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REPORT

REPORT ON

Geotechnical Investigation Proposed Residential Development Conservancy Lands - Phase 1 Ottawa, Ontario

Submitted to:
Barrhaven Conservancy East Inc.
220 Colonnade Road South, Suite 204
Ottawa, Ontario
K2E 7K3

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1.0 INTRODUCTION

This report presents the results of a geotechnical investigation carried out for Phase 1 of a proposed residential development, referred to as the Conservancy Lands, to be located off of Borrisokane Road in Ottawa, Ontario.

This geotechnical investigation included an assessment of the general subsurface conditions across the site by means of eight boreholes, two secondary boreholes, and laboratory testing. Based on an interpretation of the factual information obtained, a general description of the subsurface and groundwater conditions is presented. These interpreted subsurface conditions and available project details were used to prepare engineering guidelines on the geotechnical design aspects of the project, including construction considerations which could influence design decisions.

The reader is referred to the "Important Information and Limitations of This Report" which follows the text but forms an integral part of this document.

2.0 DESCRIPTION OF PROJECT AND SITE

Plans are being prepared for a residential development, referred to as the Conservancy Lands, to be located off of Borrisokane Road in Ottawa, Ontario. This report refers to Phase 1 of the development. The approximate location of Phase 1 is shown on the Key Map inset on the attached Site Plan (Figure 1).

The following is understood about the project and site:

- Phase 1 of the development will be located at the eastern end of 3285 Borrisokane Road.
- The total area for Phase 1 of the development is about 8.7 hectares.
- The site has a relatively flat topography.
- The site consists of undeveloped agricultural land.
- A tributary to the Jock River is present just south of the property.
- The proposed development will include residential dwellings and City parks.

Based on published geological mapping, the subsurface conditions on this site are indicated to consist of a thick deposit of silty clay. The depth to the bedrock surface is indicated to range from about 10 to 15 metres below the existing ground surface. The bedrock is indicated to consist of interbedded limestone and dolomite of the Gull River Formation.

3.0 PROCEDURE

The fieldwork for this investigation was carried out in two phases, as follows:

- The first phase of the investigation was carried out on February 14, 2017. During that time, 1 borehole (numbered 17-15) was advanced within the proposed Phase 1 development site.
- The second phase of the investigation was carried out between March 21 and April 7, 2017. During that time, 7 boreholes (numbered 17-54, 17-56, 17-57, 17-59, 17-61, 17-62 and 17-63), and 2 secondary boreholes (numbered 17-57A and 17-62A) were advanced within the proposed Phase 1 development site.

The approximate locations of the boreholes from both phases of the investigation are shown on the attached Site Plan (Figure 1).

All of the primary boreholes were advanced to a depth of about 7.6 metres below the existing ground surface. The boreholes were advanced using either track-mounted or all-terrain vehicle mounted drill rigs supplied and operated by CCC Geotechnical and Environmental Drilling of Ottawa, Ontario.

Standard penetration tests were carried out in the boreholes at regular intervals of depth and samples of the soils encountered were recovered using split spoon sampling equipment. In situ vane testing was carried out where possible in the silty clay to determine the undrained shear strength of this soil. In addition, relatively undisturbed, 73-millimetre inside diameter thin-walled Shelby tube samples of the silty clay were obtained at various depths within boreholes 17-15, 17-54, and 17-61 using a fixed piston sampler.

Secondary boreholes 17-57A and 17-62A were advanced adjacent to their respective corresponding boreholes for the sole purpose of installing shallow monitoring wells at about 3 metres depth. No soil sampling was carried out within these secondary boreholes.

Groundwater level monitoring devices (standpipes piezometers and monitoring wells) were installed in 3 boreholes for subsequent measurement of the groundwater level. A standpipe piezometer was installed in borehole 17-15. Monitoring wells were installed into boreholes 17-57A and 17-62A. The groundwater levels in the monitoring devices were measured on February 21, 2017 following the first phase of the investigation and on March 31, 2017 following the second phase of the investigation.

The fieldwork was supervised by experienced personnel from our staff who located the boreholes, directed the drilling and in situ testing operations, logged the boreholes and samples, and took custody of the soil samples retrieved. On completion of the drilling operations, samples of the soils encountered in the boreholes were transported to our laboratory for examination by the project engineer and for laboratory testing, which included natural water content determinations, Atterberg limits testing, and oedometer consolidation testing on selected soil samples.

One sample of soil from borehole 17-57 was submitted to Eurofins Environment Testing for basic chemical analysis related to potential sulphate attack on buried concrete elements and corrosion of buried ferrous elements.

The borehole locations were selected, marked in the field, and subsequently surveyed by Golder Associates personnel. The location and ground surface elevation at each borehole location were determined using a Trimble R8 GPS survey unit. The geodetic reference system used for the survey is the North American datum of 1983 (NAD83). The borehole coordinates are based on the Modified Transverse Mercator (MTM Zone 9) coordinate system. The elevations are referenced to Geodetic datum (CGVD28).

4.0 SUBSURFACE CONDITIONS

4.1 General

Information on the subsurface conditions is provided as follows:

- The Record of Borehole Sheets for this investigation are provided in Appendix A.
- The results of the basic chemical analyses are provided in Appendix B.

- A plasticity chart providing the results of the Atterberg limit testing on samples of the weathered crust is provided on Figure 2.
- A plasticity chart providing the results of the Atterberg limit testing on samples of the grey silty clay is provided on Figure 3.
- Oedometer consolidation test results are provided on Figures 4 and 5.
- A summary of undrained shear strength versus elevation is provided on Figure 6.
- The results of the natural water content and Atterberg limit testing are provided on the Record of Borehole Sheets.

In general, the subsurface conditions on this site consist of topsoil overlying a thick deposit of sensitive silty clay. The following sections provide a summary of the subsurface conditions encountered during the investigation.

4.2 Topsoil

Topsoil exists at the ground surface at all of the borehole locations. The thickness of the topsoil ranges from about 80 to 150 millimetres.

4.3 Silty Clay to Clay

A deposit of silty clay to clay (hereafter referred to collectively as silty clay) exists beneath the topsoil at all of the borehole locations. The silty clay was not fully penetrated, but was proven to extend to a depth of about 7.6 metres below the existing ground surface.

The upper portion of the silty clay has been weathered to a grey brown crust. The weathered crust extends to depths ranging from about 2.4 to 3.7 metres below the existing ground surface. Standard penetration tests carried out within the weathered crust gave SPT ‘N’ values ranging from 1 to 6 blows per 0.3 metres of penetration. In situ vane testing carried out in the lower portions of the weathered crust measured undrained shear strengths ranging from about 77 to greater than 96 kilopascals. The results of this in situ testing indicate that the weathered crust has a stiff to very stiff consistency.

The results of Atterberg limit testing carried out on samples of the weathered silty clay gave plasticity index values ranging from about 22 to 32 percent and liquid limit values ranging from about 39 to 52 percent, indicating a soil of intermediate to high (but general intermediate) plasticity soil. A plasticity chart for the weathered silty clay is provided on Figure 2. The measured water contents of the weathered silty clay ranged from about 29 to 60 percent, which is typically between the plastic and liquid limits.

The silty clay below the depth of weathering is grey in colour. The results of in situ vane testing in the grey silty clay gave undrained shear strength values ranging from about 23 to 85 kilopascals, but more typically between about 30 and 50 kilopascals, indicating a soft to stiff, but more typically a firm, consistency. Remoulded strengths are low, indicating a sensitive soil. The results of two Atterberg limit tests carried out on samples of the grey silty clay gave plasticity index values of about 20 and 51 percent and corresponding liquid limit values of about 36 and 73 percent, indicating an intermediate to high plasticity soil. A plasticity chart for the grey silty clay is provided on Figure 3. The measured water contents of the grey silty clay ranged from about 55 to 72 percent, which is generally at or above the liquid limit.

Oedometer consolidation testing was carried out on two Shelby tube samples of the grey silty clay. The results of the consolidation testing are presented on Figures 4 and 5 and are summarized in the following table.

Borehole/Sample Number	Sample Depth/Elevation (m)	C_C	C_r	e_o	σ_{vo}' (kPa)	σ_P' (kPa)	OCR
17-15 / 4	5.1 / 86.5	2.12	0.008	2.03	50	110	2.2
17-54 / 4	3.5 / 88.3	0.48	0.002	1.03	35	155	4.4

Notes:

σ_o' - Initial effective stress
C_c - Compression index
e_o - Initial void ratio
σ_P' - Apparent preconsolidation pressure
C_r - Recompression index
OCR - Overconsolidation Ratio

A chart of undrained shear strength versus elevation is provided on Figure 6.

4.4 Groundwater

Groundwater level monitoring devices (standpipes piezometers and monitoring wells) were installed in 3 boreholes for subsequent measurement of the groundwater level. The results of the groundwater level monitoring are summarized in the following table.

Borehole Number	Ground Surface Elevation (m)	Water Level Depth (mbgs)	Water Level Elevation (m)	Date of Measurement
17-15	91.55	1.00	90.55	February 21, 2017
17-57A	91.42	0.21	91.21	March 31, 2017
17-62A	91.93	-0.02	91.95	March 31, 2017

Groundwater levels are expected to fluctuate seasonally. Higher groundwater levels are expected during wet periods of the year, such as spring.

4.5 Corrosion Testing

One sample of soil from borehole 17-57 was submitted to Eurofins Environment Testing for basic chemical analysis related to potential sulphate attack on buried concrete elements and corrosion of buried ferrous elements. The results of this testing are provided in Appendix B and are summarized below.

Borehole Number/ Sample Number	Sample Depth (m)	Chloride (%)	SO_4 (%)	pH	Resistivity (Ohm-cm)
17-57 / Sa 2	1.52 – 2.13	<0.002	<0.01	8.0	6,250

5.0 DISCUSSION

5.1 General

This section of the report provides engineering guidelines on the geotechnical design aspects of this project based on our interpretation of the borehole information as well as the project requirements, and is subject to the limitations in the "Important Information and Limitations of This Report" which follows the text of this report.

5.2 Site Grading

The site is underlain by a surficial layer of stiff to very stiff weathered silty clay overlying a thick deposit of generally soft to firm unweathered grey silty clay. The unweathered grey silty clay beneath this site has a limited capacity to support additional stress, such as could be imposed by:

- The foundation loads of buildings/houses;
- The weight of grade raise fill placed on the site; and,
- The effects of groundwater level lowering (which reduces the buoyant forces that act between the soil particles), which could result from servicing and development of the site.

An increase in stress, if excessive (i.e., increasing the magnitude of stress above, or even close to, the silty clay's preconsolidation pressure), could lead to significant consolidation settlement. Due to the low hydraulic conductivity of the silty clay and the need to expel water for settlement to occur, the settlement would be long-term in nature, possibly taking many months or years to complete. Grade raises on areas underlain by compressible silty clay will therefore need to be restricted, based on leaving sufficient remaining capacity for the silty clay to also support foundation loads and the effects of groundwater level lowering, without being overstressed. If the grade is raised excessively, then significant consolidation settlement will occur.

The analyses carried out for this assessment assumes that the unit weight of the grade raise fill would be less than or equal to 18.5 kilonewtons per cubic metre (weathered brown silty clay or clear stone). It has also been assumed that the groundwater level would be lowered to about 0.5 metres above the weathered/grey silty clay interface, which is considered to be a conservative assumption.

The results of the analyses indicate the following permissible grade raises:

Assessment Area	**Permissible Grade Raise (m)**	
	Roadways	**Houses**
Phase 1	1.8	1.6

These limitations have been assessed based on leaving sufficient remaining capacity in the silty clay deposit such that strip footings up to 0.6 metres in width can be designed using a maximum allowable bearing pressure of 75 kilopascals, consistent with design in accordance with Part 9 of the Ontario Building Code.

Based on preliminary grading information provided by Barrhaven Conservancy East Inc., the proposed grades within Phase 1 of the development are lower than the permissible values given above. As such, conventional construction will be feasible, provided that the grade raise fill has a unit weight of 18.5 kilonewtons per cubic metre, or less.

As a general guideline regarding the site grading, the preparation for filling of the site should include stripping the topsoil for predictable performance of structures and services. The topsoil is not suitable as engineered fill and should be stockpiled separately for re-use in landscaping applications only.

5.3 Foundations

As discussed in the preceding section, the unweathered grey silty clay deposit has limited capacity to accept the combined load from site grading fill and foundation loads. The allowable bearing pressures for spread footing foundations at this site are therefore based on limiting the stress increases on the “softer” compressible grey silty clay to an acceptable level so that foundation settlements do not become excessive. Four important parameters in calculating the stress increase on the grey silty clay are:

- The thickness of soil below the underside of the footings and above the compressible silty clay;
- The size (dimensions) of the footings;
- The amount of surcharge in the vicinity of the foundation due to landscape fill, underslab fill, floor loads, etc., as described in Section 5.2; and,
- The effects of groundwater lowering caused by this or other construction.

It is considered that conventional houses could be supported on shallow footings founded on or within the inorganic weathered silty clay crust on this site. The topsoil would not be considered suitable to support the house foundations and must be removed from within the footprints of the houses.

Provided that the grade raises are restricted to those indicated in Section 5.2, strip footing foundations up to 0.6 metres in width can be designed using a maximum allowable bearing pressure of 75 kilopascals. As such, the house footings may be sized in accordance with Part 9 of the Ontario Building Code.

The post-construction total and differential settlements of footings sized using the above maximum allowable bearing pressure should be less than about 25 and 15 millimetres, respectively, provided that the subgrade at or below the founding level is not disturbed during construction.

The tolerance of the house foundations to accept those settlements could be increased by providing nominal amounts of reinforcing steel in the top and bottom of the foundation walls. Houses without projecting garages, but rather garages that are more interior with the overall house foundation/footprint would also be more tolerant to these settlements.

The maximum allowable bearing pressure provided for footings founded within the silty clay corresponds to settlement resulting from consolidation of these deposits. Consolidation of the silty clay is a process which takes months or longer and, as such, results from sustained loading. Therefore, the foundation loads to be used in conjunction with the allowable bearing pressure should be the full dead load plus sustained live load.

At some locations on the property, and depending on the amount of proposed grade raise (i.e., filling), the inorganic subgrade elevation may be lower than the underside of footing elevation. At these locations, the subgrade may be raised to the footing elevation using 19 millimetre crushed clear stone. The clear stone must be placed within the full zone of influence of the house foundations. The zone of influence is considered to extend out and down from the edge of the perimeter footings at a slope of 1 horizontal to 1 vertical.

5.4 Seismic Design

The seismic design provisions of the 2012 Ontario Building Code depend, in part, on the shear wave velocity of the upper 30 metres of soil and/or bedrock below founding level. Based on the 2012 Ontario Building Code methodology, this site can be assigned a Site Class of E, acknowledging that this requirement does not apply to ground oriented residential structures designed per part 9 of the Ontario Building Code. Consideration could be given to carrying out site specific shear wave velocity testing to determine if a more favourable Site Class can be attained.

The soils at this site are not considered liquefiable.

5.5 Frost Protection

The soils at this site are considered to be highly frost susceptible. Therefore, all exterior perimeter foundation elements or foundation elements in unheated areas should be provided with a minimum of 1.5 metres of earth cover for frost protection purposes. Isolated, unheated exterior footings adjacent to surfaces which are cleared of snow cover during winter months should be provided with a minimum of 1.8 metres of earth cover. Houses with conventional depth basements would satisfy these requirements.

5.6 Basement and Garage Floor Slabs

In preparation for the construction of the basement floor slabs, all loose, wet, and disturbed material should be removed from beneath the floor slabs. Provision should be made for at least 200 millimetres of 19 millimetre crushed clear stone to form the base of the basement floor slabs.

To prevent hydrostatic pressure build up beneath the basement floor slabs, it is suggested that the granular base material be positively drained. This could be achieved by providing a hydraulic link between the underslab fill material and the exterior drainage system.

The backfill material inside the garage should have a unit weight no greater than 18.5 kilonewtons per cubic metre (i.e., clear crushed stone). The garage backfill should be placed in maximum 300 millimetre thick lifts and be compacted to at least 95 percent of the material’s standard Proctor maximum dry density (SPMDD) using suitable compaction equipment. The granular base for the garage floor slab should consist of at least 150 millimetres of Granular A compacted to at least 95 percent of the materials SPMDD using suitable compaction equipment.

5.7 Basement Walls and Foundation Wall Backfill

The soils at this site are highly frost susceptible and should not be used as backfill directly against exterior, unheated, or well insulated foundation elements. To avoid problems with frost adhesion and heaving, these foundation elements should either be backfilled with non-frost susceptible sand or sand and gravel conforming to the requirements for Ontario Provincial Standard Specification (OPSS) Granular B Type I or, alternatively, a bond break such as the Platon system sheeting could be placed against the foundation walls.

Drainage of the wall backfill should be provided by means of a perforated pipe subdrain in a surround of 19 millimetre clear stone, wrapped in geotextile, which leads by gravity drainage to an adjacent storm sewer or sump pit. Conventional damp proofing of the basement walls is appropriate with the above design approach.

Should the foundations be designed in accordance with Part 4 of the Ontario Building Code, basement walls made within open cut excavations, backfilled with granular material, and effectively drained as described above should be designed to resist lateral earth pressures calculated using a triangular distribution of the stress with a magnitude of:

$$\sigma_h(z) = K_o (\gamma z + q)$$

Where: $\sigma_h(z)$ = Lateral earth pressure on the wall at depth z, kilopascals;

K_o = At-rest earth pressure coefficient, 0.5;

γ = Unit weight of retained soil, 22 kilonewtons per cubic metre;

z = Depth below top of wall, metres; and,

The lateral earth pressure equation given above is in an unfactored format and will need to be factored for Limit States Design purposes. If Platon System sheeting or similar water barrier product is used against the foundation walls, then hydrostatic groundwater pressures should also be considered in the calculation of the lateral earth pressures.

These lateral earth pressures would increase under seismic loading conditions. The earthquake-induced dynamic pressure distribution, which is to be added to the static earth pressure distribution, is a linear distribution with maximum pressure at the top of the wall and minimum pressure at its toe (i.e., an inverted triangular pressure distribution). The combined pressure distribution (static plus seismic) may be determined as follows:

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

Where:

K_{AE} = The seismic earth pressure coefficient, use 0.8 for a non-yielding wall, and,

H = The total depth to the bottom of the foundation wall, metres.

5.8 Excavations

Excavations for basements, watermain, sewers, and service connections will be primarily through the weathered silty clay crust and may extend into the grey silty clay (at least for the site services). No unusual problems are anticipated in excavating the weathered or grey silty clay using conventional hydraulic excavating equipment. In accordance with the Occupational Health and Safety Act (OHSA) of Ontario, the weathered and firm to stiff grey silty clay would be generally classified as a Type 3 soil, since these soils have a firm to very stiff consistency. Accordingly, excavations may be made with unsupported side slopes at 1 horizontal to 1 vertical, or flatter. In the event that the excavations extend into the soft grey silty clay, side slopes as flat as 3 horizontal to 1 vertical would be required (Type 4 soil).

Trench excavations could also be carried out using steeper side slopes with all manual labour carried out within a fully braced, steel trench box for worker safety. It is expected that open-cut methods and/or braced trench box support will generally be feasible.

Stockpiling of soil beside the excavations should be avoided; the weight of the stockpiled soil could lead to basal instability of braced excavations or slope instability of unsupported excavations. Stockpiles should be setback from the top of the slope a minimum distance equal to twice the depth of the excavation.

Where the subgrade for houses is found to be wet and sensitive to disturbance, consideration should be given to placing a mud slab of lean concrete over the subgrade (following inspection and approval by geotechnical personnel) or a 150 millimetre thick layer of OPSS Granular A underlain by a non-woven geotextile to protect the subgrade from construction traffic.

Present groundwater levels are generally shallow (near ground surface); therefore, excavations will extend below the groundwater level. Groundwater inflow into the excavations should feasibly be handled by pumping from sumps within the excavations. Groundwater inflow from the silty clay is expected to be low to moderate; however, the actual rate of groundwater inflow will depend on many factors including the contractor’s schedule and rate of excavation, the size of the excavation, the number of working areas being excavated at one time, and the time of year at which the excavation is made. Also, there may be instances where significant volumes of precipitation, surface runoff and/or groundwater collects in an open excavation, and must be pumped out.

Under the new regulations, a Permit-To-Take-Water (PTTW) is required from the Ministry of the Environment and Climate Change (MOECC) if a volume of water greater than 400,000 litres per day is pumped from the excavations. If the volume of water to be pumped will be less than 400,000 litres per day, but more than 50,000 litres per day, the water taking will not require a PTTW, but will need to be registered in the Environmental Activity and Sector Registry (EASR) as a prescribed activity. Based on the groundwater information collected during the current and previous investigation, it is considered unlikely that a PTTW would be required during construction for this project. However, registration in the EASR may be required. The requirement for registration (i.e., if more than 50,000 litres per day is being pumped) can be assessed at the time of construction. Registration is a quick process that will not significantly disrupt the construction schedule.

5.9 Site Servicing

At least 150 millimetres of OPSS Granular A should be used as pipe bedding for sewer and water pipes. Where unavoidable disturbance to the subgrade surface does occur, it may be necessary to place a sub-bedding layer consisting of 300 millimetres of compacted OPSS Granular B Type II beneath the Granular A or to thicken the Granular A bedding. The bedding should in all cases extend to the spring line of the pipe and should be compacted to at least 95 percent of the material’s SPMDD. The use of clear crushed stone as a bedding layer should not be permitted anywhere on this project since fine particles from the native soil or silty sand backfill could potentially migrate into the voids in the clear crushed stone and cause loss of lateral pipe support.

Cover material, from spring line of the pipe to at least 300 millimetres above the top of pipe, should consist of OPSS Granular A or Granular B Type I with a maximum particle size of 25 millimetres. The cover material should be compacted to at least 95 percent of the material’s SPMDD.

It should generally be possible to re-use the weathered silty clay as trench backfill. The high moisture content of the grey silty clay will make this material difficult to compact. If grey silty clay is excavated, this material should be wasted or re-used in landscaping applications only. If the grey silty clay is used in trenches under roadways, some long term settlement of the pavement surface should be expected.

Where the trench will be covered with a hard surfaced area (e.g., pavements, sidewalks, or paving stones), the type of native material placed in the frost zone (between subgrade level and 1.8 metres depth) should match the soil exposed on the trench walls for frost heave compatibility.

All trench backfill should be placed in maximum 300 millimetre loose lifts and be uniformly compacted to at least 95 percent of the material's SPMDD using suitable compaction equipment. Backfilling operations carried out during cold weather should avoid inclusions of frozen lumps of soil, snow and ice.

Impervious dikes or cut-offs should be constructed at 100 metre intervals in the service trenches to reduce groundwater lowering at the site due to the 'french drain' effect of the granular bedding and surround for the service pipes. It is important that these barriers extend from trench wall to trench wall and that they fully penetrate the granular materials to the trench bottom. The dikes should be at least 1.5 metres wide and could be constructed using relatively dry (i.e., compactable) grey brown silty clay from the weathered zone.

5.10 Pavement Design

In preparation for pavement construction, all topsoil, disturbed, or otherwise deleterious materials (i.e., fill materials containing organic material) should be removed from the roadway areas.

Pavement areas requiring grade raising to proposed subgrade level should be filled using acceptable (compactable and inorganic) earth borrow with a maximum unit weight of 18.5 kilonewtons per cubic metre. These materials should be placed in maximum 300 millimetre thick lifts and should be compacted to at least 95 percent of the material's SPMDD using suitable compaction equipment.

The surface of the pavement subgrade should be crowned to promote drainage of the roadway granular structure. Perforated pipe sub-drains should be provided at subgrade level extending from the catch basins for a distance of at least 3 metres longitudinally, parallel to the curb in two directions.

The pavement structure for local roads should consist of the City of Ottawa's minimum recommended pavement structure:

Pavement Component	Thickness (millimetres)
Asphaltic Concrete	90
OPSS Granular A Base	150
OPSS Granular B Type II Subbase	400

If any of the roads will be classified as collector roadways, which would include bus and truck traffic, the pavement structure for such roads should consist of:

Pavement Component	Thickness (millimetres)
Asphaltic Concrete	90
OPSS Granular A Base	150
OPSS Granular B Type II Subbase	600

The granular base and subbase materials should be uniformly compacted to at least 100 percent of the material's SPMDD using suitable vibratory compaction equipment. The asphaltic concrete should be compacted in accordance with Table 10 of OPSS 310.

The composition of the asphaltic concrete pavement should be as follows:

- Superpave 12.5 Surface Course – 40 millimetres
- Superpave 19.0 Base Course – 50 millimetres

The asphaltic cement should consist of PG 58-34 and the design of the mixes should be based on a Traffic Category B for local roads and Category C for collector roads.

5.11 Corrosion and Cement Type

One sample of soil from borehole 17-57 was submitted to Eurofins Environment Testing for basic chemical analysis related to potential sulphate attack on buried concrete elements and corrosion of buried ferrous elements. The results of this testing are provided in Appendix B.

The results indicate that concrete made with Type GU Portland cement should be acceptable for substructures. The results also indicate a potential for corrosion of exposed ferrous metal, which should be considered during the design of substructures.

5.12 Pools, Decks and Additions

5.12.1 Above Ground and In-Ground Pools

No special geotechnical considerations are necessary for the installation of in-ground pools, provided that the pool (including piping) does not extend deeper than the house footing level. A geotechnical assessment will be required if the pool extends deeper than the house foundations.

Due to the additional loads that would be imposed by the construction of above-ground pools, these should be located no closer than about 3 metres from the edge of the house. The installation of the above ground pool must not alter the existing grade within 5 metres of the house.

5.12.2 Decks

A geotechnical evaluation/assessment will be necessary for future decks, added by the homeowners, that:

- Are attached to the house;
- Require changes to the existing grades; or,
- Are heavily loaded and require spread footing or drilled pier foundations.

The geotechnical evaluation must consider the proposed grading, foundation types and sizes, depths of foundations, and design bearing pressures. Written approval from a geotechnical engineer should be required by the City prior to a building permit being issued.

5.12.3 Additions

Any proposed addition to a house (regardless of size) will require a geotechnical assessment. The geotechnical assessment must consider the proposed grading, foundation types and sizes, depths of foundations, and design bearing pressures. Written approval from a geotechnical engineer should be required by the City prior to the building permit being issued.

5.13 Trees

In general, silty clay soil has the potential to be sensitive to water depletion by trees of high water demand during periods of dry weather. When trees draw water from the clayey soil, the clay undergoes shrinkage which can result in settlement of adjacent structures.

To assess the shrinkage potential of the silty clay on this site, a total of 8 Atterberg limit tests were carried out on samples of the weathered silty clay (one from each borehole). The results of the Atterberg limit testing on this project indicate that the plasticity index values for the weathered silty clay are generally less than 40 percent (see Figure 2). Since the plasticity index is less than 40 percent, the shrinkage potential is considered low and, in that case, the tree to foundation setback distance can be reduced to 4.5 metres for small (mature tree height up to 7.5 metres) and medium sized trees (mature tree height of 7.5 to 14 metres), provided that the tree is of low to moderate water demand. Large trees (mature height greater than 14 metres) can also be considered provided that the setback distance is equal to or greater than the full mature height of the tree.

Table 1 provides a list of the common trees in decreasing order of water demand and, accordingly, decreasing risk of potential effects on structures.

6.0 ADDITIONAL CONSIDERATIONS

The soils at this site are sensitive to disturbance from ponded water, construction traffic, and frost.

All footing and subgrade areas should be inspected by experienced geotechnical personnel prior to filling or concreting to ensure that soil having adequate bearing capacity has been reached and that the bearing surfaces have been properly prepared. The placing and compaction of any engineered fill as well as sewer bedding and backfill should be inspected to ensure that the materials used conform to the specifications from both a grading and compaction point of view.

Ontario Regulation 903 would ultimately require abandonment of the piezometers installed within the boreholes for this investigation. The decommissioning of these devices should be made part of the construction contract.

Golder Associates should be retained to review the final drawings and specifications for this project prior to tendering to ensure that the guidelines in this report have been adequately interpreted.

7.0 CLOSURE

We trust that this report meets your current needs. If you have any questions, or if we may be of further assistance, please do not hesitate to contact the undersigned.

GOLDER ASSOCIATES LTD.

LICENSED PROFESSIONAL ENGINEER
S. W. DUNLOP
100151238
Sept. 28/17
PROVINCE OF ONTARIO

Stephen Dunlop, P.Eng.
Senior Geotechnical Engineer

Troy Skinner, P.Eng.
Associate, Senior Geotechnical Engineer

KM/SD/TMS/mvrd
n:\active\2017\3 proj\1771847 caivan barrhaven conservancy lands ottawa\04_reporting\geotech\05 phase 1 geotech\1771847 -rpt-01 phase 1 conservancy geotechnial report september 2017.docx

IMPORTANT INFORMATION AND LIMITATIONS
OF THIS REPORT

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

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

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

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

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

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

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT (cont'd)

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

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

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

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

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

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

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

TABLE 1

SOME COMMON TREES IN DECREASING ORDER OF WATER DEMAND

BROAD LEAVED DECIDUOUS

Poplar

Alder

Aspen

Willow

Elm

Maple

Birch

Ash

Beech

Oak

DECIDUOUS CONIFER

Larch

EVERGREEN CONIFERS

Spruce

Fir

Pine

KEY MAP

SCALE 1:100,000

LEGEND

⯐	APPROXIMATE BOREHOLE LOCATION
🟥	PHASE 1 BOUNDARY

NOTE(S)

1. THIS FIGURE IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GOLDER ASSOCIATES LTD. REPORT NO. 1771847 - PHASE 1.

REFERENCE(S)

1. LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2014
2. SOURCE: ESRI, DIGITALGLOBE, GEOEYE, I-CUBED, USDA, USGS, AEX, GETMAPPING, AEROGRID, IGN, IGP, SWISSTOPO, AND THE GIS USER COMMUNITY
3. PROJECTION: TRANSVERSE MERCATOR, DATUM: NAD 83,
COORDINATE SYSTEM: MTM ZONE 9, VERTICAL DATUM: CGVD28

0 25 50 100

1:2,500 METRES

CLIENT

BARRHAVEN CONSERVANCY EAST INC.

PROJECT

GEOTECHNICAL INVESTIGATION
CONSERVANCY LANDS – PHASE 1
OTTAWA, ONTARIO

TITLE

SITE PLAN

CONSULTANT

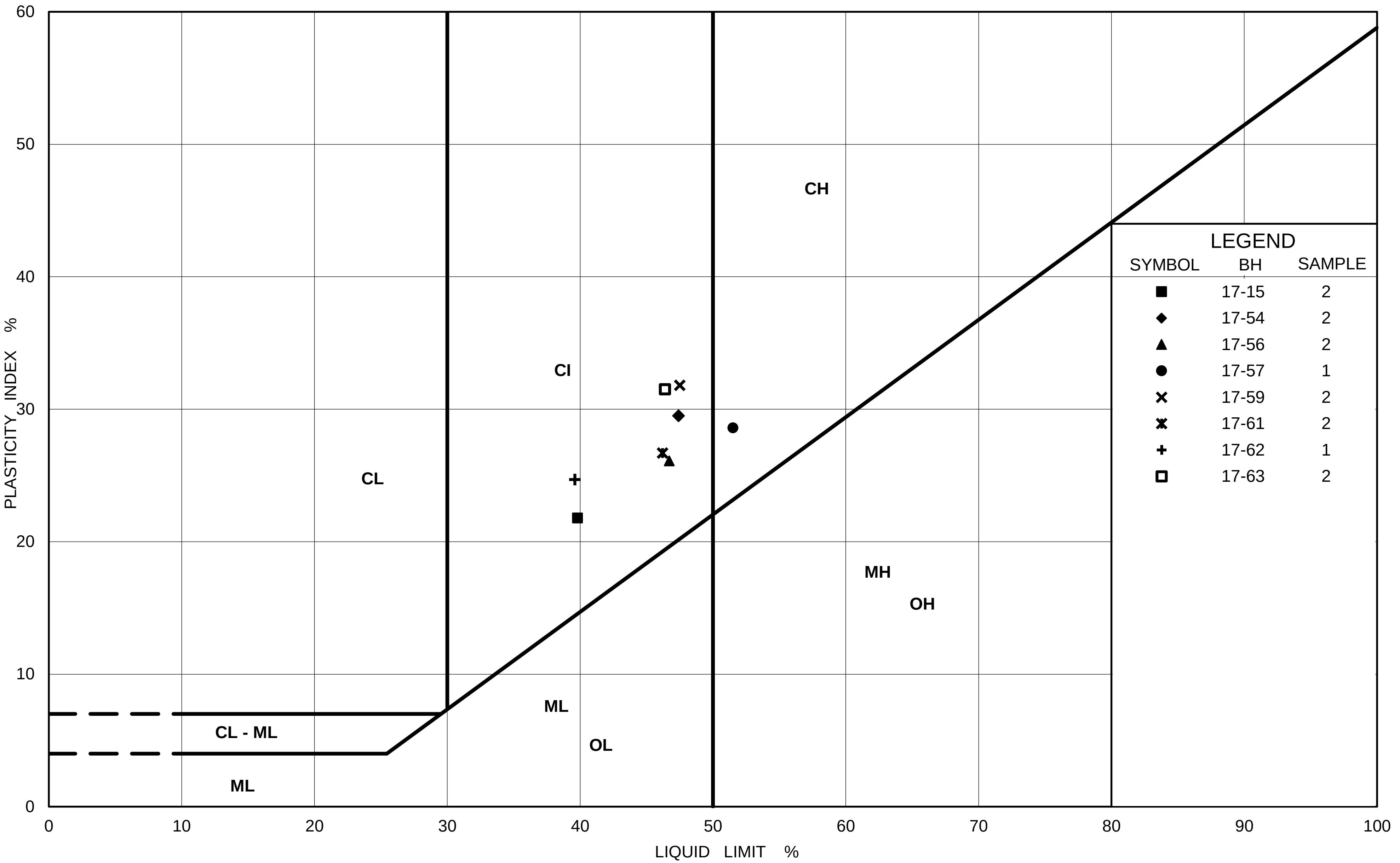
Golder Associates

YYYY-MM-DD	2017-09-26
DESIGNED	----
PREPARED	JEM/PJM
REVIEWED	SD
APPROVED	TMS

PROJECT NO.	CONTROL	REV.	FIGURE
1771847	0003	0	1

Path: N:\Active\Spatial_IM\Caivan\Conservancy_Lands\99_PROJ\1771847_BarrhavenConservancy_GeoEnviro\40_PROD\0003_Sup_Geotech_Investigation\1771847-0003-BG-0001.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: 0 25mm



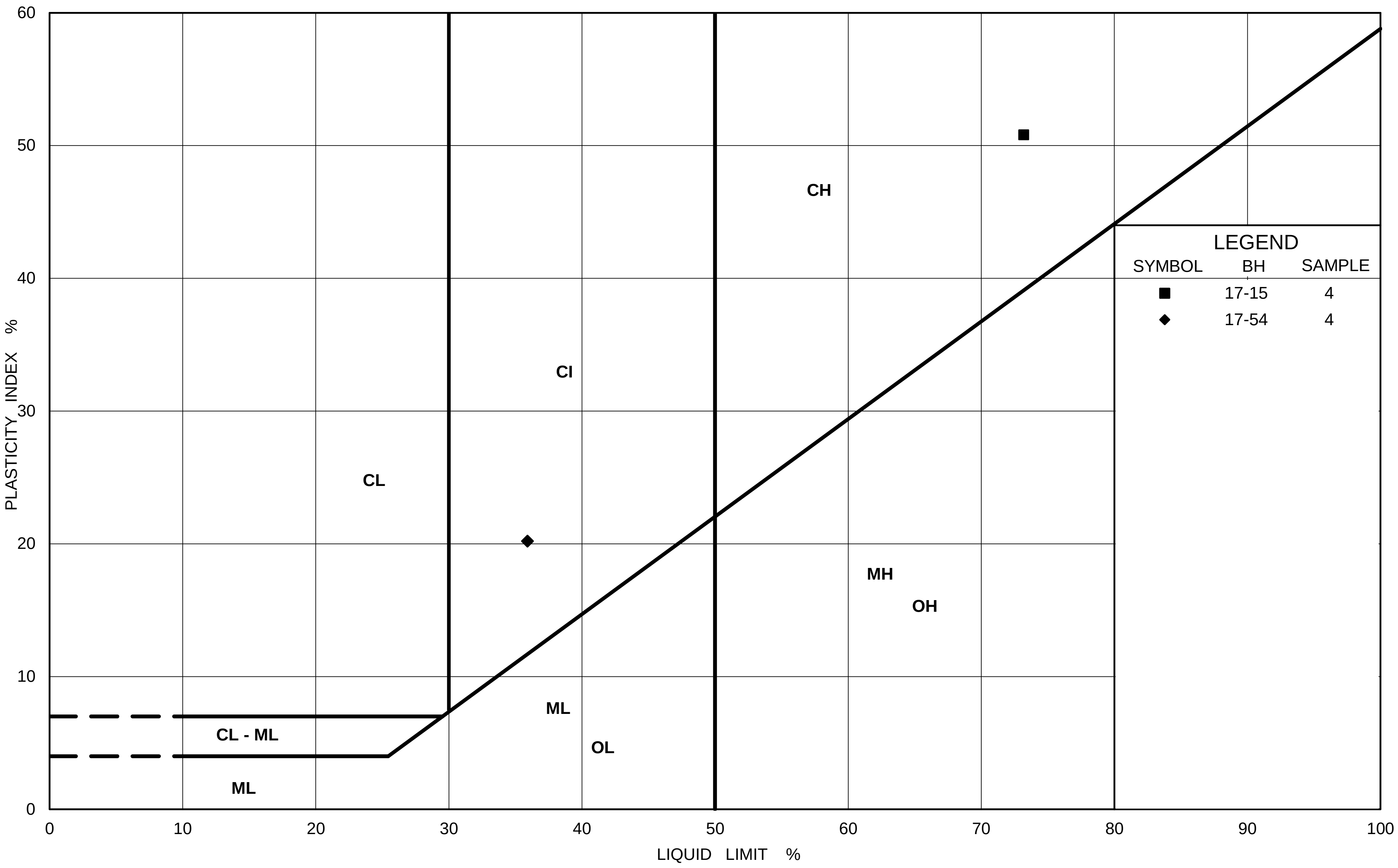
Golder Associates

PLASTICITY CHART
SILTY CLAY to CLAY (WEATHERED CRUST)

Figure : 2

Project No.: 1771847-02

Compiled By : CNM Checked By : MI



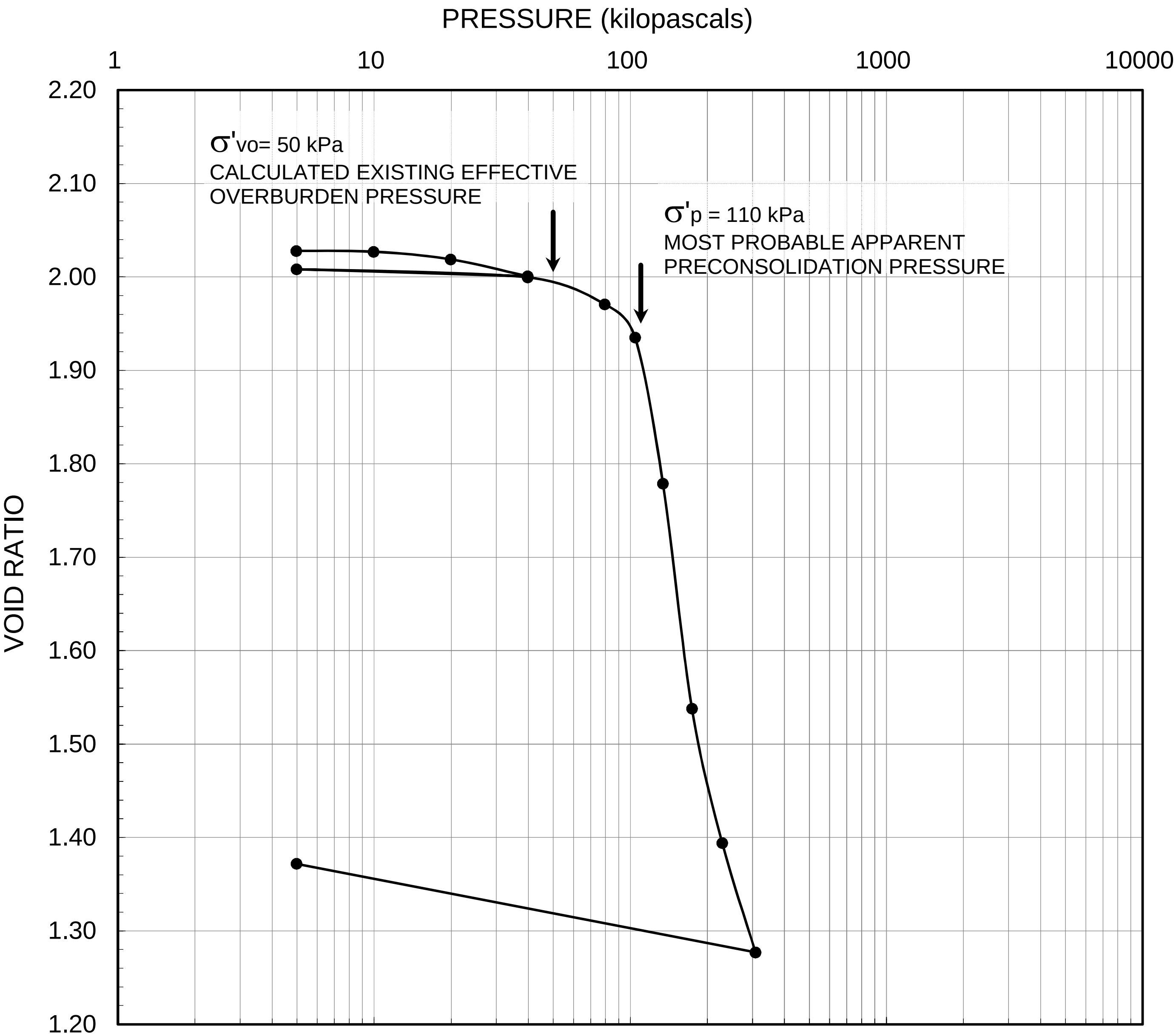
Golder Associates

PLASTICITY CHART
GREY SILTY CLAY TO CLAY

Figure : 3

Project No.: 1771847-02

Compiled By : MI Checked By : CNM



LEGEND

Borehole: 17-15	w_i = 72%	S_o = 99%	γ = 15.6 kN/m³
Sample: 4	w_f = 49%	e_o = 2.03	G_s = 2.82
Depth (m): 5.1	w_l = 73%	C_c = 2.12	
Elevation (m): 86.5	w_p = 22%	C_r = 0.008	

Golder Associates

SCALE AS SHOWN

DATE 09/25/17

CADD N/A

ENTERED MI

CHECK CNM

REVIEW KM

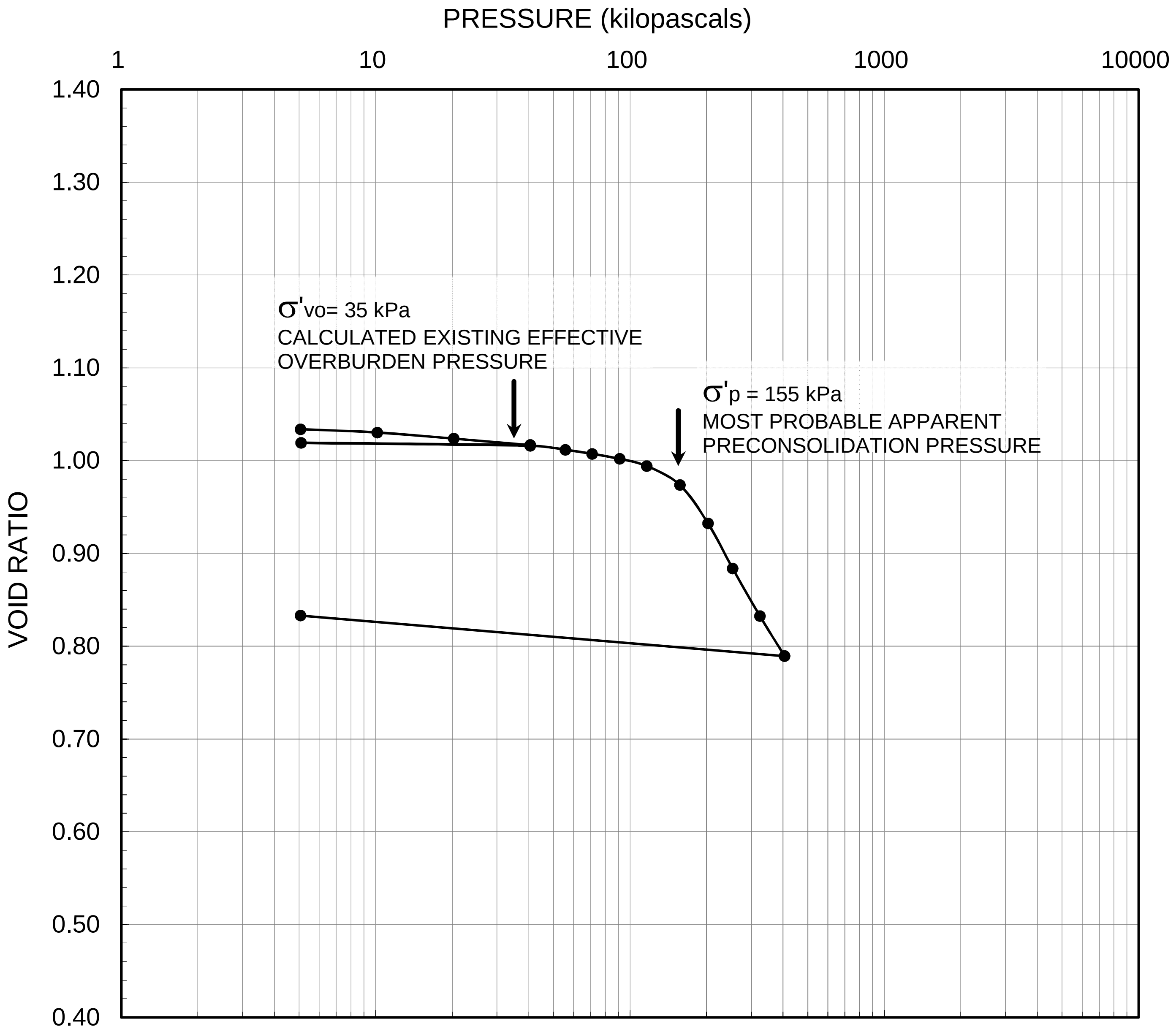
FILE No. Consolidation summary

PROJECT No. 1771847-02 REV. 2

TITLE

CONSOLIDATION TEST RESULTS

FIGURE 4



LEGEND

Borehole:	17-54	w_i =	37%	S_o =	98%	γ =	18.3 kN/m³
Sample:	4	w_f =	30%	e_o =	1.03	G_s =	2.78
Depth (m):	3.5	w_l =	36%	C_c =	0.48		
Elevation (m):	88.3	w_p =	16%	C_r =	0.002		

Golder Associates

SCALE	AS SHOWN
DATE	09/25/17
CADD	N/A
ENTERED	MI
CHECK	CNM
REVIEW	KM

FILE No. Consolidation summary

PROJECT No. 1771847-02 REV. 2

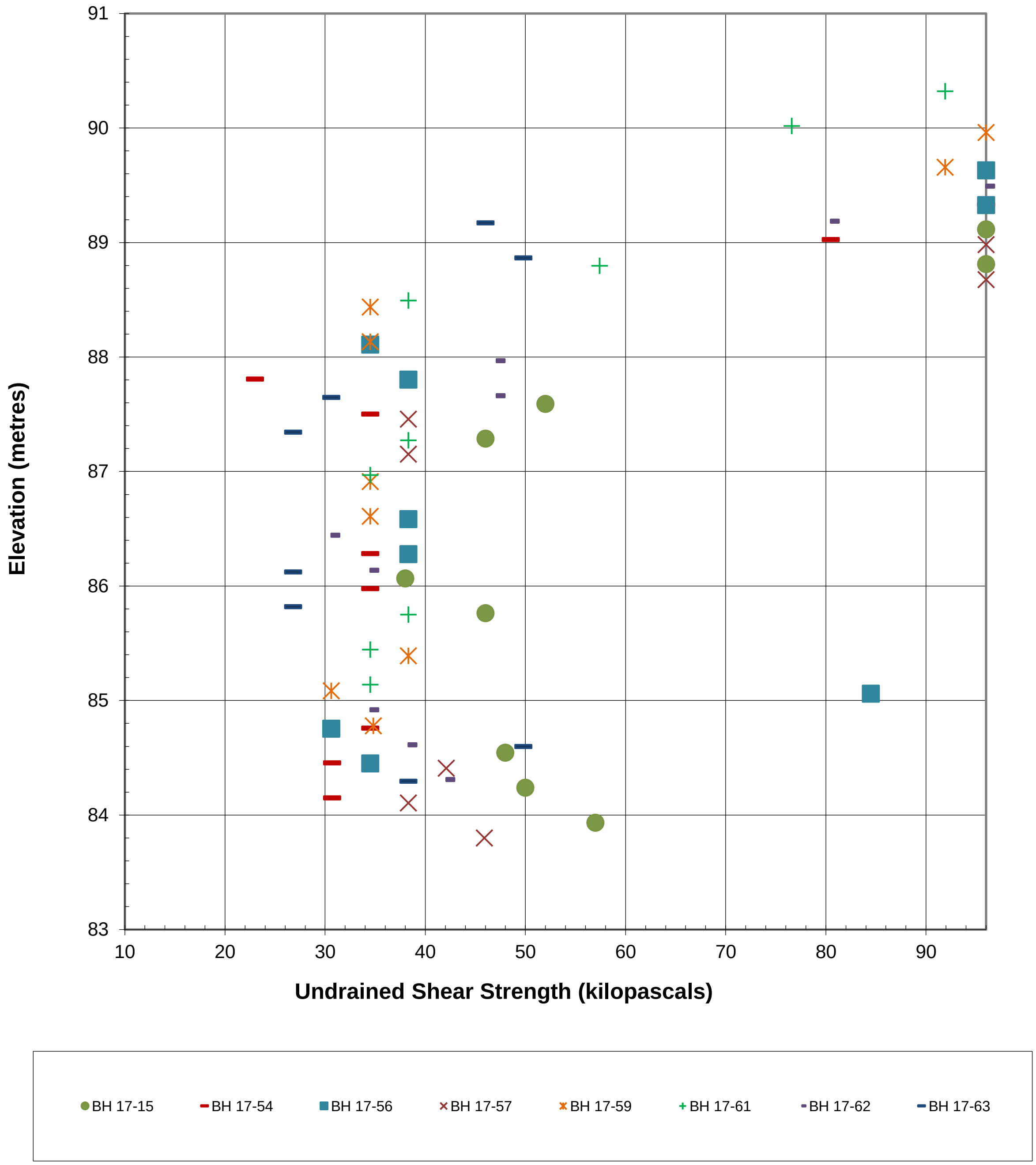
TITLE

CONSOLIDATION TEST RESULTS

FIGURE 5

SUMMARY OF UNDRAINED SHEAR STRENGTHS VERSUS ELEVATION - AREA B

FIGURE 6



Date September 26, 2017
Project 1771847-02

Golder Associates

Drawn SG
Chkd SD

APPENDIX A

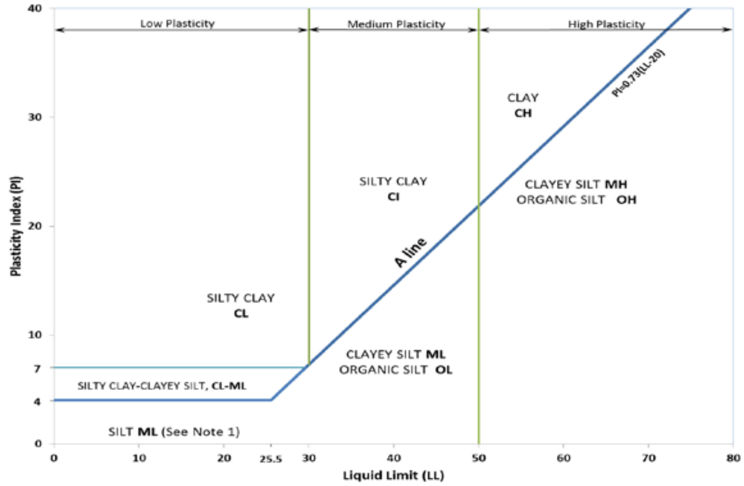
List of Abbreviations and Symbols
Record of Borehole Sheets

METHOD OF SOIL CLASSIFICATION

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

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

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



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

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

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

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

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

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

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

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

PARTICLE SIZES OF CONSTITUENTS

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

MODIFIERS FOR SECONDARY AND MINOR CONSTITUENTS

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

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split-spoon sampler for a distance of 300 mm (12 in.).

Cone Penetration Test (CPT)

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

Dynamic Cone Penetration Resistance (DCPT); N_d:

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

PH: Sampler advanced by hydraulic pressure
PM: Sampler advanced by manual pressure
WH: Sampler advanced by static weight of hammer
WR: Sampler advanced by weight of sampler and rod

SAMPLES

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

SOIL TESTS

w	water content
PL , w_p	plastic limit
LL , w_L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, Gs)
DS	direct shear test
GS	specific gravity
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
γ	unit weight

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

NON-COHESIVE (COHESIONLESS) SOILS

Compactness[2]

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

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

Field Moisture Condition

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

COHESIVE SOILS

Consistency

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

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.
2. SPT 'N' values should be considered ONLY an approximate guide to consistency; for sensitive clays (e.g., Champlain Sea clays), the N-value approximation for consistency terms does NOT apply. Rely on direct measurement of undrained shear strength or other manual observations.

Water Content

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

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
ln x	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\ \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma$ - u)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil $(\gamma' = \gamma - \gamma_w)$
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

* Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
c_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = tan δ
c′	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p′	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes:
1 $\tau = c' + \sigma' \tan \phi'$
2 shear strength = (compressive strength)/2

PROJECT: 1771847

RECORD OF BOREHOLE: 17-15

SHEET 1 OF 1

LOCATION: N 5013698.6 ;E 363499.5

BORING DATE: February 14, 2017

DATUM: CGVD28

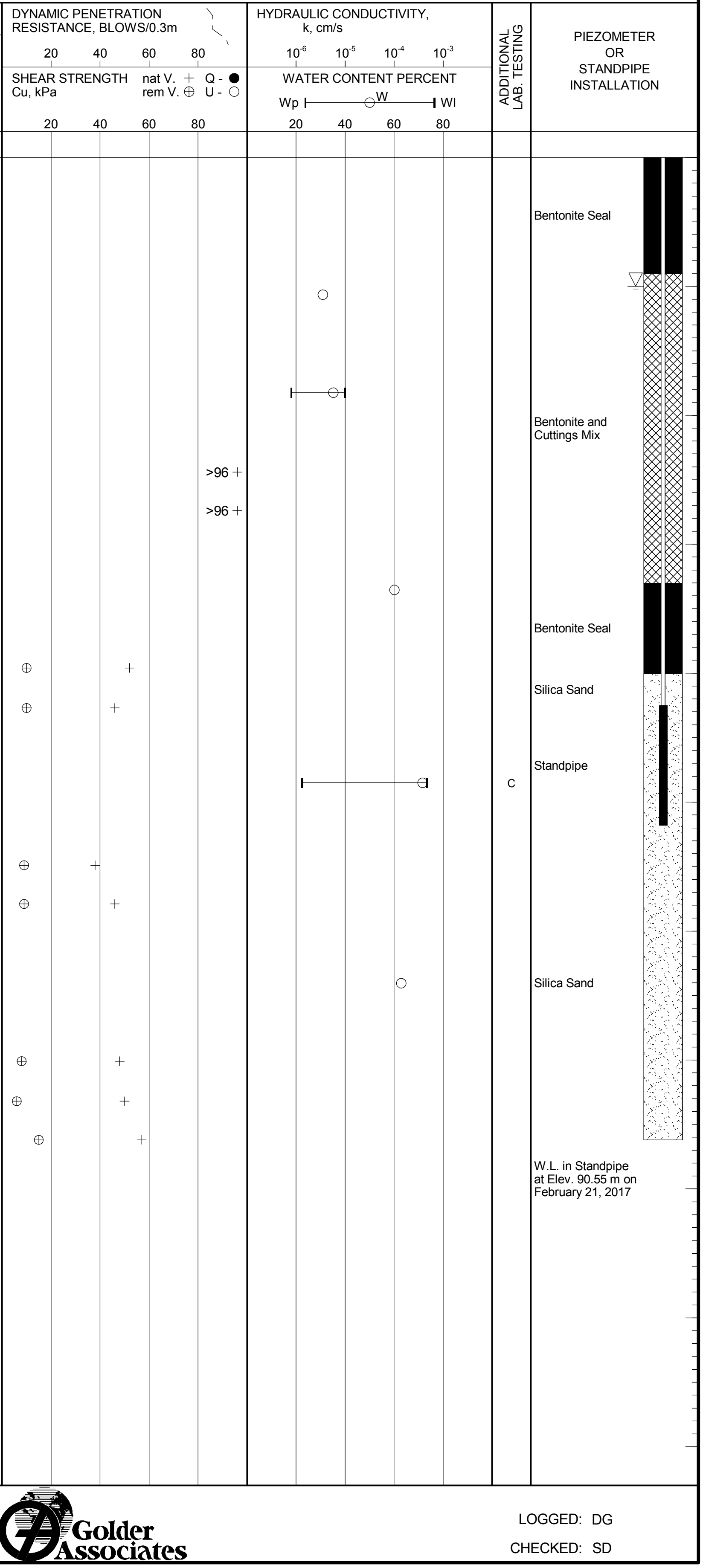
SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Power Auger, 200 mm Diam. (Hollow Stem)

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
GROUND SURFACE	91.55
TOPSOIL - (SM) SILTY SAND; dark brown; moist	0.00
(CL/CI/CH) SILTY CLAY to CLAY; grey brown (WEATHERED CRUST); cohesive, w>PL, very stiff to stiff	0.08
(CI/CH) SILTY CLAY to CLAY; grey; cohesive, w>PL, firm to stiff	87.89 3.66
End of Borehole	83.93 7.62

SAMPLES NUMBER	TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING
1	SS	3	
2	SS	2	
3	SS	1	
4	TP	PH	C
5	SS	WH	



W.L. in Standpipe at Elev. 90.55 m on February 21, 2017

DEPTH SCALE
1 : 50

LOGGED: DG
CHECKED: SD

PROJECT: 1771847

RECORD OF BOREHOLE: 17-54

SHEET 1 OF 1

LOCATION: N 5013651.5 ;E 363177.3

BORING DATE: April 5, 2017

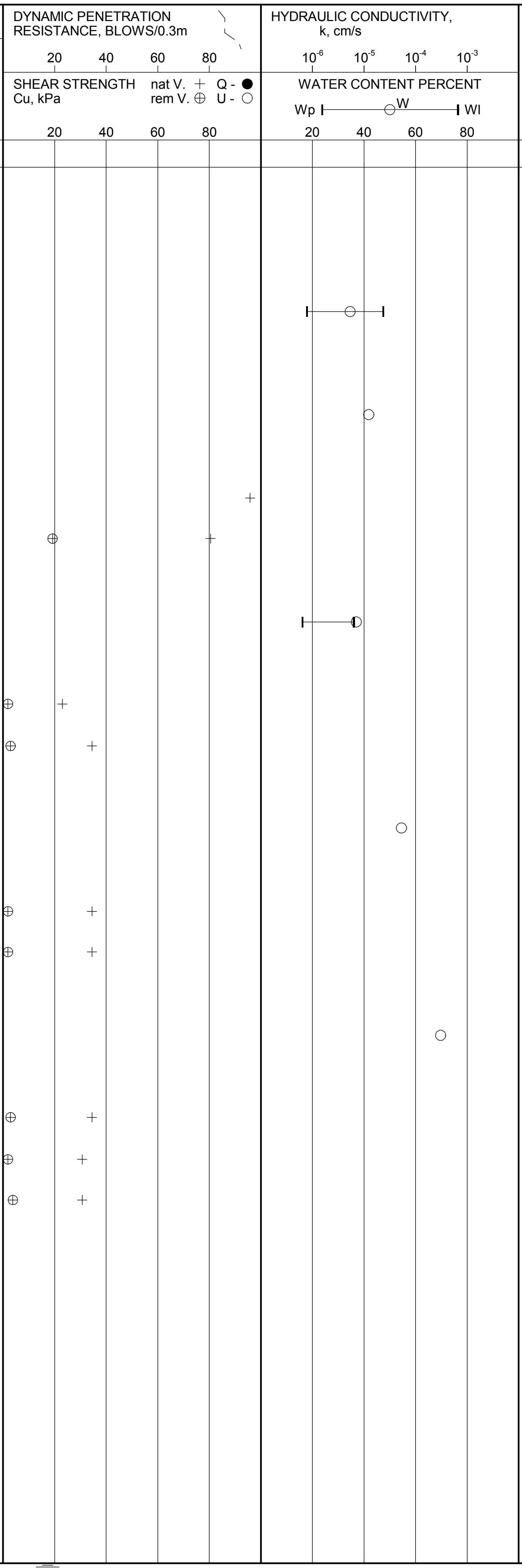
DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)
		GROUND SURFACE		91.77
0	Power Auger 200 mm Diam. (Hollow Stem)	TOPSOIL - (SM) SILTY SAND; brown, contains organic matter (rootlets); moist to wet		0.00
		(CL/CI/CH) SILTY CLAY to CLAY; grey brown, contains silty sand layers (WEATHERED CRUST); cohesive, w>PL, very stiff to stiff		0.15
3		(CI/CH) SILTY CLAY to CLAY; grey with black organic mottling; cohesive, w>PL, soft to firm		88.72 3.05
7.62		End of Borehole		84.15 7.62

SAMPLES NUMBER	TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING
1	GRAB	-	
2	SS	4	
3	SS	2	
4	TP	PH	C
5	SS	WH	
6	SS	WH	



PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE
1 : 50

LOGGED: SN

CHECKED: SD

MIS-BHS 001 1771847.GPJ GAL-MIS.GDT 09/12/17 JEM

PROJECT: 1771847

RECORD OF BOREHOLE: 17-56

SHEET 1 OF 1

LOCATION: N 5013731.8 ;E 363308.3

BORING DATE: April 5, 2017

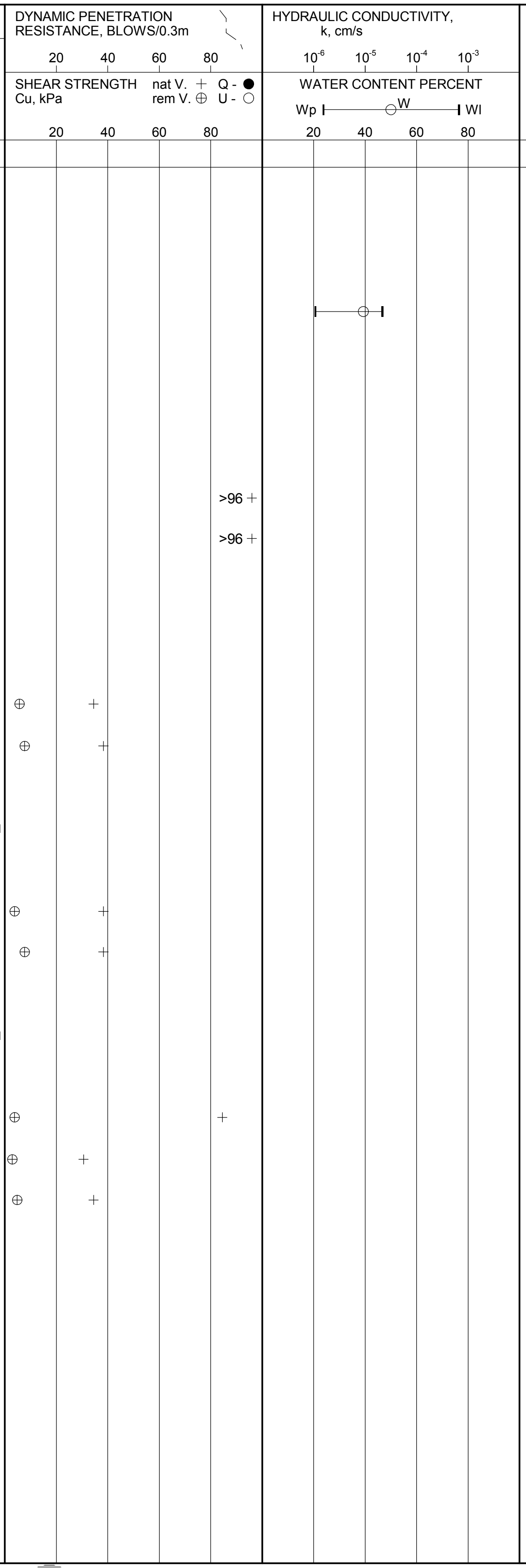
DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)
	GROUND SURFACE		92.07
Power Auger 200 mm Diam. (Hollow Stem)	TOPSOIL - (SM) SILTY SAND; brown; moist	▤	0.00
	(CL/CI/CH) SILTY CLAY to CLAY; grey brown, contains silty sand layers (WEATHERED CRUST); cohesive, w>PL, very stiff to stiff	▨	0.15
	(CI/CH) SILTY CLAY to CLAY; grey with black organic mottling, contains silty sand layers; cohesive, w>PL, firm to stiff	▨	88.41 3.66
	End of Borehole		84.45 7.62

SAMPLES NUMBER	TYPE	BLOWS/0.30m
1	GRAB	-
2	SS	3
3	SS	3
4	SS	2
5	SS	WH
6	SS	WH



ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE

1 : 50

LOGGED: SN

CHECKED: SD

PROJECT: 1771847

RECORD OF BOREHOLE: 17-57

SHEET 1 OF 1

LOCATION: N 5013625.5 ;E 363362.4

BORING DATE: March 21, 2017

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE – DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)
		GROUND SURFACE		91.42
0	Power Auger 200 mm Diam. (Hollow Stem)	TOPSOIL - (SM) SILTY SAND, trace gravel; brown; moist		0.00
		(CL/CI/CH) SILTY CLAY to CLAY; grey brown, contains silty sand layers (WEATHERED CRUST); cohesive, w>PL, very stiff		0.15
3		(CI/CH) SILTY CLAY to CLAY; grey with black organic mottling; cohesive, w>PL, firm		88.37 3.05
		End of Borehole		83.80 7.62

SAMPLES NUMBER	TYPE	BLOWS/0.30m
1	SS	5
2	SS	3
3	SS	WH
4	SS	WH
5	SS	WH
6	SS	WH

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

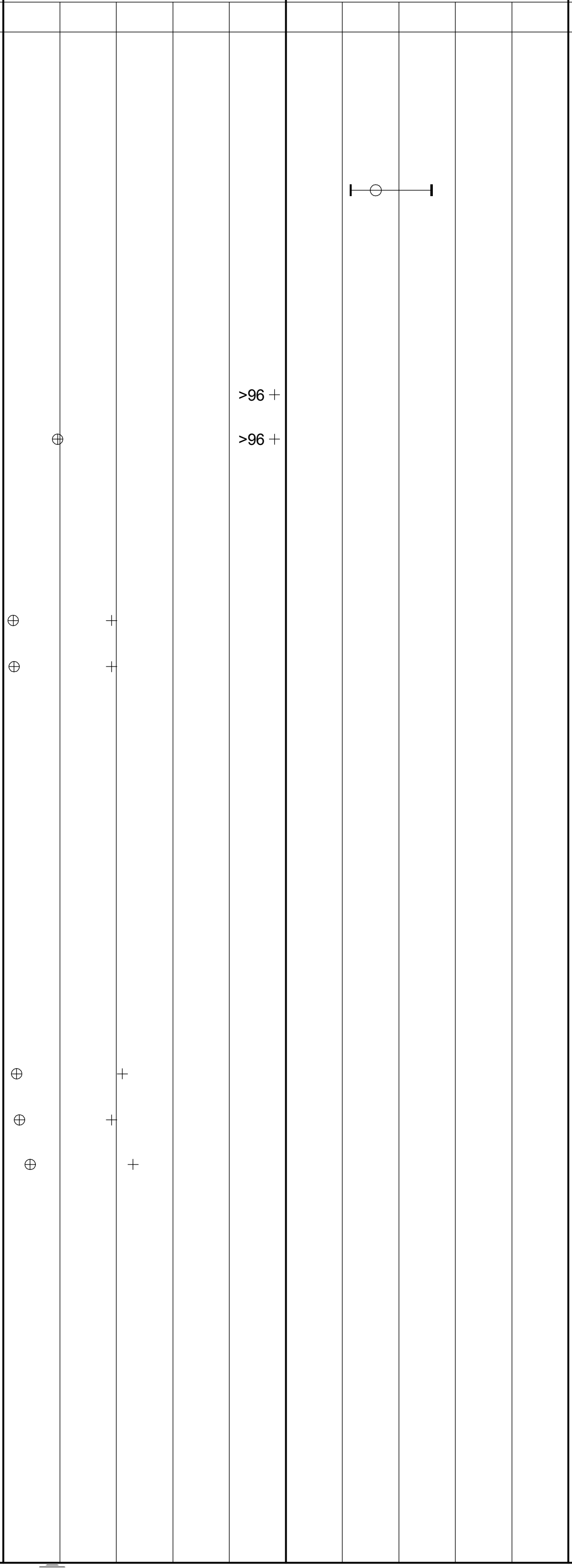
SHEAR STRENGTH Cu, kPa — nat V. + Q - ● — rem V. ⊕ U - ○
20 40 60 80

HYDRAULIC CONDUCTIVITY, k, cm/s
10^{-6} 10^{-5} 10^{-4} 10^{-3}

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

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION



MIS-BHS 001 1771847.GPJ GAL-MIS.GDT 09/12/17 JEM

DEPTH SCALE
1 : 50

LOGGED: SN
CHECKED: SD

PROJECT: 1771847

RECORD OF BOREHOLE: 17-57A

SHEET 1 OF 1

LOCATION: Adjacent to BH 17-57

BORING DATE: March 21, 2017

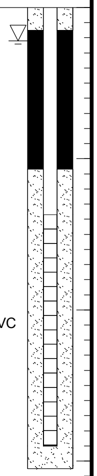
DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m 20 40 60 80 / SHEAR STRENGTH Cu, kPa nat V. + Q - ● rem V. ⊕ U - ○ 20 40 60 80	HYDRAULIC CONDUCTIVITY, k, cm/s 10^{-6} 10^{-5} 10^{-4} 10^{-3} / WATER CONTENT PERCENT Wp ⊢—○W—⊣ Wl 20 40 60 80	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		91.42							
0	Power Auger 200 mm Diam. (Hollow Stem)	Refer to Borehole 17-57 for Stratigraphy		0.00							Bentonite Seal Silica Sand 51 mm Diam. PVC #10 Slot Screen Silica Sand
3		End of Borehole		88.37 3.05							WL in Screen at Elev. 91.21 m on March 31, 2017

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10



DEPTH SCALE

1 : 50

Golder Associates

LOGGED: SN

CHECKED: SD

PROJECT: 1771847

RECORD OF BOREHOLE: 17-59

SHEET 1 OF 1

LOCATION: N 5013811.1 ;E 363438.5

BORING DATE: April 7, 2017

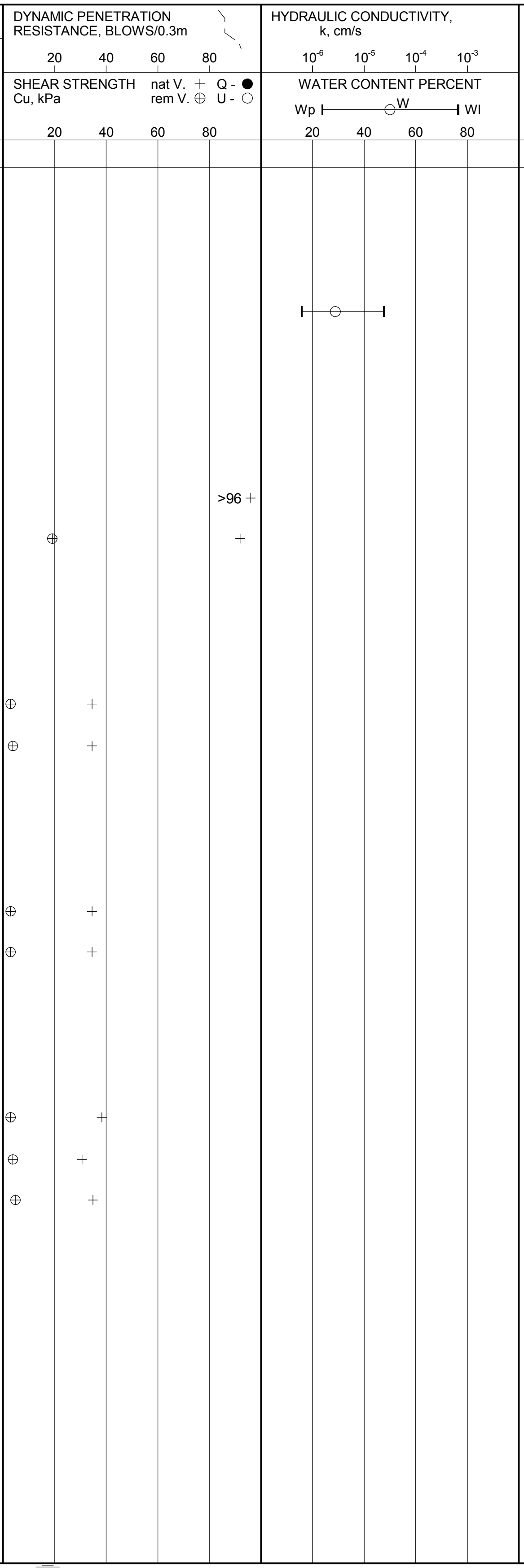
DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)
		GROUND SURFACE	92.40
0	Power Auger 200 mm Diam. (Hollow Stem)	TOPSOIL - (SM) SILTY SAND; brown; moist	0.00
		(CL/CI/CH) SILTY CLAY to CLAY; grey brown, contains silty sand seams (WEATHERED CRUST); cohesive, w>PL, very stiff to stiff	0.15
3		(CI/CH) SILTY CLAY to CLAY; grey with black organic mottling, contains silty sand seams; cohesive, w>PL, firm	89.35 3.05
		End of Borehole	84.78 7.62

SAMPLES NUMBER	TYPE	BLOWS/0.30m
1	GRAB	-
2	SS	6
3	SS	2
4	SS	1
5	SS	WH
6	SS	WH



ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE
1 : 50

LOGGED: SN
CHECKED: SD

PROJECT: 1771847

RECORD OF BOREHOLE: 17-61

SHEET 1 OF 1

LOCATION: N 5013888.7 ;E 363574.3

BORING DATE: April 5, 2017

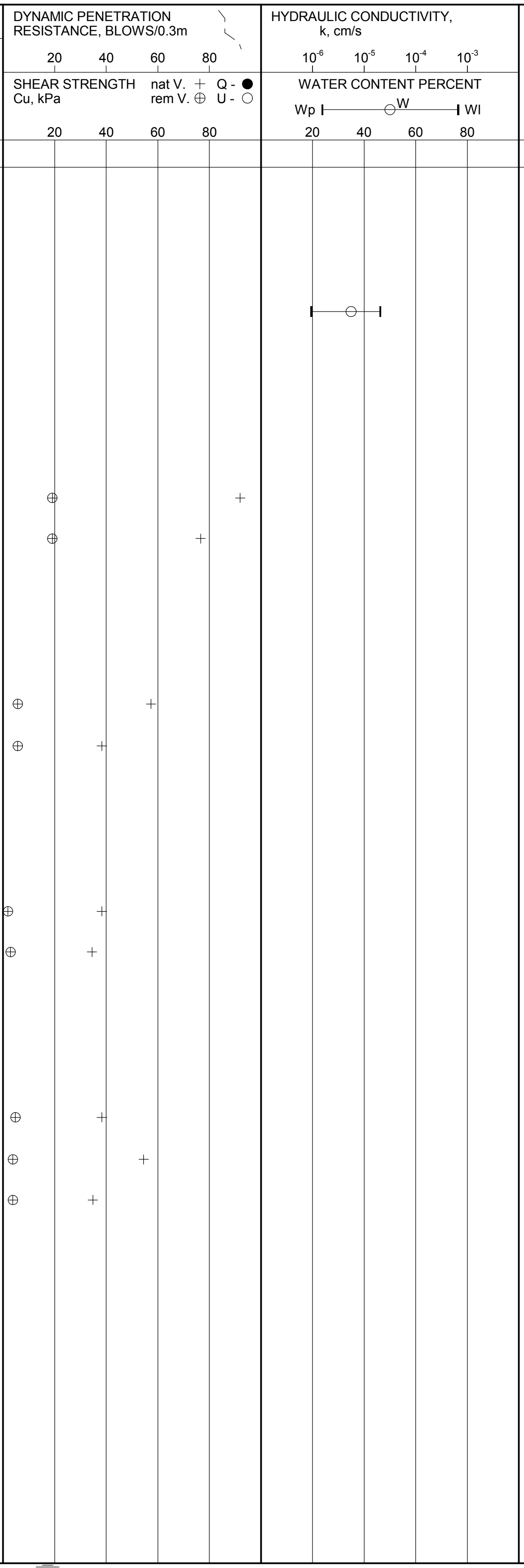
DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Power Auger 200 mm Diam. (Hollow Stem)

SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m
GROUND SURFACE	92.76			
TOPSOIL - (SM) SILTY SAND; brown, contains organic matter (rootlets); moist	0.00			
(CL/CI/CH) SILTY CLAY to CLAY; grey brown, contains silty sand seams (WEATHERED CRUST); cohesive, w>PL, very stiff to stiff	0.15	1	GRAB	-
		2	SS	3
		3	SS	2
(CI/CH) SILTY CLAY to CLAY; grey with black organic mottling, contains silty sand seams; cohesive, w>PL, firm to stiff	89.71 3.05	4	SS	WH
		5	SS	WH
		6	TP	PH
End of Borehole	85.14 7.62			



ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE METRES: 0 1 2 3 4 5 6 7 8 9 10

DEPTH SCALE
1 : 50

LOGGED: SN
CHECKED: SD

PROJECT: 1771847

RECORD OF BOREHOLE: 17-62

SHEET 1 OF 1

LOCATION: N 5013778.4 ;E 363630.8

BORING DATE: March 21, 2017

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

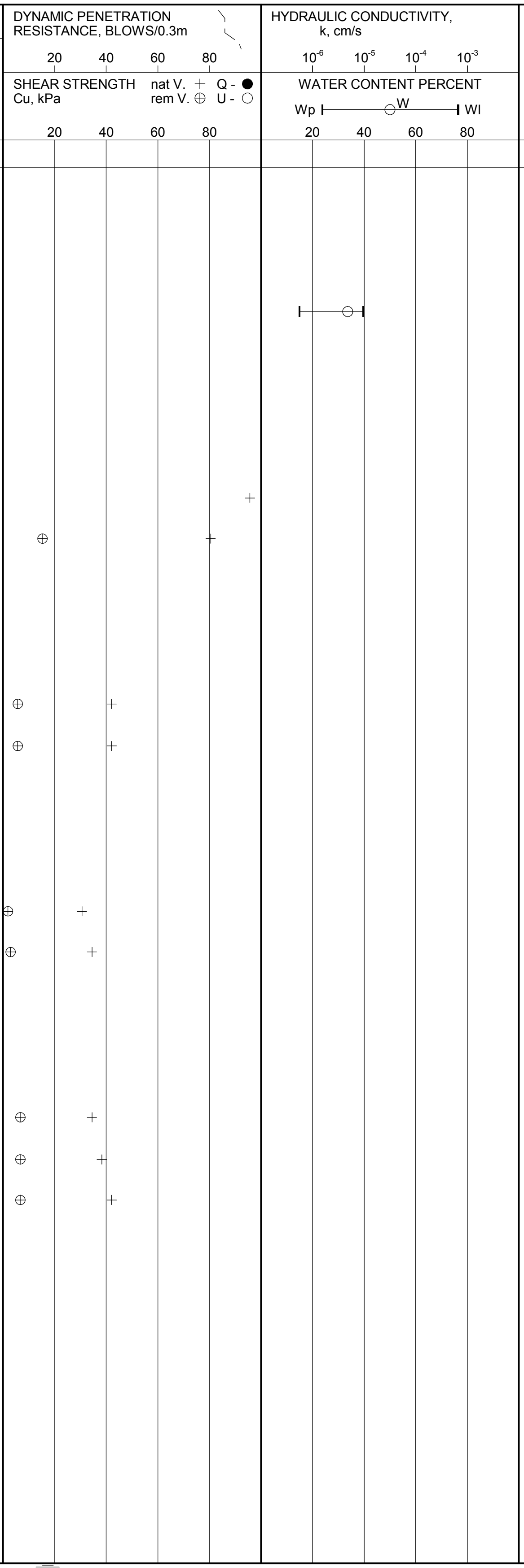
BORING METHOD: Power Auger
200 mm Diam. (Hollow Stem)

SOIL PROFILE

DEPTH SCALE METRES	DESCRIPTION	ELEV. DEPTH (m)
	GROUND SURFACE	91.93
0	TOPSOIL - (SM) SILTY SAND; dark grey, contains organic matter (rootlets); moist	0.00
	(CL/CI/CH) SILTY CLAY to CLAY; grey brown, contains silty sand layers (WEATHERED CRUST); cohesive, w>PL, very stiff to stiff	0.15
3	(CI/CH) SILTY CLAY to CLAY; grey with black organic mottling; cohesive, w>PL, firm	88.88 3.05
7.62	End of Borehole	84.31 7.62

SAMPLES

NUMBER	TYPE	BLOWS/0.30m
1	SS	4
2	SS	4
3	SS	WH
4	SS	WH
5	SS	WH



ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: SN
CHECKED: SD

PROJECT: 1771847

RECORD OF BOREHOLE: 17-62A

SHEET 1 OF 1

LOCATION: Adjacent to BH 17-62

BORING DATE: March 21, 2017

DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

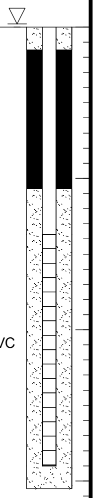
DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 20 40 60 80

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

HYDRAULIC CONDUCTIVITY, k, cm/s: 10^{-6} 10^{-5} 10^{-4} 10^{-3}

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

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.30m	DYNAMIC PENETRATION RESISTANCE / SHEAR STRENGTH	HYDRAULIC CONDUCTIVITY / WATER CONTENT PERCENT	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		91.93							
0	Power Auger 200 mm Diam. (Hollow Stem)	Refer to Borehole 17-62 for Stratigraphy		0.00							
3		End of Borehole		88.88 3.05							



Bentonite Seal

Silica Sand

51 mm Diam. PVC
#10 Slot Screen

Silica Sand

WL in Screen at
Elev. 91.95 m on
March 31, 2017

DEPTH SCALE
1 : 50

LOGGED: SN

CHECKED: SD

RECORD OF BOREHOLE: 17-63

PROJECT: 1771847

SHEET 1 OF 1

LOCATION: N 5013683.7 ;E 363676.5

BORING DATE: April 5, 2017

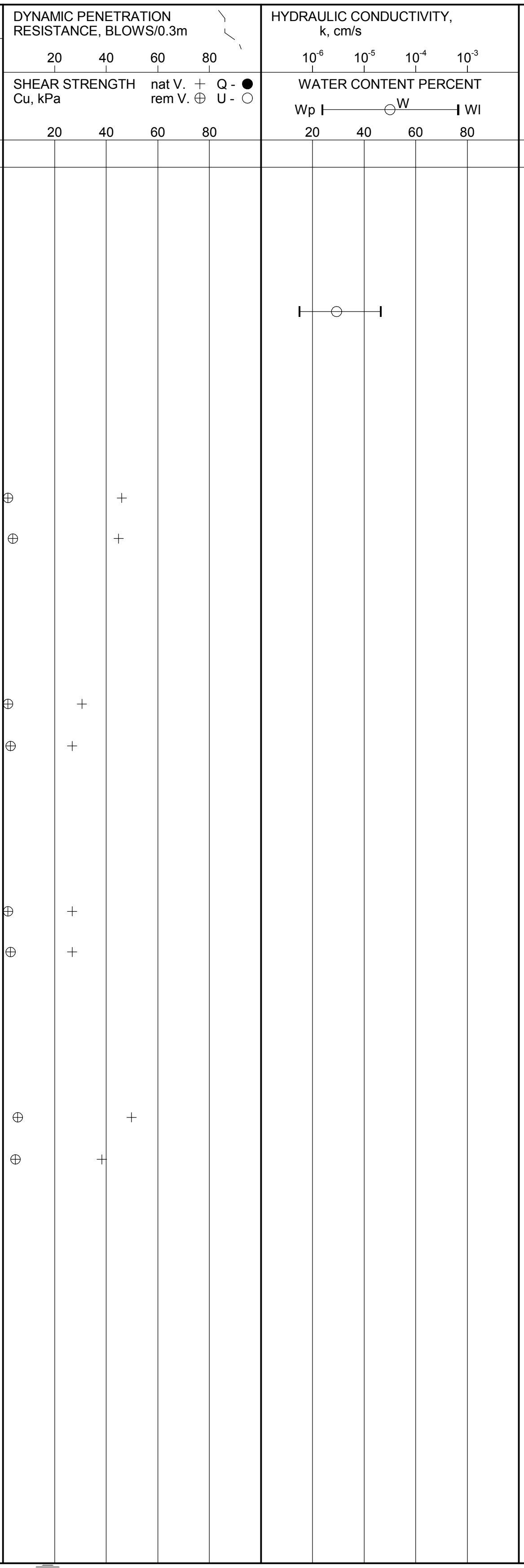
DATUM: CGVD28

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

BORING METHOD: Power Auger, 200 mm Diam. (Hollow Stem)

DEPTH SCALE METRES	DESCRIPTION	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.30m
	GROUND SURFACE	91.61			
0	TOPSOIL - (SM) SILTY SAND; brown; moist	0.00			
	(CL/CI/CH) SILTY CLAY to CLAY; grey brown, contains silty sand layers (WEATHERED CRUST); cohesive, w>PL, very stiff to stiff	0.15	1	GRAB	-
1			2	SS	4
2			3	SS	3
	(CI/CH) SILTY CLAY to CLAY; grey with black organic mottling; cohesive, w>PL, firm	89.17 2.44			
3			4	SS	WH
5			5	SS	WH
6			6	SS	WH
	End of Borehole	84.05 7.56			



ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: SN

CHECKED: SD

MIS-BHS 001 1771847.GPJ GAL-MIS.GDT 09/12/17 JEM

APPENDIX B

Results of Basic Chemical Analyses
Eurofins Environment Testing Report No. 1705915

Certificate of Analysis

Client: Golder Associates Ltd. (Ottawa)
1931 Robertson Road
Ottawa, ON
K2H 5B7
Attention: Mr. Steve Dunlop
PO#:
Invoice to: Golder Associates Ltd. (Ottawa)

Report Number: 1705915
Date Submitted: 2017-04-21
Date Reported: 2017-04-28
Project: 1771847
COC #: 817524

				Lab I.D.	1289222
				Sample Matrix	Soil
				Sample Type	
				Sampling Date	2017-03-30
				Sample I.D.	BH17-57 sa2 5-7
Group	**Analyte**	**MRL**	**Units**	**Guideline**	
Agri. - Soil	pH	2.0			8.0
General Chemistry	Electrical Conductivity	0.05	mS/cm		0.16
	Resistivity	1	ohm-cm		6250
	SO4	0.01	%		<0.01
Subcontract	Cl	0.002	%		<0.002

Guideline = *** = Guideline Exceedence**

All analysis completed in Ottawa, Ontario (unless otherwise indicated by ** which indicates analysis was completed in Mississauga, Ontario).
Results relate only to the parameters tested on the samples submitted.
Methods references and/or additional QA/QC information available on request.

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

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For more information, visit golder.com

Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 44 1628 851851
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

solutions@golder.com
www.golder.com

Golder Associates Ltd.
1931 Robertson Road
Ottawa, Ontario, K2H 5B7
Canada
T: +1 (613) 592 9600