GEI Consultants

Consulting
Engineers and
Scientists

Geotechnical Investigation

Proposed Residential Development – Two Semi-Detached Dwellings

157 Ardagh Road, Barrie, Ontario

Submitted to:
DataTamer Inc.
15 Corner Brook Trail
Innisfil, ON L9S 1P5

Submitted by:
GEI Consultants, Inc.
647 Welham Road, Unit 14
Barrie, Ontario, L4N 0B7
705-719-7994

November 17, 2021
Project No. 2103057

Table of Contents

1. Introduction 1

2. Procedures and Methodology 2

3. Subsurface Conditions 3
- 3.1 General Overview 3
- 3.2 Stratigraphy 3
- 3.3 Groundwater 4

4. Engineering Design Parameters & Analysis 6
- 4.1 Foundation Design 6
- 4.2 Earth Pressures 7
- 4.3 Slab on Grade Design 8
- 4.4 Basement Drainage 9
- 4.5 Site Servicing 10
- 4.6 Pavement Design 11

5. Constructability Considerations 14
- 5.1 Excavations 14
- 5.2 Temporary Groundwater Control 14
- 5.3 Compaction Specification 15
- 5.4 Quality Verification Services 16
- 5.5 Site Work 17

6. Limitations and Conclusions 18
- 6.1 Limitations 18
- 6.2 Conclusion 19

Figures

1. Site Location Plan
2. Borehole Location Plan
3. Geological Cross-Section A-A’

Appendices

A. Borehole Logs
B. Geotechnical Laboratory Data
C. Typical Details

1. Introduction

GEI Consultants (GEI) was retained to complete a subsurface investigation and provide a geotechnical report for the proposed residential development consisting of two semi-detached residential dwellings to be constructed at 157 Ardagh Road in Barrie, Ontario. A site location plan is enclosed as Figure 1.

The existing property is rectangular in shape is 25 metres wide (east to west) and 40 metres long (north to south). The property is bounded by Ardagh Road to the north, and existing single family residential properties to the east, west and south. The property currently contains a detached garage, driveway and manicured lawn areas. The topography within the study area slopes down from south to north with a maximum difference in elevation, as measured at the borehole locations, of about 2.2 metres.

GEI was provided the following document for review in preparation of this report: *"Zoning By-Law Amendment, Pre-Consultation Review, Planning Comments"* File: D28-058-2021, dated July 13, 2021, by the City of Barrie.

It is understood by email correspondence with Innovative Planning Solutions that the development will consist of two semi-detached residential dwellings. It is expected that the dwellings will be municipally serviced and that there is a possibility that the dwellings will have up to one basement level. Proposed site grades were not provided to GEI but there are not expected to be any significant grade changes to accommodate the development.

Based on the comments in a letter from Gary Matthie, Senior Development Services Technologist at the City of Barrie from July 9, 2021 as part of the pre-consultation application package, the following is required:

"*The Owner will be required to provide a geotechnical/hydrogeological investigation letter/report in support of this development. The report must address groundwater levels and any impact those levels may have on the proposed building foundation and recommendations for pavement structures (i.e., light, medium and heavy duty). The report will further confirm that the proposed development will not impact any wells within a 300 m radius of the subject property.*"

The purpose of the geotechnical investigation was to assess the subsurface soil conditions at the site by advancing three (3) exploratory boreholes, each with a monitoring well installation, to provide geotechnical engineering recommendations in support of the proposed residential dwellings. This report summarizes the borehole findings, provides design recommendations for foundations, slabs on grade, site grading, basement drainage, and earth pressures and pavements, and provides considerations for constructability such as soil excavation, compaction, and temporary groundwater control.

2. Procedures and Methodology

Prior to the commencement of drilling activities, the locations of underground utilities including natural gas, electrical, telephone, water, etc. were marked out by public and private utility locating companies. The fieldwork for the drilling program was carried out on September 9 and 13, 2021. A total of three boreholes (Boreholes 1 to 3) were advanced on site by a drilling subcontractor retained by GEI. The boreholes were advanced using a track-mounted drill, hollow stem augers and standard soil sampling equipment. All samples were collected as per ASTM D1586 to assess the strength characteristics of the substrate.

The boreholes were advanced to depths of 8.1 to 8.2 metres below existing grade (local Elev. 95.5 to 93.2 metres). The horizontal locations were laid out in the field by GEI prior to the drilling operations. Ground surface elevations of the boreholes were measured using survey equipment in relation to a temporary benchmark (top of catch basin, located in westbound lane of Ardagh Road adjacent to the subject property), with an assumed local elevation of 100.00 metres. GPS coordinates were measured with a handheld GPS unit and were referenced to the NAD 83 geodetic datum.

The GEI field staff examined and classified characteristics of the soils encountered in the boreholes, including the presence of fill materials, made groundwater observations during and upon completion of the drilling, recorded observations of borehole construction, and processed the recovered samples. Soil sampling was conducted at regular intervals for the full depth of the borehole. All recovered soil samples were logged in the field, carefully packaged and transported to the laboratory for more detailed examination and classification. In the laboratory, the samples were classified as to their visual and textural characteristics and geotechnical laboratory testing for grain size was carried out with the results provided in Appendix B.

Three (3) monitoring wells were installed (one per borehole) by GEI on site to facilitate long-term groundwater monitoring. Monitoring well construction is shown on the borehole logs in Appendix A.

3. Subsurface Conditions

3.1 General Overview

The detailed soil profiles encountered in the boreholes are indicated on the attached borehole logs in Appendix A, and the geotechnical laboratory results are included in Appendix B. Borehole locations are shown on Figure 2. A geological cross-section illustrating the subsurface conditions is included as Figure 3. It should be noted that the conditions indicated on the borehole logs and cross-section are for specific locations only and can vary between and beyond the locations. It should be noted that the soil boundaries indicated on the borehole logs are inferred from non-continuous sampling and observations during drilling. These boundaries are intended to reflect approximate transition zones and should not be interpreted as exact planes of geological change.

In addition, the descriptions provided in the borehole logs are inferred from a variety of factors, including: visual observations of the soil samples retrieved, laboratory testing, measurements prior to and after drilling, and the drilling process itself (speed of drilling, shaking/grinding of the augers, etc.). The passage of time also may result in changes in conditions interpreted to exist at locations where sampling was conducted.

3.2 Stratigraphy

3.2.1 Topsoil and Earth Fill

All the boreholes encountered a nominal surficial topsoil layer ranging in thickness between 50 to 100 mm.

Earth fill was encountered underlying the topsoil layer in all three boreholes. The earth fill extended to depths of 2.3 to 2.6 metres below grade (local Elev. 101.3 to 98.8 metres). The earth fill ranged from sand & gravel, to sand, to silty sand with variable amounts of gravel. Trace organics were also encountered within the earth fill in some boreholes. The Standard Penetration Test (SPT) results ("N" Values) measured in the earth fill ranged from 2 to 20 blows per 300 mm of penetration, indicating a very loose to compact relative density, with an average value of 7 (loose).

3.2.2 Native Soils

Underneath the surficial topsoil layer, all three boreholes encountered a glacial till deposit comprising silty sand to silt & sand with trace gravel and trace to some clay. In general, the upper 0.5 to 1.5 metres of the glacial till contained some clay and was cohesive, and the lower zone of the glacial till contained trace clay and was cohesionless. The glacial till was encountered at depths of 2.3 to 2.6 metres below grade (local Elev. 101.3 to 98.8 metres) and extended to depths of 3.1 to 7.6 metres below grade (local Elev. 100.5 to 93.8 metres). The glacial till deposit was generally moist and brown, turning grey with depth. The measured SPT "N" Values ranged from 7 to 15 blows per 300 mm of penetration in the upper cohesive zone of the deposit, indicating a firm to very stiff consistency. Pocket penetrometer testing was used to approximate the undrained shear strength in this zone, and the measured values ranged from approximately 50 to 90 kPa. The SPT "N" Values measured in the lower cohesionless zone of the glacial till range from 32 to 36 blows per 300 mm of penetration, indicating a dense relative density. Although cobbles and boulders were not specifically encountered in the boreholes, their presence in the deposit should be anticipated. Two grain size distribution curves of this deposit are included in Appendix B.

Underlying the glacial till deposit in all boreholes, a deposit consisting of sand with trace to some gravel and trace silt was encountered. The sand deposit was encountered at depths of 3.1 to 7.6 metres below grade (local Elev. 100.5 to 93.8 metres) and extended beyond the vertical depth of investigation at depths of 8.1 to 8.2 metres below grade (local Elev. 95.5 to 93.2 metres). The sand was generally grey and wet, and the measured SPT "N" Values ranged from 21 to 40 blows per 300 mm of penetration, indicating a compact to dense relative density. One grain size distribution curve of this deposit is included in Appendix B.

3.3 Groundwater

Unstabilized groundwater level measurements and cave measurements were taken upon completion of drilling of each borehole. These measurements provide a rough estimate of the possible excavation and temporary groundwater control constructability considerations that may arise. Unstabilized groundwater measurements taken ranged between 3.4 to 4.0 metres below existing grade. The boreholes remained open upon completion of drilling.

A 50 mm diameter PVC monitoring well with a 1.5-metre-long screen was installed in Borehole 1 and a 3.0-metre-long screen was installed in the remaining boreholes. Monitoring well construction and groundwater measurements are shown on the borehole logs in Appendix A, and the results are summarized in the table below.

Monitoring Well	**Well Screen Location**		**Strata Screened**	**Depth / Local Elev. (m) of Groundwater Table**
	Depth (m)	**Local Elev. (m)**		**October 19, 2021**
BH 1	5.9 to 7.4	95.4 to 93.9	Silty Sand to Silt & Sand Glacial Till; Possibly Sand	1.46 / 99.92
BH 2	4.6 to 7.6	97.9 to 94.9	Sand	2.56 / 99.92
BH 3	4.6 to 7.6	99.0 to 96.0	Sand	3.60 / 99.99

It is noted that the glacial till deposit increases in thickness from south to north across the site, and the depth to the underlying sand deposit also increases from south to north. The silty sand to silt & silt glacial till contains about 38 to 61% fines (based on the grain size analysis in Appendix B) and is considered to have a moderate to lower permeability, but will typically preclude the free flow of water. The deeper sand deposits encountered across the site or cohesionless earth fill are permeable and will allow for the free flow of water when wet.

The stabilized groundwater levels in the monitoring wells were measured to be at local Elev. 100.0 metres, which ranges from about 1.5 to 3.6 metres below grade. However, Monitoring Wells 2 and 3 were fully screened in the deeper sand deposit and Monitoring Well 1 likely extended partially into the deeper sand deposit (between sampling depths). It is expected that these water levels reflect the groundwater head within the permeable sand deposit, confined underneath the lower-permeability glacial till. This indicates that the deeper sands in Monitoring Wells 1 and 2 are pressurized with a groundwater head of approximately 2 to 6 metres above the top of the sand deposit.

Measured moisture contents and visual observations of the earth fill encountered in Borehole 1 (which extended to a depth of 2.6 metres below grade) indicate that the earth fill is moist, and groundwater was not encountered. This corroborates that the groundwater level measured to be 1.5 metres below grade at Borehole 1 reflects the head in the deep sands and does not represent the near-surface groundwater conditions. Excavations that penetrate through the glacial till deposit and into the deeper wet sands in the northern half of the site will encounter artesian groundwater conditions.

A perched groundwater condition was not encountered but may develop within the earth fill zone at the interface with the underlying glacial till during / after precipitation events or snowmelt. Groundwater levels are expected to show seasonal fluctuations and vary in response to prevailing climate conditions. Additional details on groundwater and in-situ permeability are provided in GEI's hydrogeological study under a separate cover.

4. Engineering Design Parameters & Analysis

It is understood by email correspondence with Innovative Planning Solutions that the development will consist of two semi-detached residential dwellings. It is expected that the dwellings will be municipally serviced and that there is a possibility that the dwellings will have up to one basement level. The property contains a detached garage, driveway and manicured lawn areas. The topography within the study area slopes down from south to north with a maximum difference in elevation, as measured at the borehole locations, of about 2.2 metres. Proposed site grades were not provided to GEI but there are not expected to be any significant grade changes to accommodate the development.

Reference should be made to the Ontario Building Code which stipulate the geotechnical design and construction requirements for the type of residential structures being proposed at this site.

4.1 Foundation Design

The topsoil and earth fill are not suitable for the support of new building foundations. The undisturbed glacial till deposit with a firm to very stiff consistency (where relatively higher clay content was encountered) or dense relative density encountered in the boreholes at or below 2.3 to 2.6 metres existing grade (at or below local Elev. 101.3 to 98.3 metres) is suitable for the support of new foundations.

It is recommended that all foundations be founded on the glacial till as high as possible above the deeper sands, as there are significant dewatering implications and the potential for basal heave of the founding subgrade where foundation excavations extend too deep into the glacial till or into the underlying wet sands. GEI **must** review final foundation designs (especially if a basement level will be constructed) to verify the foundation design parameters provided below and to verify there will be no impacts due to the underlying pressurized sand deposit.

Foundations at this site may be constructed as conventional spread and strip footing foundations that extend down to bear on the undisturbed glacial till as described above. Foundations set on the undisturbed glacial till at depths of 2.3 to 2.6 metres below existing grade may be designed using a geotechnical reaction at SLS of 100 kPa, for an estimated settlement of 25 mm or less. The maximum factored geotechnical resistance at ULS is 150 kPa.

It is important to note that these bearing capacities are applicable for foundations set onto the glacial till, which as encountered at depths of 2.3 to 2.6 metres below existing grades. If the grade is raised prior to foundation construction, the foundations must be extended through any new grade raise in addition to the required depth to reach the competent bearing level.

It is noted that in the area of the existing on-site structures that may be demolished, deeper fill may be present. As such, earth fill and existing foundations / obstructions (if any) must be fully removed and the new foundations must extend down to competent native and undisturbed glacial till, as discussed above.

The minimum strip and spread footing widths to be used shall be dictated as per the Ontario Building Code, regardless of loading considerations. Footings stepped from one level to another must be at a slope not exceeding 7 vertical to 10 horizontal. This concept should also be applied to excavations for new foundations in relation to existing footings or underground services unless rigid shoring is provided. All footings exposed to ambient air temperature throughout the year must be provided with a minimum of 1.2 metres of earth cover or equivalent insulation for frost protection.

The foundation design parameters provided above are predicated on the assumption that the foundation subgrade surface is undisturbed, and that all deleterious, softened, disturbed, organic, and caved material is removed. The foundation excavation must be done in such a way that groundwater is controlled to prevent any disturbance to the foundation base. Temporary groundwater control is discussed in Section 5.2.

The foundation subgrade must be reviewed by the geotechnical engineer or building inspector prior to concrete placement to ensure the foundation design parameters provided above are applicable, and to provide remedial recommendations if necessary. If the foundation excavation will be open for a prolonged period of time, the foundation subgrade should be protected with a skim coat of lean mix concrete (after the subgrade inspection), to ensure that no deterioration will occur due to weather effects.

4.2 Earth Pressures

Underground levels, basements, retaining walls, cantilevered shoring walls and shoring walls with a single level of earth anchors all must be designed to resist unbalanced lateral earth pressures imparted from the weight of adjacent soils. Lateral earth pressures are calculated using the following equation:

$$\boldsymbol{P = K[\gamma h + q]}$$

where, **P** = the horizontal pressure at depth, **h** (m)
K = the earth pressure coefficient (dimensionless)
h = depth below surface in metres
γ = the bulk unit weight of soil, (kN/m^3)
q = surcharge loading (kPa)

The above equation assumes that a drainage system is present which prevents the build up of any hydrostatic pressure behind the structure subjected to the unbalanced lateral earth pressures. If this is not the case, the equation must be revised to also incorporate the submerged unit weight of the soil multiplied by the earth pressure coefficient, in addition to the water pressure itself.

The values for use in the design of structures subjected to unbalanced lateral earth pressures at this site are as follows:

Soil Type	**γ - Bulk Unit Weight (kN/m^3)**	**φ - Friction Angle (degrees)**	**Earth Pressure Coefficient (dimensionless)**		
			K_a - Active	**K_o – At-Rest**	**K_p - Passive**
Granular ‘B’ (OPSS 1010)	21.0	32	0.31	0.47	3.25
Earth Fill	19.0	30	0.33	0.50	3.00
Firm to Very Stiff Glacial Till	21.0	31	0.32	0.48	3.12
Dense Glacial Till or Sand	21.0	38	0.24	0.38	4.20

The calculation of the earth pressure coefficients is based on Rankine theory, which provides a conservative estimate as no friction between the soil and the structure is accounted for. The earth pressure coefficients provided above are only applicable for flat ground surfaces beyond the structure and must be increased for sloping ground surfaces.

The earth pressure coefficients referenced within the above table are a function of the friction angle of the adjacent soil, and both the degree and direction of movement of the structure subjected to unbalanced lateral earth pressures. For structures that are restrained at the top (such as basement walls), the at-rest earth pressure coefficient will apply. For structures that allow for 0.1 to 1% of movement away from the soil, the full active earth pressure coefficient will apply. For structures that allow for 1 to 10% of movement into the soil, the full passive earth pressure coefficient will apply. The percentage movement is based on the height of the structure.

Other types of structures such as shoring walls with multiple rows of tiebacks and soil nail walls are subject to different loading conditions and must be analyzed separately.

4.3 Slab on Grade Design

The topsoil and any soft, wet, organic, or highly disturbed earth fill are not suitable for the support of a slab on grade. Approved earth fill and undisturbed glacial till are suitable for the support of a lightly supported unreinforced concrete slab on-grade.

The subgrade for the slab on grade must be assessed by the geotechnical engineer, prior to the placement of an aggregate base. If the subgrade will consist of the earth fill, it must be surface compacted to 98% Standard Proctor Maximum Dry Density (SPMDD). A glacial till subgrade should be proof-rolled and inspected. If any soft or weak subgrade areas are identified, or if there are areas containing excessive amounts of deleterious/organic material, they must be locally sub-excavated and backfilled with approved clean earth fill or imported granular material and compacted to a minimum of 98% SPMDD.

The modulus of subgrade reaction appropriate for design of a slab on grade on the earth fill (provided it is surface compacted to 98% SPMDD) is 20,000 kPa/m. The modulus of subgrade reaction appropriate for design of a slab on grade on the undisturbed glacial till is 30,000 kPa/m.

All building floor slabs must be provided with a capillary moisture barrier and drainage layer. This is made by placing the concrete slab on a minimum 200 mm layer of 19 mm clear stone (OPSS.MUNI 1004) compacted by vibration to a dense state. The upper 50 mm of clear stone can be replaced with 19 mm crusher run limestone for a working surface. The clear stone and a cohesionless subgrade must be separated by a geotextile such as Terrafix 270R (or approved equivalent) to prevent the migration of fines into the clear stone layer which could result in loss of support for the slab. If the subgrade consists entirely of cohesive glacial till, the geotextile is not required.

4.4 Basement Drainage

For new structures that will be slab on grade with no basement levels, perimeter and under-slab drainage at the foundation level is not required, provided that the underside of concrete slab is at least 200 mm above the prevailing grade of the site and the surrounding surfaces slope away from the building at a gradient of at least 2% to promote surface water run-off and to reduce groundwater infiltration adjacent to foundations. To minimize infiltration of surface water, the upper 150 mm of backfill could comprise relatively impervious compacted soil material.

Where basements are constructed, all basement foundation walls must be provided with damp-proofing provisions in conformance to the Ontario Building Code. Backfill along the foundation wall must consist of Granular ‘B’ Type 1 (OPSS 1010) for a minimum lateral distance of 600 mm out from the foundation wall. Alternatively, if a filtered cellular drainage media is provided adjacent to the foundation wall, the backfill may consist of common earth fill.

For buildings with basements, a perimeter drainage system must be installed that will remove any water that infiltrates into the building backfill, to ensure that any water does not infiltrate into the basement. The perimeter drains must consist of minimum 100 mm diameter perforated pipes wrapped in filter socks, sufficiently covered on all sides by 19 mm clear stone. Perimeter drains should be directed to the sump underneath the basement floor in solid pipes so as not to surcharge the underfloor drainage layer with water. All sump pumps should be on emergency power for redundancy in case of a power outage. A typical basement drainage detail is included in Appendix C. Additional considerations are provided in the hydrogeological study under a separate cover.

If the dwelling will have a basement level, in conditions where there is a high groundwater level and relatively permeable soils coupled with a basement level as part of the proposed building design, it is common practice to set the basement level a minimum of 0.5 metres above the seasonally high groundwater level. If the basement level is set near or within the prevailing groundwater level, it is possible that perimeter drainage issues may occur in the future (e.g. sump pump failure, blockage of drainage pipes, etc.), which would lead to potential foundation cracking and basement flooding. Basements can be set below the groundwater table provided these risks are fully acknowledged and all obligations set by the governing bodies in the jurisdiction are met which stipulate minimum clearance distances between basement slab elevation and seasonal high groundwater table.

In addition to the seasonal high groundwater level, it is recommended to keep any potential basements at the site as high as possible above the wet sand deposit underlying the glacial till. Excavations that extend too deep into the glacial till in the northern half of the site may encounter basal heave due to the pressurized sands below the glacial till. This could also create issues for foundation construction as discussed in Section 4.1. GEI **must** be provided with site grading and basement plans when available for commentary.

GEI is carrying out monthly groundwater level measurements for one year along with a hydrogeological study for the site, provided under a separate cover. Additional details pertaining to groundwater at the site is provided in the hydrogeological study.

4.5 Site Servicing

4.5.1 Bedding

The type of material and depth of granular bedding below the pipe will, to some extent, depend on the method of construction used by the contractor. Pipe bedding for flexible pipes should follow the requirements in Ontario Provincial Standard Drawing 802.010 or 802.013 or applicable municipal standards. Pipe bedding for rigid pipes should follow the requirements in Ontario Provincial Standard Drawings 802.030 to 802.033 or applicable municipal standards.

A subgrade consisting of the earth fill, silty sand glacial till or cohesionless sand at the site will provide adequate support for pipes with the bedding requirements as laid out in the above referenced OPS drawings. Where disturbance of the trench base has occurred from groundwater seepage, construction traffic, etc., the disturbed soils should be sub-excavated and replaced with suitably compacted granular fill. If weak zones are encountered, additional bedding materials and differing construction practices may be required and should be determined during construction.

If the site servicing will extend below the glacial till and into the deeper sands, positive dewatering to lower the groundwater level to at least 0.5 metres below the bottom of the excavation prior to excavation will be required. GEI **must** be provided with final site servicing plans for review when available.

Regardless of whether flexible or rigid pipes are implemented, granular bedding and cover material should consist of a well graded, free draining material, such as Granular "A" (OPSS.MUNI 1010). All granular bedding must be compacted to a minimum of 98% SPMDD. Clear stone or high-performance bedding is permitted at this site provided it is fully wrapped in a non-woven filter fabric to prevent the migration of fines and loss of pipe support.

4.5.2 Backfill

Excavated glacial till or earth fill may be used as backfill in trenches, as foundation wall backfill, within excavations, etc. provided the moisture content is within 2% of optimum and the soil does not contain excessive organics or deleterious materials (see Section 5.3 for more details on soil compaction). The backfill should be compacted to a minimum of 98% SPMDD. In confined areas the layer thickness will have to be reduced to utilize smaller compaction equipment efficiently or by using granular material instead of locally sourced fill. Any backfill that is frozen, contains a high percentage of organic material (topsoil, peat, etc.) or moisture, or has otherwise unsuitable deleterious inclusion should not be used as backfill. The maximum cobble or boulder size should not exceed half of the loose lift thickness (i.e. all particles with a diameter greater than 100 mm should be removed).

Where trenches are within settlement sensitive areas (e.g. the roadway, parking lot, sidewalks, etc.), backfill within the frost penetration depth of 1.2 metres should consist of native, non-organic, excavated material consistent with the soils surrounding the trench. If this technique is not undertaken, then frequently problems arise with yearly differential frost heave movements between the trench backfill and the adjacent native soil. This would occur, for example, if imported granular fill was used to backfill the trenches. Alternatively, if different soil is used as the backfill due to issues with achieving compaction, a frost taper of 5H:1V can be implemented to help mitigate the potential for differential settlement and frost heave.

4.6 Pavement Design

4.6.1 Subgrade Preparation

Final grading plans were not provided to GEI at the time of writing this report. A review of the borehole data suggests that the proposed pavement subgrade will consist of very loose to loose earth fill. The topsoil is not a suitable subgrade and must be removed. The loose earth fill will be an adequate subgrade for the support of a pavement structure, provided it is surface compacted to 98% SPMDD, inspected, and approved by a geotechnical engineer at the time of construction and does not contain excessive amounts of organics or deleterious materials. A glacial till subgrade should be proof rolled and inspected by the geotechnical engineer. If any soft or weak subgrade areas are identified, or if there are areas containing excessive amounts of moisture or deleterious/organic material, they must be locally sub-excavated and backfilled with approved clean earth fill or imported granular material and compacted to a minimum of 98% SPMDD. Any fill placed to raise the grades of the pavement subgrade must be compacted to 98% SPMDD.

The subgrade resilient modulus appropriate for design of a pavement structure on the earth fill (provided it is surface compacted to 98% SPMDD) is 20,000 kPa/m.

The long-term performance of the pavement structure is highly dependent upon the subgrade support conditions. Stringent construction control procedures must be maintained to ensure that uniform subgrade moisture and density conditions are achieved as much as possible when fill is placed, and the natural subgrade is not disturbed or weakened after it is exposed.

4.6.2 Drainage

Control of surface water is an important factor in achieving a good pavement life. The need for adequate subgrade drainage cannot be over-emphasized. The subgrade must be free of depressions and sloped (at a minimum grade of 3 percent) to provide effective drainage toward subgrade drains or ditches / swales adjacent to the pavement. Grading adjacent to pavement areas should be designed to ensure that water is not allowed to pond adjacent to the outside edges of the pavement. Typical pavement drainage details are included in Appendix C.

4.6.3 Pavement Structure

The industry pavement design methods are based on a design life of 15 to 20 years for typical weather conditions depending on actual traffic volumes. Light duty pavement is recommended for car parking and driving areas. Heavy duty pavement is recommended for fire truck, garbage truck, or bus routes. The following pavement thickness design is provided on the above noted considerations and subgrade basis.

Pavement Layer	Compaction Requirements	Minimum Component Thickness	
		Light Duty	Heavy Duty
Surface Course Asphaltic Concrete: HL3 (OPSS 1150) with PG 58-28 Asphalt Cement (OPSS.MUNI 1101)	OPSS 310	40 mm	40 mm
Binder Course Asphaltic Concrete: HL8 (OPSS 1150) with PG 58-28 Asphalt Cement (OPSS.MUNI 1101)		50 mm	70 mm
Base Course:		150 mm	150 mm

Pavement Layer	Compaction Requirements	Minimum Component Thickness	
		Light Duty	Heavy Duty
Granular A (OPSS.MUNI 1010)	100% Standard Proctor Maximum Dry Density (ASTM-D698)		
Subbase Course: Granular B Type I or II (OPSS.MUNI 1010)		300 mm	450 mm

The granular materials should be placed in lifts 200 mm thick or less and be compacted to a minimum of 100% SPMDD for both granular base and subbase. Asphalt materials should be rolled and compacted as per OPSS 310. The granular and asphalt pavement materials and their placement should conform to OPSS 310, 501, 1010 and 1150.

If the pavement construction occurs in wet, winter or inclement weather, it may be necessary to provide additional subgrade support for heavy construction traffic by increasing the thickness of the granular subbase, base or both. Further, traffic areas for construction equipment may experience unstable subgrade conditions. These areas may be stabilized utilizing additional thickness of granular materials.

It should be noted that in addition to adherence of the above pavement design recommendations, a close control on the pavement construction process will also be required in order to obtain the desired pavement life. Therefore, it is recommended that regular inspection and testing should be conducted during the pavement construction to confirm material quality, thickness, and to ensure adequate compaction.

5. Constructability Considerations

5.1 Excavations

Excavations must be carried out in accordance with the Occupational Health and Safety Act, Ontario Regulation 213/91 (as amended), Construction Projects, Part III - Excavations, Section 222 through 242. Where workers must enter a trench or excavation the soil must be suitably sloped and/or braced in accordance with the OHSA. These regulations designate four (4) broad classifications of soils to stipulate appropriate measures for excavation safety. The regulation stipulates safe slopes of excavation as follows based on the soils encountered at this site:

- *Type 3 Soils – Earth fill, glacial till, and dewatered sands:* Trench sidewalls to be constructed no steeper than 1 horizontal to 1 vertical from the base of the excavation.
- *Type 4 Soils – Sands below the groundwater table:* Trench sidewalls to be constructed no steeper than 3 horizontal to 1 vertical from the base of the excavation.

If more than one soil type is encountered in an excavation, the most conservative soil type must be followed for sloping the sidewalls of the excavation.

Minimum support system requirements for steeper excavations are stipulated in Sections 235 through 238 and 241 of the OHSA and include provisions for timbering, shoring and moveable trench boxes. To reduce the potential for instability of the trench excavations, materials excavated from the service trenches and/or other fill materials or heavy equipment should not be placed near the crest of the trench excavations.

Cobbles and boulders embedded in the glacial till may be encountered in construction excavations. It is important to note that soils encountered in the construction excavations may vary significantly across the site. Our preliminary soil classifications are based solely on the materials encountered in the boreholes advanced on site. The contractor should verify that similar conditions exist throughout the proposed area of excavation. If different subsurface conditions are encountered at the time of construction, we recommend that GEI be contacted immediately to evaluate the conditions encountered.

5.2 Temporary Groundwater Control

The groundwater conditions at the site are discussed in Section 3.3. Although groundwater was measured in the monitoring wells at depths of 1.5 to 3.6 metres below grade (local Elev. 100.0 metres), this represents the groundwater head within the deeper confined sand deposit below the lower-permeability glacial till and does not reflect the near-surface groundwater conditions.

A perched groundwater condition was not encountered but may develop within the earth fill zone at the interface with the underlying glacial till during / after precipitation events or snowmelt. The upper 2.3- to 2.6-metre-thick zone of earth fill was moist (not wet) and unstabilized water was not encountered. Some minor perched water may also be present within the glacial till. Based on the drilling observations, moisture contents, and experience on previous construction sites along Ardagh Road within 250 metres of the site (which encountered similar subsurface conditions), it is expected that seepage entering excavations made into the earth fill and glacial till can be controlled using conventional sump pump systems.

On a preliminary basis, excavations are not expected to extend into the wet sand deposits underlying the silty sand/silt and sand glacial till. Any seepage from excavations within the upper fill and/or glacial till or runoff from precipitation events can be controlled using a conventional sump pump system.

If excavations are to extend into the lower wet sand deposits positive dewatering including well points and/or deep wells may be required. In particular, the lower sands in the northern half of the site are considered pressurized due to the confining glacial till deposit, and the sands will need to be dewatered and/or de-pressurized before excavations can feasibly extend beyond the upper glacial till. Dewatering and/or de-pressurization of the lower sand unit may also be required for excavations extending deeper than 1 metre into the glacial till in the northern half of the site to prevent basal heaving/blowout of the subgrade. The groundwater pressure head within the sands would need to be lowered to at least 0.5 metres below the bottom of a proposed excavation, or 0.5 metres below the bottom of the glacial till for excavations made deeper into the glacial till.

Additional details on temporary groundwater control are provided in the hydrogeological study by GEI provided under a separate cover. GEI should be provided with final site servicing, grading, and foundation drawings for review to verify the proposed excavation depths and potential dewatering implications.

The exact scenario where these groundwater control techniques will work are estimates only and are directly correlated to how coarse/fine the native soils are in an excavation, and both the lateral and vertical extent of the cohesionless deposits encountered. If the groundwater table is not controlled during construction, the base of the excavations will probably be unstable, leading to difficulties in excavating and placement of pipes or footings. A dewatering contractor must review and assess the subsurface conditions to verify which dewatering techniques will work for the site and proposed utility installations, based on their experience and interpretation of the data. A test dig could be carried out to assist prospective contractors determine the most appropriate dewatering methods based on their own means and methods.

5.3 Compaction Specification

Standard Proctor Maximum Dry Density (SPMDD) is the level to which a soil or aggregate is compacted. To achieve the specified SPMDD as indicated in this report, all soils or aggregates must be placed in lift thicknesses no greater than 200 mm. If this is not the case, only the upper portion of the lift will be adequately compacted, and the lower portion of the lift has a high probability of not meeting compaction specifications. In addition, industry standard equipment used to determine the degree of compaction consists of nuclear densometers. These devices have an inherent limitation in that they cannot test beyond 300 mm in depth, and so the degree of compaction beyond this depth cannot be quantitatively determined.

Along with lift thickness, ensuring that the soil or aggregate is within 2% of its optimum moisture content ensures that the specified compaction can be reached. If the soil or aggregate is too dry/wet, it is either very difficult or impossible to reach the specified compaction. This is especially true for when higher compaction specifications such as 98% and 100% SPMDD are required.

The soil below the groundwater table at this site is generally wet of optimum and should not be re-used as fill at the site. Based on our review of the soil types encountered in the boreholes with associated moisture contents, the soils at this site (above the groundwater table) are considered as follows:

- One third of in-situ soil above the groundwater table: At or near optimum moisture content.
- One third of in-situ soil above the groundwater table: Above optimum moisture content.
- One third of in-situ soil above the groundwater table: Below optimum moisture content.

The zones with higher moisture content will require moisture conditioning prior to re-use in areas that require compaction. Moisture could be reduced by tilling the soil, spreading the soil out, or blending it with drier material. Soil that is dry of optimum could be blended with wetter soil or have water added prior to re-use. It must be also noted that the above percentages can change significantly based on the time of year in which construction occurs, as the prevailing weather can have a significant effect on the moisture content of stockpiled and in-situ soil.

In addition to the above compaction specifications, in any areas where compacted fill will be placed over the exposed native soil subgrade, any loose, soft, wet or unstable areas should be sub-excavated, and backfilled with clean earth fill or Granular ‘B’ (OPSS.MUNI 1010) compacted to a minimum of 98% SPMDD. This recommendation applies to site servicing, slab and pavement subgrades.

5.4 Quality Verification Services

On-site quality verification services are an integral part of the geotechnical design function, and for foundations and retaining walls, are required under the Ontario Building Code. Quality verification services are used to confirm that construction is being conducted in general conformance with the requirements as outlined in the drawings, reports and specifications prepared for the proposed development.

GEI Consultants can provide all the on-site quality verification services outlined below:

- The subgrade for shallow foundations may be field reviewed by the geotechnical engineer as required by the municipal regulating authority.
- Installation of retaining structures over 1.0 metres high and related backfilling operations must be field reviewed on a continuous basis by the geotechnical engineer as required in the OBC.
- Part-time monitoring of the subgrade support capabilities, material quality, lift thickness, moisture content, degree of compaction, etc. is recommended for the following areas to ensure the recommendations within this report are followed and they perform adequately in the long-term;
    - Slab-on-grades;
    - Pavement structure (granulars and asphalt); and
    - Bedding/backfilling of site servicing.
- Testing of the concrete (compressive strength, slump, air content, etc.) and testing of the asphalt (asphalt content and gradation) are recommended to ensure that the quality of the materials being brought to site meet the requirements of the project.

5.5 Site Work

The soils found at this site may become weakened when subjected to traffic, particularly when wet. If there is site work carried out during periods of wet weather, then it can be expected that the subgrade will be disturbed unless an adequate granular working surface is provided to protect the integrity of the subgrade soils from construction traffic. Subgrade preparation works cannot be adequately accomplished during wet weather and the project must be scheduled accordingly. The disturbance caused by the traffic can result in the removal of disturbed soil and use of granular fill material for site restoration or underfloor fill that is not intrinsic to the project requirements.

The most severe loading conditions on the subgrade may occur during construction. Consequently, special provisions such as end dumping and forward spreading of earth and aggregate fills or restricted construction lanes may be required, especially if construction is carried out during unfavourable weather.

If construction proceeds during freezing weather conditions, adequate temporary frost protection for the founding subgrade and concrete must be provided. The soil at this site is susceptible to frost damage. Consideration must be given to frost effects, such as heave or softening, on exposed soil surfaces in the context of this particular project development.

6. Limitations and Conclusions

6.1 Limitations

The recommendations and comments provided are necessarily on-going as new information of underground conditions becomes available. More specific information with respect to the conditions between samples, or the lateral and vertical extent of materials may become apparent during excavation operations. The interpretation of the borehole information must, therefore, be validated during excavation operations. Consequently, conditions not observed during this investigation may become apparent. Should this occur, GEI should be contacted to assess the situation and additional testing and reporting may be required.

GEI should be retained for a general review of the final design drawings and specifications to verify that this report has been properly interpreted and implemented. If not accorded the privilege of making this review, GEI will assume no responsibility for interpretation of the recommendations in the report.

The comments given in this report are intended only for the guidance of the design engineers. The number of boreholes required to determine the localized underground conditions between boreholes affecting construction costs, techniques, sequencing, equipment, scheduling, etc. could be greater than has been carried out for design purposes. Contractors bidding on or undertaking the works should, in this light, decide on their own investigations, as well as their own interpretations of the factual borehole results, so that they may draw their own conclusions as to how the subsurface conditions may affect them.

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

6.2 Conclusion

It is recognized that municipal/regional governing bodies, in their capacity as the planning and building authority under Provincial statues, will make use of and rely upon this report, cognizant of the limitations thereof, both as are expressed and implied.

We trust this report is complete within our terms of reference, and the information presented is sufficient for your present purposes. If you have any questions, or when we may be of further assistance, please do not hesitate to contact our office.

Yours Truly,

GEI Consultants

Prepared By:

LICENSED PROFESSIONAL ENGINEER
A.JAFAROV
100070788
Nov. 17, 2021
PROVINCE OF ONTARIO

Anar Jafarov, P.Eng.
Geotechnical Engineer

Reviewed By:

LICENSED PROFESSIONAL ENGINEER
A.WINKELMANN
100150146
Nov. 17, 2021
PROVINCE OF ONTARIO

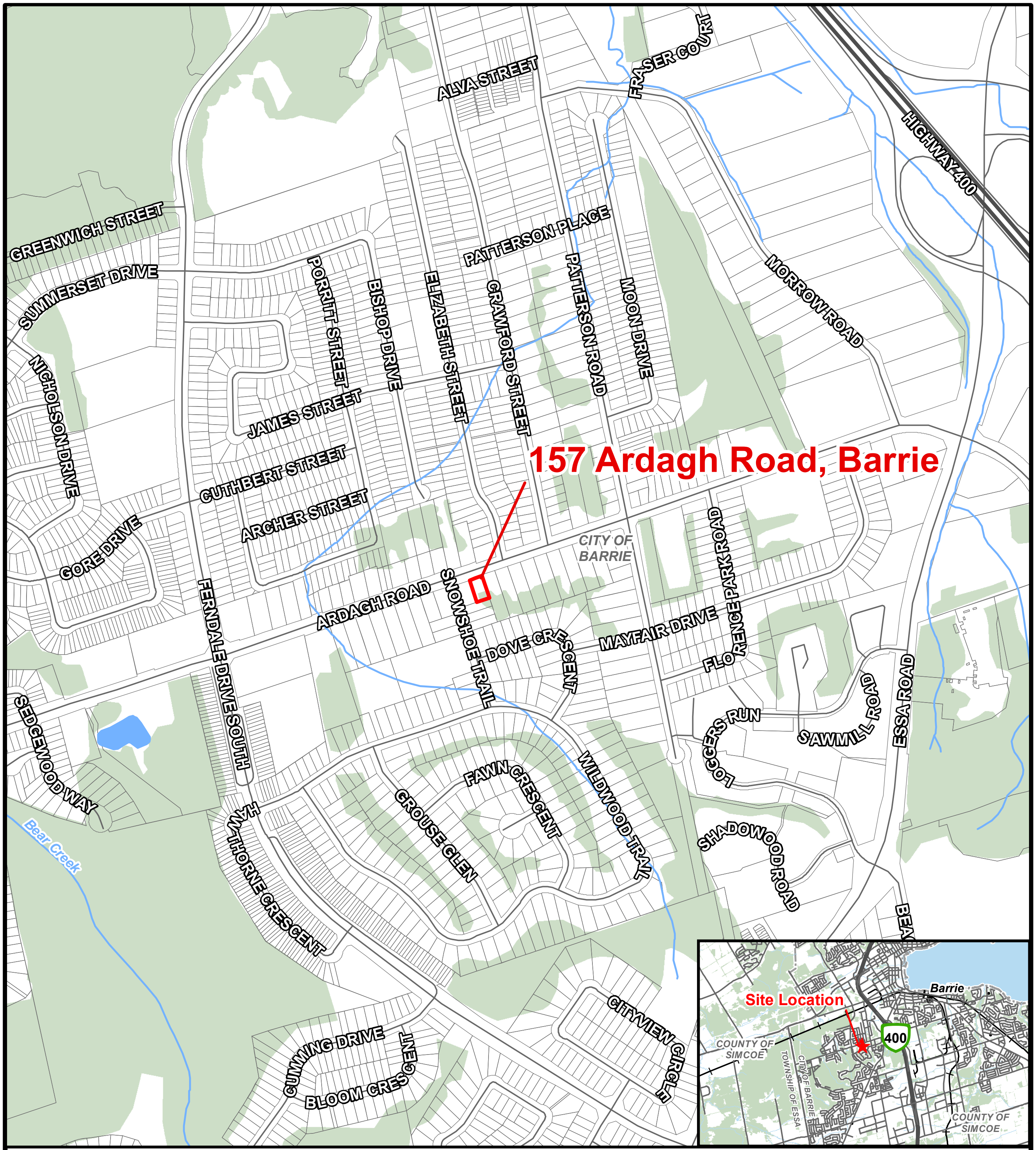
Alexander Winkelmann, P.Eng.
Geotechnical and Earth Sciences Manager

Figures

Site Location Plan

Borehole Location Plan

Geological Cross-Section A-A’



NOTES:

1. Coordinate System: NAD 1983 UTM Zone 17N.
2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2021.
3. Parcels: City of Barrie 'Tax Parcels' Feature Service, 2021.

Legend

- 🟥 Site Location
- ☐ Parcels
- ☐ Municipal Boundary, Lower/Single Tier
- ☐ Municipal Boundary, Upper Tier
- ┼ Railway
- — Watercourse
- 🟦 Waterbody
- 🟩 Wooded Area

N

0 125 250 m

1:10,000

157 Ardagh Road
Barrie, ON

DataTamer Inc.

GEI Consultants

Project: 2103057

SITE LOCATION PLAN

October 2021

Fig. 1

NOTES:
1. Coordinate System: NAD 1983 UTM Zone 17N.
2. Orthoimagery © First Base Solutions, 2021. Imagery taken in 2020.

Legend

- ▭ Approximate Property Boundary
- ⌖ Approximate Borehole/Monitoring Well Location
- ↔ Cross Section Location
- [xx.xx] Groundwater Level (masl) (October 19, 2021)

N

0 3.5 7
m
1:300

157 Ardagh Road
Barrie, ON

DataTamer Inc.

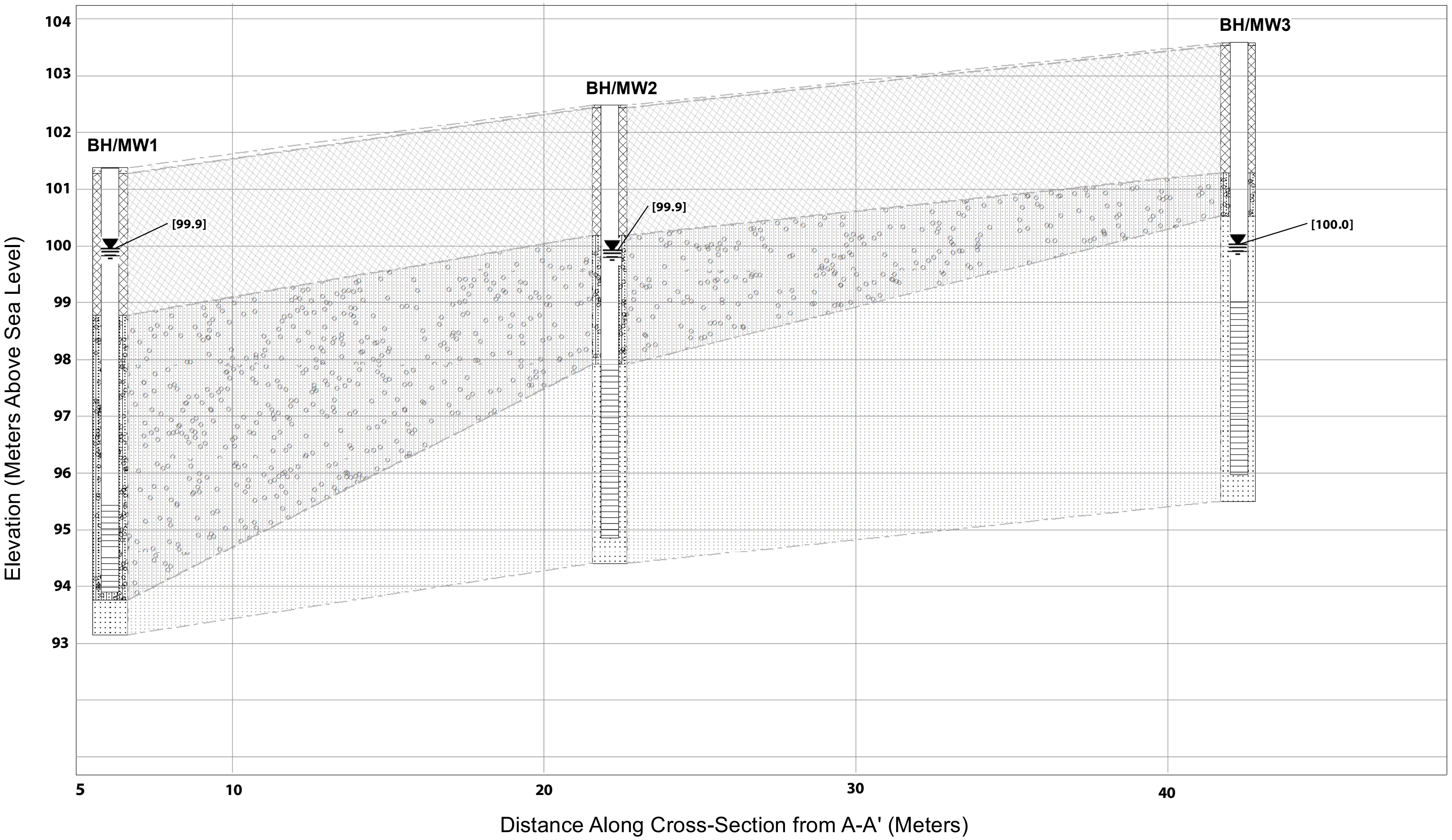
GEI Consultants

Project: 2103057

BOREHOLE LOCATION PLAN (AERIAL)

November 2021

Fig. 2



Legend

Water Level In Monitoring Well

[xx.xx] Groundwater Level (masl), Measured Oct19, 2021.

Strata symbols

- Topsoil
- Fill
- Silty Sand to Silt and Gravel Glacial Till
- Sand

NOTES:

1. Subsurface conditions known only at borehole locations.

157 Ardagh Road
Barrie, ON

DataTamer Inc.

GEI Consultants

Project: 2103057

Geological Cross Section A-A'

November 2021

Fig. 3

Appendix A

Borehole Logs

RECORD OF BOREHOLE No. 1

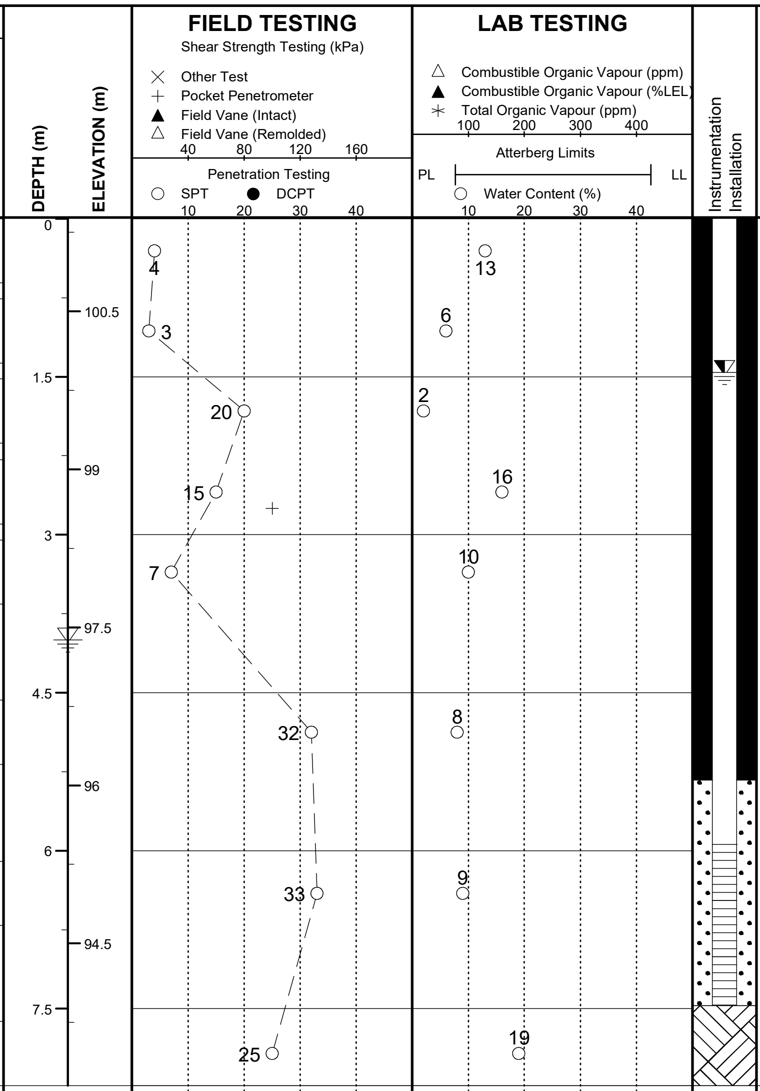
GEI Consultants

Project Number: **2103057**
Project Client: **DataTamer Inc.**
Project Name: **157 Ardagh Road**
Project Location: **Barrie, Ontario**
Drilling Location: **See Figure 2**

Drilling Method: **Hollow Stem Augers**
Logged By: **AJ**
Reviewed By: **AW**

Drilling Machine: **Track Mount**
Northing: **4912235**
Easting: **602880**
Date Started: **Sep. 9/21**
Date Completed: **Sep. 9/21**

LITHOLOGY PROFILE		SOIL SAMPLING				COMMENTS & GRAIN SIZE DISTRIBUTION (%)			
Depth / Elevation	DESCRIPTION (Local 101.38m)	Sample Type	Sample Number	Recovery (%)	SPT "N" Value	GR	SA	SI	CL
0.1 / 101.3	Topsoil = 100mm								
	FILL: Sand, Trace Gravel, Very Loose to Loose, Brown, Moist	SS	1	25	4				
		SS	2	33	3				
1.5 / 99.9	FILL: Sand and Gravel, Compact, Brown, Moist	SS	3	38	20				
2.6 / 98.8	SILTY SAND to SILT & SAND GLACIAL TILL, Some Clay, Trace Gravel, Very Stiff, Brown, Moist	SS	4A 4B	83	15				
	--- Firm ---	SS	5	88	7				
	--- Trace Clay, Dense ---	SS	6	75	32				
		SS	7	96	33	3	59	28	10
7.6 / 93.8	SAND, Trace to Some Gravel, Trace Silt, Compact, Grey, Wet	SS	8	96	25				
8.2 / 93.2	End of Borehole @ 8.2m								



GEI CONSULTANTS

647 Welham Road, Unit 14
Barrie, Ontario L4N 0B8
T : (705) 719-7994
www.geiconsultants.com

Groundwater depth encountered on completion of drilling: **4.0m**

Cave depth after auger removal: **Open**

Groundwater depth observed on **Oct. 19/21** at a depth of: **1.46m**

Borehole details presented do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified geotechnical engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying 'Explanation of Boring Log'.

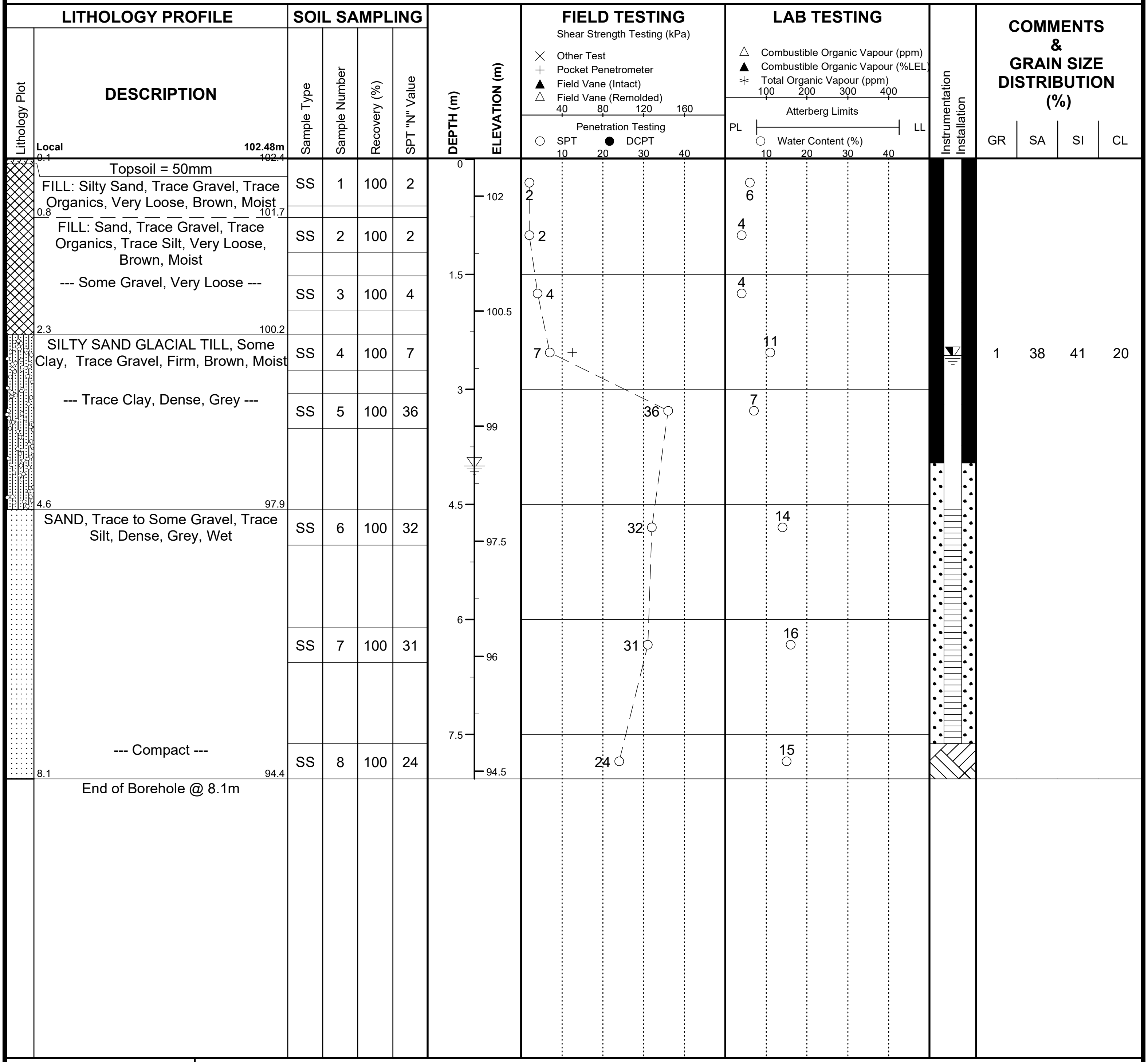
Scale: **1 :75**

RECORD OF BOREHOLE No. 2

GEI Consultants

Project Number: **2103057**
Project Client: **DataTamer Inc.**
Project Name: **157 Ardagh Road**
Project Location: **Barrie, Ontario**
Drilling Location: **See Figure 2**

Drilling Method: **Hollow Stem Augers**
Drilling Machine: **Track Mount**
Logged By: **BH**
Reviewed By: **AW**
Northing: **4912224**
Easting: **602894**
Date Started: **Sep. 13/21**
Date Completed: **Sep. 13/21**



LITHOLOGY PROFILE

Depth (m)	Elevation (m)	DESCRIPTION
	Local 102.48m	
0.1	102.4	Topsoil = 50mm
0.8	101.7	FILL: Silty Sand, Trace Gravel, Trace Organics, Very Loose, Brown, Moist
2.3	100.2	FILL: Sand, Trace Gravel, Trace Organics, Trace Silt, Very Loose, Brown, Moist --- Some Gravel, Very Loose ---
4.6	97.9	SILTY SAND GLACIAL TILL, Some Clay, Trace Gravel, Firm, Brown, Moist --- Trace Clay, Dense, Grey ---
8.1	94.4	SAND, Trace to Some Gravel, Trace Silt, Dense, Grey, Wet --- Compact ---
		End of Borehole @ 8.1m

SOIL SAMPLING

Sample Type	Sample Number	Recovery (%)	SPT "N" Value	Water Content (%)	GR	SA	SI	CL
SS	1	100	2	6				
SS	2	100	2	4				
SS	3	100	4	4				
SS	4	100	7	11	1	38	41	20
SS	5	100	36	7				
SS	6	100	32	14				
SS	7	100	31	16				
SS	8	100	24	15				

COMMENTS & GRAIN SIZE DISTRIBUTION (%)

GEI CONSULTANTS

647 Welham Road, Unit 14
Barrie, Ontario L4N 0B8
T : (705) 719-7994
www.geiconsultants.com

Groundwater depth encountered on completion of drilling: **4.0m**

Cave depth after auger removal: **Open**

Groundwater depth observed on **Oct. 19/21** at a depth of: **2.56m**

Borehole details presented do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified geotechnical engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying 'Explanation of Boring Log'.

Scale: **1 :75**

RECORD OF BOREHOLE No. 3

Project Number: **2103057**
Project Client: **DataTamer Inc.**
Project Name: **157 Ardagh Road**
Project Location: **Barrie, Ontario**
Drilling Location: **See Figure 2**

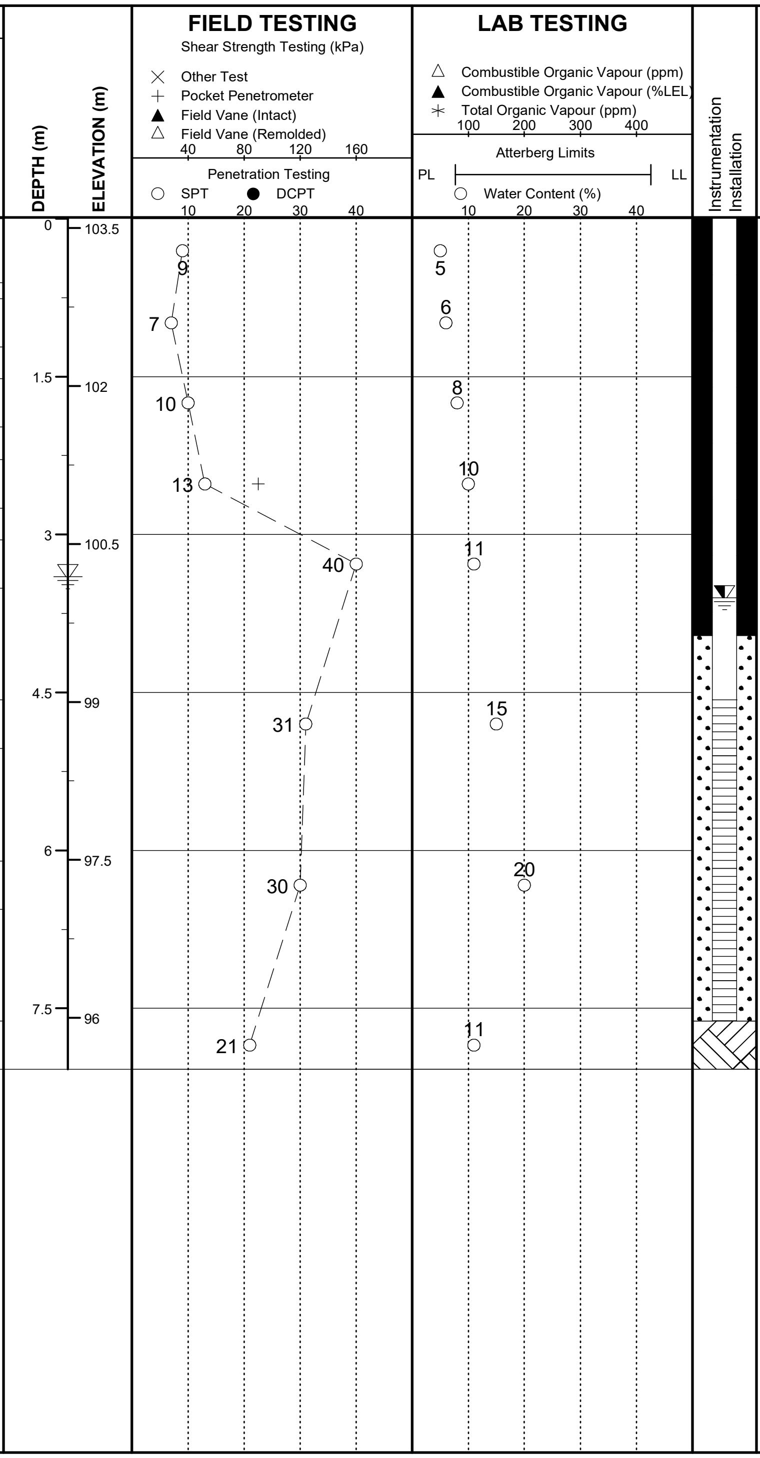
Drilling Method: **Hollow Stem Augers**
Drilling Machine: **Track Mount**
Logged By: **BH**
Northing: **4912202**
Date Started: **Sep. 13/21**
Reviewed By: **AW**
Easting: **602900**
Date Completed: **Sep. 13/21**

LITHOLOGY PROFILE

Depth (m)	Elevation (m)	DESCRIPTION
Local	103.59m	
0.1	103.5	Topsoil = 50mm
		FILL: Sand, Trace Silt, Loose, Brown, Moist
2.3	101.3	SILTY SAND to SILT & SAND GLACIAL TILL, Some Clay, Trace Gravel, Stiff, Brown, Moist
3.1	100.5	SAND, Trace to Some Gravel, Trace Silt, Dense, Grey, Moist to Wet
		--- Wet ---
		--- Compact ---
8.1	95.5	End of Borehole @ 8.1m

SOIL SAMPLING

Sample Type	Sample Number	Recovery (%)	SPT "N" Value	Water Content (%)	GR	SA	SI	CL
SS	1	100	9	5				
SS	2	100	7	6				
SS	3	100	10	8				
SS	4	100	13	10				
SS	5	100	40	11				
SS	6	100	31	15				
SS	7	100	30	20				
SS	8	100	21	11	7	88	(5)	



COMMENTS & GRAIN SIZE DISTRIBUTION (%)

GEI CONSULTANTS

647 Welham Road, Unit 14
Barrie, Ontario L4N 0B8
T : (705) 719-7994
www.geiconsultants.com

Groundwater depth encountered on completion of drilling: **3.4m**

Cave depth after auger removal: **Open**

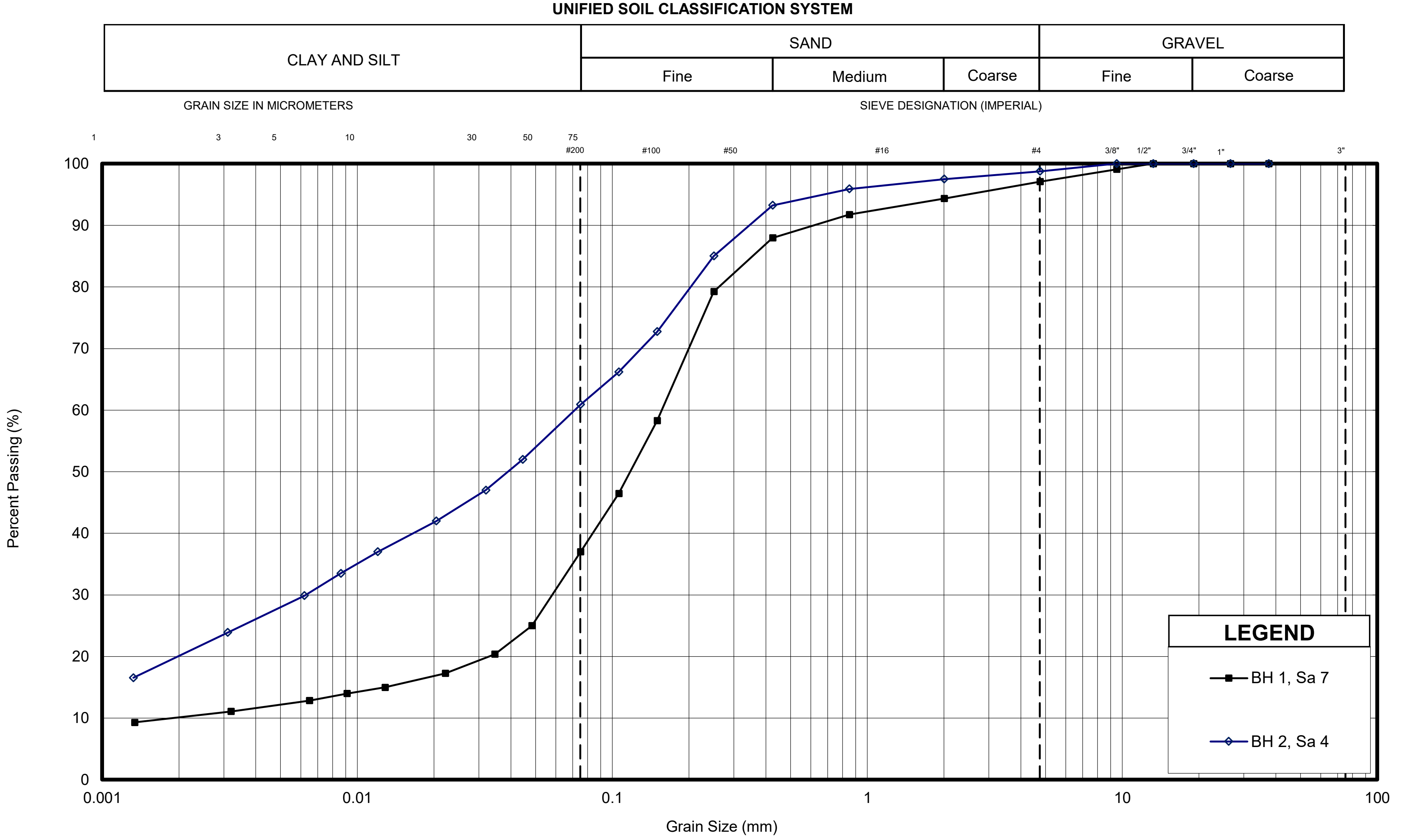
Groundwater depth observed on **Oct. 19/21** at a depth of: **3.60m**

Borehole details presented do not constitute a thorough understanding of all potential conditions present and require interpretative assistance from a qualified geotechnical engineer. Also, borehole information should be read in conjunction with the geotechnical report for which it was commissioned and the accompanying 'Explanation of Boring Log'.

Scale: **1 :75**

Appendix B

Geotechnical Laboratory Testing



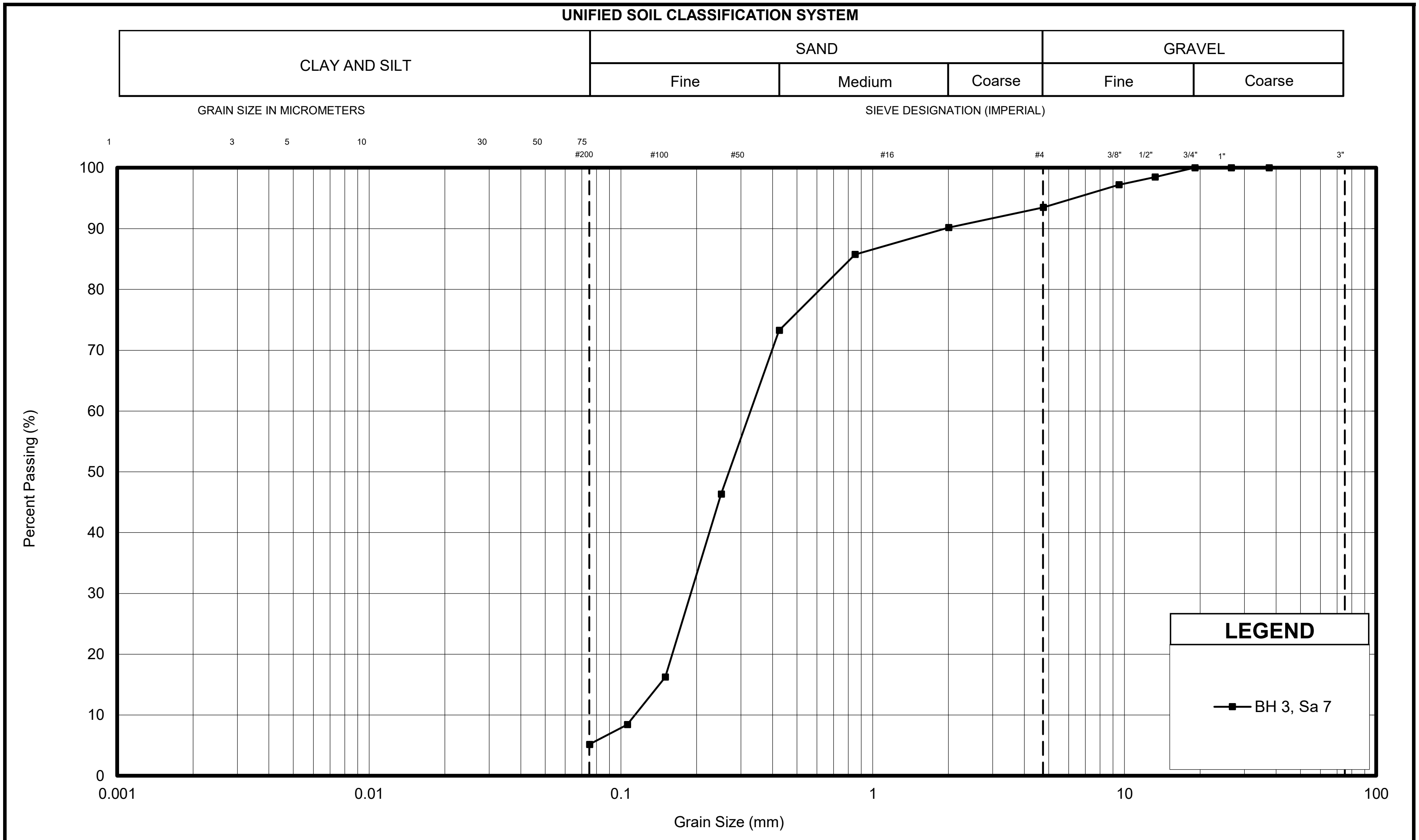
Sample	Description	Gr.	Sa.	Si.	Cl.	D_{10}	D_{30}	D_{60}	C_u	C_c
BH 1, Sa 7	SILTY SAND GLACIAL TILL, Trace Clay, Trace Gravel	3	59	28	10	0.002	0.058	0.16	82.9	11.6
BH 2, Sa 4	SILT & SAND GLACIAL TILL, Some Clay, Trace Gravel	1	38	41	20	-	0.006	0.072	-	-

GEI Consultants

GRAIN SIZE DISTRIBUTION

SILTY SAND to SAND & SILT GLACIAL TILL

APP. No.	B1
REF. No.	2103057
DATE	November 2021



Sample	Description	Gr.	Sa.	Si.	Cl.	D_{10}	D_{30}	D_{60}	C_u	C_c
BH 3, Sa 7	SAND, Trace Gravel, Trace Fines	7	88	5		0.11	0.19	0.327	2.9	1.0

GEI Consultants

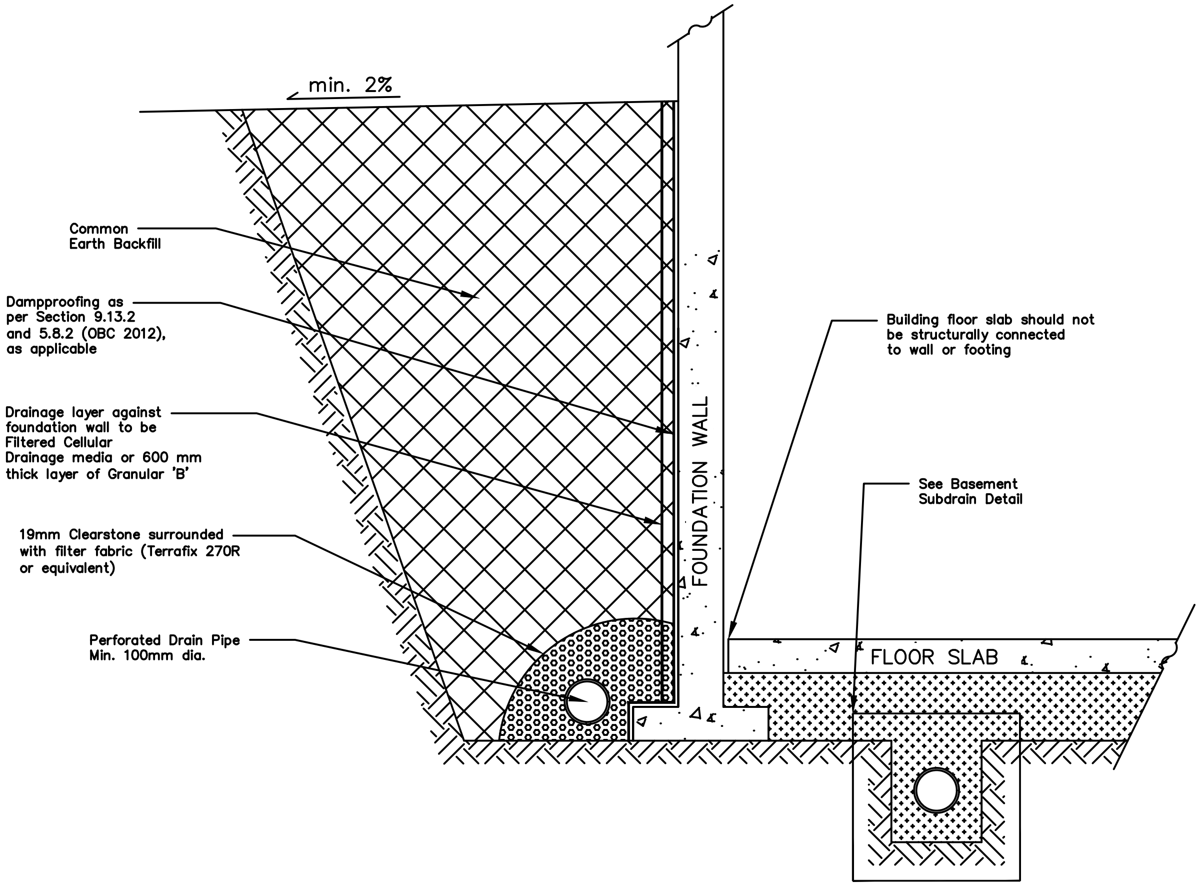
GRAIN SIZE DISTRIBUTION

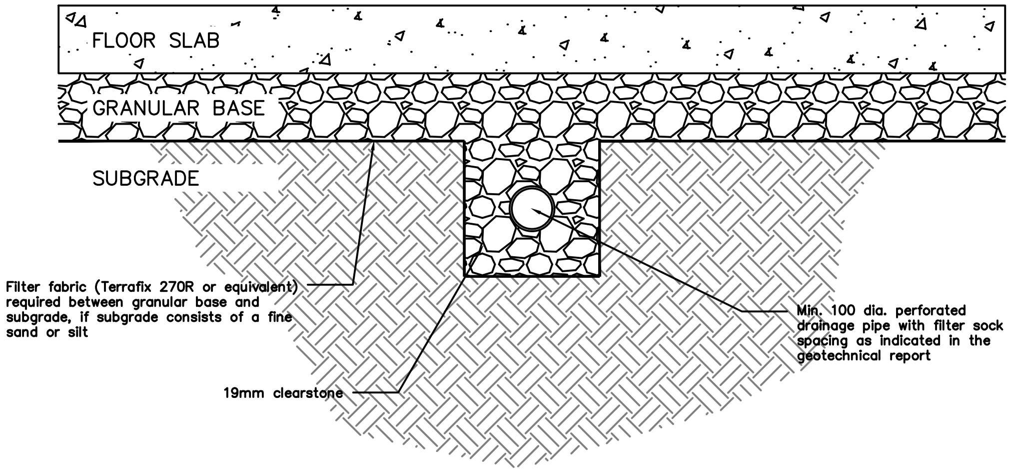
SAND

APP. No.	B2
REF. No.	2103057
DATE	November 2021

Appendix C

Typical Details

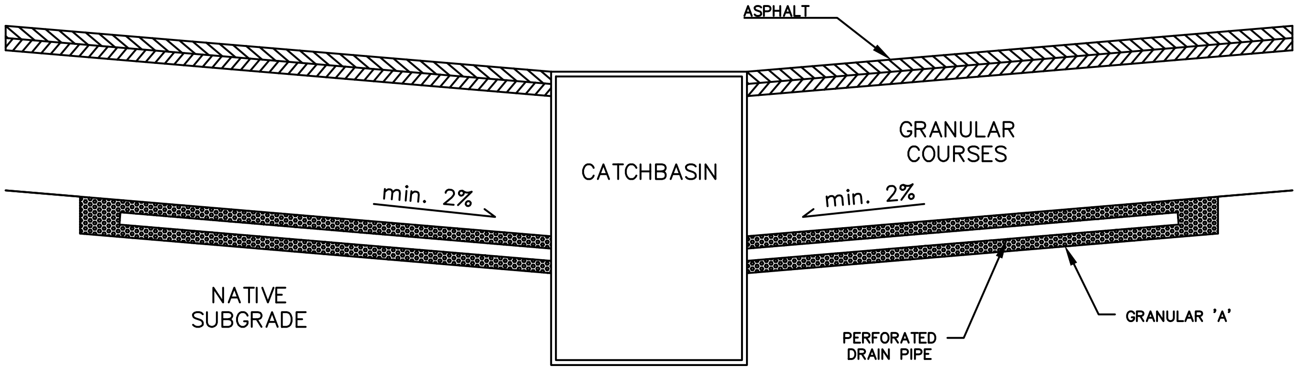


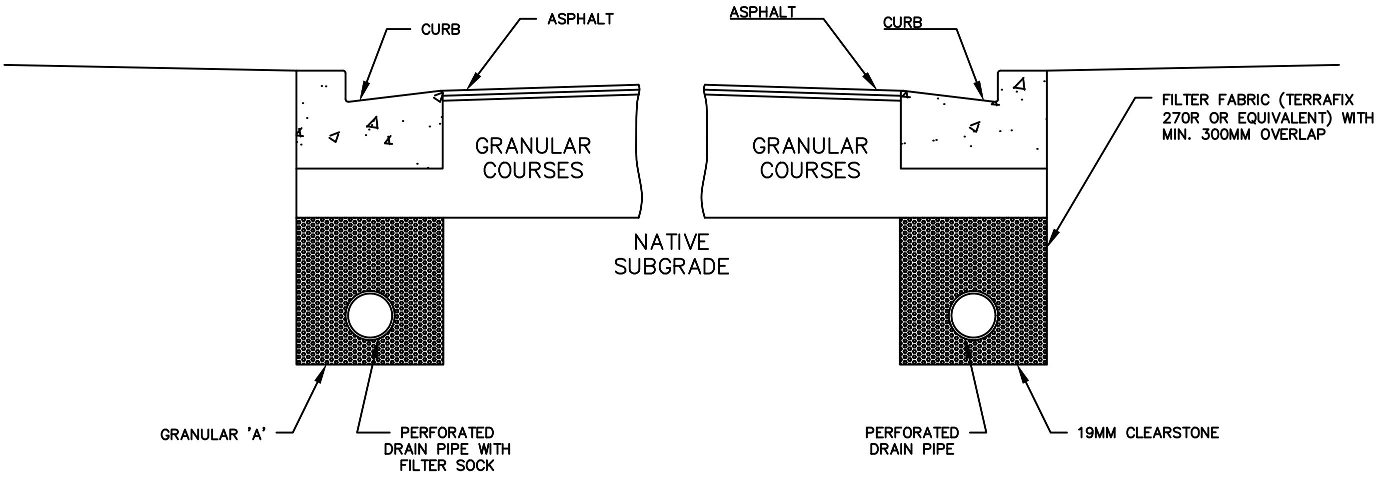


GEI Consultants

647 Welham Rd, Unit 14, Barrie, ON, L4N 0B7
P: (705) 719-7994

BASEMENT FOUNDATION WALL & SUBFLOOR DRAINAGE TYPICAL DETAIL

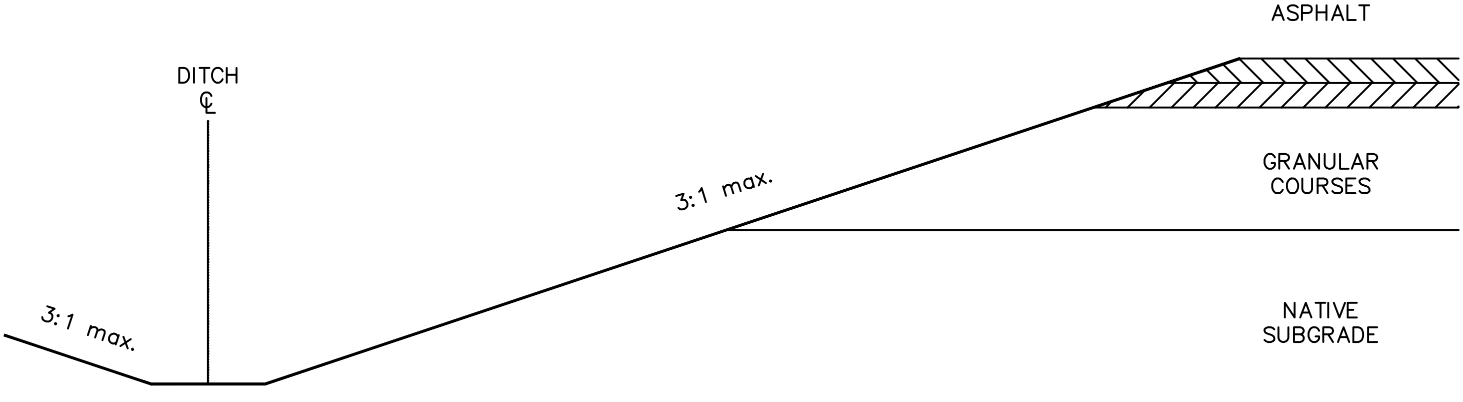




Unwrapped Trench

Wrapped Trench

Urban Cross Sections



Rural Cross Section

PAVEMENT DRAINAGE ALTERNATIVES TYPICAL DETAILS

GEI Consultants

647 Welham Rd, Unit 14, Barrie, ON, L4N 0B7