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A REPORT TO
GRANITE ENGINEERING SERVICES

A GEOTECHNICAL INVESTIGATION FOR PROPOSED COMMERCIAL AND RESIDENTIAL DEVELOPMENT

1240 AND PART OF 1358 ANDERSON LINE

TOWNSHIP OF SEVERN (COLDWATER)

REFERENCE NO. 1905-S166

FEBRUARY 2020

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1.0 INTRODUCTION

In accordance with the authorization dated May 24, 2019, from Ms. Catherine DeNardis of Granite Engineering Services, a geotechnical investigation was carried out in a parcel of land including 1240 and part of 1358 Anderson Line, in the Township of Severn (Coldwater), for a proposed Commercial and Residential Development.

The purpose of the investigation was to reveal the subsurface conditions and determine the engineering properties of the disclosed soils for the design and construction of the proposed development. The geotechnical findings and resulting recommendations are presented in this Report.

2.0 SITE AND PROJECT DESCRIPTION

The Township of Severn (Coldwater) is situated within the physiographic region known as Simcoe Lowland, where the till plains have been partly eroded by glacial Lake Algonquin and in places filled with lacustrine sand, silt and clay.

The site of investigation, including 1240 Anderson Line and the northeast portion of 1358 Anderson Line, in the Township of Severn (Coldwater), is presently a farm field encompassing an area of approximately 20.2 acres. The property fronts on the west side of Anderson Line, with a wetland to the west and a drainage channel to the north. The existing site gradient is relatively flat, with slight drops to the south and west.

A review of the Conceptual Site Plan, prepared by Granite Engineering Services, indicates that a majority of the site will be developed for a residential subdivision with reserved blocks for a retirement residence and a stormwater management pond. The subdivision will be provided with a municipal roadway and services. The south part of the land will be designated for future commercial use.

3.0 FIELD WORK

The field work, consisting of 13 boreholes extending to a depth ranging from 6.4 to 9.9 m, was performed between September 17 and 19, 2019, at the locations shown on the Borehole Location Plan, Drawing No. 1.

The boreholes 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 cohesionless strata is inferred from the ‘N’ values and the consistency of the cohesive strata is inferred from the ‘N’ values and justified by the undrained shear strength.

Weak and soft clay was contacted in the borehole locations. Split-spoon samples were recovered for soil classification and laboratory testing. A relatively undisturbed clay sample was also collected from Borehole 5 for consolidation testing in the laboratory.
In situ vane shear tests were performed in the soft clay stratum to determine the shear strength and sensitivity.

Dynamic cone penetration tests (DCPT) were also conducted beyond the sampling depth of 7.0 m at Boreholes 9 and 12, to evaluate the depth of the weak clay stratum. Virtual refusal, having a blow count of over 100 blows per 30 cm of penetration, was encountered at a depth of 9.9 m from grade.

The ground elevation at each borehole location was determined with reference to the “Top of Manhole” at the intersection of Anderson Line and Donlands Court, as shown on Drawing No. 1. It has a geodetic elevation of El. 180.46 m, as shown in the topographic survey provided by Granite Engineering Services.

4.0 **SUBSURFACE CONDITIONS**

The site is a farm field. The investigation has disclosed that beneath a topsoil veneer, the site is underlain by a clay deposit, overlying a sandy silt till stratum.

Detailed descriptions of the encountered subsurface conditions are presented on the Borehole Logs, Figures 1 to 13, inclusive. The Subsurface Profile is plotted in Drawing Nos. 2 and 3. The engineering properties of the disclosed soils are discussed herein.

4.1 **Topsoil** (All Boreholes)

The revealed topsoil ranges from 20 to 30 cm in thickness. Thicker topsoil layers may occur in places beyond the borehole locations, especially in the low-lying areas. The topsoil is unstable and compressible and must be removed for development.

The topsoil can only be reused for landscaping purpose. It must not be buried within the building envelope or deeper than 1.0 m from grade so it will not adversely impact on the environmental well-being of the developed areas.

4.2 **Clay** (All Boreholes)

The clay deposit predominates the revealed soil stratigraphy. It was contacted beneath the topsoil extending to a depth of 5.6 m to more than 7.2 m.

The clay contains silt. Grain size analyses were performed on 3 representative samples; the results are plotted on Figures 14 and 15, indicating 40% to over 80% of clay content.

The Atterberg Limits of the 3 representative samples and the natural water content of all the clay samples were determined. The natural water content and the Atterberg Limits are plotted on the Borehole Logs and summarized in Table 1.

Table 1 - Soil Plasticity of Selected Clay Samples

Borehole No.	Sample Depth	Plastic Limit, w_P	Liquid Limit, w_L	Plasticity Index $PI = w_L - w_P$	Soil Plasticity	Natural Water Content
1	4.8 m	26	54	28	High	77%
6	1.7 m	26	52	26	High	41%
12	3.2 m	20	34	14	Medium	43%

The results show that the clay is medium or high plasticity. The clay-rich soil of high plasticity is very sensitive to moisture changes, leading to excessive volume changes due to shrinkage and swelling.

The natural water content of the clay deposit ranges from 20% to 77%, with a median of 34%, indicating saturated conditions below a depth of 2 to 4 m from the prevailing ground surface.

The obtained 'N' values range from 12 to less than 4 blows per 30 cm of penetration below a depth of 2 to 3 m from grade. The thickness of the weak clay ranges from 3 m at Borehole 1 to almost 7 m as revealed from the penetration records in Boreholes 9 and 12.

In situ vane shear tests were performed in the weak clay stratum. The undrained shear strength values, in the range from 18 kPa to over 120 kPa, are plotted on the Borehole Logs.

The sensitivity ranges from 4 to 12, indicating the overall strength is sensitive to slightly quick to remoulding.

A relatively undisturbed clay sample was collected from the soft stratum for one-dimensional consolidation test (ASTM D2435-96) in our laboratory. The test results are plotted in

Figure 17, indicating a pre-consolidation stress of 170 kPa. With an existing effective stress of the overburden at 85 kPa, the over-consolidation Ratio (OCR) of clay at this level is 2.0. The test results are summarized in Table 2.

Table 2 - Consolidation Test Results

Sample ID	**Borehole 5, Depth 4.6 m**
Natural Water Content	60%
Plastic Limit, w_P	27
Liquid Limit, w_L	50
Undrained Shear Strength, c_u	35 kPa
Effective Stress due to Overburden, σ_o'	85 kPa
Preconsolidation Stress, σ_p'	170 kPa
Overconsolidation Ratio, OCR= σ_p'/σ_o'	2.0
Recompression Index, C_r	0.072
Compression Index, C_c	0.280

The engineering properties of the clay deposit relating to the development are given below:

- High frost susceptibility and high soil-adfreezing potential.
- Low water erodibility.
- The clay-rich soil of high plasticity is sensitive to moisture changes, leading to excessive volume changes due to shrinkage and swelling.
- It is virtually impermeable, having the estimated coefficient of permeability less than 10^{-7} cm/sec. The runoff coefficients are:

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

- The soft clay layer may undergo long-term settlement if it is subject to high loading.
- The shear strength is derived from the consistency and is inversely dependent on soil moisture. It will be susceptible to reduction in shear strength if remoulded.
- In excavation, the soft stratum may be subject to base heaving. To reduce the risk of base heaving, the excavation should be flattened and no spoil should be stockpiled beside the excavation.
- Very poor pavement-supportive material, with an estimated California Bearing Ratio (CBR) value of less than 3%.
- High corrosivity to buried metal, an estimated electrical resistivity of 2000 ohm·cm.

4.3 **Sandy Silt Till** (Boreholes 1, 2, 3 and 5)

The sandy silt till stratum was encountered at the lower stratigraphy in some of the borehole locations, below 5.6 to 7 m from grade. It contains a random mixture of soil particle sizes ranging from clay to gravel with silt being the predominant fraction. Grain size analysis was performed on a representative sample; the result is plotted on Figure 16.

The natural water content values of the till samples range from 9% to 14%, indicating moist conditions.

The till is heterogeneous in structure. Hard resistance to augering was encountered, showing occasional cobbles and boulders are embedded in the till mantle. The obtained ‘N’ values range from 12 to over 100 per 30 cm, showing compact to very dense in relative density.

The engineering properties of the till deposit are listed below:

- Moderately high frost susceptibility.
- Moderately low permeable, with an estimated coefficient of permeability of 10^{-5} to 10^{-6} cm/sec, and runoff coefficients of:

Slope	
0% - 2%	0.11 to 0.15
2% - 6%	0.16 to 0.20
6% +	0.23 to 0.28

- The shear strength is primarily derived from internal friction and is augmented by cementation.
- The till will be stable in steep cuts; however, under prolonged exposure, localized sheet collapse may occur.
- A fair pavement-supportive material, with an estimated CBR value of 8%.
- Moderate corrosivity to buried metal, an estimated electrical resistivity of 4500 ohm·cm.

4.4 **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 3.

Table 3 - Estimated Water Content for Compaction

Soil Type	Determined Natural Water Content (%)	Water Content (%) for Standard Proctor Compaction	
		100% (optimum)	Range for 95% or +
Clay/Silty Clay	20 to 77	18 to 25	14 to 30
Sandy Silt Till	9 to 14	13	9 to 17

The above values show that the clay is generally too wet; it will require aeration for a 95% or + Standard Proctor compaction. Aeration can be achieved by spreading the soils thinly on the ground in dry, warm weather.

The clay-rich soil of high plasticity is very sensitive to moisture changes, leading to excessive volume changes due to shrinkage and swelling. It is not recommended for reuse as backfill for the foundation walls or in the active zone near the ground surface.

If the compaction of the clay 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.

5.0 GROUNDWATER CONDITIONS

Groundwater seepage encountered during augering of the boreholes was recorded on the field logs. The boreholes were checked for the presence of groundwater upon completion. The data is plotted on the Borehole Logs and summarized in Table 4.

Table 4 - Groundwater Levels

Borehole No.	Ground Elevation (m)	Borehole Depth (m)	Seepage Encountered During Augering		Recorded Groundwater Level on Completion	
			Depth (m)	Amount	Depth (m)	El. (m)
1	180.0	6.4	3.0	Slight	Dry	-
2	179.8	6.7	2.3	Slight	Dry	-
3	179.2	6.6	2.3	Slight	5.5	173.7
4	179.2	7.0	2.3	Slight	2.7	176.5
5	180.0	6.6	3.0	Slight	Dry	-
6	179.8	7.2	2.3	Slight	Dry	-
7	179.3	7.0	1.5	Slight	4.6	174.7
8	179.3	7.0	2.3	Slight	5.8	173.5
9	179.1	9.9	2.3	Slight	3.4	175.7
10	180.2	7.0	3.0	Slight	Dry	-
11	179.9	7.0	4.6	Slight	Dry	-
12	180.4	9.9	3.0	Slight	Dry	-
13	180.0	7.0	1.5	Slight	Dry	-

Free groundwater level was recorded in 5 boreholes, at a depth ranging from 2.7 to 5.8 m from grade, or El. 173.5 to 176.5 m, upon the completion of drilling. It represents the groundwater regime in the vicinity, which will fluctuate with the seasons.

6.0 DISCUSSION AND RECOMMENDATIONS

This investigation has disclosed that beneath a topsoil veneer, the site is underlain by a clay deposit of stiff to very soft in consistency, overlying compact to very dense sandy silt till below 5.6 to 7 m from grade in some borehole locations.

Free groundwater was recorded in 5 boreholes at a depth ranging from 2.7 to 5.8 m from grade or El. 173.5 to 176.5 m upon the completion of drilling. It represents the groundwater regime in the vicinity, which will fluctuate with the seasons.

The Conceptual Site Plan indicates that a majority of the site will be developed for a residential subdivision, with reserved blocks for a retirement residence and a stormwater management pond. The subdivision will be provided with a municipal roadway and services. The south part of the land will be designated for future commercial use. The geotechnical findings which warrant special consideration are presented below:

1. The topsoil is unstable and compressible; it must be removed for development.
2. The soft clay stratum below 2 to 3 m from the prevailing ground surface is relatively weak and may undergo long-term settlement under excessive loading. If the site will be regraded with additional earth filling, settlement monitoring will be required before installation of site services and road construction. A review of the site grading plan is necessary for the assessment of pregrading or pre-loading requirement.
3. In some particular locations, the settlement can be sped up by pre-loading with an earth embankment and installation of wick drains.
4. The on site clay-rich soil of high plasticity is very sensitive to moisture changes, leading to excessive volume changes due to shrinkage and swelling. It is not recommended for reuse to backfill the foundation walls or in the active zone near the ground surface.
5. Bottom heaving may occur in deep excavation extending into the soft clay. Any excavation extending below 3 m must be cut at 1 vertical:2 or + horizontal and the spoil must be placed at a distance equal to 2 times the depth of the excavation.
6. Groundwater seepage in excavations can be collected into sump pits and removed by conventional pumping.

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 subsurface variances become apparent during construction, a geotechnical engineer must be consulted to determine whether the following recommendations require revision.

6.1 Site Preparation

The site grading plan of the development has not been finalized at the time of report preparation. A review of the site grading plan is necessary for the assessment of pregrading or pre-loading requirement.

In areas where earth fill is required to raise the site, it is generally more economical to place an engineered fill for development. The engineering requirements for a certifiable fill for road construction, municipal services, slab-on-grade, and house footings are presented below:

1. The existing topsoil must be removed, and the subgrade must be inspected and proof-rolled prior to any fill placement. Ploughed soils and badly weathered soils should also

be subexcavated, sorted free of topsoil inclusions and deleterious materials, if any, aerated and properly compacted in layers.

2. Inorganic soils must be used for the fill, and they must be uniformly compacted in lifts 20 cm thick to 98% or + of their maximum Standard Proctor dry density up to the proposed finished grade. The soil moisture must be properly controlled near the optimum. If the foundations are to be built soon after the fill placement, the densification process for the engineered fill must be increased to 100% of the maximum Standard Proctor compaction.
3. If the engineered fill is compacted with the moisture content on the wet side of the optimum, the underground services and pavement construction should not begin until the pore pressure within the fill mantle has completely dissipated. This must be further assessed at the time of the engineered fill construction.
4. If imported fill is to be used, it should be inorganic soils, free of any deleterious material with environmental issue (contamination). Any potential imported earth fill from off site must be reviewed for geotechnical and environmental quality by the appropriate personnel as authorized by the developer or agency before it is hauled to the site.
5. If the engineered fill is to be left over the winter months, adequate earth cover, or equivalent, must be provided for protection against frost action.
6. The engineered fill must extend over the entire graded area; the engineered fill envelope and finished elevations must be clearly and accurately defined in the field, and they must be precisely documented by qualified surveyors.
7. Placement of engineered fill and backfill material shall be free of any frozen material.
8. Where the ground is wet due to subsurface water seepage, an appropriate subdrain scheme must be implemented prior to the fill placement.
9. Where the fill is to be placed on sloping ground steeper than 1 vertical:3 horizontal, the face of the sloping ground must be flattened to 3 + so that it is suitable for safe operation of the compactor and the required compaction can be obtained.
10. The fill operation must be inspected on a full-time basis by a technician under the direction of a geotechnical engineer.
11. The footing and underground services subgrade must be inspected by the geotechnical consulting firm that inspected the engineered fill placement. This is to ensure that the foundations are placed within the engineered fill envelope, and the integrity of the fill has not been compromised by interim construction, environmental degradation and/or disturbance by the footing excavation.
12. Any excavation carried out in certified engineered fill must be reported to the geotechnical consultant who supervised the fill placement in order to document the

locations of the excavation and/or to supervise reinstatement of the excavated areas to engineered fill status.

13. If construction on the engineered fill does not commence within a period of 2 years from the date of certification, the condition of the engineered fill must be assessed for re-certification.
14. Despite stringent control in the placement of the engineered fill, variations in soil type and density may occur in the engineered fill. Therefore, the strip footings and the upper section of the foundation walls constructed on the engineered fill may require continuous reinforcement with steel bars, depending on the uniformity of the soils in the engineered fill and the thickness of the engineered fill underlying the foundations. Should the footings and/or walls require reinforcement, the required number and size of reinforcing bars must be assessed by considering the uniformity as well as the thickness of the engineered fill beneath the foundations.
15. In sewer construction, the engineered fill is considered to have the same structural proficiency as a natural inorganic soil.

The soft clay stratum below 2 to 3 m from the prevailing ground surface is relatively weak and may undergo long-term settlement under excessive loading. The area with additional earth filling must be monitored for settlement before installation of site services and road construction.

Where earth filling will exceed the pre-consolidation pressure of 170 kPa, equivalent to an additional factored earth thickness of around 2 m, long-term settlement may occur. Due to the clay-rich soil of high plasticity, the duration of settlement will last for years. However, the settlement can be sped up by pre-loading the area with an earth embankment above the pregrading level and the installation of wick drains. A review of the site grading plan is necessary for the assessment of pregrading or pre-loading requirement.

6.2 Foundations

After site grading and the settlement monitoring is complete, conventional footings can be constructed on the engineered fill or on undisturbed natural soils. As a general guide, recommended soil bearing pressures of 50 kPa (SLS) and 80 kPa (ULS) can be used for the design of the footings. The total and differential settlements of footings are estimated within 25 mm and 20 mm, respectively.

The footing subgrade must be inspected by a geotechnical engineer, or a geotechnical technician under the supervision of a geotechnical engineer, to assess its suitability for bearing the designed foundations.

If the footing subgrade consists of saturated soils, a concrete mud-slab should be placed immediately after excavation and inspection to prevent construction disturbance and costly rectification.

Footings exposed to weathering, or in unheated areas, should have at least 1.6 m of earth cover for protection against frost action.

Perimeter subdrains and dampproofing of the foundation walls will be required for underground structures. The subdrains must be encased in a fabric filter and discharged into positive outlets.

For commercial slab-on-grade structures or mid-rise buildings, deep foundations of caissons or helical piers extending into the dense sandy silt till stratum are recommended. Additional and deeper boreholes will be required to determine the founding depth and the bearing capacities of deep foundations.

The foundations should meet the requirements specified in the latest Ontario Building Code, and the structure should be designed to resist an earthquake force using Site Classification ‘E’ (soft soil). The Site Classification for individual structures can be reviewed separately, if necessary.

6.3 <u>**Underground Structures**</u>

The founding depth of the basement structure must be at least 1 m above the stabilized groundwater or the saturated clay stratum.

The perimeter walls of the underground structure should be designed to sustain a lateral earth pressure calculated using the soil parameters stated in Section 6.8. In general, the basement walls must be dampproofed and provided with perimeter subdrains encased in a fabric filter. The foundation wall backfill should consist of free-draining granular material, or the exterior walls must be lined with synthetic sheet drains.

The on site clay-rich soil of high plasticity is very sensitive to moisture changes, leading to excessive volume changes due to shrinkage and swelling. It is not recommended for reuse to backfill the foundation walls or in the active zone near the ground surface.

The basement slab should be constructed on a granular base, 20 cm in thickness, consisting of 20-mm Crusher-Run Limestone, or equivalent, compacted to its maximum Standard Proctor dry density. The subgrade for slab-on-grade construction should consist of sound natural soil or properly compacted inorganic earth fill.

The subgrade should be inspected and assessed by proof-rolling prior to slab-on-grade construction. Where badly weathered or soft subgrade is detected, it should be subexcavated and replaced with inorganic material, uniformly compacted to 98% or + of the maximum Standard Proctor dry density.

6.4 **Underground Services**

If the site is to be raised by earth filling, the underground services should not be constructed until the settlement is complete by monitoring from settlement plates.

The underground services can be constructed on sound natural soils or in engineered fill. A Class ‘B’ bedding, consisting of compacted 20-mm Crusher-Run Limestone, or equivalent, is recommended for pipe construction. The pipe joints should be leak-proof, or wrapped with an appropriate waterproof membrane.

In order to prevent pipe floatation when the sewer trench is deluged with water derived from infiltrated precipitation during construction, a soil cover at least equal in thickness to the diameter of the pipe should be in place at all times after completion of the pipe installation.

Openings to subdrains and catch basins, if any, should be shielded with a fabric filter to prevent blockage by silting.

For estimation purposes for the anode weight requirements, the estimated electrical resistivities given for the disclosed soils can be used. The proposed anode weight must meet the minimum requirements as specified by Township of Severn (Coldwater) and the County of Simcoe.

6.5 **Backfilling in Trenches and Excavated Areas**

The on site clay-rich soil of high plasticity is very sensitive to moisture changes, leading to excessive volume changes due to shrinkage and swelling. It is not recommended for reuse to backfill the foundation walls or in the active zone near the ground surface. In addition, the soils are mostly too wet and must be aerated prior to reuse for backfill and compaction. The backfill in service trenches should be compacted to at least 95% of its maximum

Standard Proctor dry density. In the zone within 1.0 m below the pavement subgrade and slab-on-grade, the materials should be compacted with the water content 2% to 3% drier than the optimum, and the compaction should be increased to at least 98% of the respective maximum Standard Proctor dry density. This is to provide the required stiffness for pavement construction.

In normal construction practice, the problem areas of settlement largely occur adjacent to manholes, catch basins, service crossings, foundation walls and columns. In areas which are inaccessible to a heavy compactor, imported sand backfill should be used.

Narrow trenches for service crossings should be cut at 1 vertical:2 or + horizontal so that the backfill can be effectively compacted. Otherwise, soil arching will prevent the achievement of proper compaction. The lift of each backfill layer should either be limited to a thickness of 20 cm, or the thickness should be determined by test strips.

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 soils have a water content on the dry side of the optimum, it would be impossible to wet the soils 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 in a narrow vertical trench section, or when the trench box is removed. 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 final surfacing of the new pavement and the slab-on-grade construction.
- 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.

6.6 Pavement Design

The proposed subdivision will consist of local roads and collectors. The recommended pavement design is presented in Table 5.

Table 5 - Pavement Design

Course	Thickness (mm)	OPS Specifications
Asphalt Surface	40	HL-3
Asphalt Binder Local Road Collector	 50 75	HL-4
Granular Base	150	OPSS Granular 'A' or equivalent
Granular Sub-base Local Road Collector	 300 450	OPSS Granular 'B' or equivalent

After fine grading, the pavement subgrade must be proof-rolled. Any soft spot as identified must be rectified by subexcavation and replaced with dry inorganic material, compacted to the specified density.

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 water content 2% to 3% drier than the optimum. In the lower zone, a 95% or + Standard Proctor compaction is considered adequate.

All the granular bases should be compacted to 100% of their maximum Standard Proctor dry density.

The in situ clay-rich soil is very sensitive to moisture changes. A homogeneous soil is recommended in the subgrade to prevent excessive differential movement.

The subgrade will suffer a strength regression if water is allowed to saturate the mantle. The following measures should, therefore, be incorporated in the construction procedures and road design:

- The subgrade should be properly crowned and smooth-rolled to allow interim precipitation to be properly drained.
- Lot areas adjacent to the road should be properly graded to prevent ponding of large amounts of water. Otherwise, the water will seep into the subgrade mantle and induce

a regression of the subgrade strength, with costly consequences for the pavement construction.

- If the road is to be constructed during the wet seasons or the subgrade is unstable, further thickening of the granular sub-base may be required. This can be determined at the time of road construction.
- Fabric filter-encased subdrains will be required in the subgrade along both sides of the road. The subdrains should be connected to a positive outlet where water can be drained from the site.

6.7 **Stormwater Management Pond** (Borehole 9)

A stormwater management (SWM) pond is proposed in the vicinity of Borehole 9. Detailed design of the pond, however, is not available at the time of report preparation.

According to the borehole finding, the pond area consists of medium to high plasticity clay. The estimated coefficient of permeability of the clay is expected to be less than 10^{-7} cm/sec, and the rate of percolation is above 80 min/cm or less than 7 mm/hr. An impermeable clay liner is not necessary for the pond construction.

Where the sides and bottom of the pond excavation may consist of localized sand or silt layers, it should be subexcavated and replaced with the on site clay material. Upon completion of the pond excavation, the surface of the pond should be treated by remoulding through the use of sheepsfoot roller during the compaction process in order to close up any fissures and enhance the uniformity at the bottom.

The side slopes should be maintained at 1 vertical (V):3 horizontal (H) or flatter above the wet perimeter, and at 1V:4H below the wet perimeter of the pond. The final slopes must be vegetated and/or sodded to prevent runoff erosion.

If earth embankment and control structures are to be constructed in the pond, further review of the site grading and subsoil is necessary to determine the appropriate measures to prevent long-term settlement beneath the embankment.

6.8 **Soil Parameters**

The recommended soil parameters for the project design are given in Table 6.

Table 6 - Soil Parameters

Unit Weight and Bulk Factor	**Unit Weight (kN/m^3)**		**Estimated Bulk Factor**	
	Bulk	**Submerged**	**Loose**	**Compacted**
Sandy Silt Till	22.5	12.5	1.33	1.05
Clay	21.0	11.0	1.30	1.00

Effective Shear Strength Parameters	**Cohesion c' (kPa)**	**Internal Angle of Friction ϕ'**
Sandy Silt Till	5	33°
Clay	10	12°

Lateral Earth Pressure Coefficients	**Active K_a**	**At Rest K_0**	**Passive K_p**
Sandy Silt Till	0.32	0.48	3.12
Clay	0.44	0.60	2.20

Maximum Allowable Soil Pressure (SLS) For Thrust Block Design	
Engineered Fill and Sound Native Soils	30 kPa

6.9 Excavation

Excavation should be carried out in accordance with Ontario Regulation 213/91. The types of soils are classified in Table 7.

Table 7 - Classification of Soils for Excavation

Material	Type
Sound Till	2
Firm or stiff Silty Clay	3
Very soft or wet Silty Clay	4

In excavation, the groundwater yield is expected to be slow in rate and limited in quantity. It can be collected into the sumps and removed by conventional pumping.

Bottom heaving may occur in steep excavation extending into the soft clay. Any excavation extending into the soft clay must be cut at 1 vertical:3 or + horizontal and the spoil must be placed at a distance equal to 2 times the depth of the excavation.

7.0 LIMITATIONS OF REPORT

This report was prepared by Soil Engineers Ltd. for the account of Granite Engineering Services and for review by the designated agencies, consultants and contractors. Use of the report is subject to the conditions and limitations of the contractual agreement.

The material in the report reflects the judgment of Kelvin Hung, P.Eng., and Bennett Sun, 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
02/13/2020
K. W. K. HUNG
100124295
PROVINCE OF ONTARIO

Kelvin Hung, P.Eng.

LICENSED PROFESSIONAL ENGINEER
CHUN C. B. SUN
Feb 13, 2020
PROVINCE OF ONTARIO

Bennett Sun, P.Eng.
KH/BS: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

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JOB NO.: 1905-S166

LOG OF BOREHOLE NO.: 1

FIGURE NO.: 1

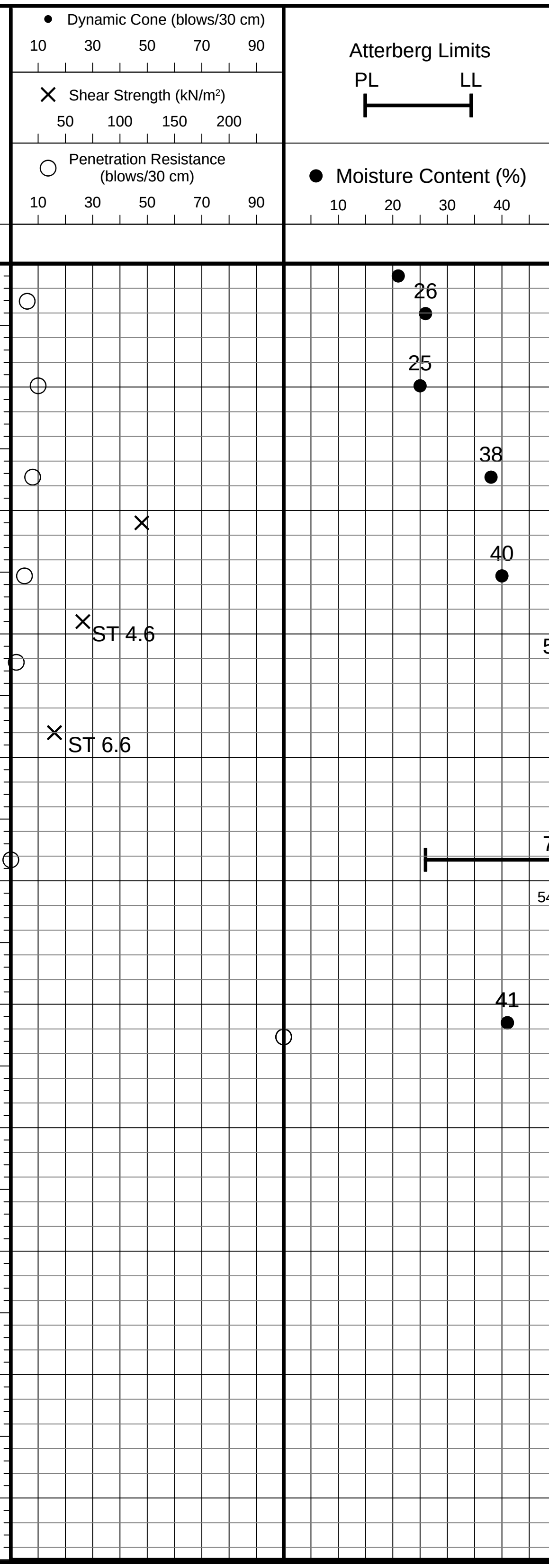
PROJECT DESCRIPTION: Proposed Commercial and Residential Development

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 1240 and Part of 1358 Anderson Line
Township of Severn (Coldwater)

DRILLING DATE: September 18, 2019

El. (m) / Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value	Depth Scale (m)	WATER LEVEL
180.0	Ground Surface					
0.0	**20 cm TOPSOIL**	1A	DO	6	0	
	Stiff to very soft	1B				
	weathered	2	DO	10	1	
		3	DO	8	2	
	SILTY CLAY	4	DO	5		
	brown / grey	5	DO	2	3	
	a trace of sand occ. silt seams and layers				4	Dry on completion
		6	DO	0	5	
173.7		7A	DO	50/10	6	
173.6 / 6.4	Grey, very dense **SANDY SILT TILL** a trace of gravel occ. sand layers, cobbles and boulders	7B				
	END OF BOREHOLE				7 8 9 10	



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JOB NO.: 1905-S166

LOG OF BOREHOLE NO.: 2

FIGURE NO.: 2

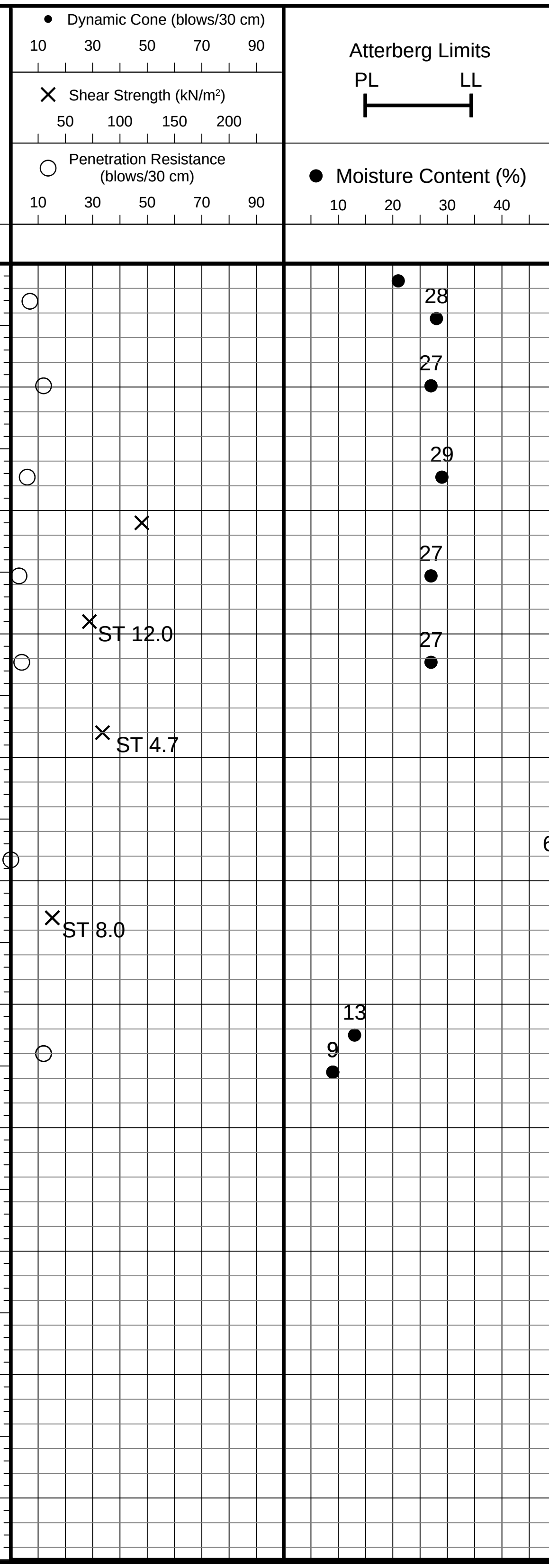
PROJECT DESCRIPTION: Proposed Commercial and Residential Development

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 1240 and Part of 1358 Anderson Line
Township of Severn (Coldwater)

DRILLING DATE: September 18, 2019

El. (m) / Depth (m)	SOIL DESCRIPTION	Sample Number	Type	N-Value	Depth Scale (m)	Moisture Content (%)	WATER LEVEL
179.8	Ground Surface						
0.0	**28 cm TOPSOIL**	1A	DO	7	0		Dry on completion
	Stiff to very soft	1B				28	
	weathered	2	DO	12	1	27	
	SILTY CLAY	3	DO	6		29	
		4	DO	3	2	27	
		5	DO	4	3	27	
	a trace of sand, occ. silt seams and layers; brown / grey				4		
		6	DO	0		60	
173.4 / 6.4	Grey, compact **SANDY SILT TILL** a trace of gravel occ. sand layers, cobbles and boulders	7A	DO	12	6	13	
173.1 / 6.7	**END OF BOREHOLE**	7B				9	



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JOB NO.: 1905-S166

LOG OF BOREHOLE NO.: 3

FIGURE NO.: 3

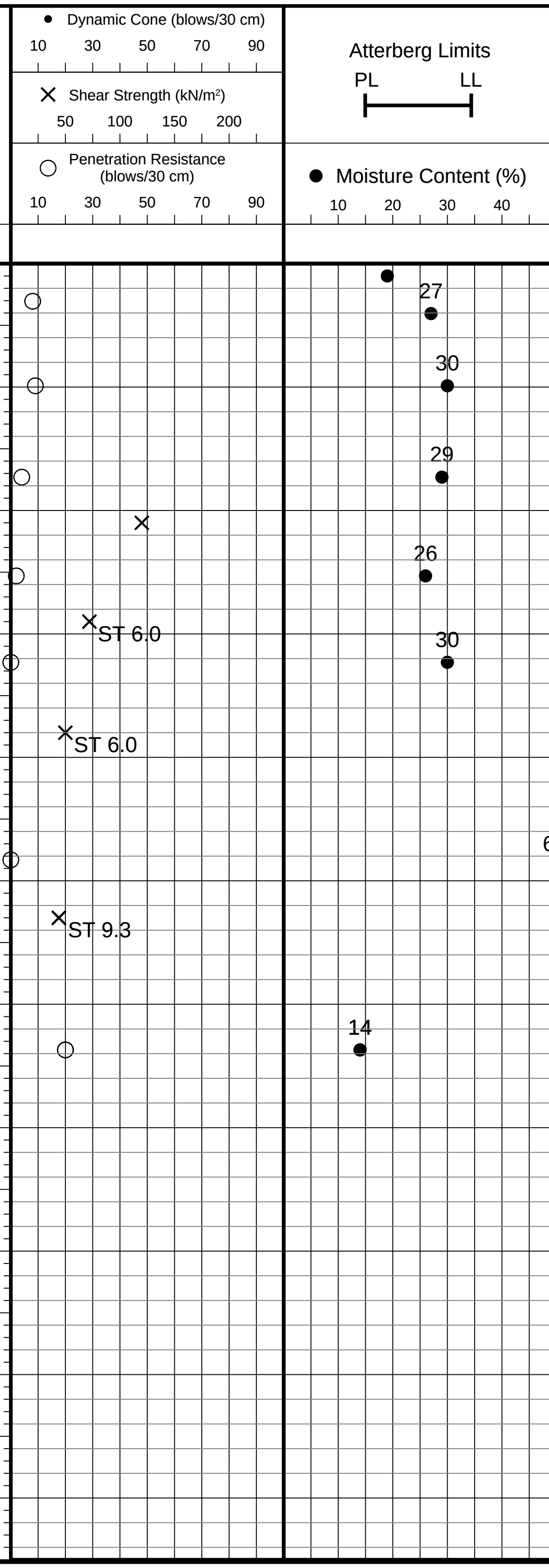
PROJECT DESCRIPTION: Proposed Commercial and Residential Development

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 1240 and Part of 1358 Anderson Line
Township of Severn (Coldwater)

DRILLING DATE: September 19, 2019

El. (m) / Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value	Depth Scale (m)
179.2	Ground Surface				
0.0	**20 cm TOPSOIL**	1A	DO	8	0
	Stiff to very soft	1B			
	weathered / brown / grey	2	DO	9	1
		3	DO	4	2
	SILTY CLAY	4	DO	2	
		5	DO	0	3
	a trace of sand occ. silt seams and layers (grey / brown)				4
		6	DO	0	5
173.6 5.6	Grey, compact **SANDY SILT TILL** a trace of gravel occ. sand layers, cobbles and boulders	7	DO	20	6
172.6 6.6	**END OF BOREHOLE**				7, 8, 9, 10



WATER LEVEL

W.L. @ El. 173.7 m on completion

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JOB NO.: 1905-S166

LOG OF BOREHOLE NO.: 4

FIGURE NO.: 4

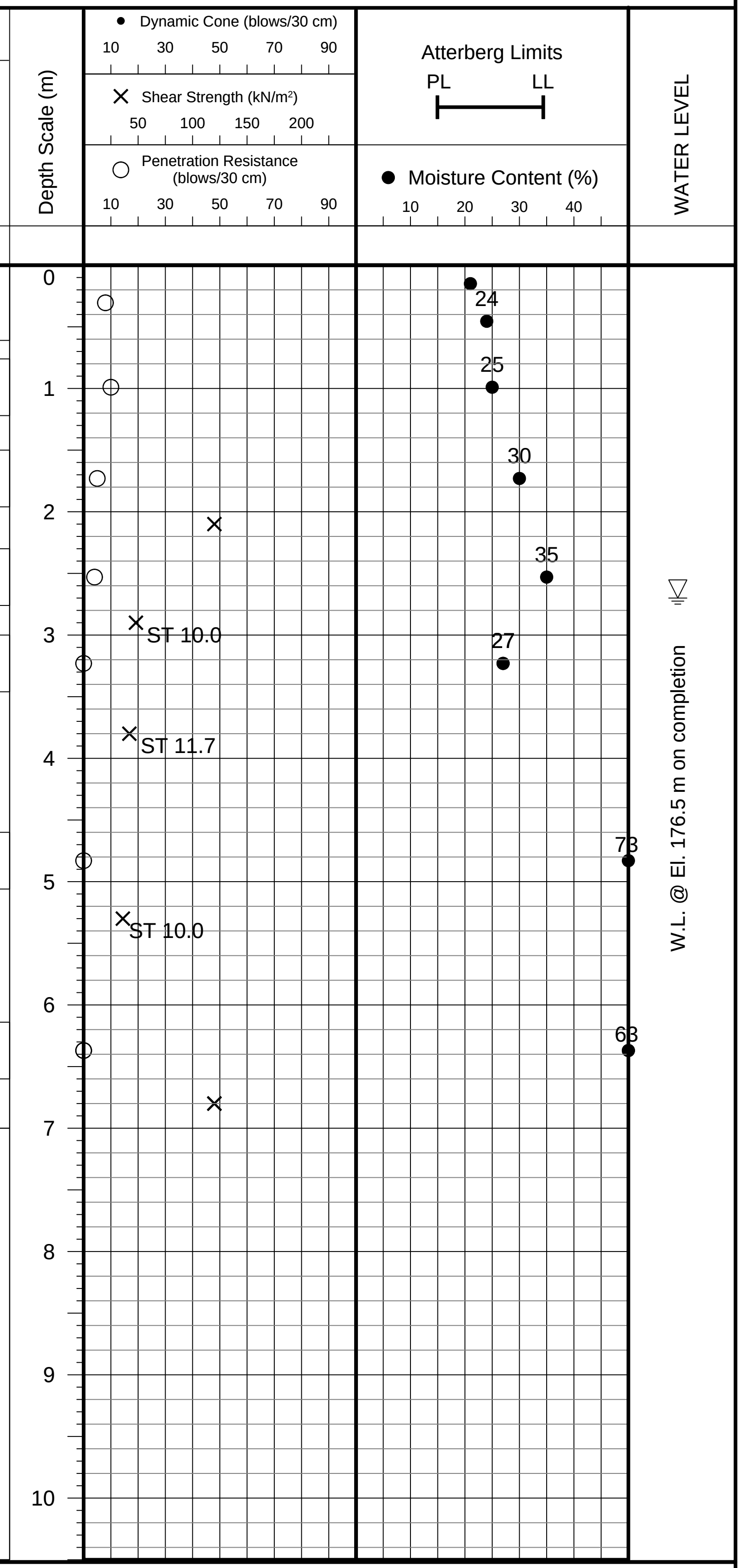
PROJECT DESCRIPTION: Proposed Commercial and Residential Development

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 1240 and Part of 1358 Anderson Line
Township of Severn (Coldwater)

DRILLING DATE: September 19, 2019

El. (m) / Depth (m)	SOIL DESCRIPTION	Samples: Number	Type	N-Value
179.2	Ground Surface			
0.0	**30 cm TOPSOIL**	1A	DO	8
	Stiff to very soft	1B		
	weathered	2	DO	10
		3	DO	5
	brown / grey			
	SILTY CLAY	4	DO	4
	grey / brown	5	DO	0
	a trace of sand occ. silt seams and layers; brown / grey			
		6	DO	0
		7	DO	0
172.2 7.0	**END OF BOREHOLE**			



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JOB NO.: 1905-S166

LOG OF BOREHOLE NO.: 5

FIGURE NO.: 5

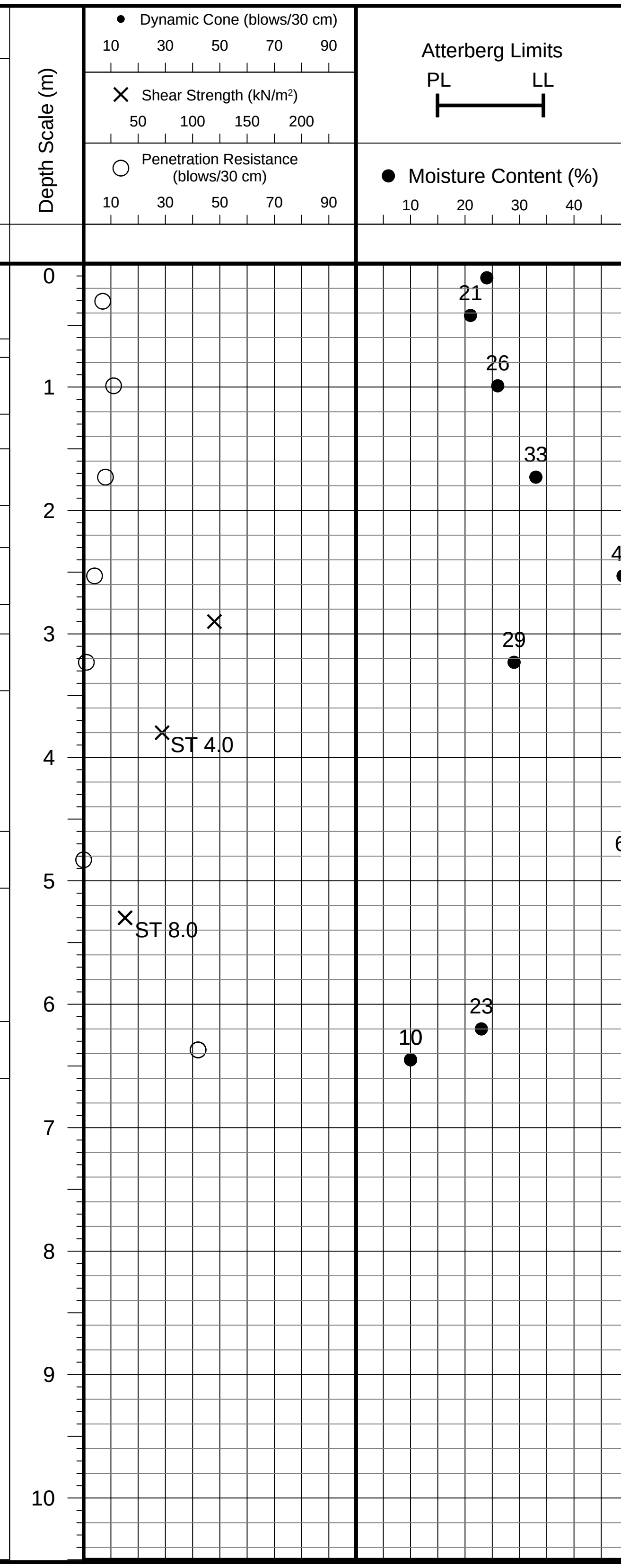
PROJECT DESCRIPTION: Proposed Commercial and Residential Development

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 1240 and Part of 1358 Anderson Line, Township of Severn (Coldwater)

DRILLING DATE: September 18, 2019

El. (m) / Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
180.0	Ground Surface			
0.0	**23 cm TOPSOIL**	1A	DO	7
	Stiff to very soft	1B		
	weathered	2	DO	11
		3	DO	8
	brown / grey			
	SILTY CLAY	4	DO	4
	grey / brown	5	DO	1
	a trace of sand, occ. silt seams and layers; brown / grey			
		6	DO	0
173.7 / 6.3	Grey, dense **SANDY SILT TILL**, a trace of gravel, occ. sand layers, cobbles and boulders	7A	DO	42
173.4 / 6.6	**END OF BOREHOLE**	7B		



WATER LEVEL

Dry on completion

Soil Engineers Ltd.

JOB NO.: 1905-S166

LOG OF BOREHOLE NO.: 6

FIGURE NO.: 6

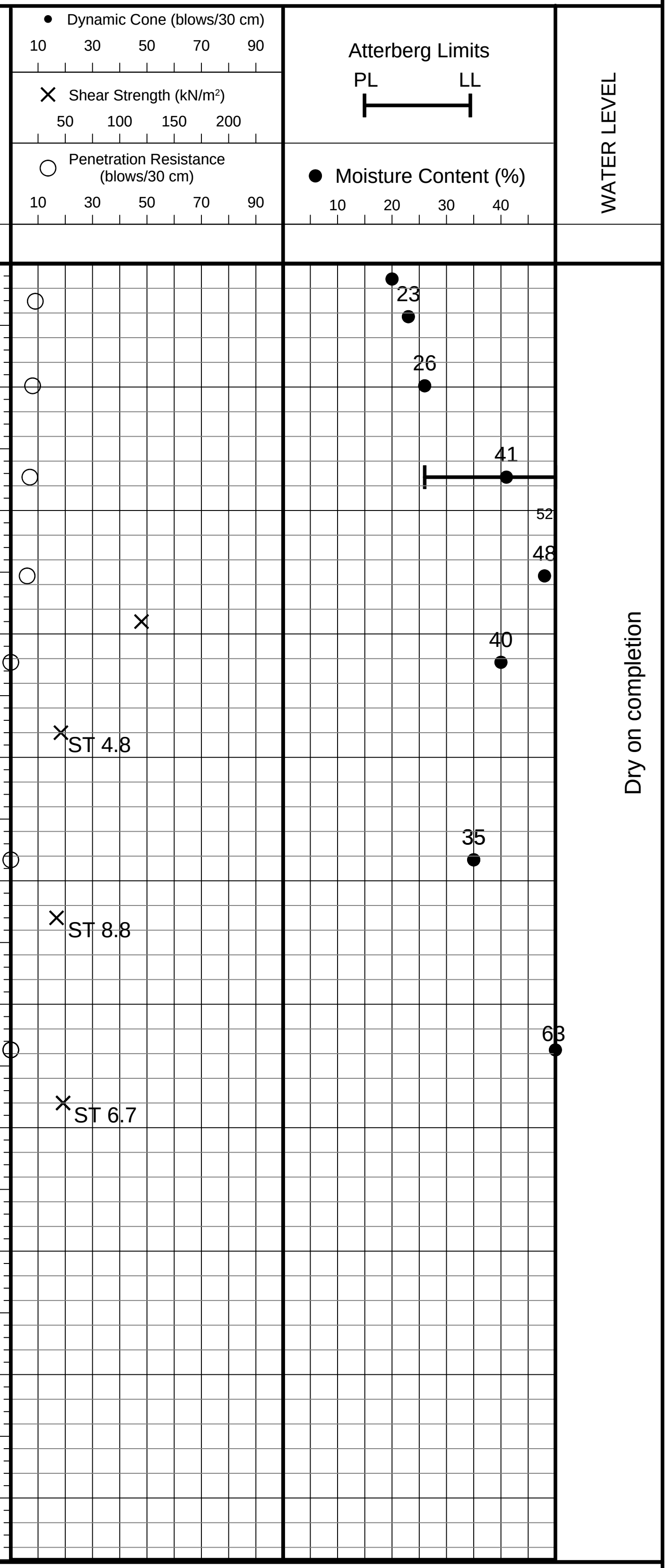
PROJECT DESCRIPTION: Proposed Commercial and Residential Development

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 1240 and Part of 1358 Anderson Line
Township of Severn (Coldwater)

DRILLING DATE: September 19, 2019

El. (m) / Depth (m)	SOIL DESCRIPTION	Sample Number	Type	N-Value	Depth Scale (m)
179.8	Ground Surface				
0.0	**25 cm TOPSOIL**	1A	DO	9	0
	Stiff to very soft	1B			
	weathered	2	DO	8	1
		3	DO	7	
	SILTY CLAY	4	DO	6	2
		5	DO	0	3
	a trace of sand occ. silt seams and layers brown / grey				4
		6	DO	0	5
		7	DO	0	6
172.6 7.2	**END OF BOREHOLE**				7



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JOB NO.: 1905-S166

LOG OF BOREHOLE NO.: 7

FIGURE NO.: 7

PROJECT DESCRIPTION: Proposed Commercial and Residential Development

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 1240 and Part of 1358 Anderson Line
Township of Severn (Coldwater)

DRILLING DATE: September 19, 2019

El. (m) / Depth (m)	SOIL DESCRIPTION	Number	Type	N-Value	Shear Strength (kN/m²)	Moisture Content (%)
179.3 / 0.0	Ground Surface					
	30 cm TOPSOIL	1A	DO	6		
	SILTY CLAY, Stiff to very soft	1B				25
	weathered	2	DO	8		29
		3	DO	5		24
	brown / grey	4	DO	5		45
		5	DO	1		55
	a trace of sand, occ. silt seams and layers				ST 9.4	
		6	DO	0	ST 6.3	50
		7	DO	0	ST 7.0	64
172.3 / 7.0	**END OF BOREHOLE**					

Dynamic Cone (blows/30 cm): 10 30 50 70 90

Shear Strength (kN/m²): 50 100 150 200

Penetration Resistance (blows/30 cm): 10 30 50 70 90

Atterberg Limits: PL LL

Moisture Content (%): 10 20 30 40

Depth Scale (m): 0 1 2 3 4 5 6 7 8 9 10

WATER LEVEL: W.L. @ El. 174.7 m on completion

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JOB NO.: 1905-S166

LOG OF BOREHOLE NO.: 8

FIGURE NO.: 8

PROJECT DESCRIPTION: Proposed Commercial and Residential Development

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 1240 and Part of 1358 Anderson Line
Township of Severn (Coldwater)

DRILLING DATE: September 19, 2019

El. (m) / Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value	Depth Scale (m)
179.3	Ground Surface				
0.0	**25 cm TOPSOIL**	1A	DO	8	0
	Stiff to very soft	1B			
	weathered	2	DO	10	1
	brown / grey	3	DO	7	2
	SILTY CLAY	4	DO	6	
	grey / brown	5	DO	2	3
	a trace of sand occ. silt seams and layers brown / grey				4
		6	DO	1	5
		7	DO	0	6
172.3 7.0	**END OF BOREHOLE**				7

Depth Scale (m): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

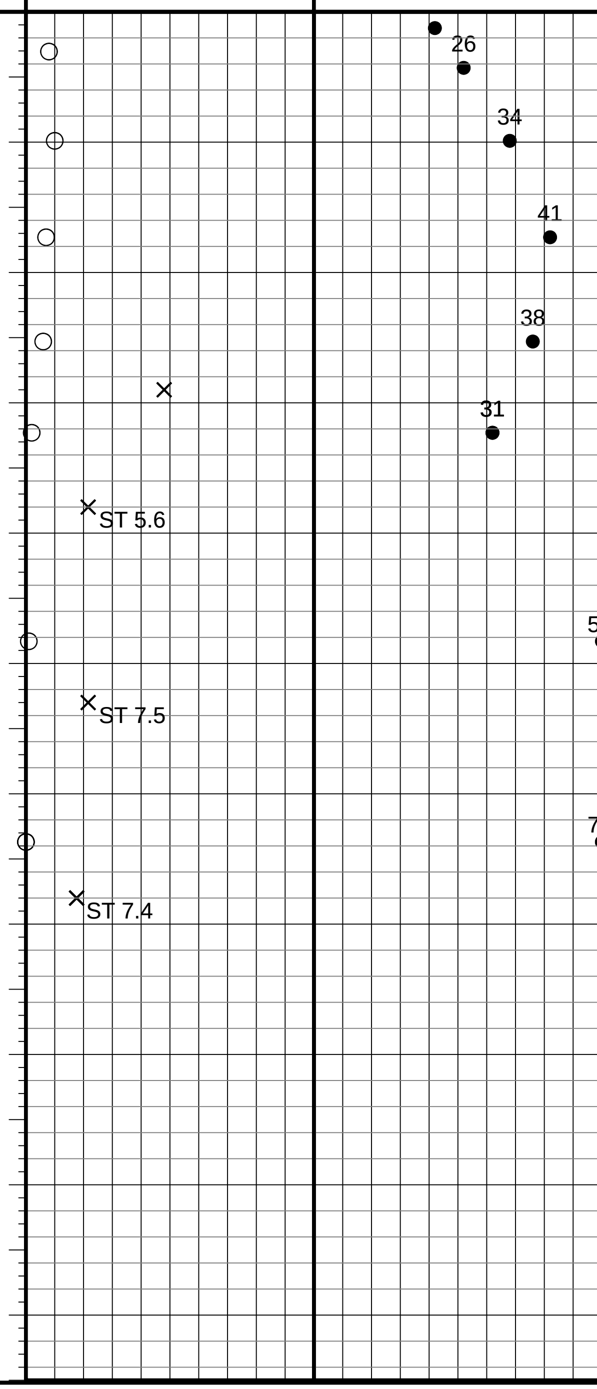
• Dynamic Cone (blows/30 cm): 10, 30, 50, 70, 90

× Shear Strength (kN/m²): 50, 100, 150, 200

○ Penetration Resistance (blows/30 cm): 10, 30, 50, 70, 90

Atterberg Limits: PL ⊢—⊣ LL

● Moisture Content (%): 10, 20, 30, 40



WATER LEVEL: W.L. @ El. 173.5 m on completion

Soil Engineers Ltd.

JOB NO.: 1905-S166

LOG OF BOREHOLE NO.: 9

FIGURE NO.: 9

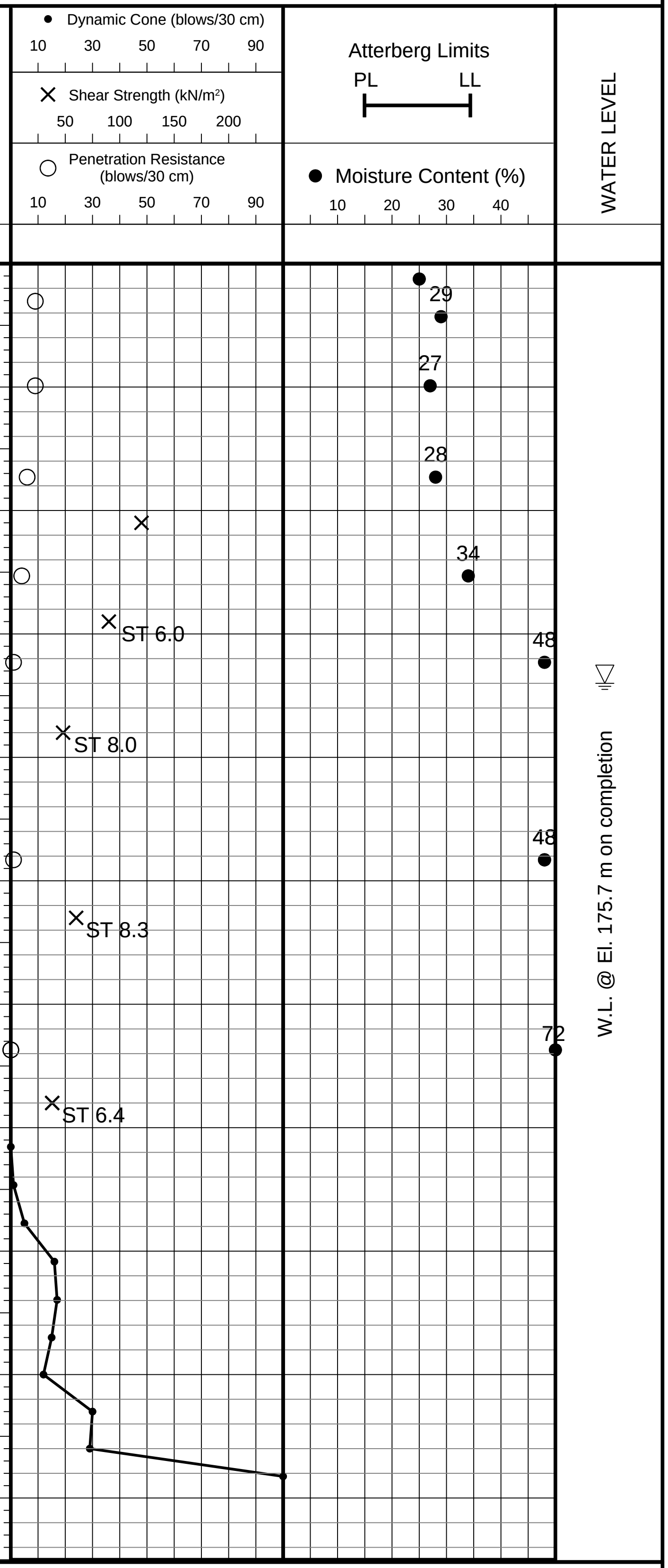
PROJECT DESCRIPTION: Proposed Commercial and Residential Development

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 1240 and Part of 1358 Anderson Line
Township of Severn (Coldwater)

DRILLING DATE: September 19, 2019

El. (m) / Depth (m)	SOIL DESCRIPTION	Samples: Number	Type	N-Value	Depth Scale (m)
179.1	Ground Surface				
0.0	**25 cm TOPSOIL**	1A	DO	9	0
	Stiff to very soft	1B			
	weathered	2	DO	9	1
		3	DO	6	
	brown / grey				2
	SILTY CLAY	4	DO	4	
		5	DO	1	3
	a trace of sand occ. silt seams and layers				4
		6	DO	1	5
		7	DO	0	6
172.1 / 7.0	**END OF BOREHOLE**				7
	CONE PENETRATION TESTS				8–9
9.9	**END OF CONE PENETRATION TESTS**				10



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JOB NO.: 1905-S166

LOG OF BOREHOLE NO.: 10

FIGURE NO.: 10

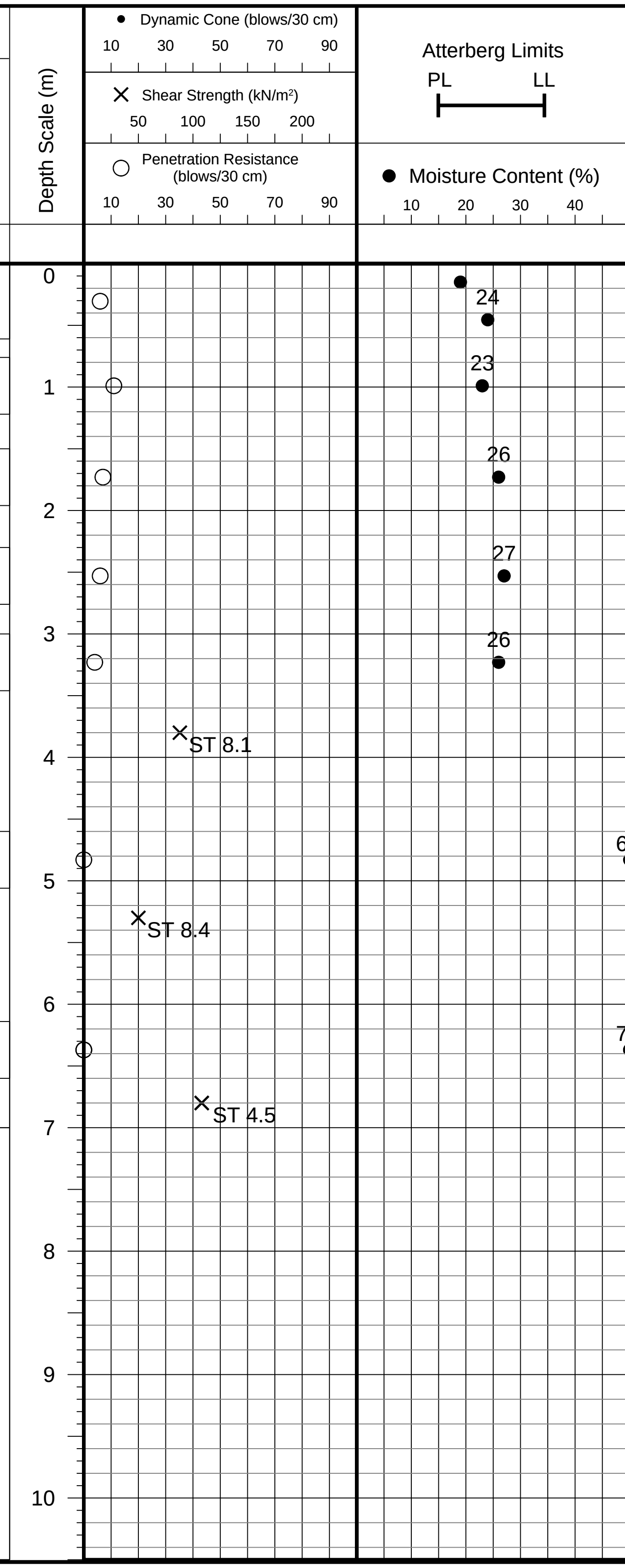
PROJECT DESCRIPTION: Proposed Commercial and Residential Development

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 1240 and Part of 1358 Anderson Line
Township of Severn (Coldwater)

DRILLING DATE: September 18, 2019

El. (m) / Depth (m)	SOIL DESCRIPTION	Samples: Number	Type	N-Value	WATER LEVEL
180.2	Ground Surface				
0.0	**30 cm TOPSOIL**	1A	DO	6	Dry on completion
	Stiff to very soft	1B			
	weathered	2	DO	11	
	brown / grey	3	DO	7	
	SILTY CLAY	4	DO	6	
	grey / brown	5	DO	4	
	a trace of sand occ. silt seams and layers brown / grey				
		6	DO	0	
		7	DO	0	
173.2 7.0	**END OF BOREHOLE**				



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JOB NO.: 1905-S166

LOG OF BOREHOLE NO.: 11

FIGURE NO.: 11

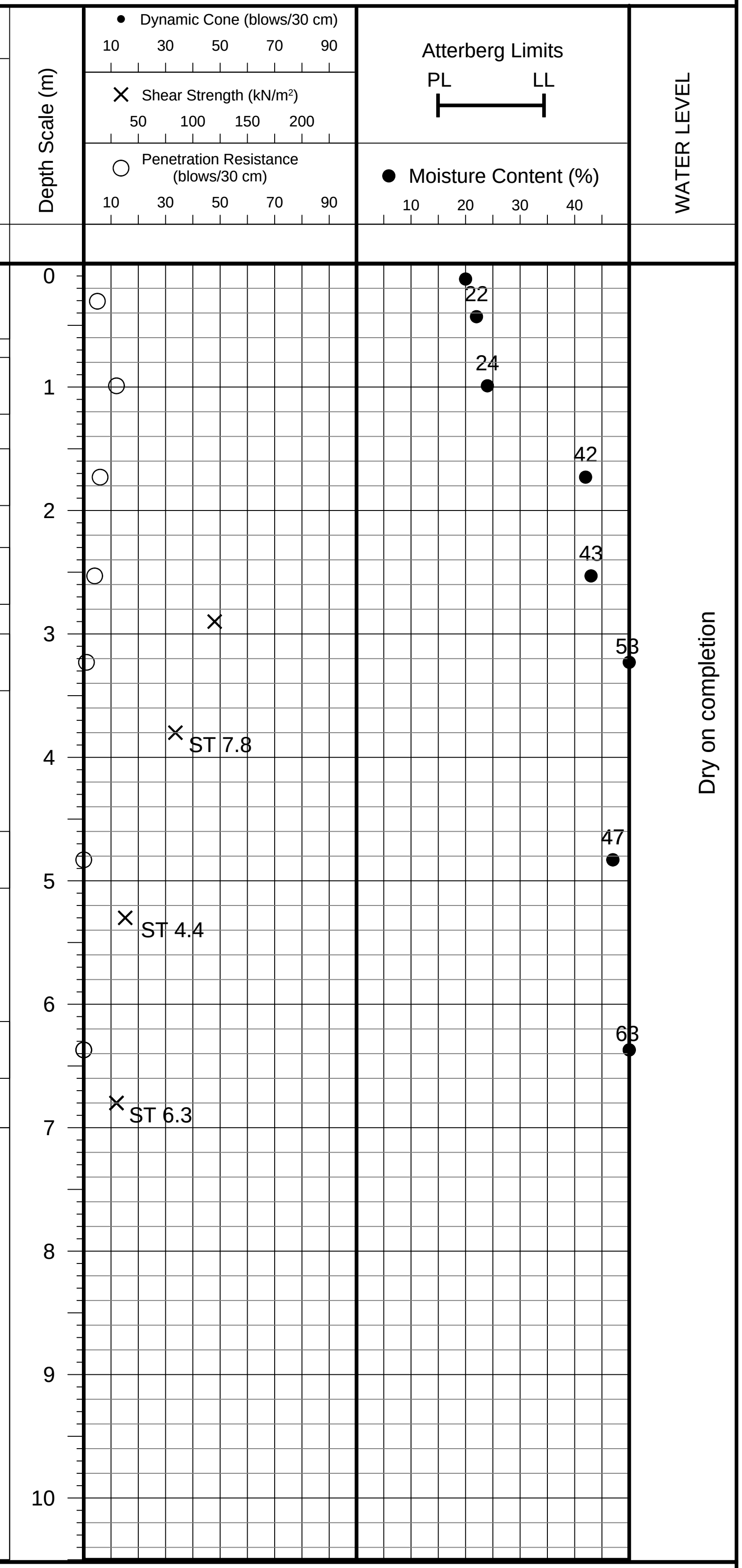
PROJECT DESCRIPTION: Proposed Commercial and Residential Development

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 1240 and Part of 1358 Anderson Line
Township of Severn (Coldwater)

DRILLING DATE: September 18, 2019

El. (m) / Depth (m)	SOIL DESCRIPTION	Number	Type	N-Value
179.9	Ground Surface			
0.0	**25 cm TOPSOIL**	1A	DO	5
	Stiff to very soft	1B		
	weathered	2	DO	12
		3	DO	6
	brown / grey			
	SILTY CLAY	4	DO	4
		5	DO	1
	a trace of sand occ. silt seams and layers			
		6	DO	0
		7	DO	0
172.9 7.0	**END OF BOREHOLE**			



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JOB NO.: 1905-S166

LOG OF BOREHOLE NO.: 12

FIGURE NO.: 12

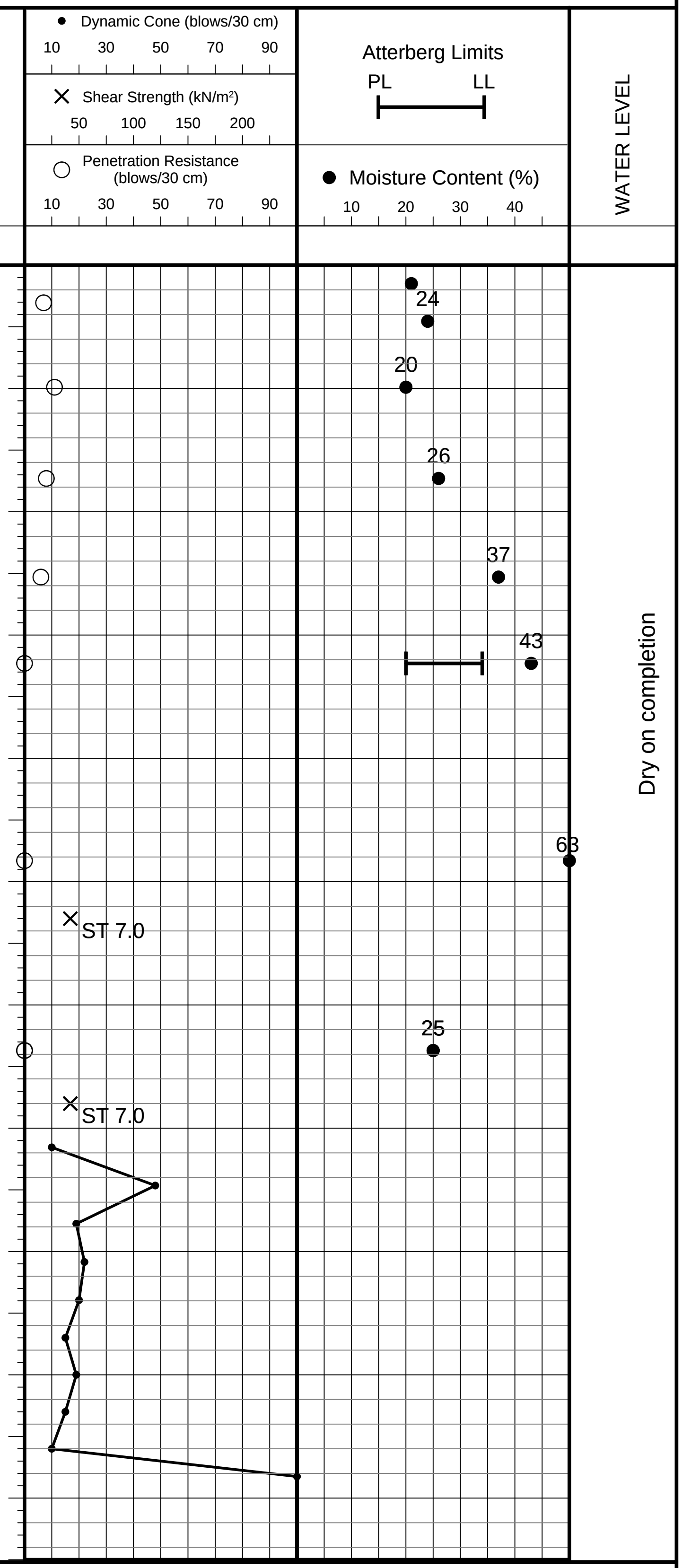
PROJECT DESCRIPTION: Proposed Commercial and Residential Development

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 1240 and Part of 1358 Anderson Line
Township of Severn (Coldwater)

DRILLING DATE: September 17, 2019

El. (m) / Depth (m)	SOIL DESCRIPTION	Sample Number	Type	N-Value	Depth Scale (m)
180.4	Ground Surface				
0.0	**30 cm TOPSOIL**	1A	DO	7	0
	Stiff to very soft	1B			
	weathered	2	DO	11	1
	brown / grey	3	DO	8	2
	SILTY CLAY	4	DO	6	
	grey / brown	5	DO	0	3
	a trace of sand, occ. silt seams and layers; brown / grey				4
		6	DO	0	5
		7	DO	0	6
173.4 / 7.0	**END OF BOREHOLE**				7
	CONE PENETRATION TESTS				8, 9
9.9	**END OF CONE PENETRATION TESTS**				10



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JOB NO.: 1905-S166

LOG OF BOREHOLE NO.: 13

FIGURE NO.: 13

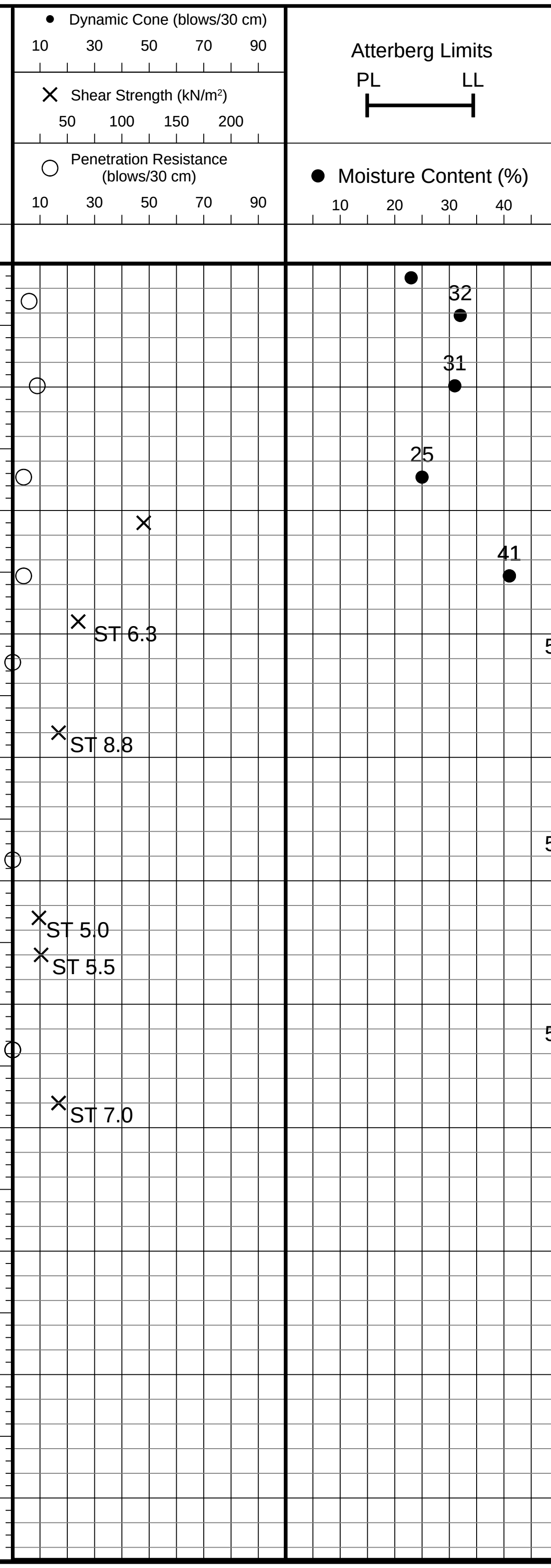
PROJECT DESCRIPTION: Proposed Commercial and Residential Development

METHOD OF BORING: Flight-Auger

PROJECT LOCATION: 1240 and Part of 1358 Anderson Line
Township of Severn (Coldwater)

DRILLING DATE: September 18, 2019

El. (m) / Depth (m)	SOIL DESCRIPTION	SAMPLES: Number	Type	N-Value	Depth Scale (m)
180.0	Ground Surface				
0.0	**23 cm TOPSOIL**	1A	DO	6	0
	Stiff to very soft	1B			
	weathered	2	DO	9	1
	SILTY CLAY	3	DO	4	
	brown / grey				2
		4	DO	4	
		5	DO	0	3
	a trace of sand occ. silt seams and layers				4
		6	DO	0	5
					6
		7	DO	0	
173.0 / 7.0	**END OF BOREHOLE**				7
					8
					9
					10



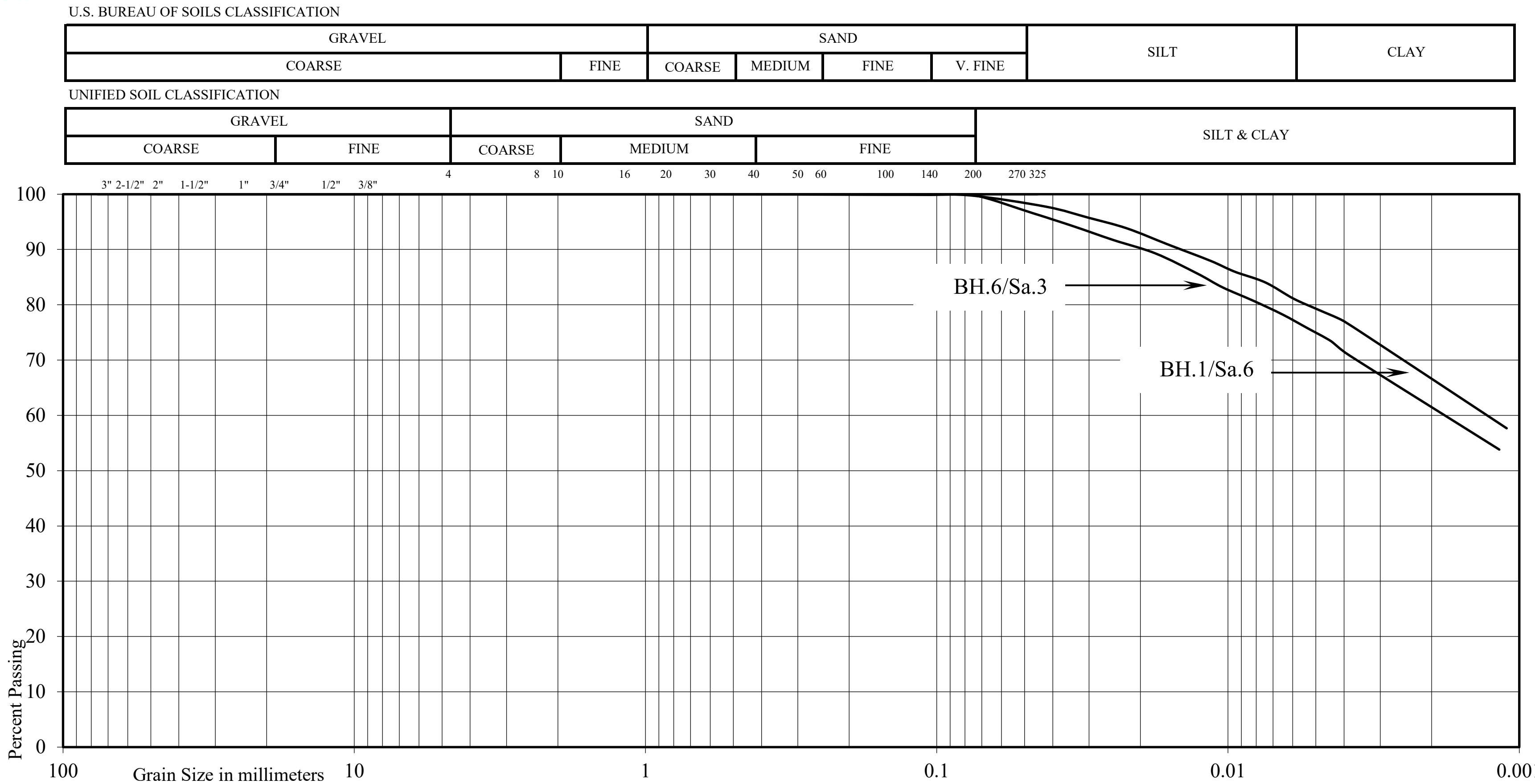
WATER LEVEL

Dry on completion

GRAIN SIZE DISTRIBUTION

Soil Engineers Ltd.

Reference No: 1905-S166



Project: Proposed Commercial and Residential Development

Location: 1240 and Part of 1358 Anderson Line, Township of Severn (Coldwater)

Borehole No:	1	6
Sample No:	6	3
Depth (m):	4.8	1.7
Elevation (m):	175.2	178.1

BH./Sa.	1/6	6/3
Liquid Limit (%) =	54	52
Plastic Limit (%) =	26	26
Plasticity Index (%) =	28	26
Moisture Content (%) =	77	41
Estimated Permeability (cm./sec.) =	10^{-7}	10^{-7}

Classification of Sample [& Group Symbol]: CLAY, some silt .

Figure: 14

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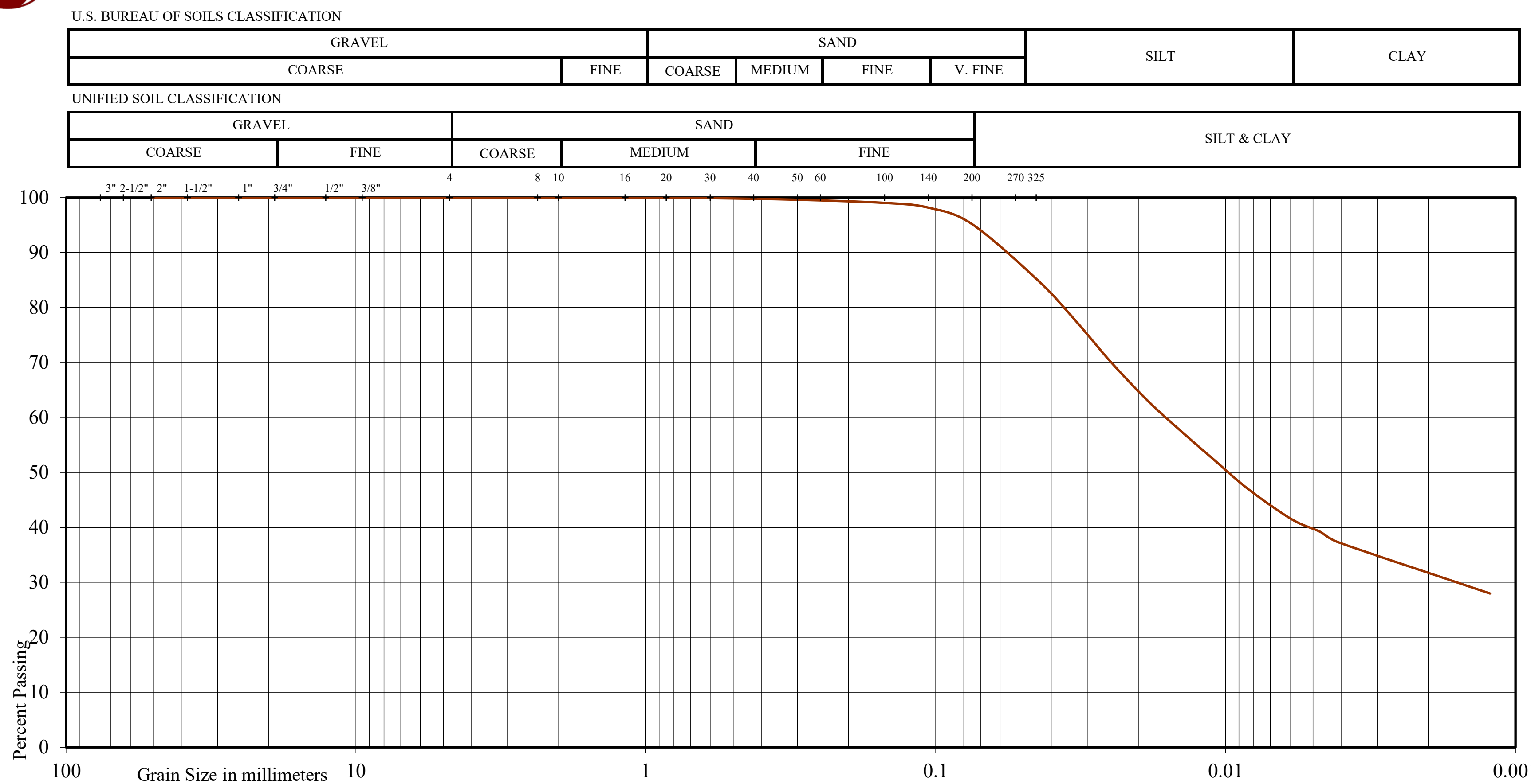
GRAIN SIZE DISTRIBUTION

Reference No: 1905-S166



Project: Proposed Commercial and Residential Development

Location: 1240 and Part of 1358 Anderson Line, Township of Severn (Coldwater)

Liquid Limit (%) = 34

Plastic Limit (%) = 20

Borehole No: 12

Plasticity Index (%) = 14

Sample No: 5

Moisture Content (%) = 43

Depth (m): 3.2

Estimated Permeability

Elevation (m): 177.2

(cm./sec.) = 10^{-7}

Classification of Sample [& Group Symbol]:	CLAY, silty, a trace of fine sand

Figure: 15

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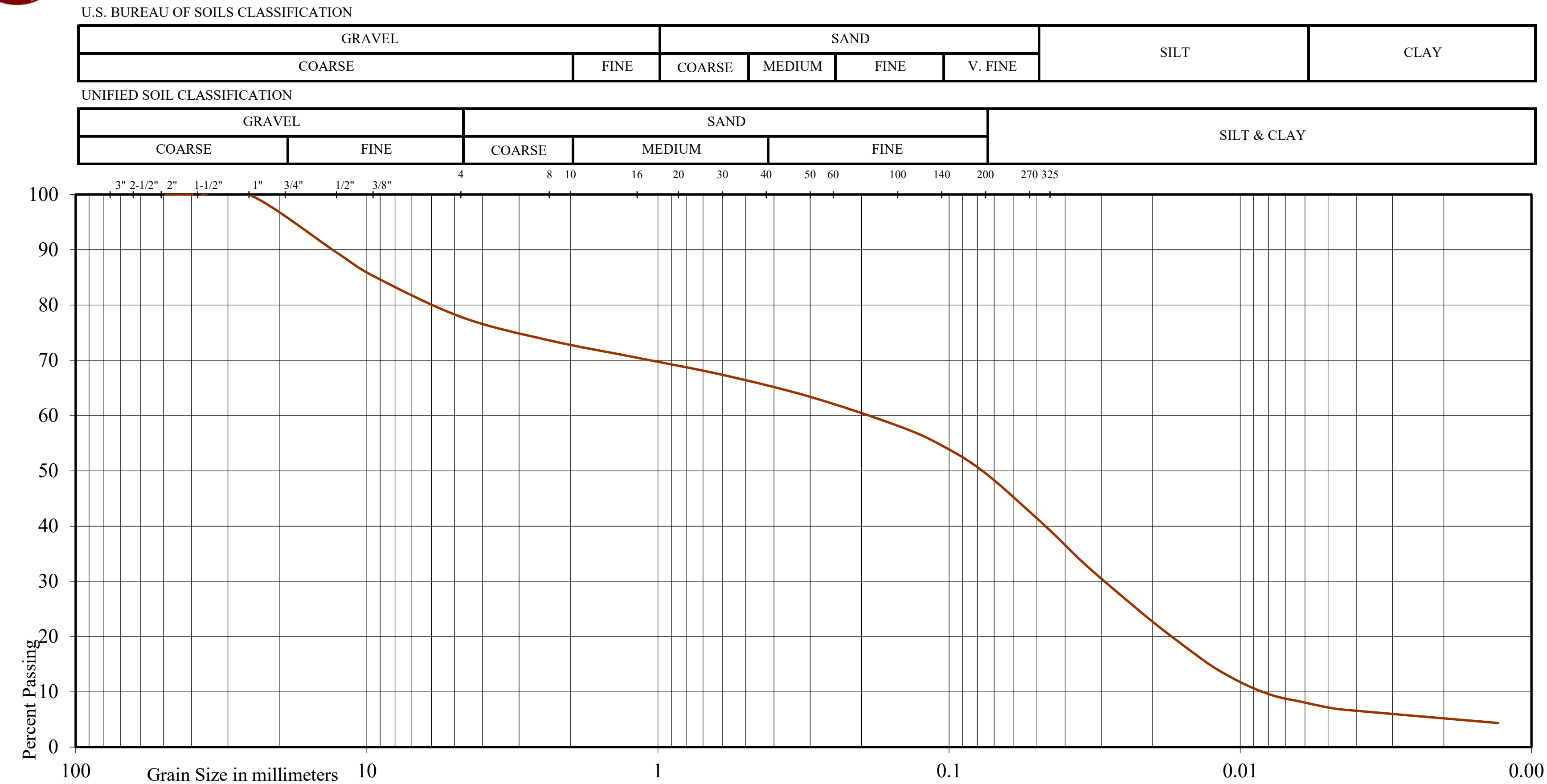
GRAIN SIZE DISTRIBUTION

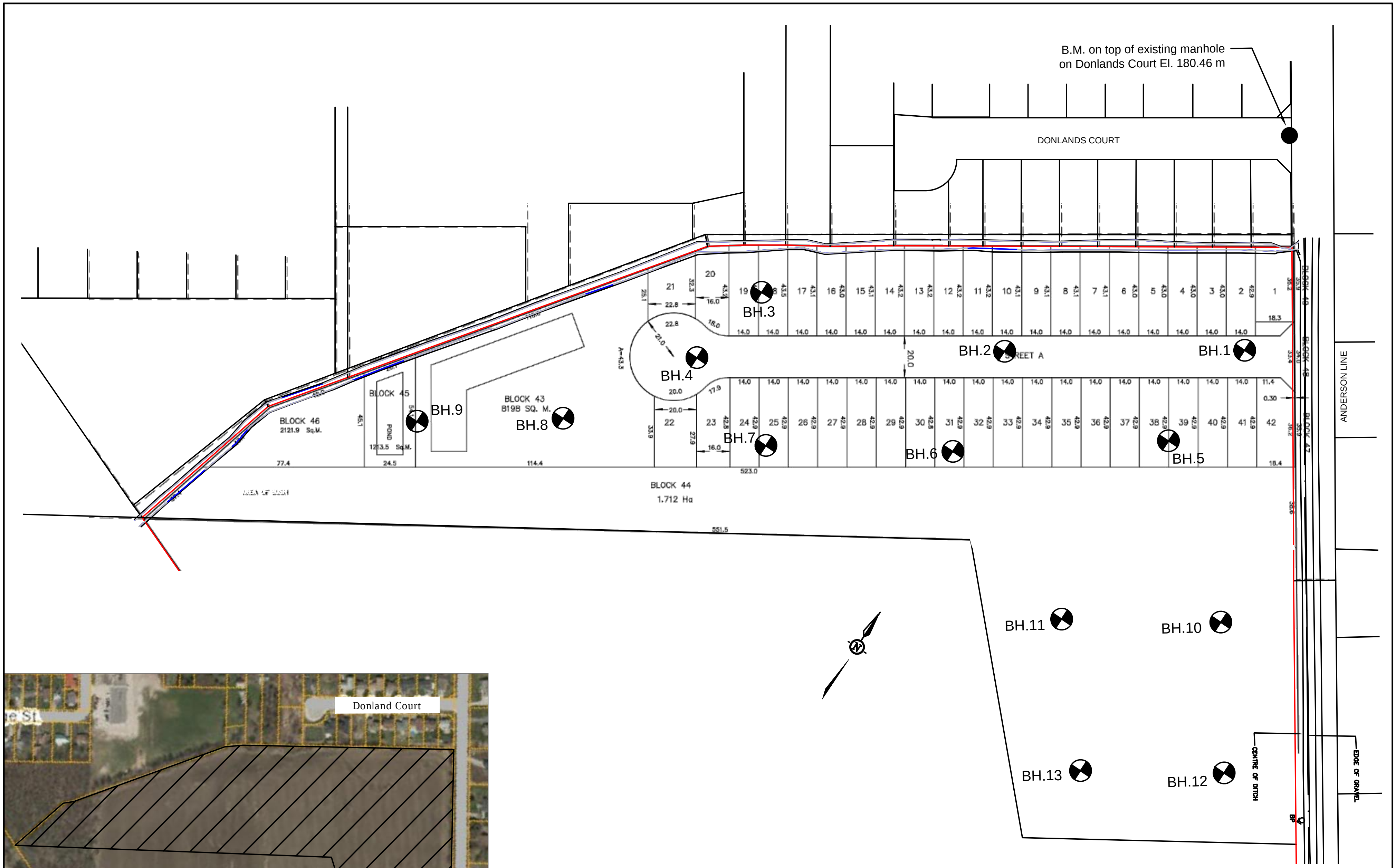
Reference No: 1905-S166



Project:	Proposed Commercial and Residential Development		
Location:	1240 and Part of 1358 Anderson Line, Township of Severn (Coldwater)	Liquid Limit (%) =	-
		Plastic Limit (%) =	-
Borehole No:	3	Plasticity Index (%) =	-
Sample No:	7	Moisture Content (%) =	14
Depth (m):	6.4	Estimated Permeability	
Elevation (m):	172.8	(cm./sec.) =	10^{-5}

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

Figure: 16



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90 WEST BEAVER CREEK ROAD, SUITE #100, RICHMOND HILL, ONTARIO L4B 1E7 · TEL: (416) 754-8515 · FAX: (905) 881-8335

BOREHOLE LOCATION PLAN

SITE: 1240 and 13698 Anderson Line, Township of Severn (Coldwater)

DESIGNED BY: -	CHECKED BY: -	DWG NO.: 1
SCALE: 1:2500	REF. NO.: 1905-S166	DATE: February 2020 — REV -

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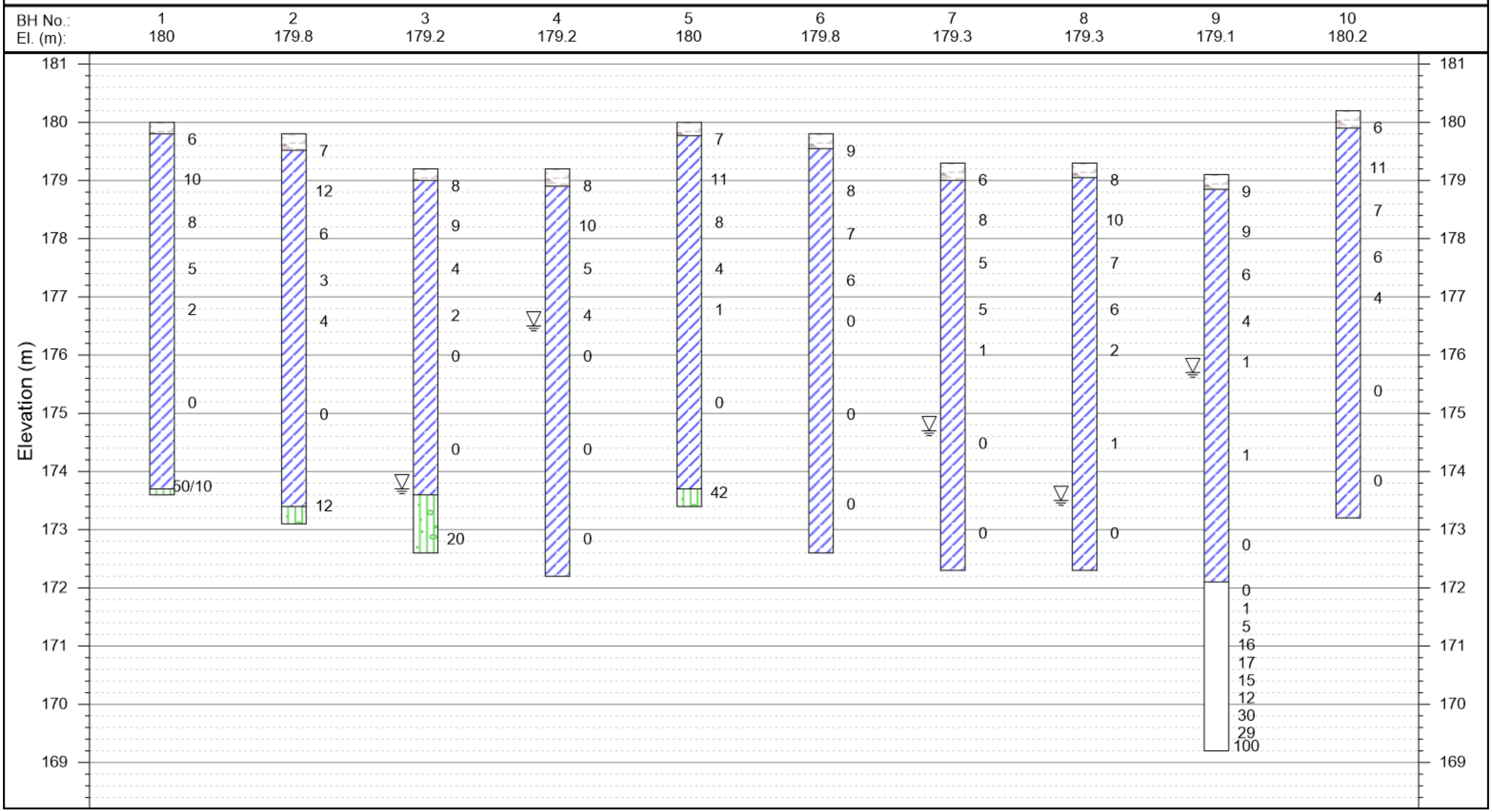
SUBSURFACE PROFILE
DRAWING NO. 2
SCALE: AS SHOWN
SUBDIVISION BLOCK

JOB NO.:	1905-S166
REPORT DATE:	February 2020
PROJECT DESCRIPTION:	Proposed Commercial and Residential Development
PROJECT LOCATION:	1240 and Part of 1358 Anderson Line Township of Severn (Coldwater)

LEGEND

TOPSOIL CONE TEST SANDY SILT TILL SILTY CLAY

WATER LEVEL (END OF DRILLING)



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GEOTECHNICAL | ENVIRONMENTAL | HYDROGEOLOGICAL | BUILDING SCIENCE

SUBSURFACE PROFILE
DRAWING NO. 3
SCALE: AS SHOWN
COMMERCIAL BLOCK

JOB NO.: 1905-S166
REPORT DATE: February 2020
PROJECT DESCRIPTION: Proposed Commercial and Residential Development
PROJECT LOCATION: 1240 and Part of 1358 Anderson Line
Township of Severn (Coldwater)

LEGEND

TOPSOIL | CONE TEST | SILTY CLAY

WATER LEVEL (END OF DRILLING)

BH No.:	10	11	12	13
El. (m):	180.2	179.9	180.4	180