hours to assess the trench conditions.

7.0 LIMITATIONS OF REPORT

This report was prepared by Soil Engineers Ltd. for the account of 2528233 Ontario Inc., and for review by its designated agents, financial institutions, and government agencies. Use of the report is subject to the conditions and limitations of the contractual agreement. The material in the report reflects the judgment of Frank Lee, P.Eng., and Bernard Lee, P.Eng, in light of the information available to it at the time of preparation. Any use which a Third Party makes of this report, and/or any reliance on decisions to be made based on it are the responsibility of such Third Parties. Soil Engineers Ltd. accepts no responsibility for damages, if any, suffered by any Third Party as a result of decisions made or actions based on this report.

SOIL ENGINEERS LTD.

LICENSED PROFESSIONAL ENGINEER
Jan 28
K. M. LEE
26094508
PROVINCE OF ONTARIO

Frank Lee, P.Eng.

LICENSED PROFESSIONAL ENGINEER
Jan 28, 201[illegible]
B. P. Y. LEE
100104568
PROVINCE OF ONTARIO

Bernard Lee, P.Eng.
FL/BL:dd

LIST OF ABBREVIATIONS AND DESCRIPTION OF TERMS

The abbreviations and terms commonly employed on the borehole logs and figures, and in the text of the report, are as follows:

SAMPLE TYPES

AS	Auger sample
CS	Chunk sample
DO	Drive open (split spoon)
DS	Denison type sample
FS	Foil sample
RC	Rock core (with size and percentage recovery)
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

PENETRATION RESISTANCE

Dynamic Cone Penetration Resistance:

A continuous profile showing the number of blows for each foot of penetration of a 2-inch diameter, 90° point cone driven by a 140-pound hammer falling 30 inches.

Plotted as '—●—'

Standard Penetration Resistance or 'N' Value:

The number of blows of a 140-pound hammer falling 30 inches required to advance a 2-inch O.D. drive open sampler one foot into undisturbed soil.

Plotted as '○'

WH	Sampler advanced by static weight
PH	Sampler advanced by hydraulic pressure
PM	Sampler advanced by manual pressure
NP	No penetration

SOIL DESCRIPTION

Cohesionless Soils:

'N' (blows/ft)	Relative Density
0 to 4	very loose
4 to 10	loose
10 to 30	compact
30 to 50	dense
over 50	very dense

Cohesive Soils:

Undrained Shear Strength (ksf)	'N' (blows/ft)	Consistency
less than 0.25	0 to 2	very soft
0.25 to 0.50	2 to 4	soft
0.50 to 1.0	4 to 8	firm
1.0 to 2.0	8 to 16	stiff
2.0 to 4.0	16 to 32	very stiff
over 4.0	over 32	hard

Method of Determination of Undrained Shear Strength of Cohesive Soils:

x 0.0 Field vane test in borehole; the number denotes the sensitivity to remoulding

△ Laboratory vane test

□ Compression test in laboratory

For a saturated cohesive soil, the undrained shear strength is taken as one half of the undrained compressive strength

METRIC CONVERSION FACTORS

1 ft = 0.3048 metres

1lb = 0.454 kg

1 inch = 25.4 mm

1ksf = 47.88 kPa

JOB NO.: 1812-S063

LOG OF BOREHOLE NO.: 1

FIGURE NO.: 1

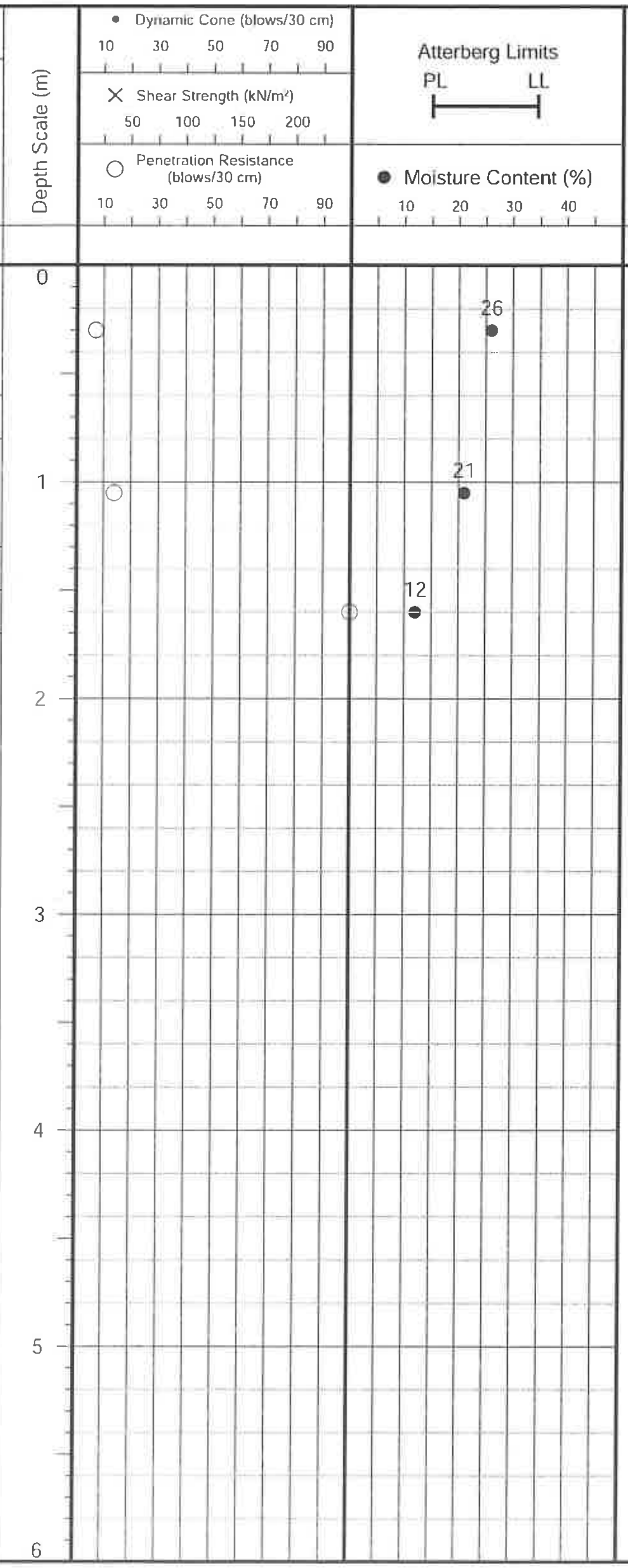
PROJECT DESCRIPTION: Proposed 4-Storey Building
with 1-Level Underground Parking

PROJECT LOCATION: 1 Lockhart Road
Town of Collingwood

METHOD OF BORING: Flight-Auger

DRILLING DATE: November 4, 2016

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
188.5 0.0	Ground Surface **70 cm TOPSOIL**			
	with rock fragments Brown **EARTH FILL** silty clay with topsoil layers	1 2	DO DO	7 14
187.1 1.4	Brown, very dense **SANDY SILT TILL** with rock fragments	3	DO	50/5
186.8 1.7	**END OF BOREHOLE** **Refusal to augering** **Inferred shallow bedrock**			



WATER LEVEL

▽ W.L. @ El. 187.34 m on completion

Soil Engineers Ltd.

JOB NO.: 1812-S063

LOG OF BOREHOLE NO.: 2

FIGURE NO.: 2

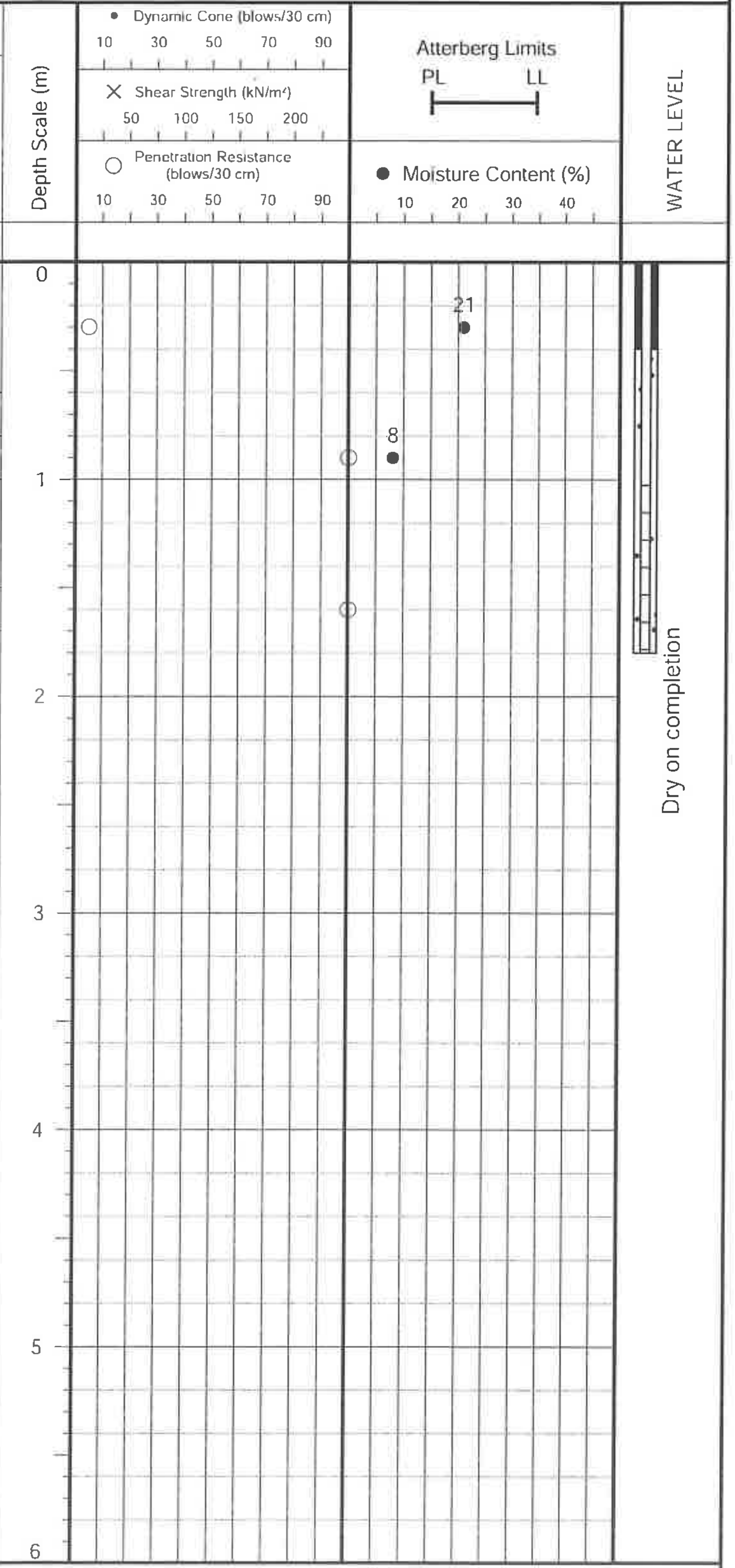
PROJECT DESCRIPTION: Proposed 4-Storey Building
with 1-Level Underground Parking

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 1 Lockhart Road
Town of Collingwood

DRILLING DATE: November 4, 2016

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value
188.6	Ground Surface			
0.0	**40 cm TOPSOIL**			
		1	DO	5
	Brown, loose to very dense weathered			
		2	DO	NP
	SANDY SILT TILL occ. wet sand and silt seams and layers, cobbles and boulders			
		3	DO	NP
186.8 1.8	**END OF BOREHOLE** **Refusal to augering** **Inferred shallow bedrock** Installed 50 mm Ø monitoring well to 1.8 m provided with a steel protective casing			



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Page: 1 of 1

JOB NO.: 1812-S063

LOG OF BOREHOLE NO.: 3

FIGURE NO.: 3

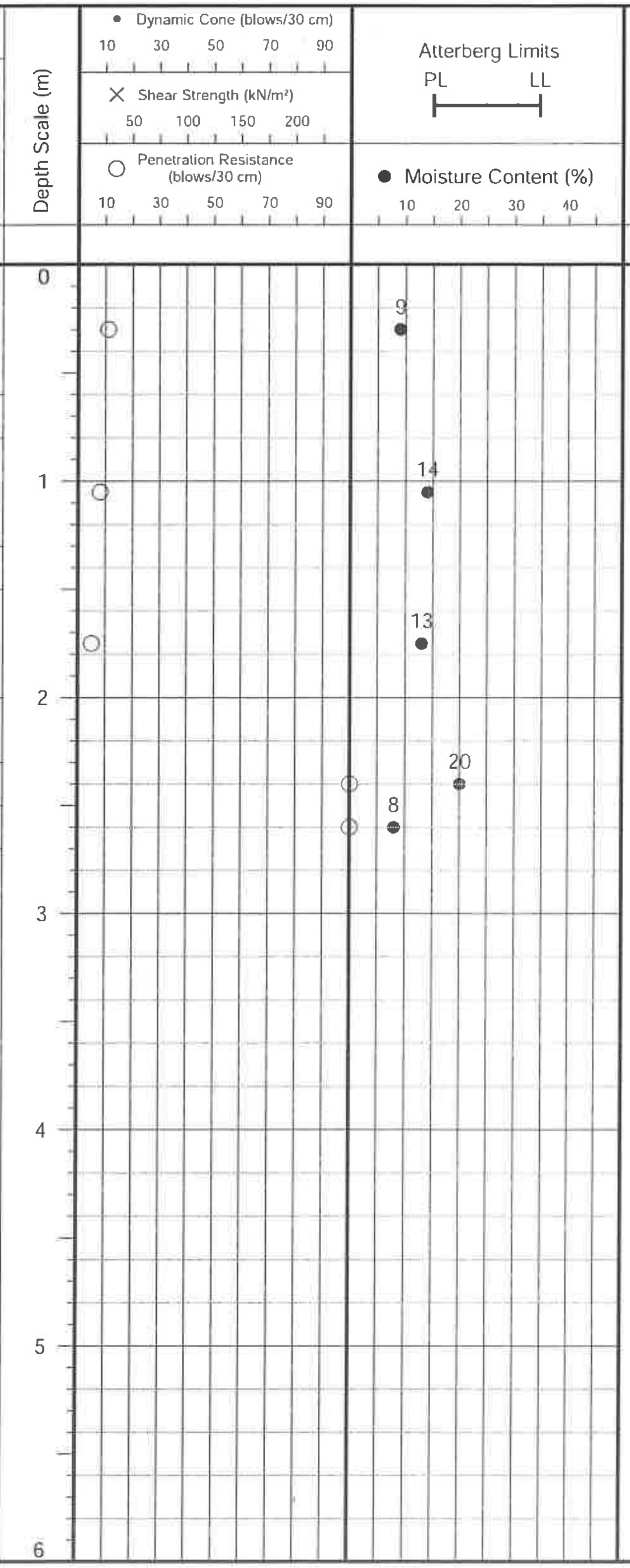
PROJECT DESCRIPTION: Proposed 4-Storey Building
with 1-Level Underground Parking

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 1 Lockhart Road
Town of Collingwood

DRILLING DATE: November 4, 2016

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
188.7	Ground Surface			
0.0	**70 cm TOPSOIL**	1	DO	11
	Brown **EARTH FILL** silty clay and silty sand traces of sand and gravel with topsoil layers	2	DO	8
		3	DO	5
186.6 2.1	Brown, very dense **SANDY SILT TILL** with rock fragments	4	AS	100
		5	DO	100/3
186.0 2.7	**END OF BOREHOLE** **Refusal to augering** **Inferred shallow bedrock**			



WATER LEVEL

W.L. @ El. 187.28 m on completion

Soil Engineers Ltd.

JOB NO.: 1812-S063

LOG OF BOREHOLE NO.: 4

FIGURE NO.: 4

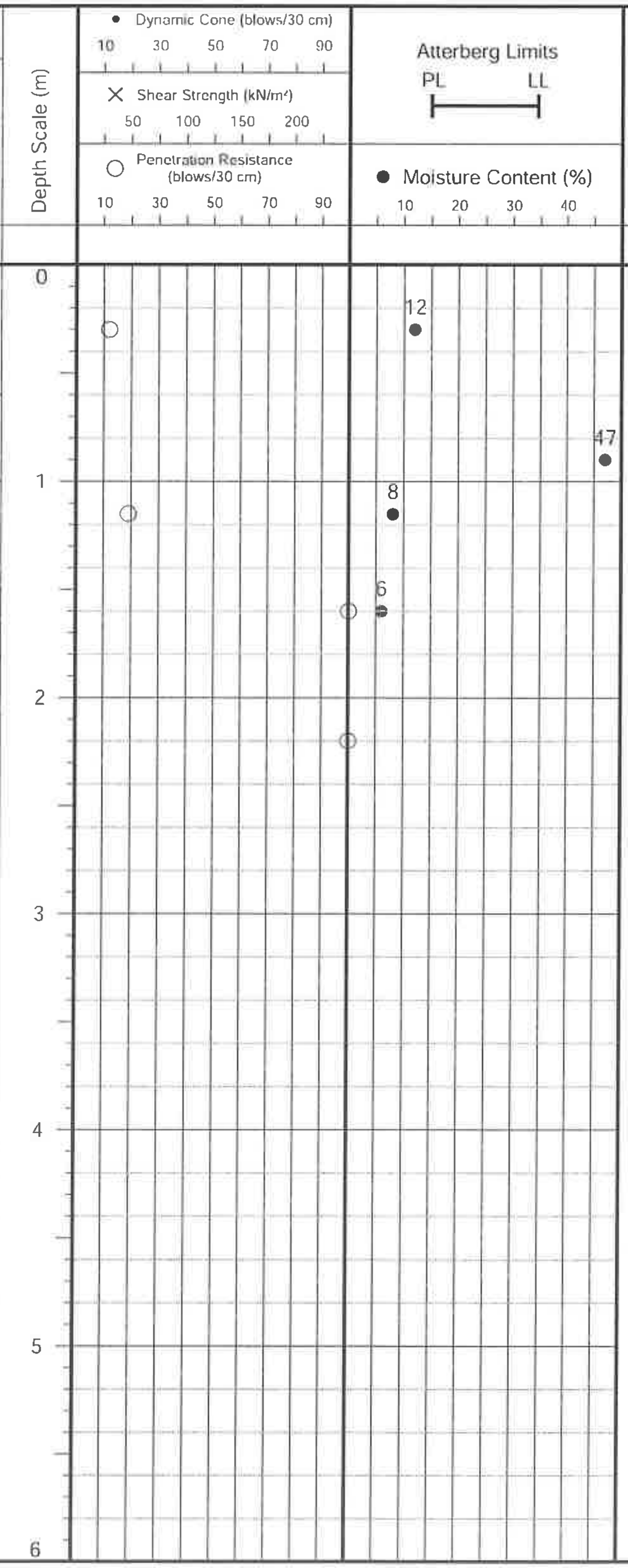
PROJECT DESCRIPTION: Proposed 4-Storey Building
with 1-Level Underground Parking

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 1 Lockhart Road
Town of Collingwood

DRILLING DATE: November 4, 2016

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES		
		Number	Type	N-Value
188.8	Ground Surface			
0.0	**30 cm TOPSOIL**			
	Brown **EARTH FILL** sand with topsoil and peat layers	1	DO	12
		2A	DO	
187.8 1.0	Brown, compact to very dense **SANDY SILT TILL** occ. wet sand and silt seams and layers, cobbles and boulders	2B	DO	19
		3	DO	50/15
		4	DO	NP
186.4 2.4	**END OF BOREHOLE** **Refusal to augering** **Inferred shallow bedrock**			



WATER LEVEL

∇ W.L. @ El. 187.39 m on completion

JOB NO.: 1812-S063

LOG OF BOREHOLE NO.: 5

FIGURE NO.: 5

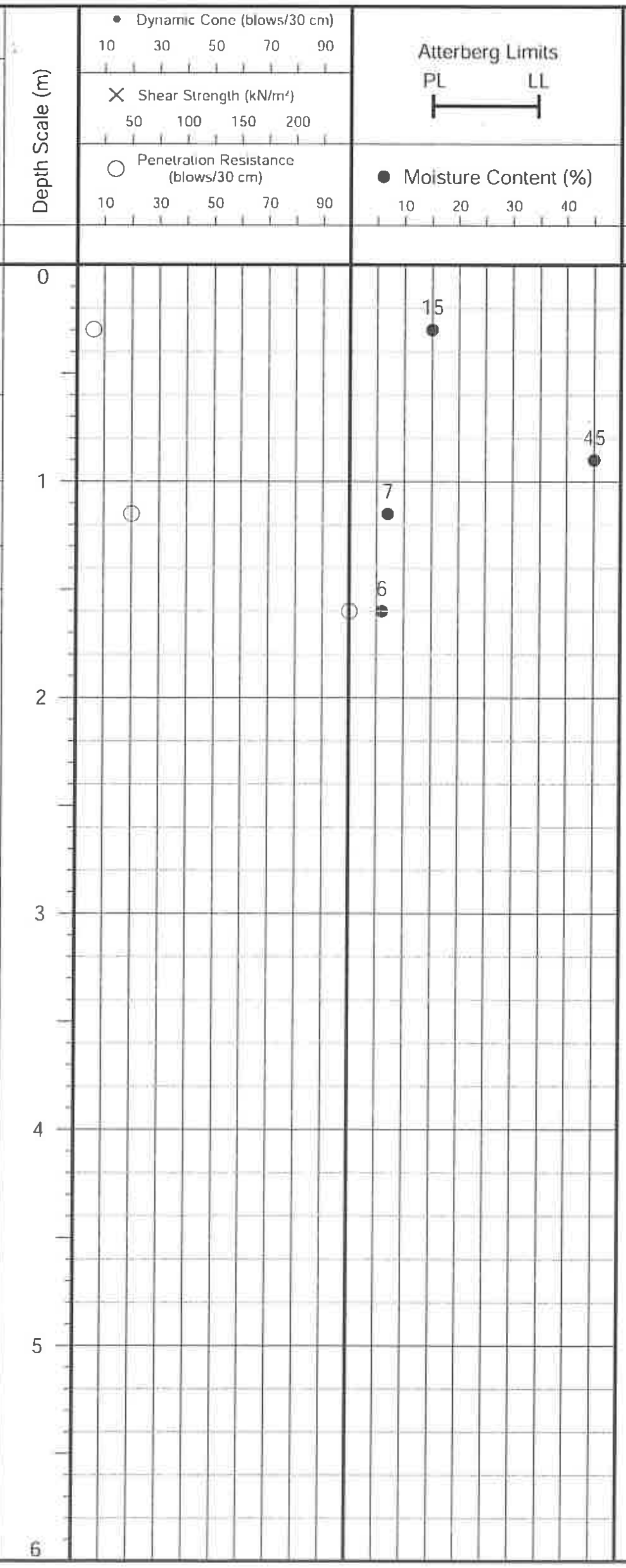
PROJECT DESCRIPTION: Proposed 4-Storey Building
with 1-Level Underground Parking

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 1 Lockhart Road
Town of Collingwood

DRILLING DATE: November 4, 2016

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value	WATER LEVEL
189.1	Ground Surface				
0.0	**30 cm TOPSOIL**				Dry on completion
	Brown **EARTH FILL** sand with peat layers	1	DO	6	
		2A	DO		
188.1 1.0	Brown, compact to very dense **SANDY SILT TILL**	2B	DO	20	
		3	DO	70/15	
187.4 1.7	**END OF BOREHOLE**				



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JOB NO.: 1812-S063

LOG OF BOREHOLE NO.: 6

FIGURE NO.: 6

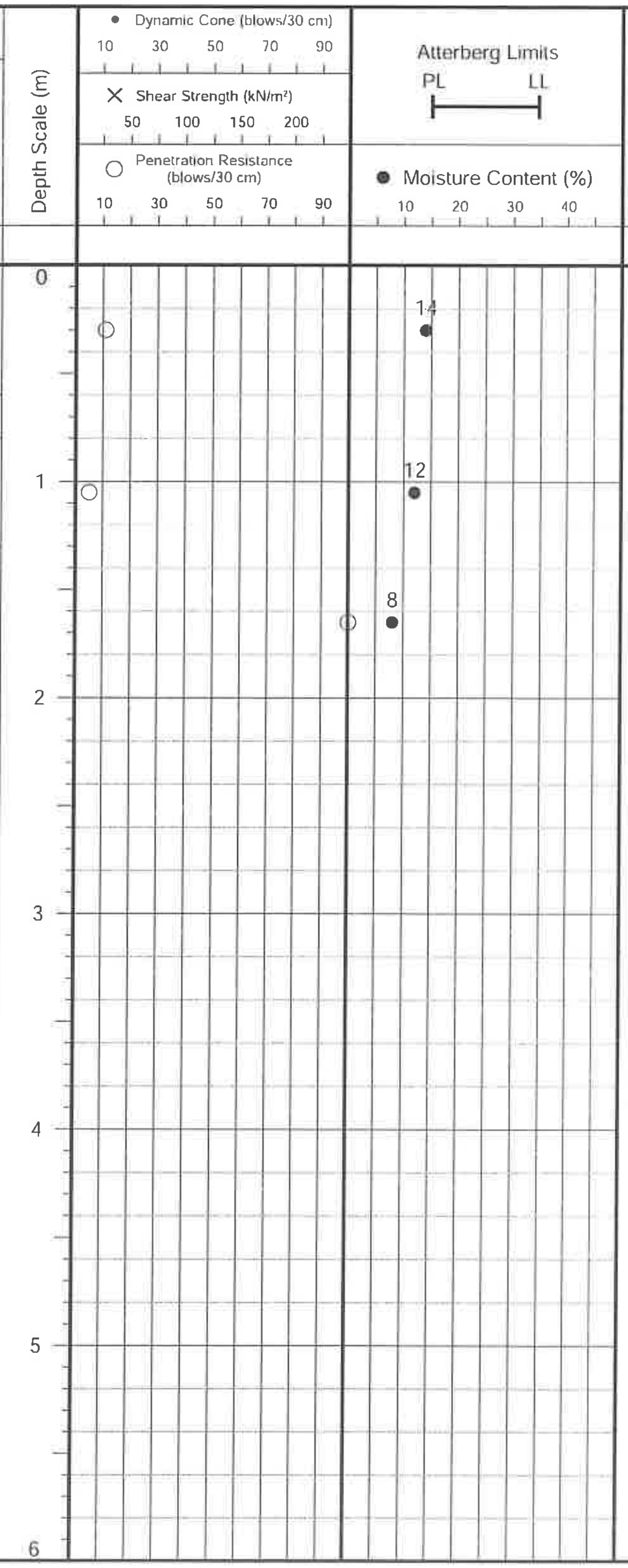
PROJECT DESCRIPTION: Proposed 4-Storey Building
with 1-Level Underground Parking

PROJECT LOCATION: 1 Lockhart Road
Town of Collingwood

METHOD OF BORING: Flight-Auger

DRILLING DATE: November 4, 2016

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value	WATER LEVEL
189.0	Ground Surface				
0.0	**20 cm TOPSOIL**				
	Black **EARTH FILL** sand and silty clay	1	DO	11	
		2	DO	5	
187.6 1.4	Brown, hard **SILTY CLAY**	3	DO	50/15	Dry on completion
187.2 1.8	**END OF BOREHOLE**				



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Page: 1 of 1

JOB NO.: 1812-S063

LOG OF BOREHOLE NO.: 101

FIGURE NO.: 7

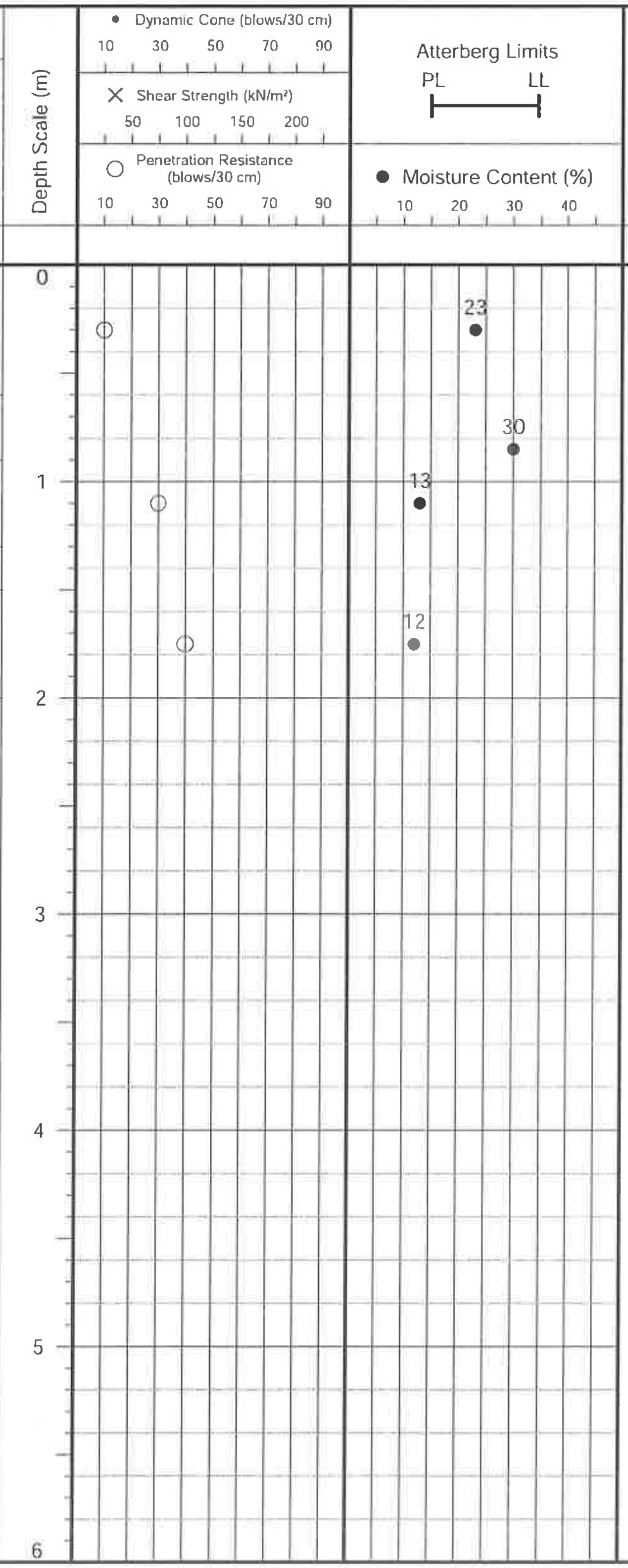
PROJECT DESCRIPTION: Proposed 4-Storey Building
with 1-Level Underground Parking

PROJECT LOCATION: 1 Lockhart Road
Town of Collingwood

METHOD OF BORING: Flight-Auger

DRILLING DATE: January 8, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value
188.9	Ground Surface			
0.0	**90 cm TOPSOIL**	1	DO	10
		2A	DO	
	Brown, compact **SANDY SILT TILL**	2B	DO	30
187.5 1.4	Brown, dense **SILTY SAND TILL**	3	DO	40
186.9 2.0	**END OF BOREHOLE** **Refusal to augering** **Inferred shallow bedrock**			



WATER LEVEL

∇ W.L. @ El. 187.7 m on completion

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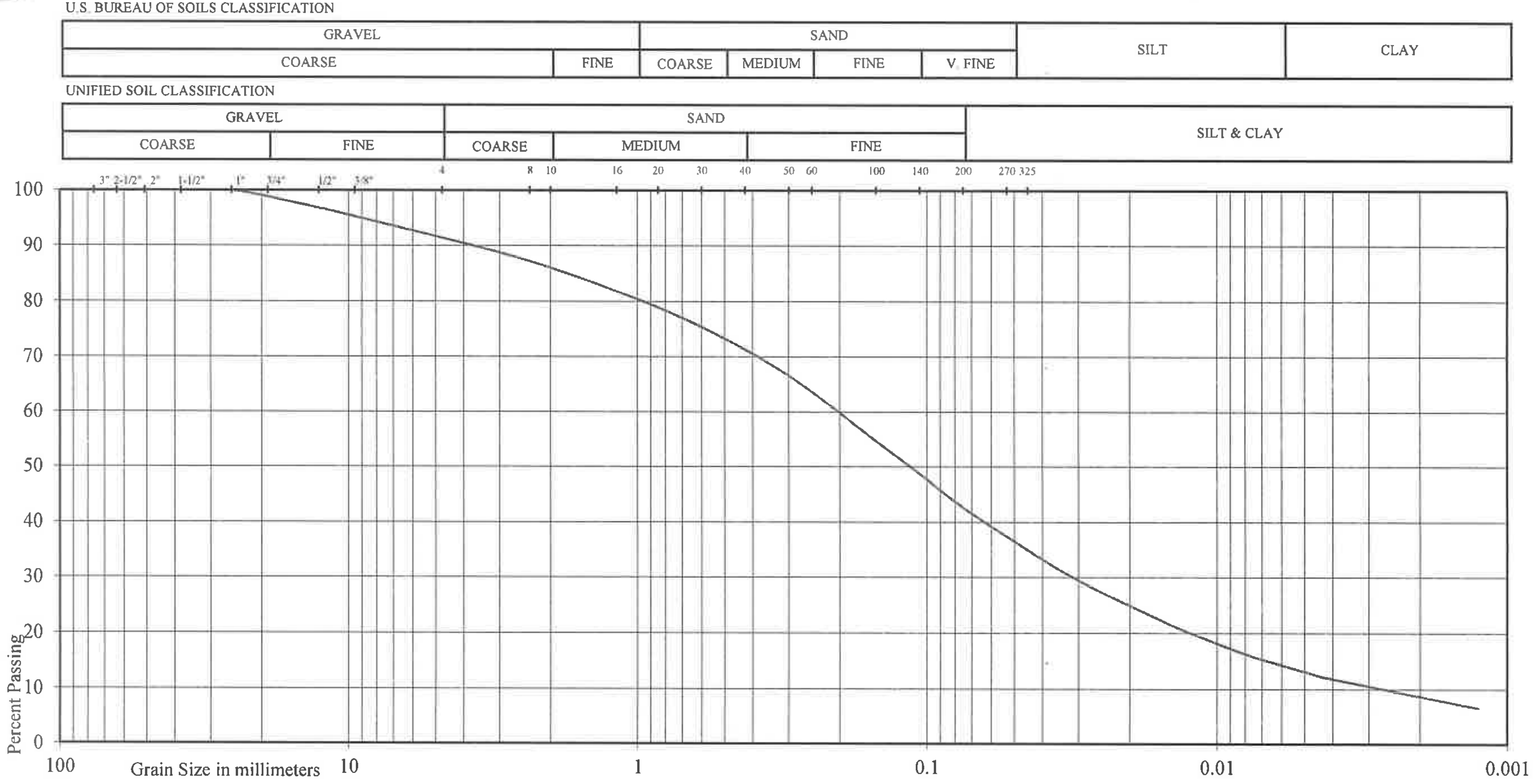
GRAIN SIZE DISTRIBUTION

Reference No: 1812-S063



Project: Proposed 4-Storey Building with 1-Level Underground Parking

Location: 1 Lockhard Road, Town of Collingwood

Borehole No: 3

Sample No: 2

Depth (m): 1.1

Elevation (m):

Liquid Limit (%) = -

Plastic Limit (%) = -

Plasticity Index (%) = -

Moisture Content (%) = 14

Estimated Permeability (cm./sec.) = 10^{-6}

Classification of Sample [& Group Symbol]: SILTY SAND FILL, traces of clay and gravel

Figure: 8

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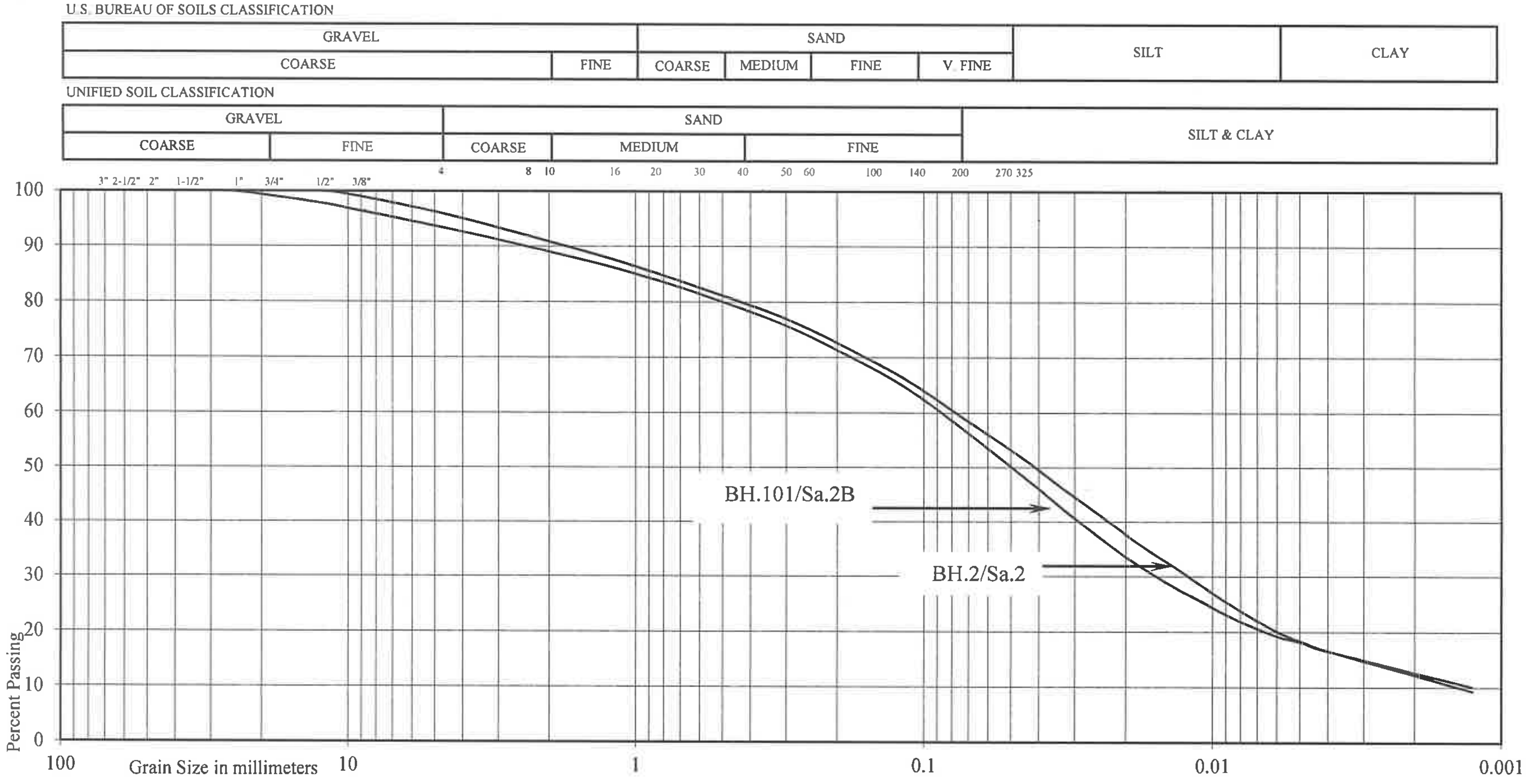
GRAIN SIZE DISTRIBUTION

Reference No: 1812-S063



Project:	Proposed 4-Storey Building with 1-Level Underground Parking	
Location:	1 Lockhart Road, Town of Collingwood	
Borehole No:	2	101
Sample No:	2	2B
Depth (m):	0.9	1.1
Elevation (m):		

BH./Sa.	2/2	101/2B
Liquid Limit (%) =	-	-
Plastic Limit (%) =	-	-
Plasticity Index (%) =	-	-
Moisture Content (%) =	8	13
Estimated Permeability (cm./sec.) =	10^{-6}	10^{-6}

Classification of Sample [& Group Symbol]: SANDY SILT TILL, some clay, a trace of gravel

Figure: 9

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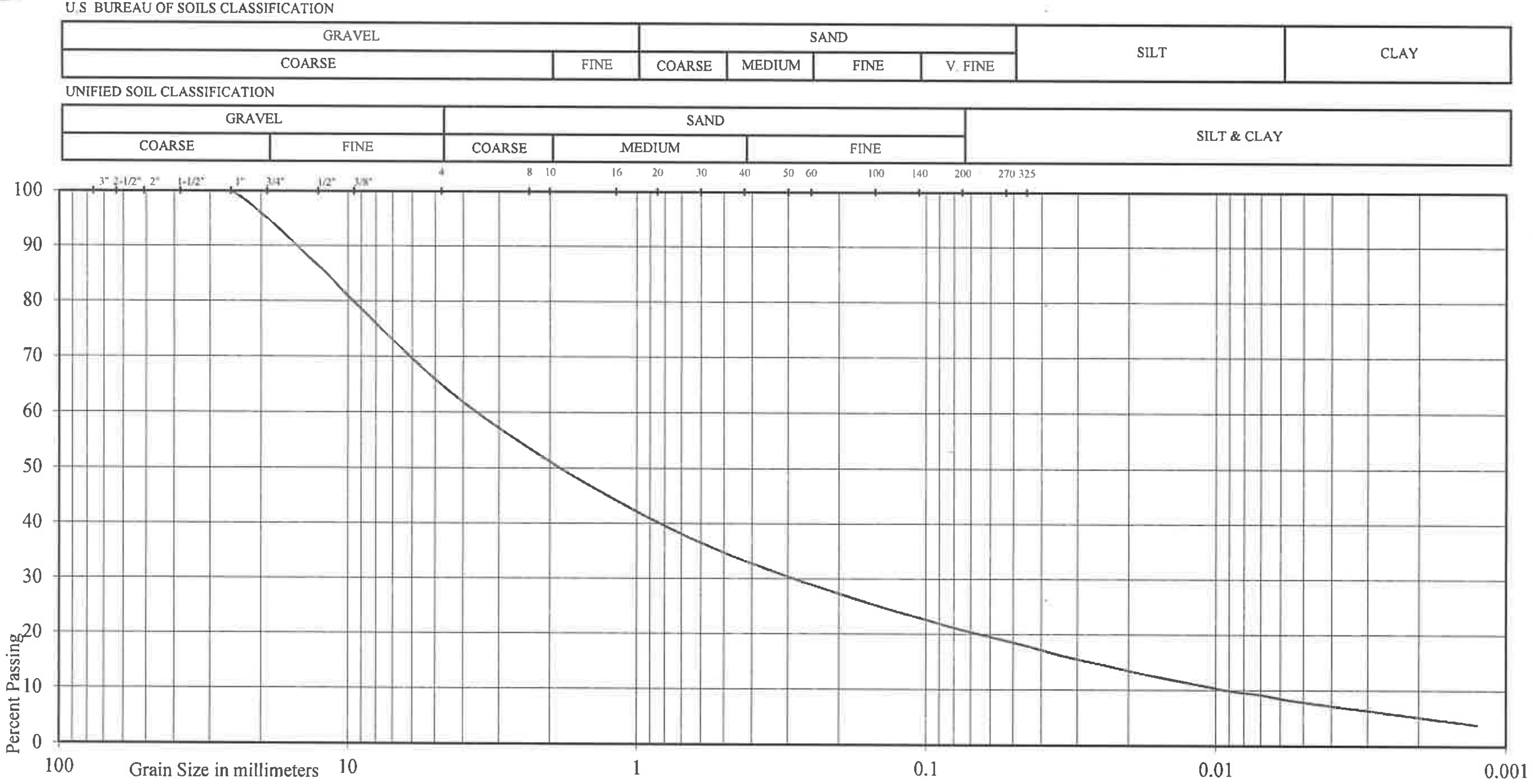
GRAIN SIZE DISTRIBUTION

Reference No: 1812-S063



Project: Proposed 4-Storey Building with 1-Level Underground Parking

Location: 1 Lockhard Road, Town of Collingwood

Borehole No: 101

Sample No: 3

Depth (m): 1.7

Elevation (m):

Liquid Limit (%) = -

Plastic Limit (%) = -

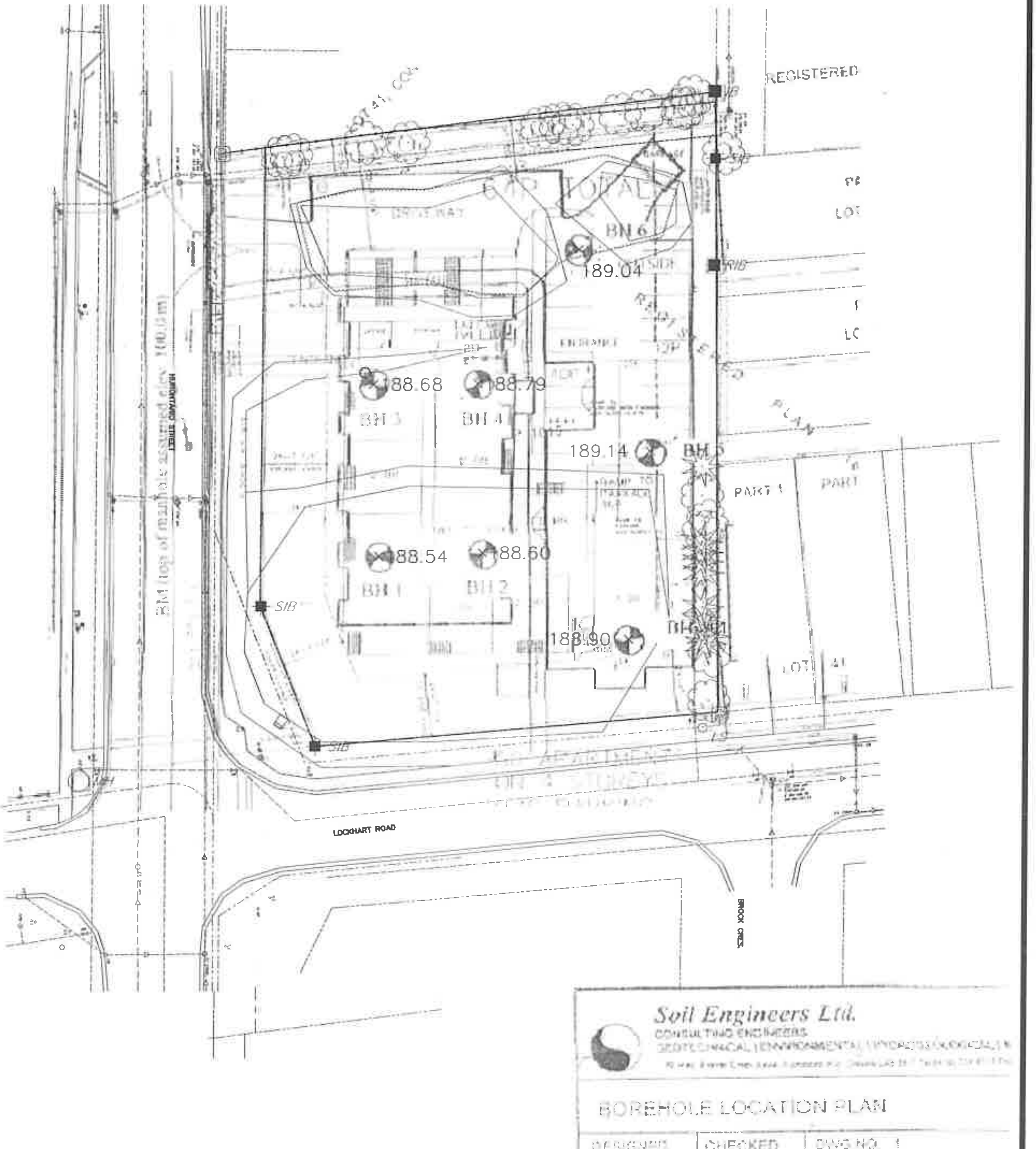
Plasticity Index (%) = -

Moisture Content (%) = 12

Estimated Permeability (cm./sec.) = 10^{-4}

Classification of Sample [& Group Symbol]: SILTY SAND TILL, gravelly, a trace of clay

Figure: 10



TATHAM ENGINEERING

RDL EXPORT
655 HURONTARIO STREET
TOWN OF COLLINGWOOD
EXISTING ELEVATIONS ON BOREHOLE PLAN

SCALE: 1:750	DATE: JUN/20	DWG NO. 1

Drawing Name: 116222-TX02-Borehole Plan.dwg, Plotted: Jun 11, 2020

Soil Engineers Ltd.
CONSULTING ENGINEERS
GEOTECHNICAL | ENVIRONMENTAL | HYDROGEOLOGICAL | BUILDING SCIENCE

SUBSURFACE PROFILE
DRAWING NO. 2
SCALE: AS SHOWN

JOB NO.:	1812-S063
REPORT DATE:	January, 2019
PROJECT DESCRIPTION:	Proposed 4-Storey Building with 1-Level Underground Parking
PROJECT LOCATION:	1 Lockhart Road Town of Collingwood

LEGEND

- TOPSOIL
- SILTY SAND TILL
- SANDY SILT TILL
- SILTY CLAY
- FILL
- ∇ WATER LEVEL (END OF DRILLING)