REPORT

Geotechnical Investigation

Proposed Residential Development
Nicolls Island Road - Parcel - 'A'
Riverside South
Ottawa, Ontario

Submitted to:

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by Nicolls Island Holdings Inc. (The Regional Group) to conduct a geotechnical investigation for the proposed residential development to be located west of River Road and about 500 metres north of Nicolls Island Road in Ottawa, Ontario. The site is to be developed as shown on Figure 1, and consists of residential dwellings and a pumping station structure to be located on the northeast extent of the site.

The current geotechnical investigation included an assessment of the general subsurface conditions at the site by means of eleven boreholes and selected geotechnical laboratory testing. Based on an interpretation of the factual information obtained, a general description of the subsurface 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.

A site reconnaissance was performed to determine the state oferosion along the northern and western slopes that border the site, as well as to confirm the top of the slopes for the limit of hazard land recommendations.

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

Based on information provided by The Regional Group, plans have been developed for a residential subdivision on a site located west of River Road and about 500 metres north of Nicolls Island Road in Ottawa, Ontario.

The site is about 210 by 260 metres in plan dimension, although somewhat irregular in shape as shown on Figure 1. The property is generally bounded to the east by existing residences along River Road, to the west by the RCMP Campground (which is located along the east bank of the Rideau River), to the north by undeveloped land and to the south by undeveloped land. The site is generally flat, with a gentle slope from east to west, and has slopes along the north and west boundaries.

A slope, approximately six metres in height, separates the site from the adjacent lower-lying RCMP Campground to the west, while the north boundary slope ranges between about 4 and 8 metres in height. The northern watercourse flows from east to west along the north boundary of the site within a shallow valley.

The site is currently undeveloped and consists of agricultural land with treelines along the north, east and west boundaries. A line of trees also extends along a linear drainage feature through the middle portion of the site in a north – south direction.

Based on a review of the published geological mapping, the subsurface conditions at the site are expected to consist of a deposit of silty clay overlaying glacial till, which in turn is underlain by bedrock. The available geological mapping suggests that the bedrock surface is in the order of 10 to 15 metres depth below the existing ground surface and consists of dolostone of the Oxford Formation.

3.0 INVESTIGATION PROCEDURES

The field work for the current geotechnical investigation was carried out between July 20 and 21, 2016. During that time, six boreholes (numbered 16-1 to 16-6) were advanced within the project limit. These boreholes were advanced to depths ranging from about 5.8 to 8.3 metres below the existing ground surface.

Additional investigation was also carried out between June 5 and 6, 2019, during which time a total of five boreholes (numbered 19-01 to 19-05) were advanced at approximate locations shown on Figure 1. Borehole 19-01 was advanced to a depth of 13.5 metres within the area of the proposed pumping station, while boreholes 19-02 to 19-05 were advanced to depths ranging between about 3.8 and 4.0 metres below the existing ground surface.

All the boreholes of the current investigations were advanced using a track-mounted, continuous flight hollow-stem auger drill rig, supplied and operated by CCC Geotechnical and Environmental Drilling Company of Ottawa, Ontario.

Standard Penetration Tests (SPT) were carried out within the overburden at regular intervals of depth in general conformance with ASTM D 1586. Soil samples were recovered using 35 millimetres inside diameter split-spoon sampling equipment or grab samples from the sides of selected boreholes. In-situ vane testing was carried out, where possible, in the silty clay deposit to measure the undrained shear strength of this soil unit.

Standpipe piezometers were sealed into boreholes 16-1, 16-5 and 19-01 to allow subsequent measurements of the groundwater level across the site. The groundwater levels in the standpipe piezometers installed in boreholes 16-1 and 16-5, and borehole 19-01 were measured on July 21, 2016 and July 26, 2019, respectively.

The boreholes were backfilled with bentonite pellets, mixed with soil cuttings and the site conditions were restored following completion of work.

The field work was supervised by Golder staff who located the boreholes, directed the drilling operations and in situ testing, logged the subsurface conditions encountered in the boreholes, and took custody of the soil samples retrieved.

Upon completion of the drilling operations, samples of the soils encountered in the boreholes were transported to our laboratory for further examination and for geotechnical laboratory testing, which included natural water content measurements, grain size distribution and Atterberg Limits testing on selected soil samples.

One sample of soil from borehole 16-03 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 marked in the field and surveyed by Golder personnel. The borehole coordinates and ground surface elevations were measured 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).

In addition, Golder previously carried out a due diligence study for the site and the results were provided in the following draft report:

- Report to The Regional Group titled "*Preliminary Geotechnical Assessment, Due Diligence Study, Nicolls Island Road – Parcel 'A', Riverside South, Ottawa, Ontario*" dated August 2015 (Report Number 1534482-4000).

4.0 SUBSURFACE CONDITIONS

4.1 General

Information on the subsurface conditions is presented as follows:

- Record of Borehole Sheets from the current investigation are provided in Appendix A.
- The results of the laboratory testing are provided in Appendix B.
- The results of chemical testing are provided in Appendix C.

Results of the water content measurements are provided on the respective Record of Borehole Sheets.

The subsurface conditions on the site generally consist of topsoil, or silty sand to sandy silt underlain by a weathered silty clay crust. The weathered silty clay crust is underlain by a layer of glacial till over bedrock.

The following sections present a more detailed overview of the subsurface conditions encountered during the field investigation.

4.2 Topsoil

Topsoil was encountered at the ground surface in all boreholes 19-01 to 19-05, as well as in boreholes 16-4 and 16-6. The thickness of the topsoil ranged from about 120 to 300 millimetres. The topsoil generally consisted of moist, dark brown, silt and sand to sandy silt and contains organic matter, roots and rootlets.

4.3 Fill

Fill was encountered below the topsoil in borehole 19-01 and generally consists of silty clay with some sand. The fill extends to a depth of 3.5 m below the existing ground surface.

The results of SPT testing carried out within the fill in this borehole gave SPT ‘N’ values ranging from 2 to 4 blows per 0.3 metres of penetration indicating a stiff to very stiff consistency.

4.4 Sandy Silt to Silty Sand

A deposit of sandy silt to silty sand was encountered below the topsoil in boreholes 19-02 and 16-6, as well as at the ground surface in boreholes 16-1, 16-2, 16-3, and 16-5. The sandy silt to silty sand extended to depths varying between 200 and 600 millimetres below the existing ground surface.

SPT testing carried out within the layer gave SPT ‘N’ values ranging from 6 to 11 blows per 0.3 metres, indicating a loose to compact state of compactness.

4.5 Silty Clay to Clay

The topsoil, sandy silt to silty sand or fill, where encountered, were underlain by a deposit of silty clay to clay (referred hereafter as “silty clay”) at all borehole locations. The upper portion of the silty clay has been weathered to a grey brown crust. This weathered crust is typically stiffer, less sensitive, and exhibits a higher apparent pre-consolidation pressure than the underlain unweathered silty clay.

The weathered crust was fully penetrated in boreholes 19-01, and 16-01 to 16-06, to depths ranging between about 3.8 and 6.1 metres below the existing ground surface, while in boreholes 19-02 to 19-05, the weathered crust was proven to the borehole termination depths ranging between 3.8 and 4 metres below the existing ground surface.

SPT testing carried out within the weathered silty clay crust gave SPT ‘N’ values ranging from 2 to 14 blows per 0.3 metres of penetration, indicating a generally stiff to very stiff consistency.

Beneath the weathered crust, the clay is grey in colour. The unweathered clay was fully penetrated in borehole 19-01 to a depth of 9.8 metres below the ground surface, while in other boreholes, where encountered, the grey silty clay was proven to borehole termination depths ranging from about 5.8 to 8.3 metres below the existing ground surface. A thin layer, 100 millimetres thick, of sand and gravel was encountered within the silty clay deposit in borehole 16-4, at a depth of about 5.6 metres below the existing ground surface.

SPT testing carried out within the grey silty clay layer gave SPT ‘N’ values ranging from weight of hammer (WH) to 5 blows per 0.3 metres of penetration.

In-situ vane shear testing carried out within the grey silty clay deposit gave undrained shear strength (S_u) values ranging from 31 to more than 96 kilopascals, but more typically in the range of 42 to 75 kilopascals, indicating a firm to very stiff consistency.

In-situ vane testing was also carried out on remolded grey silty clay samples and gave S_u values varying between 6 to 18 kilopascals. Based on the ratio of the in-situ shear strength to the remolded shear strength ranging from 3 to 8, the grey silty clay is classified as medium sensitive to sensitive according to Canadian Foundation Engineering Manual (CFEM, 2006) classification.

The results of Atterberg limit testing carried out on eight samples of the weathered and unweathered silty clay deposit gave plasticity index values ranging from about 24 to 44 percent and liquid limit values ranging from about 40 to 68 percent, indicating a soil of intermediate to high plasticity. Results of the Atterberg limit testing are provided on Figure B-4 in Appendix B.

The results of shrinkage limit testing carried out on two samples from the silty clay deposit gave a shrinkage value of about 15 percent and a shrinkage ratio of about 1.9. The results of shrinkage limit testing are provided in Appendix B.

The measured natural water content of 27 samples of the weathered silty clay ranged from about 9 to 67 percent and the results are provided on the corresponding Record of Borehole sheets.

The result of grain size distribution testing on two samples of the silty clay from the current investigation are provided on Figures B-1 and B-2 in Appendix B.

4.6 Glacial Till

A deposit of glacial till was encountered beneath the silty clay in boreholes 19-01 and 16-1, at depths of 9.8 and 5.3 metres, respectively. The glacial till generally consists of a heterogeneous mixture of gravel, cobbles, and boulders in a matrix of sandy silt. This layer was not fully penetrated in either of the boreholes, except borehole 19-01 that was terminated on inferred bedrock at a depth of about 13.5 metres below the existing ground surface.

SPT testing carried out within the glacial till gave SPT ‘N’ values ranging from about 10 to 24 blows per 0.3 metres of penetration, indicating a compact state of packing.

The measured natural water content of three samples of the glacial till were between about 10 and 12 percent.

The grain size distribution testing on one sample of the glacial till from the current investigation is provided on Figure B-3 in Appendix B.

4.7 Groundwater

Standard piezometers were installed into boreholes 16-1, 16-5 and 19-01 for subsequent groundwater level measurements. The following table summarizes the depths and the elevations of the groundwater level measured in the standard piezometers installed at the site.

Borehole No.	Geologic Unit of Screened Interval	Ground Elevation (m)	Groundwater Level Depth (mbgs)	Groundwater Elevation (m)	Date of Measurement
19-01	Till	88.5	5.0	83.5	June 26, 2019
16-1	Till & Silty Clay	85.5	5.7	79.8	August 2, 2016
16-5	Silty Clay	86.7	2.9	83.8	August 2, 2016

It should be noted that groundwater levels are expected to fluctuate seasonally. Higher groundwater levels are expected during wet periods of the year, such as spring.

4.8 Corrosion Testing

One soil sample from borehole 16-3 was submitted to Eurofins Environment Testing for chemical analysis related to potential corrosion of exposed buried steel and potential sulphate attack on buried concrete elements (corrosion and sulphate attack). The test results are provided in Appendix C and are summarized below.

Borehole No.	Sample Depth (m)	Chloride (%)	Sulphate (%)	pH	Resistivity (ohm-cm)
BH 16-3 / Sa 3	1.5 – 2.1	0.002	< 0.01	7.6	8,330

5.0 DISCUSSION

5.1 General

This section of the report provides engineering guidelines on the geotechnical design aspects of the project based on our interpretation of the available information described herein and project requirements. Contractors bidding on or undertaking the works should examine the factual results of the investigation, satisfy themselves as to the adequacy of the factual information for construction, and make their own interpretation of the factual data as it affects their proposed construction techniques, schedule, safety, and equipment capabilities.

Reference should be made to the “Important Information and Limitations of This Report” which follows the text but forms an integral part of this document

5.2 Site Grading

In general, the subsurface conditions on this site consist of weathered silty clay overlaying a relatively thick firm to stiff deposit of grey (unweathered) silty clay underlain by glacial till. The groundwater level ranged from about 2.9 to 5.7 metres below existing ground surface. The unweathered silty clay deposits have 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.
- 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.

It is conventional practice to allow the stress increase on the silty clay to be about 80 percent of the difference between the existing natural stress level and the preconsolidation pressure (i.e., of the overconsolidation). This margin (of 20 percent) is left between the final stress level and the preconsolidation pressure because the effects of 'secondary compression' can cause large settlements even at stress levels just slightly below the preconsolidation pressure. The margin also allows for some uncertainty in the actual value of the preconsolidation pressure, the groundwater levels, the unit weight of the fill, etc.

Based on the subsurface conditions encountered during the investigations, the site can be subdivided into two areas based on the amount of permissible grade raise, indicated as Area A and Area B as shown on Figure 1. The following table provides the maximum permissible grade raises for each of the assessment areas indicated on Figure 1. It should be noted that only Area A has been shown on Figure 1, and Area B refers to the rest of the site.

The analyses carried out for this assessment assumes that the unit weight of the grade raise fill would be less than or equal to 19.0 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.

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

Assessment Area	Maximum Permissible Grade Raise with Conventional Backfill (metres)
A	1.5
B	2.7

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

The maximum permissible grade raises for Areas A and B were calculated based on the following criteria:

- The houses will have conventional depth basements, with founding levels in the range of 2 to 2.4 metres below finished grade.
- Any fill required for site grading (above original grade) and the backfill within the garages (and porches) would have a unit weight of *no* more than 19.0 kilonewtons per cubic metre. Silty clay (such as present on this site) would be suitable for exterior fill. Granular fills and crushed stone typically have higher unit weights and, if these materials are to be used, the maximum permissible grade raises would be reduced and would need to be re-evaluated.

The above permissible grade raises are based on some simplifying generalizations regarding the grading design and subsurface conditions on this site. It is possible that slightly higher permissible grade raises could be accommodated in some areas based on a refinement of the analyses once more specific information is available on:

- The lot grading
- The shape of the house footprint and the proximity of surrounding houses/foundations
- The footing levels and foundation embedment

Where the above noted grade raise restrictions cannot be achieved, an alternative method of increasing the permissible grade raise for the houses might be using lighter backfill materials within the garages and porches, and around the foundations of the entire house using Geofoam (EPS) lightweight fill or preloading/surcharging Area A and allowing the consolidation settlements to occur over a period of 9 to 15 months (estimate).

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

It must, however, be noted that the above assessments are preliminary in nature, and based on a very specific set of parameters. The impact on any grade raise above the aforementioned permissible grade raise values will need to be evaluated, on a house-by-house basis, once the detailed site grading design is complete.

5.3 Material Reuse

The native soils encountered at the site are not considered to be generally suitable for reuse as structural/engineered fill. Within foundation areas, imported engineered fill should be used.

The native sandy silt to silty sand, and silty clay may be suitable for use as controlled fill beneath pavement areas, provided they are not too wet to place and compact. These materials can also be reused in non-structural areas (i.e., landscaping).

5.4 Foundations

It is considered that the proposed residential development will be supported on spread footings founded on or within the surficial weathered silty clay deposit.

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

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

Provided that the grade raises are restricted to those indicated in Section 5.2, spread footing foundations up to 0.6 metres in width and pad footings up to 2.0 metres square 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 (OBC).

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 founding level is not disturbed during construction.

The tolerance of the house foundations to accept those settlements could be improved by providing nominal levels 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 correspond to settlement resulting from consolidation of these deposits. Consolidation of the clayey soils 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.

The proposed grading may also result in some of the footing levels being above the surface of the native inorganic subgrade soil (following removal of the topsoil and any surficial fill material). Where this is the case, the subgrade should be raised to the footing elevation using engineered fill consisting of 19 millimetre crushed clear stone having a unit weight not exceeding about 19.0 kilonewtons per cubic metre (i.e., similar to the native soil). The use of clear stone is recommended so as to avoid possible settlements associated with the use of heavier material. The engineered fill should be placed to occupy the full house footprint and the full zone of influence/support for the foundations. That zone is considered to extend down and out from the outside edge of the perimeter foundations at a slope of 1H:1V (horizontal:vertical). The engineered fill 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 vibratory compaction equipment. To avoid settlements resulting from loss of soil into the voids in the clear stone, it should be fully encapsulated in a geotextile. The geotextile should be placed on the bottom, sides, and over the top of the clear stone. A Class II non-woven geotextile should be used, with a Filtration Opening Size (FOS) not exceeding 150 microns, in accordance with Ontario Provincial Standard Specifications (OPSS) 1860. Footings founded on or within properly placed engineered fill can also be designed using a maximum allowable bearing pressure of 75 kilopascals.

5.5 Seismic Design

The seismic design provisions of the 2012 OBC depend, in part, on the shear wave velocity of the upper 30 metres of soil and/or bedrock below founding level. The OBC also permits the Site Class to be specified based solely on the stratigraphy and in situ testing data, rather than from direct measurement of the shear wave velocity. Based on this methodology, it is considered that a Site Class of E would be applicable to the design of low-rise structures at this site.

It should be noted that the seismic Site Class is not directly applicable to structures designed in accordance with Part 9 of the OBC (i.e., conventional housing); however, this assessment is provided to address City of Ottawa requirements that relate to housing on Site Class E sites. It should also be noted that a more favourable Site Class value could likely be assigned for the site, if seismic shear wave velocity testing is carried out.

5.6 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 and/or 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.

5.7 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 19.0 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 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 material’s SPMDD using suitable compaction equipment.

5.8 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 be backfilled with non-frost susceptible sand or sand and gravel conforming to the requirements for 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 basement wall backfill should be provided by means of a perforated pipe subdrain in a surround of 19 millimetre clear stone, fully 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.

Where design of basement walls in accordance with Part 4 of the 2012 Ontario Building Code is required, walls 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 base magnitude of $K_o\gamma H$, where:

K_o = The lateral earth pressure coefficient in the ‘at rest’ state, use 0.5;

γ = The unit weight of the granular backfill, use 21.5 kilonewtons per cubic metre; and,

H = The height of the basement wall in metres.

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.

5.9 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 silty clay crust 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. Excavation side slopes below the groundwater level in the silty clay would need to be cut back at 3 horizontal to 1 vertical (i.e., Type 4 soils).

Alternatively, for site service installations, 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.

The groundwater depth encountered at this site ranges between about 2.9 and 5.8 metres below existing ground surface; therefore, excavations for the foundation construction will not extend below the groundwater level. However, the excavations for the site services might extend below the groundwater level. In this case, the 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 current 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 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) and can be assessed at the time of construction. Registration is a quick process that is not expected to significantly disrupt the construction schedule.

5.10 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 compacted OPSS Granular B Type II beneath the Granular A or to thicken the Granular A bedding. This will be particularly likely where the trench floor level is within silt, but also in the unweathered silty clay. The bedding material 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 crushed clear stone as a bedding layer should not be permitted anywhere on this project since fine particles from the sandy backfill materials or silty soils on the trench walls 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 drier weathered silty clay as trench backfill.

However, the high moisture content of the deeper unweathered silty clay deposit makes this soil difficult to handle and compact. If these materials are excavated during installation of the site services, they should be wasted or should only be used as backfill in the lower portion of the trenches to limit the amount of long-term settlement of the roadway surface. If the unweathered silty clay is used in trenches under roadways, long term settlement of the pavement surface should be expected. Some significant padding of the roadways may be required prior to final paving. In that case, it would also be prudent to delay final paving for as long as practical. Where the trench will be covered with hard surfaced areas, 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.

Trench backfill 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.

Impervious dykes or cut-offs should be constructed at 100 metre intervals in the service trenches where these extend 2 metres or deeper below existing grades, 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 dykes 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.

5.11 Pavement Design

The following provides guidelines for the subdivision pavements.

5.11.1 Profile Grade

It is anticipated that some filling will be carried out to achieve profile grade within the development. Raising the grade within the development is acceptable from a geotechnical point of view provided that the restrictions for grade raise fill as discussed in Section 5.2 are considered.

5.11.2 Subgrade Preparation

In preparation for pavement construction, all topsoil and any unsuitable fill (i.e., fill containing organic matter) should be excavated from the pavement areas for predictable pavement performance.

Those portions of the fill not containing organic matter may be left in place provided that some long term settlement of the pavement surface can be tolerated. However, the surface of the fill material at subgrade level should be proof rolled with a heavy smooth drum roller under the supervision of qualified geotechnical personnel to compact the surface of the existing fill and to identify soft areas requiring sub-excavation and replacement with more suitable fill.

Areas requiring grade raising to proposed subgrade level should be filled using acceptable (compactable and inorganic) earth borrow (OPSS.MUNI 206/212) or Select Subgrade Material (SP F-3147). The native weathered silty clay at the site might be suitable for this purpose but that would need to be confirmed by the geotechnical engineer at the time of construction. Subgrade fill 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.

5.11.3 Granular Pavement Materials

The granular base and subbase for new construction should consist of Granular A and Granular B Type II (City of Ottawa F-3147), respectfully.

5.11.4 Pavement Design

The pavement structure for car parking areas should consist of:

Pavement Component	Thickness (mm)
Asphaltic Concrete	50
OPSS Granular A Base	150
OPSS Granular B Type II Subbase	400

The pavement structure for access roadways and truck traffic areas should consist of:

Pavement Component	Thickness (mm)
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 in car parking areas should be as follows:

- Superpave 12.5 Surface Course – 50 millimetres

The composition of the asphaltic concrete pavement in access roadways and truck traffic areas should be as follows:

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

The asphaltic concrete should meet the requirements of City of Ottawa specification F-3106. As such, the Performance Graded Asphalt Cement (PGAC) should consist of PG 54-34 and both mixes should be based on Traffic Category B for roadways.

The above pavement designs are based on the assumption that the pavement subgrade has been acceptably prepared (i.e., where the trench backfill and grade raise fill have been adequately compacted to the required densities and the subgrade surface not disturbed by construction operations or precipitation). Depending on the actual conditions of the pavement subgrade at the time of construction, it could be necessary to increase the thickness of the subbase and/or to place a woven geotextile beneath the granular materials.

5.11.5 Pavement Structure Compaction

Adequate compaction of the granular roadway materials will be essential to the continued acceptable performance of the roadway. Compaction should be carried out in conformance with procedures outlined in OPSS 501 “Construction Specification for Compacting” with compacted densities of the various materials being in accordance with Subsection 501.08.02 Method A. The granular base and subbase material should be uniformly compacted to at least 100 percent of the material’s SPMDD using suitable vibratory compaction equipment. Compaction of the asphaltic concrete should be carried out in accordance with OPSS 310, Table 10.

The placement and compaction of any engineered fill, as well as sewer and watermain bedding and backfill, should be inspected to ensure that the materials used conform to the specifications from both a grading and compaction viewpoint. In addition, compaction testing and sampling of the asphaltic concrete used on site should be carried out to make sure that the materials used, and level of compaction achieved during construction meet the project requirements.

5.12 Corrosion and Cement Type

A soil sample from borehole 16-3 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 C.

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.

5.13 Pools, Decks and Additions

The following guidelines are provided to address some typical requirements of the City of Ottawa.

5.13.1 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 2 metres from the outside wall of the house. In addition, the installation of an above-ground pool should not be permitted to alter the existing grades within 2 metres of the house. Provided these restrictions are adhered to, no further geotechnical assessment should be required for above-ground pools.

5.13.2 Decks

It is considered that, in general, no particular geotechnical evaluation/assessment will be necessary for future decks, added by the homeowners, except where:

- The deck will be attached to the house; and/or,
- The deck will be heavily loaded and require spread footing or drilled pier foundations (i.e., where the deck will be designed in accordance with Part 9 of the OBC and require a building permit).

5.13.3 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 of Ottawa prior to the building permit being issued.

5.14 Trees

The clay soils on this site are potentially sensitive to water depletion by trees of high water demand during periods of dry weather. When trees draw water from clay soil, the clay undergoes shrinkage, which can result in settlement of adjacent structures. Some restrictions could therefore need to be imposed on the planting of trees of higher water demand in close proximity to the foundations of houses or other structures founded at shallow depth.

The grain size distribution test result carried out on one sample of weathered silty clay indicates that the percentage of the soil particles finer than 0.475 millimetres in diameter is 100 percent. The results of Atterberg limit testing carried out on three samples of the weathered silty clay from shallow depth (i.e., presumably near or below the underside of the footings) gave an average plasticity index and liquid limit values of 30 and 48 percent, respectively.

The results of the shrinkage test are provided in Appendix B and indicate that the weathered silty clay at this site has a shrinkage limit of about 15 and a shrinkage ratio of about 1.9.

Based on the results of the laboratory testing, the plasticity index of the clay soil encountered within the residential development is generally below 40 percent.

Therefore, it should be acceptable to reduce the set-back distances for small size (mature tree height up to 7.5 metres) and medium size (mature tree height 7.5 to 14 metres) trees to 4.5 metres from the foundations within the residential development. However, in accordance with current City guidelines, the following conditions must also be met:

- The underside of footing elevation must be 2.1 metres or greater below the lowest finished grade;
- Available soil volume must be provided for small and medium trees as per the guidelines;
- Tree species must be very low to moderate Potential Subsistence Risk;
- The foundation walls should be reinforced at least nominally, to provide ductility; and
- The grading must promote drainage towards the tree root zone.

The required set-backs can be evaluated once further details are available on the site grading design. For example, where the grading will result in structures founded on engineered fill, the restrictions may not apply.

5.15 Pumping Station

A proposed pumping station including a wet well and associated structures will be located on the northeast corner of the site, approximately near borehole 19-01, as shown on Figure 1. Based on the preliminary information provided, it is understood that the wet well structure would be 2.4 m in diameter and have a founding elevation of about 79.8 metres above sea level (masl) (i.e., about 8.7 metres below the existing ground surface).

The ground conditions at the proposed pumping station consist of 3.5 metres of silty clay fill underlain by a native deposit of stiff to very stiff silty clay extending to a depth of about 9.8 metres below the existing ground surface, which in turn is underlain by glacial till. Auger refusal was encountered at a depth of about 13.5 metres below the existing ground surface. The groundwater at borehole 19-01 was encountered at a depth of about 5 metres below the existing ground surface (i.e., elevation 83.5 masl).

The geotechnical assessments and associated detailed design of the pumping station will be provided later (i.e., in the detailed design stage), once the detailed information on pumping station subsurface structure and the proposed method of construction are available and provided.

5.16 Slope Stability Assessment

5.16.1 Site Reconnaissance

The site is bounded to the northeast and southeast by residential buildings, to the north by a watercourse flowing through a forested valley, and to the east by River Road. The southern boundary is established through vacant agricultural lands and to the west lies a campground backing onto the Rideau River. The slopes under assessment extend along the western and northern boundaries of the site.

The survey of the existing slopes at the site was carried out by Annis, O’Sullivan, Vollebekk Limited (AOV) on July 2016 and later completed by two additional cross-sections by Golder (June 2019). The approximate locations of the surveyed slope cross-sections (labelled A-A’ to K-K’) are shown on Figure 1.

A reconnaissance of the northern and western slopes was conducted on May 31, 2019. At the time of the site visit, these slopes were mostly covered with grass, vegetation and tall and mature trees. The purpose of the site visits was to observe the state of the erosion at the toe the slopes. At the time of the site visit, the northern watercourse was gently flowing from east to west, with a water elevation of less than 0.3 metres along most of the observed length. A linear drainage feature in a south to north direction is present within the middle portion of the site, with evidence of water flow during periods of heavy rainfall.

The northern slope is approximately 250 metres in length between cross-sections A-A’ and G-G’ and inclined from steeper than 1H:1V to 2H:1V, on average. This slope extends from a watercourse crossing at the northwest corner of the site to River Road in the east. The floodplain along the south riverbank is variable in width ranging from less than one metre to about 15 metre. The watercourse is tight against the riverbank in several locations such as at or near cross-sections A-A’, B-B’, D-D’, east of F-F’ and G-G’, where signs of significant active erosion were observed along the northern slopes with several indications of recent shallow and surficial slope failures (see photographs in Appendix D). These surficial failures occurred as a result of toe erosion. The northern slopes range from about 4.5 to 8 metres in height. The approximate top of slope location is highlighted on Figures 1 and 2. The shallow linear drainage feature in the middle of the site was found to be free of water at the time our visit, and without any indication of active erosion.

The western slope is approximately 225 metres in length and stretches between north of cross-section H-H’ to south of cross-section K-K’, reaching from the southwestern site boundary to the watercourse crossing in the northwest corner of the site. The slope varies in height from about 5 to 6 metres and is less steep compared to the northern slope. The toe of the slope extends along the ditch of a road for the campground, with no visible indication of water flow. The slope is inclined between about 1.5H:1V and 4H:1V. No sign of erosion was observed along the western slopes facing the campground.

Photographic records of the northern watercourse bank slope, as well as the western slope adjacent to the campground, are provided in Appendix D.

5.16.2 Slope Stability Analysis

Ontario Ministry of Natural Resources (MNR) guidelines were referenced to assess the stability condition of the slopes along the northern (and western) extent of the site. According to these guidelines, any land which is sloped or inclined more steeply than about 11 degrees from horizontal (5H:1V) and has a grade difference of more than 2 metres across it has the potential for instability. Therefore, the stability assessment of these slopes would be required. Limit equilibrium slope stability analyses were carried out for the slope stability assessment.

For this assessment, five cross-sections along the northern slope were selected as “critical” cross-sections; that is cross-sections A-A’, C-C’, D-D’, F-F’ and G-G’. In view of the relative uniformity of the slope geometry over the western slope of the site, only two reprehensive cross-sections I-I’ and K-K’ were selected for detailed analyses. These cross-sections were selected on the basis of being the highest slopes, having the steepest inclinations, and having active erosion at the toe of the slope, which is considered to be the most critical of the conditions along the slope.

In general, slope failures occur when the forces (or rotational moments) generated by the weight of the soil in a slope and external loads exceed the shear strength of the soil. The six main parameters involved in the engineering analysis of the stability of a slope are:

- The geometry of the slope;
- The subsurface stratigraphy within the slope (i.e., the composition of the various soil layers within the slope and their depth, thickness, and orientation);
- The groundwater conditions (i.e., the groundwater levels and the hydraulic gradient/flow conditions);
- The strength parameters for the soils;
- The unit weights (i.e., densities) of the soils within the slope; and
- External loads on the slope, such as from foundations of structures, filling above the slope, or earthquakes.

The geometries of the slopes used in the analyses were based on the surveyed data obtained for the site.

The subsurface stratigraphy used in the analyses was based on the results of the subsurface investigation completed for the site. The interpreted subsurface conditions consist of fill or sandy silt to silty sand overlying a deposit of very stiff weathered silty clay crust, overlying unweathered silty clay, which in turn is underlain by glacial till.

The selected soil stratigraphy and strength parameters used in the analyses are given in the table below.

Soil Type	**Bulk Unit Weight, γ (kN/m^3)**	**Shear Strength Parameters**		
		Undrained Shear Strength, c_u (kPa)	**Effective Angle of Internal Friction, φ' (degrees)**	**Effective Cohesion, c' (kPa)**
Silty Clay (Fill)	17.5	45	28	7.5
Sandy Silty to Silty Sand	17.5	N/A	34	0
Silty Clay (Weathered Crust)	17.5	75	36	7.5
Silty Clay	16.5	75	32	7.5
Glacial Till	21	N/A	36	0

The soil parameters given in the above table were based on the results of the laboratory testing and previous experience with similar soils in eastern Ontario.

The groundwater level within the slopes was assumed in the analyses based on the results of groundwater measurements. The groundwater was found to be approximately near or above the weathered crust and underlying unweathered silty clay.

The stability of the slopes was evaluated for:

- Drained (i.e., long-term, static) conditions, for which effective stress soil parameters were used;
- Undrained (i.e., short-term, static) conditions, for which total stress soil parameters were considered; and,
- Seismic conditions (i.e., the dynamic loading conditions during an earthquake), for which a horizontal seismic coefficient of 0.14 was used for the analyses. This value is based on the peak horizontal ground acceleration for the site as specified in the 2015 NBC with half that value being used, per standard practice.

The stability of the slopes was evaluated using 2-dimensional limit equilibrium methods and the commercially available SLOPE/W software. The Morgenstern-Price method was used to compute the factor of safety.
The factor of safety is defined as the ratio of the magnitude of the forces/moments tending to resist failure to the magnitude of the forces/moments tending to cause failure. Theoretically, a slope with a factor of safety of less than 1.0 will fail and one with a factor of safety of 1.0 or greater will stand. However, because the modeling is not exact and natural variations exist for all of the parameters affecting slope stability, a factor of safety of 1.5 is used to define a stable slope (for static loading conditions), and/or to define the 'safe' set-back distance from an unstable slope.

For seismic loading conditions, a factor of safety of 1.1 is typically used.

A summary of the slope stability analyses for the different loading scenarios explained above are presented below:

Location	Cross-Section	Factor of Safety		
		Static Condition (Drained)	Static Condition (Undrained)	Seismic Condition
Northern Slope	A-A’	1.84	3.38	2.53
	C-C’	2.33	3.63	2.34
	D-D’	2.20	3.52	2.50
	F-F’	1.94	2.83	1.96
	G-G’	2.08	2.97	2.11
Western Slope	I-I’	2.67	3.85	2.47
	K-K’	2.45	4.14	2.79

The results of the stability analyses carried out for the drained (i.e., static) conditions indicate that the factor of safety against global instability of the northern and western slopes is generally between 1.8 and 2.3, which can be considered stable. Similarly, an acceptable factor of safety against instability were obtained in undrained condition analyses.

The factor of safety against global instability of the western slope for both drained and undrained conditions and under static loaning were also acceptable.

The factor of safety against instability under *seismic* loading for both northern and western slopes were greater than 1.1 and therefore these slopes are also considered to be stable during a design earthquake event.

Results of the slope stability analyses are graphically provided on Figures E-1 to E-21 in Appendix E.

5.16.3 Limits of Hazard Lands

In view of the active erosion along the northern watercourse banks, the slope surface and the adjacent table land would be classified as Hazard Lands in accordance with Ministry of Natural Resources and Forestry (MNRF) guidelines, and provincial planning policies. These lands would therefore be unsuitable for development with either private development or significant infrastructure.

In accordance with the MNRF guidelines, a set-back distance is required from the slope crest for development such that the factor of safety against global instability meets or exceeds 1.5 (under static conditions) and 1.1 (under seismic conditions).

The set-back distance from the slope crest to the Limit of Hazard Lands is required to include three components, as appropriate, namely:

- A “*Stable Slope Allowance*”, which is determined as the limit beyond which there is an acceptable factor of safety (i.e., greater than about 1.5 static or 1.1 seismic) against the table land being impacted by a slope failure.

- An “*Erosion Allowance*”, to account for future movement of the slope toe, in the table land direction, as a result of erosion along the slope toe/ northern watercourse bank. The magnitude of the Erosion Allowance depends upon the type of soil being eroded at the slope toe, the severity of the erosion, and the watercourse characteristics.
- An “*Access Allowance*” of 6 metres, to allow a corridor by which equipment could travel to access and repair a future slope failure. This Access Allowance is included in the determination of the Limit of Hazard Lands wherever the development could restrict future slope access.

The *Stable Slope Allowance* was assessed by carrying out further stability analyses to determine if a set-back distance from the slope crest (which there is a factor of safety of at least 1.5 against instability) would be required. Based on the results of the slope stability assessment, the slopes along the northern and western boundaries of the site are stable and therefore a *Stable Slope Allowance* is not required.

Based on the provided preliminary grading plan, the filling on top of the table land and along the northern slope would start about 15 metres behind the top of slope crest, with a grading slope ranging from 2% to 7% away toward the table land (i.e., to form the backyard of the proposed dwellings along this slope). The total thickness of the filling would be about 0.5 to 2 metres at distances varying from about 35 to 45 metres behind the slope crest. In consideration of the height of the watercourse bank along the northern slope (i.e., 4.5 to 8 metres), and considerable distance of the proposed grade raise fill from the slope crest, the effect of grade raise filling on the stability of the northern watercourse bank would be negligible and therefore was not considered in the analyses.

In consideration of the MNRF guideline, an *Erosion Allowance* needs to be applied wherever there is active erosion, or the potential for active erosion based on the flow velocities. *Erosion Allowances* of 9.0 metres are required for the northern slope. An *Erosion Allowance* of 2 metres would also be required for the western slope where no sign of active erosion was identified during our site assessments.

The *Access Allowance* included in the MNRF procedures for defining the Limit of Hazard Lands is intended to provide a corridor of sufficient width across the table land that equipment could access the site of a future slope failure to undertake a repair. The MNRF documents do not provide specific guidance on those situations where the *Access Allowance* need be applied. However, as a general guideline, an *Access Allowance* of 6 metres should be included wherever the development plans would preclude equipment access to the slope.

The following table provides a summary of the various “set-back” components that are applicable for determining the total set-back for this site. The total set-backs (or the limit of hazard lands) are shown on Figure 1.

Location	**Cross-Section**	**Stable Slope Allowance (metres)**	**Erosion Allowance (metres)**	**Access Allowance (metres)**	**Total Set-Back (1) (metres)**
Northern Slope	A-A’ to G-G’	N/A	9	6	15
Western Slope	H-H’ to K-K’	N/A	2	6	8

Note: (1) Referenced from the slope crest (see Figures 1 and 2).

The above Limit of Hazard Lands assessment is based on erosion protection not being installed along the northern watercourse bank (i.e., slope toe). If erosion protection were to be installed then, at least for those specific sections of bank and slope where erosion protection measures were installed, an *Erosion Allowance* need not be included or can significantly be reduced, in the determination of the Limit of Hazard Lands. Furthermore, if erosion protection were to be considered, other studies and regulatory approvals might be required, such as with respect to natural environmental impacts.

Based on the preliminary site plan of the proposed development, the linear drainage feature (as previously described above) will be located within the entire length of Lot No. 7, as can be seen on Figure 1. As a result, a large portion of Lot No. 7 and parts of Lots. No. 6 and 8 would be located inside of the total set-backs provided in this report (i.e., 15 metres). It is our understanding that this drainage feature will be backfilled (with depths of filling ranging from 2 to 3.5 metres) to push back the top of the slope crest and associated total set-back towards the north and behind the property limit by 15 to 20 m. The proposed backfilling area is also shown on Figure 1. Culvert and outlet structures will also be installed along the linear drainage feature to maintain the flow and accommodate stormwater. No geotechnical concern with regards to the alterations to the existing slope and linear drainage feature is anticipated from a slope stability perspective; however, Golder should be retained to assess the stability of the new slope when the actual depth and extent of the backfilling, along with the final slope inclination, are decided in the detailed design stage.

Based on the preliminary grading plan it is anticipated that an emergency overland flow route for the site will also be located in the rear yards at Lots No. 10 and 11. Any outlet discharging the flow over the slope must be adequately protected against surface erosion by providing a layer of riprap (or any equivalent solution) over the slope to reduce the surface erosion. The erosion mitigation measures should, therefore, be reviewed by Golder at these locations as part of detailed design.

The following additional points should be noted:

- The set-back to the Limit of Hazard lands provided above has been evaluated based on the thickness and extent of the preliminary filling/grading plan as well as the proposed layout for the residential development as shown on Figure 1.
- If modification/disturbance to the slope is proposed where required to accommodate underground services or planned landscaping, the results of this assessment will need to be re-assessed.
- Provided the slope is not disturbed by construction and that the above set-backs are respected, it is not considered that stabilization measures will be required. The slope would ideally be left undisturbed, or at least any disturbance should be minimized or restricted to limited parts of the slope.
- The soils that form the slopes are vulnerable to erosion. Surface water as part of the development should not be directed to flow over the slope, unless a proper erosion protection measure is provided.

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 placement 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.

At the time of the writing of this report, only preliminary details for the proposed subdivision were available. Golder Associates should be retained to review the final drawings and specifications for this project prior to construction to ensure that the guidelines in this report have been adequately interpreted.

The groundwater level monitoring devices (i.e., standpipe piezometers or wells) installed at the site will require decommissioning at the time of construction in accordance with Ontario Regulation 128/03. However, it is expected that most of the wells can be more economically abandoned as part of the construction contract. If that is not the case or is not considered feasible, abandonment of the monitoring devices can be carried out separately.

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.

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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, **Nicolls Island Holdings Inc. c/o Regional Group.** 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.

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.

KEY MAP

SCALE 1:50,000

LEGEND

- ⌖ APPROXIMATE BOREHOLE LOCATION
- ⌖ PROPOSED BOREHOLE LOCATION
- ROADWAY
- TOPOGRAPHIC CONTOUR, metres
- FENCE
- WATERCOURSE
- NEW TOP OF SLOPE
- NEW FINAL SETBACK
- TOP OF SLOPE
- 15 m OFFSET FROM TOP OF SLOPE
- LIMIT OF HAZARD
- A A' SLOPE CROSS-SECTION LOCATION
- 🟪 BACKFILLED AREA
- ☐ PROPERTY PARCEL
- ▨ WETLAND
- 🟦 WATERBODY
- 🟥 STUDY AREA
- ▨ AREA A

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)

1. NEW TOP OF SLOPE AND NEW FINAL SETBACK, AND BACKFILLED AREA DIGITIZED FROM CLIENT PLAN, 116037-CP11, MARCH 14, 2019.
2. LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2014
3. SERVICE LAYER CREDITS: SOURCES: ESRI, HERE, GARMIN, USGS, INTERMAP, INCREMENT P, NRCAN, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), ESRI KOREA, ESRI (THAILAND), NGCC, (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
4. BASE PLAN PROVIDED IN ELECTRONIC FORMAT FROM THE REGIONAL GROUP, MAY 2019
5. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
COORDINATE SYSTEM: MTM ZONE 9 VERTICAL DATUM: CGVD28

0 15 30 60

1:1,500 METRES

CLIENT
THE REGIONAL GROUP

PROJECT
NICOLLS ISLAND ROAD
GEOTECHNICAL INVESTIGATION
PARCEL 'A', OTTAWA, ONTARIO

TITLE
SITE PLAN AND LOCATION OF CROSS-SECTIONS

CONSULTANT
GOLDER

YYYY-MM-DD	2020-03-19
DESIGNED	AG
PREPARED	ABD/BR
REVIEWED	AG
APPROVED	MSS

PROJECT NO.	PHASE	REV.	FIGURE
1534482	20000	A	1

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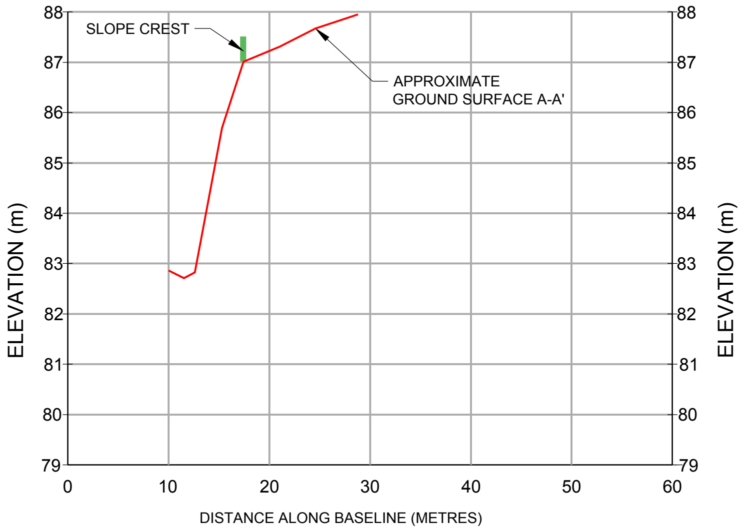
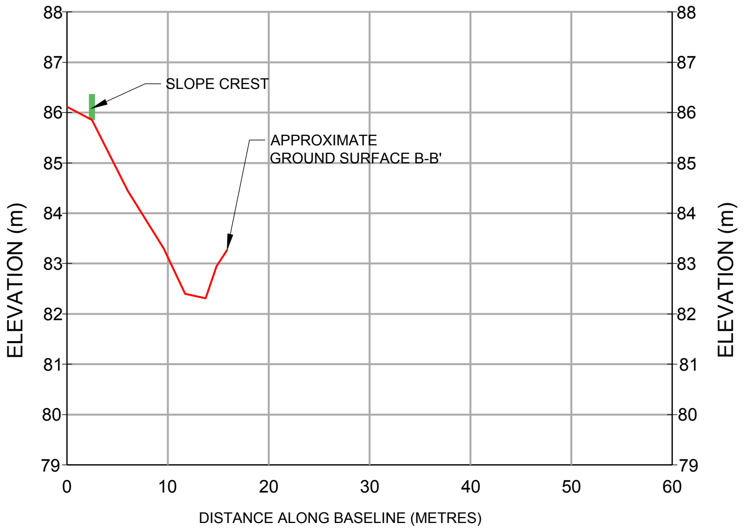
25mm IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

LEGEND

🟥	GROUND SURFACE
🟩	SLOPE CREST



PROFILE A-A'
1:200 m



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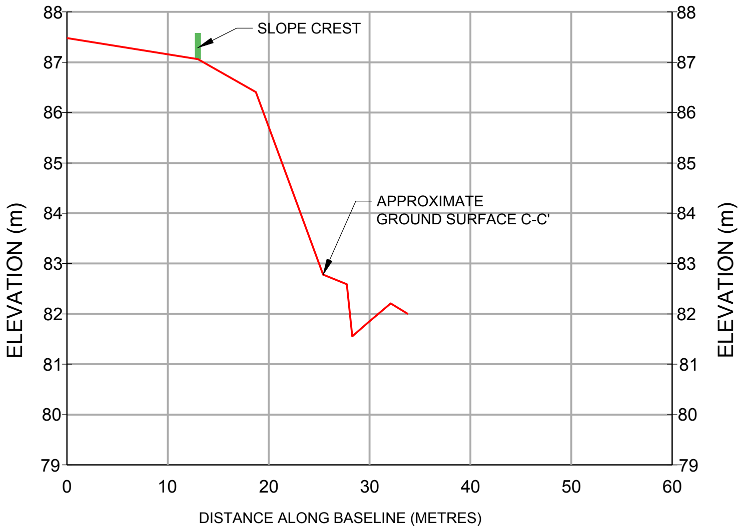

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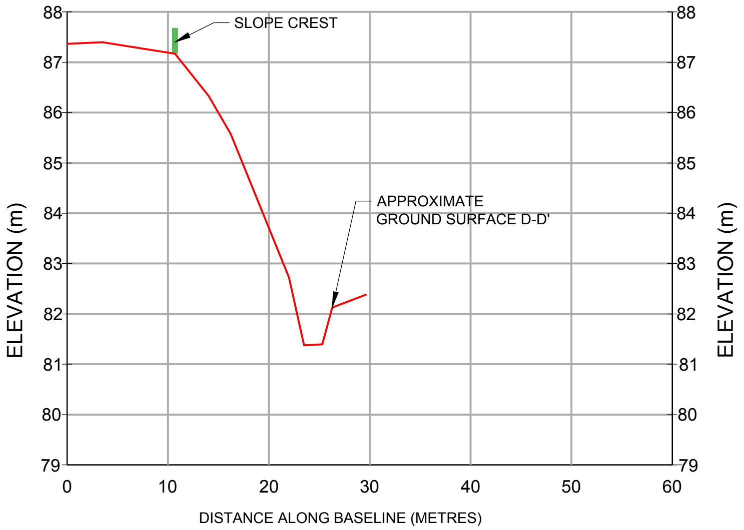

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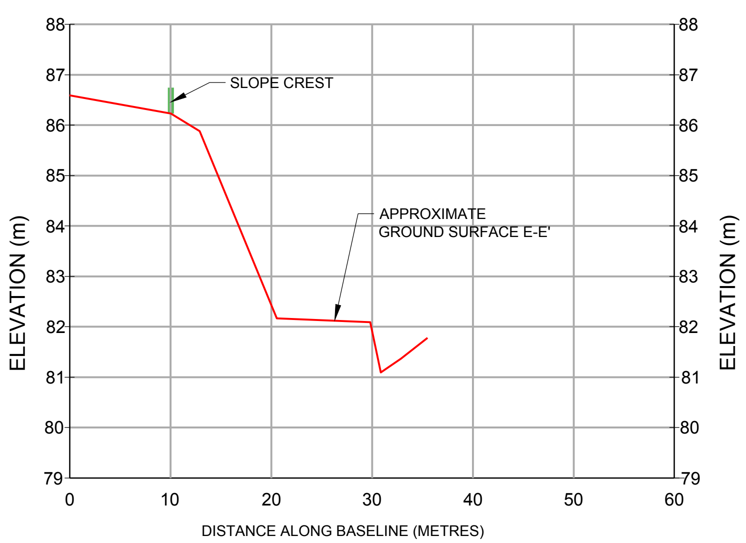

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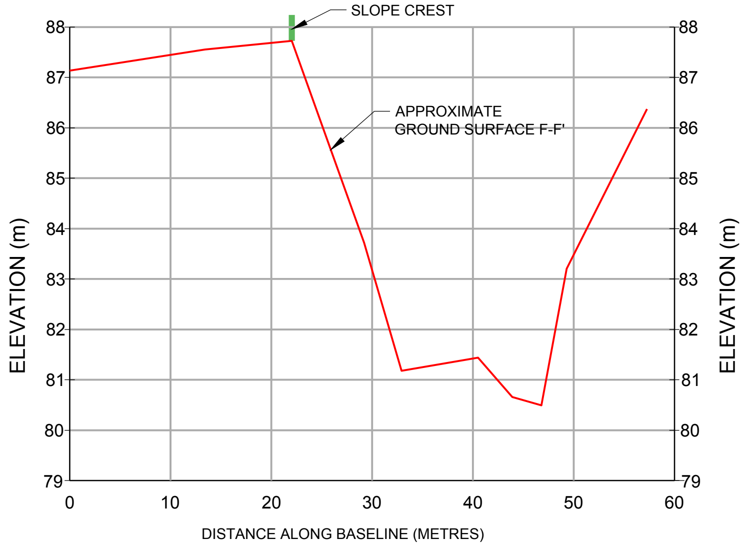

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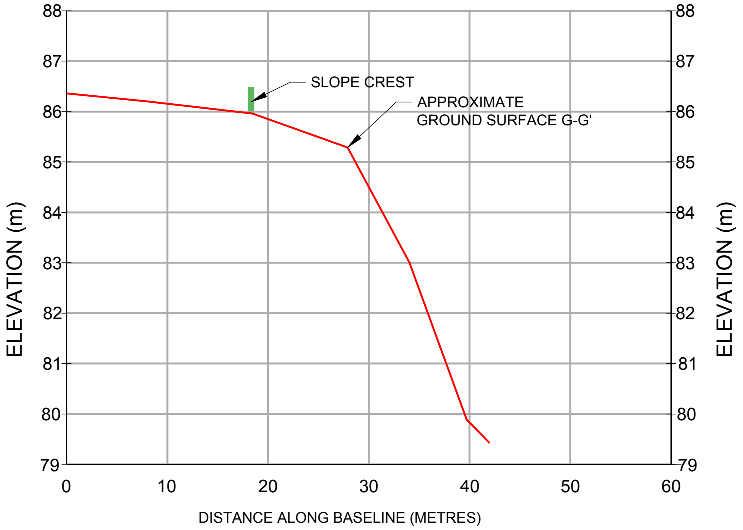

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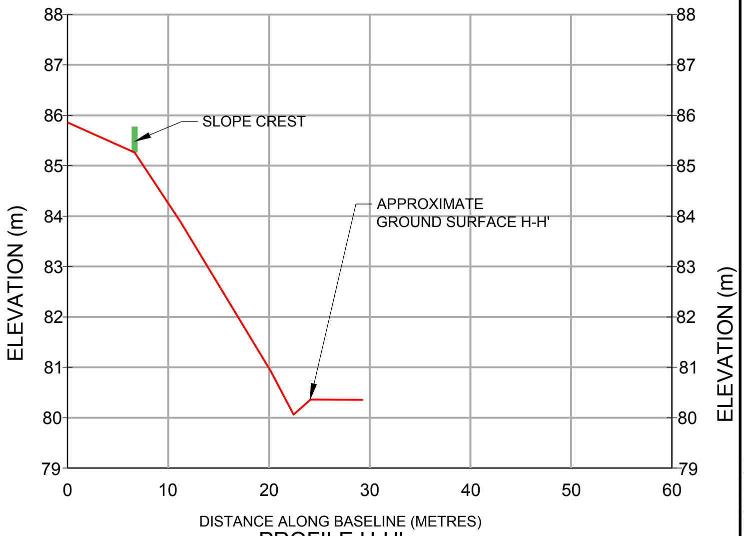

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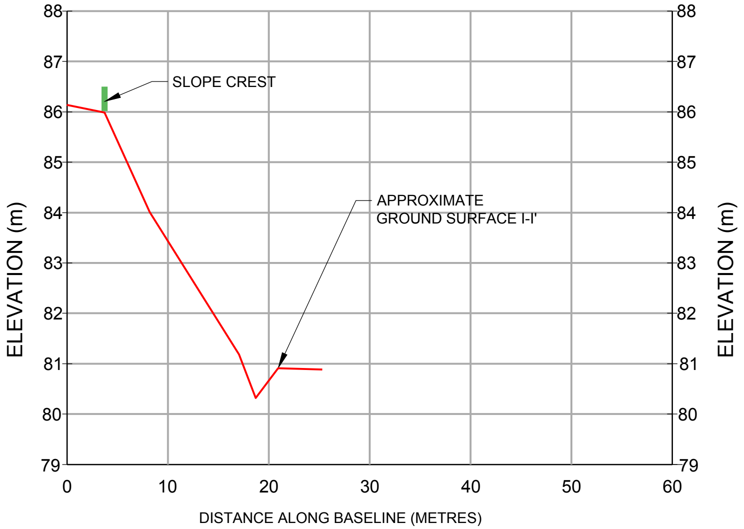

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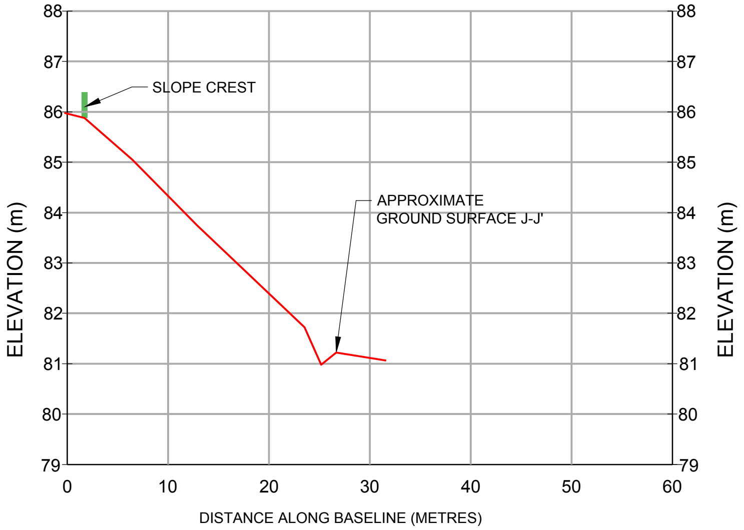

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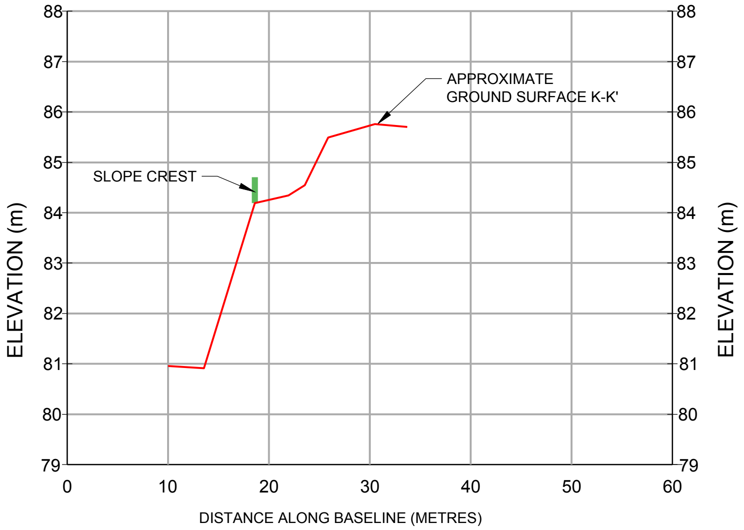
1:200 m



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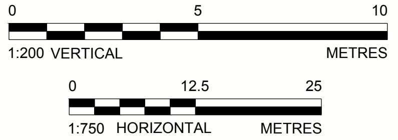

CLIENT
THE REGIONAL GROUP

PROJECT
NICOLLS ISLAND ROAD
GEOTECHNICAL INVESTIGATION
PARCEL 'A', OTTAWA, ONTARIO

TITLE
CROSS-SECTIONS

CONSULTANT

GOLDER

YYYY-MM-DD	2019-03-28
DESIGNED	AG
PREPARED	ABD
REVIEWED	AG
APPROVED	MSS

PROJECT NO.	CONTROL	REV.	FIGURE
1534482	20000	0	2

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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25 mm

APPENDIX A

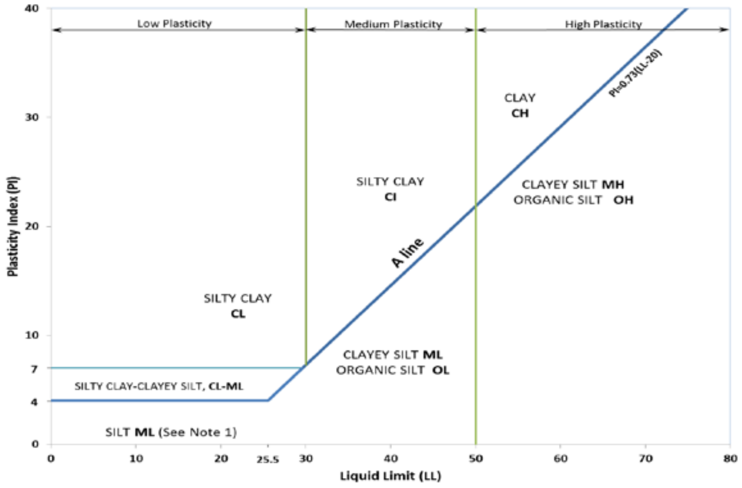
Record of Borehole Sheets

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	$Cu = \frac{D_{60}}{D_{10}}$	$Cc = \frac{(D_{30})^2}{D_{10} x D_{60}}$	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)
> 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.). Values reported are as recorded in the field and are uncorrected.

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
DD	Diamond Drilling
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
GS	Grab Sample
MC	Modified California Samples
MS	Modified Shelby (for frozen soil)
RC	Rock core
SC	Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size (Shelby tube)
TP	Thin-walled, piston – note size (Shelby tube)
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 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 to 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 the effects of overburden pressure.
2. Definition of compactness terms are based on SPT 'N' ranges as provided in Terzaghi, Peck and Mesri (1996). Many factors affect the recorded SPT 'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), overburden pressure, groundwater conditions, and grainsize. As such, the recorded SPT 'N' value(s) should be considered only an approximate guide to the soil compactness. These factors need to be considered when evaluating the results, and the stated compactness terms should not be relied upon for design or construction.

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 = $(w_l - w_p)$
NP	non-plastic
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 = $\tan \delta$
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

LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERINGS STATE

Fresh: no visible sign of rock material weathering.

Faintly weathered: weathering limited to the surface of major discontinuities.

Slightly weathered: penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

Moderately weathered: weathering extends throughout the rock mass but the rock material is not friable.

Highly weathered: weathering extends throughout rock mass and the rock material is partly friable.

Completely weathered: rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

BEDDING THICKNESS

Description	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 m to 2 m
Medium bedded	0.2 m to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	Less than 6 mm

JOINT OR FOLIATION SPACING

Description	Spacing
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

GRAIN SIZE

Term	Size*
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: * Grains greater than 60 microns diameter are visible to the naked eye.

CORE CONDITION

Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, as measured along the centerline axis of the core, relative to the length of the total core run. RQD varies from 0% for completely broken core to 100% for core in solid segments.

DISCONTINUITY DATA

Fracture Index

A count of the number of naturally occuring discontinuities (physical separations) in the rock core. Mechanically induced breaks caused by drilling are not included.

Dip with Respect to Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90^{o} angle is horizontal.

Description and Notes

An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

Abbreviations

JN	Joint
FLT	Fault
SH	Shear
VN	Vein
FR	Fracture
SY	Stylolite
BD	Bedding
FO	Foliation
CO	Contact
AXJ	Axial Joint
KV	Karstic Void
MB	Mechanical Break
PL	Planar
CU	Curved
UN	Undulating
IR	Irregular
K	Slickensided
PO	Polished
SM	Smooth
SR	Slightly Rough
RO	Rough
VR	Very Rough

PROJECT: 1534482

RECORD OF BOREHOLE: 19-01

SHEET 1 OF 2

LOCATION: N 5011640.9 ;E 445126.2

BORING DATE: June 6, 2019

DATUM: Geodetic

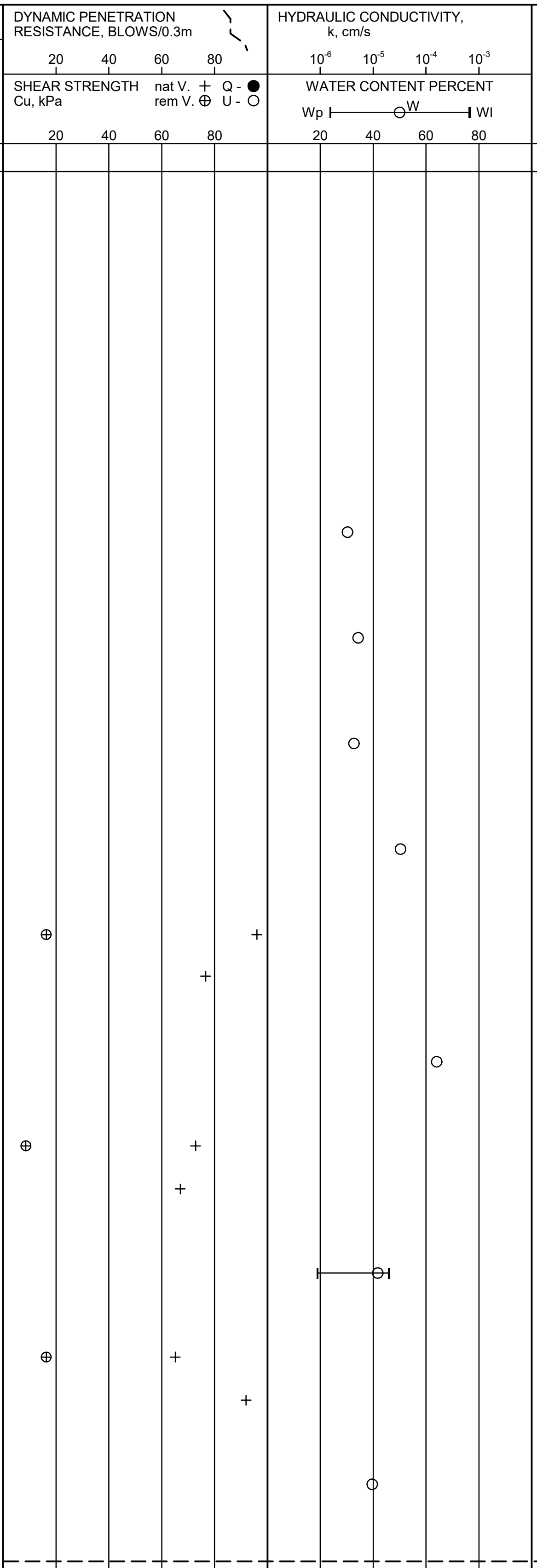
SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

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

DEPTH SCALE METRES	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)
	GROUND SURFACE		88.46
0	TOPSOIL - (ML) sandy SILT; dark brown, contains organics		0.00
	FILL - (CL) SILTY CLAY, some sand; grey brown, contains organics and bricks; cohesive, w>~PL, stiff		88.34 0.12
	(CI/CH) SILTY CLAY; grey brown, fissured, contains silty fine sand seams (WEATHERED CRUST); cohesive, w>~PL, stiff to very stiff		84.95 3.51
	(CI/CH) SILTY CLAY; grey; cohesive, w>PL, stiff		82.97 5.49
	(CI, CL-ML) SILTY CLAY to CLAYEY SILT; grey, layered; cohesive, w>PL, stiff to very stiff		80.84 7.62
			78.71 9.75
10	*CONTINUED NEXT PAGE*		

NUMBER	TYPE	BLOWS/0.30m
1	SS	2
2	SS	4
3	SS	2
4	SS	3
5	SS	3
6	SS	2
7	SS	WH
8	SS	3
9	SS	1
10	SS	11



PIEZOMETER OR STANDPIPE INSTALLATION

Flush Mount Casing

Silica Sand

Bentonite Seal

Native Backfill and Bentonite Mix

Bentonite Seal

DEPTH SCALE

1 : 50

GOLDER

LOGGED: PAH

CHECKED: AL

PROJECT: 1534482

RECORD OF BOREHOLE: 19-01

SHEET 2 OF 2

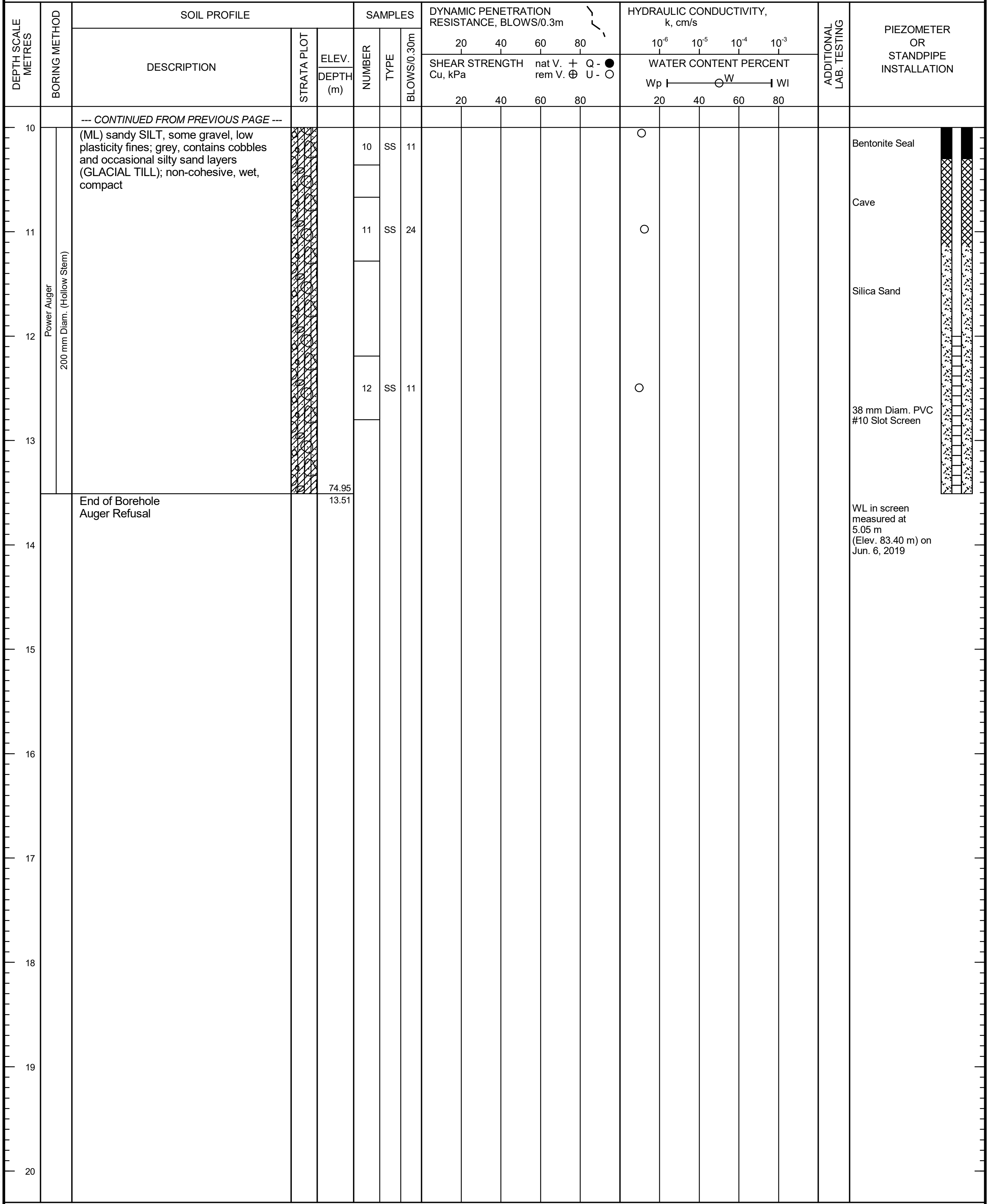
LOCATION: N 5011640.9 ;E 445126.2

BORING DATE: June 6, 2019

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm



DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.30m	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---					
10	Power Auger 200 mm Diam. (Hollow Stem)	(ML) sandy SILT, some gravel, low plasticity fines; grey, contains cobbles and occasional silty sand layers (GLACIAL TILL); non-cohesive, wet, compact		10	SS	11	Bentonite Seal
							Cave
11				11	SS	24	
							Silica Sand
12				12	SS	11	
							38 mm Diam. PVC #10 Slot Screen
13			74.95 13.51				
		End of Borehole Auger Refusal					WL in screen measured at 5.05 m (Elev. 83.40 m) on Jun. 6, 2019
14							
15							
16							
17							
18							
19							
20							

DEPTH SCALE
1 : 50

GOLDER

LOGGED: PAH
CHECKED: AL

PROJECT: 1534482

RECORD OF BOREHOLE: 19-02

SHEET 1 OF 1

LOCATION: N 5011595.6 ;E 445032.9

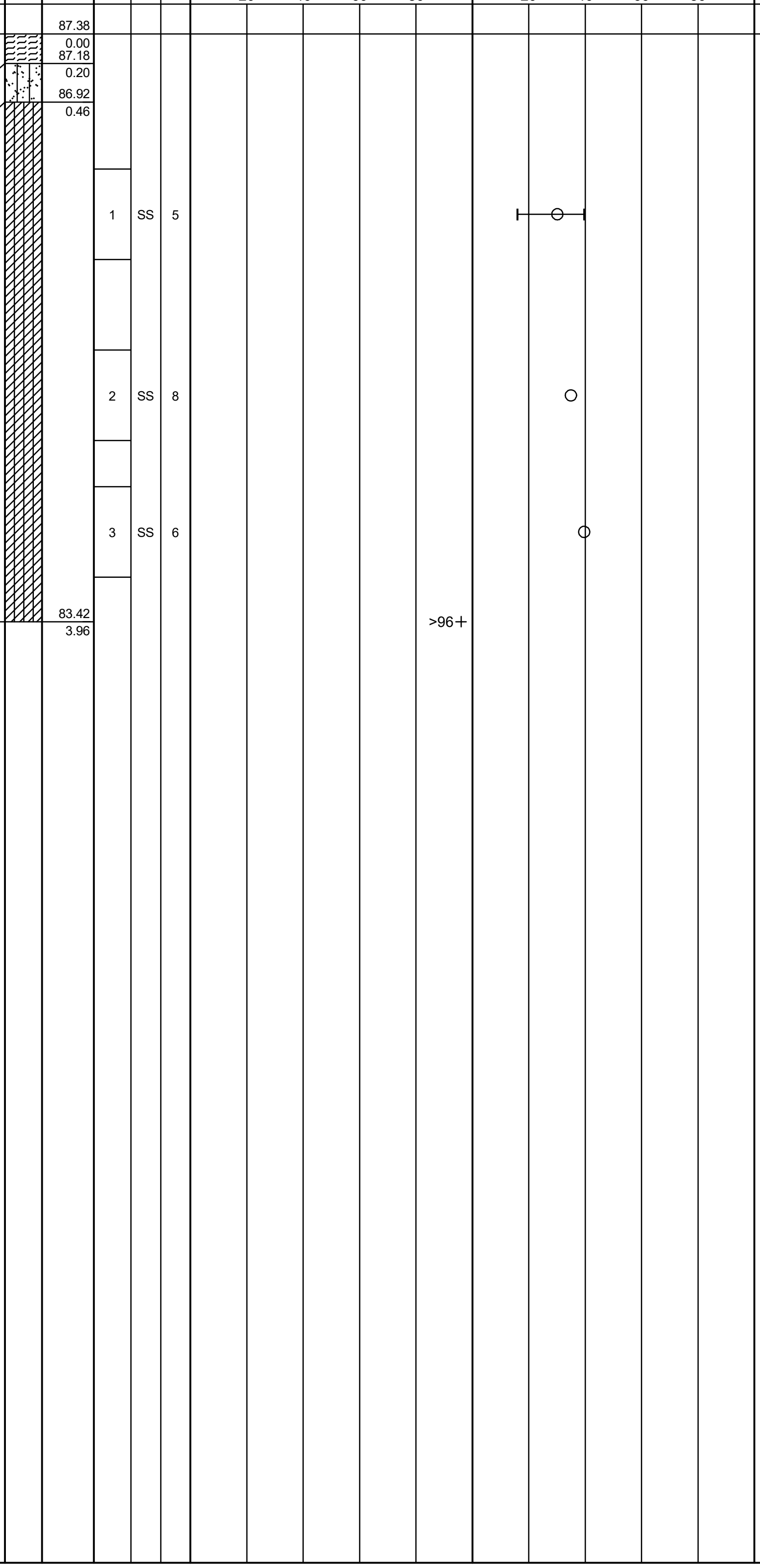
BORING DATE: June 5, 2019

DATUM: Geodetic

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		87.38							
0	Power Auger 200 mm Diam. (Hollow Stem)	TOPSOIL - (SM) SILTY SAND, fine; dark brown, contains organic matter		0.00							
		(SM) SILTY SAND, fine; brown; non-cohesive, moist, loose		87.18 0.20							
		(CI/CH) SILTY CLAY; grey brown, fissured, contains silty fine sand seams (WEATHERED CRUST); cohesive, w>~PL, very stiff		86.92 0.46							
1					1	SS	5				
2					2	SS	8				
3					3	SS	6				
4		End of Borehole		83.42 3.96				>96+			
5											
6											
7											
8											
9											
10											



DEPTH SCALE
1 : 50

GOLDER

LOGGED: PAH
CHECKED: AL

PROJECT: 1534482

RECORD OF BOREHOLE: 19-03

SHEET 1 OF 1

LOCATION: N 5011568.5 ;E 444961.9

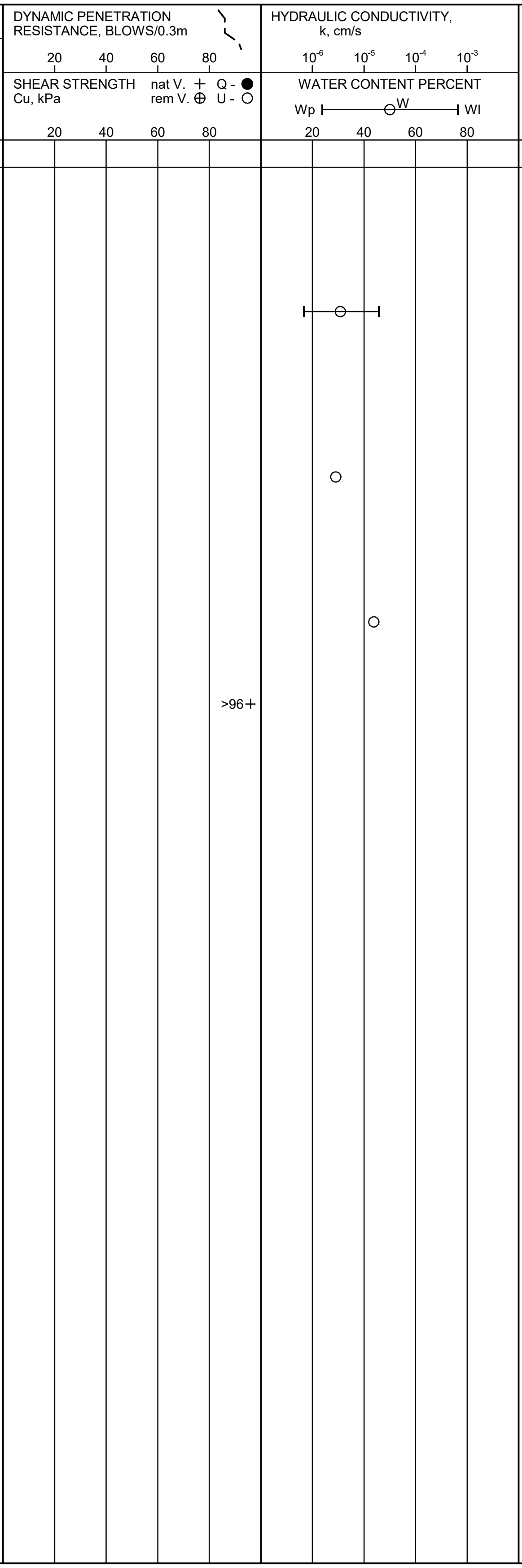
BORING DATE: June 5, 2019

DATUM: Geodetic

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	TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		87.10					
0	Power Auger 200 mm Diam. (Hollow Stem)	TOPSOIL - (CL) SILTY CLAY; dark brown, contains organic matter		0.00					
		(CI/CH) SILTY CLAY; grey brown, fissured, contains silty fine sand seams (WEATHERED CRUST); cohesive, w>~PL, very stiff		86.90 0.20					
1					1	SS	6		
2					2	SS	4		
3					3	SS	5		
4		End of Borehole		83.14 3.96					
5									
6									
7									
8									
9									
10									



DEPTH SCALE
1 : 50

GOLDER

LOGGED: PAH
CHECKED: AL

PROJECT: 1534482

RECORD OF BOREHOLE: 19-04

SHEET 1 OF 1

LOCATION: N 5011487.0 ;E 444979.9

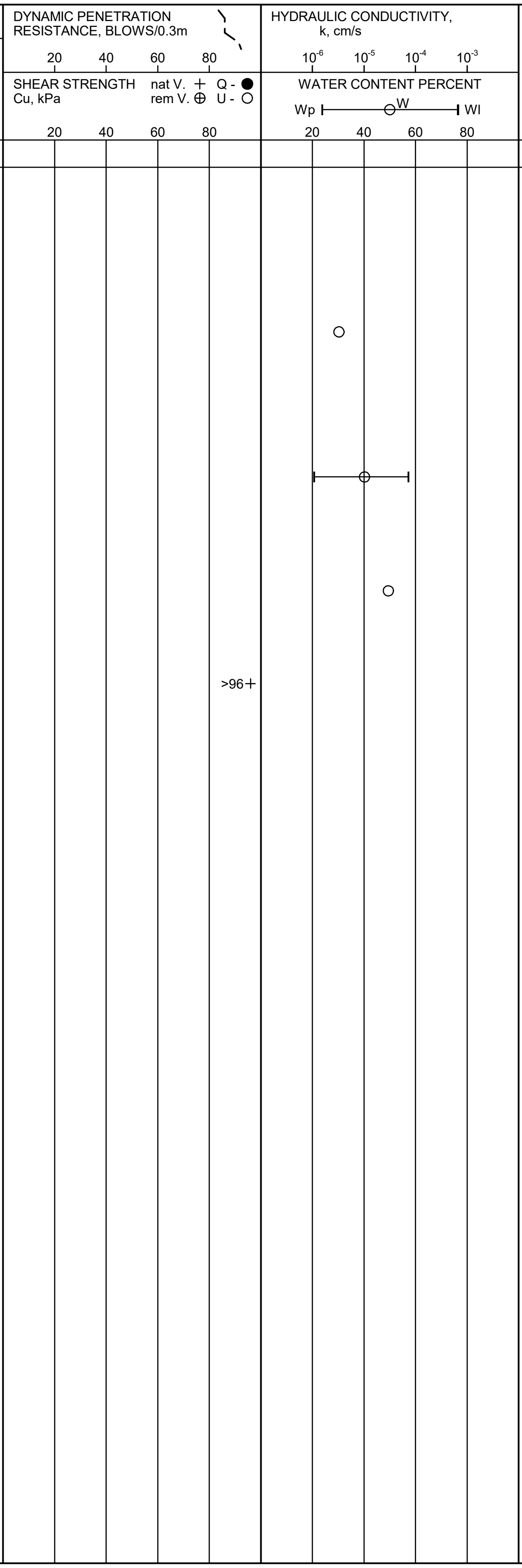
BORING DATE: June 5, 2019

DATUM: Geodetic

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	TYPE	BLOWS/0.30m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		86.77					
0	Power Auger 200 mm Diam. (Hollow Stem)	TOPSOIL - (CL) SILTY CLAY; dark brown, contains organic matter		0.00					
		(CI/CH) SILTY CLAY; grey brown, fissured, contains silty fine sand seams (WEATHERED CRUST); cohesive, w>~PL, very stiff		86.54 0.23					
1					1	SS	4		
2					2	SS	6		
3					3	SS	5		
		End of Borehole		82.96 3.81					
4									
5									
6									
7									
8									
9									
10									



DEPTH SCALE

1 : 50

GOLDER

LOGGED: PAH

CHECKED: AL

MIS-BHS 001 1534482.GPJ GAL-MIS.GDT 20-2-27 ZS

PROJECT: 1534482

RECORD OF BOREHOLE: 19-05

SHEET 1 OF 1

LOCATION: N 5011523.6 ;E 445053.6

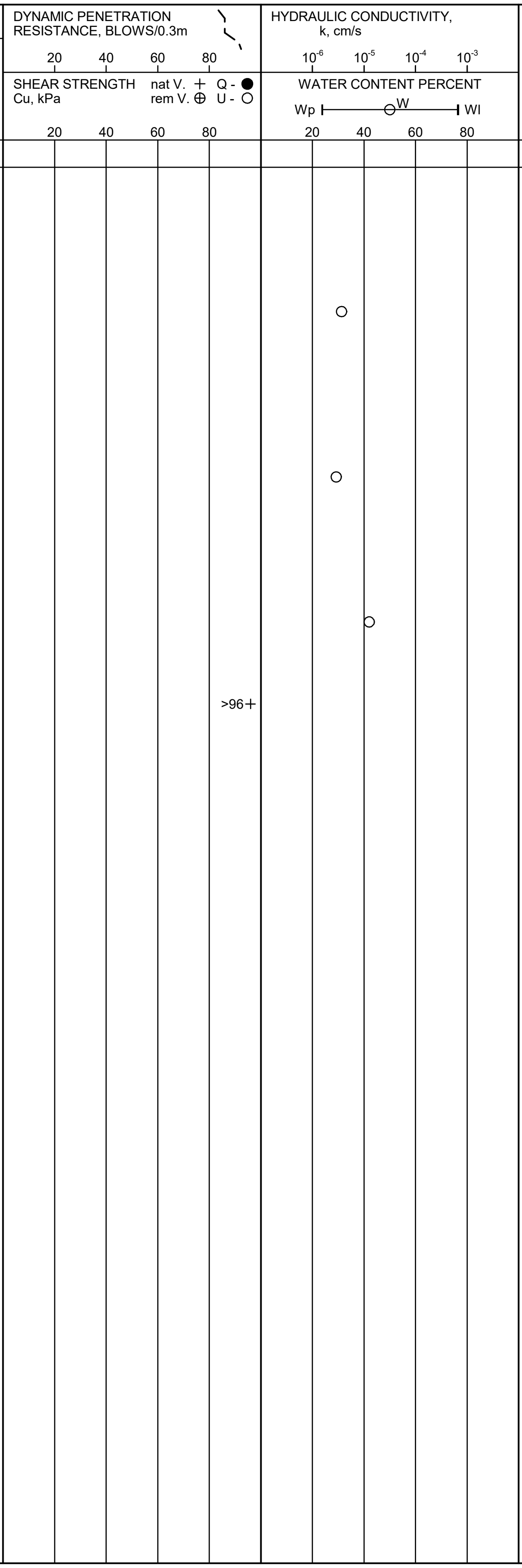
BORING DATE: June 5, 2019

DATUM: Geodetic

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	SHEAR STRENGTH Cu, kPa	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		87.58						
0	Power Auger 200 mm Diam. (Hollow Stem)	TOPSOIL - (CL) SILTY CLAY; dark brown, contains organic matter		0.00						
		(CI/CH) SILTY CLAY; grey brown, fissured, contains silty fine sand seams (WEATHERED CRUST); cohesive, w>~PL, very stiff		87.33 0.25						
1					1	SS	6			
2					2	SS	4			
3					3	SS	5			
4		End of Borehole		83.62 3.96				>96+		
5										
6										
7										
8										
9										
10										



DEPTH SCALE

1 : 50

GOLDER

LOGGED: PAH

CHECKED: AL

PROJECT: 1534482

RECORD OF BOREHOLE: 16-1

SHEET 1 OF 1

LOCATION: See Site Plan

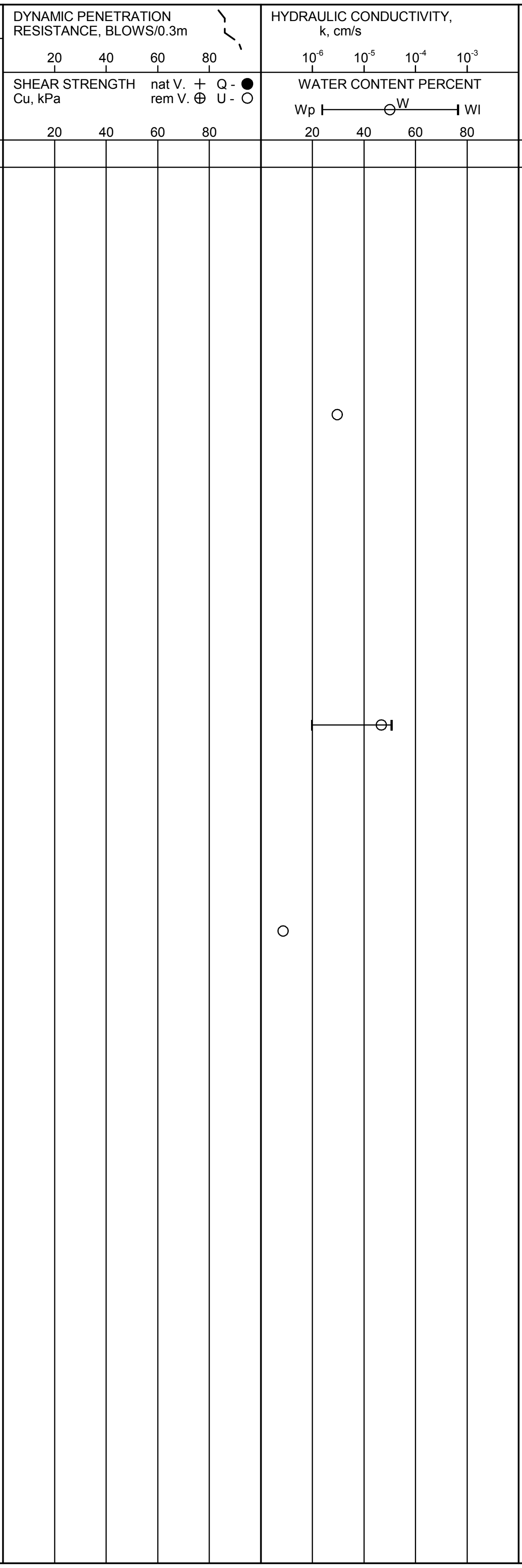
BORING DATE: July 20, 2016

DATUM: Geodetic

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	TYPE	BLOWS/0.30m	PIEZOMETER OR STANDPIPE INSTALLATION
		GROUND SURFACE		85.54				
0	Power Auger 200 mm Diam. (Hollow Stem)	(ML) sandy SILT; brown: non-cohesive, moist, loose		0.00	1	SS	8	Bentonite Seal
		(CI/CH) SILTY CLAY to CLAY; grey brown, contains silty sand seams (WEATHERED CRUST); non-cohesive, w>PL; very stiff		84.93 0.61	2	SS	14	
					3	SS	11	Native Backfill and Bentonite
					4	SS	8	
					5	SS	6	
					6	SS	7	Bentonite Seal
					7	SS	5	Silical Sand
		(ML) sandy SILT, some gravel; grey (GLACIAL TILL); non-cohesive, wet, loose to compact		80.21 5.33	8	SS	10	Standpipe
		End of Borehole		79.44 6.10				WL in Standpipe at Elev. 79.80 m on Aug. 2, 2016



ADDITIONAL LAB. TESTING

DEPTH SCALE

1 : 50

GOLDER

LOGGED: JD

CHECKED: SAT

PROJECT: 1534482

RECORD OF BOREHOLE: 16-2

SHEET 1 OF 1

LOCATION: See Site Plan

BORING DATE: July 21, 2016

DATUM: Geodetic

SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

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

SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)
GROUND SURFACE		87.15
(ML) sandy SILT; brown; non-cohesive, moist, compact	▨	0.00
(CI/CH) SILTY CLAY to CLAY, trace sand; grey brown, contains silty sand seams; cohesive, w>PL, very stiff	▨	86.54 0.61
(CI/CH) SILTY CLAY to CLAY; grey; cohesive, w>PL, stiff	▨	82.58 4.57
End of Borehole		79.23 7.92

SAMPLES NUMBER	TYPE	BLOWS/0.30m
1	SS	11
2	SS	8
3	SS	6
4	SS	4
5	SS	4
6	SS	4
7	SS	WH
8	SS	1
9	SS	4

SHEAR STRENGTH Cu, kPa (nat V. + Q - ● rem V. ⊕ U - ○): vane tests at approx. 5.5 m and 5.8 m depth (rem V. ⊕ and nat V. +); at approx. 7 m: >96+

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m; HYDRAULIC CONDUCTIVITY, k, cm/s; WATER CONTENT PERCENT (Wp, W, Wl); ADDITIONAL LAB. TESTING; PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE 1 : 50

GOLDER

LOGGED: JD

CHECKED: SAT

PROJECT: 1534482

RECORD OF BOREHOLE: 16-3

SHEET 1 OF 1

LOCATION: See Site Plan

BORING DATE: July 20, 2016

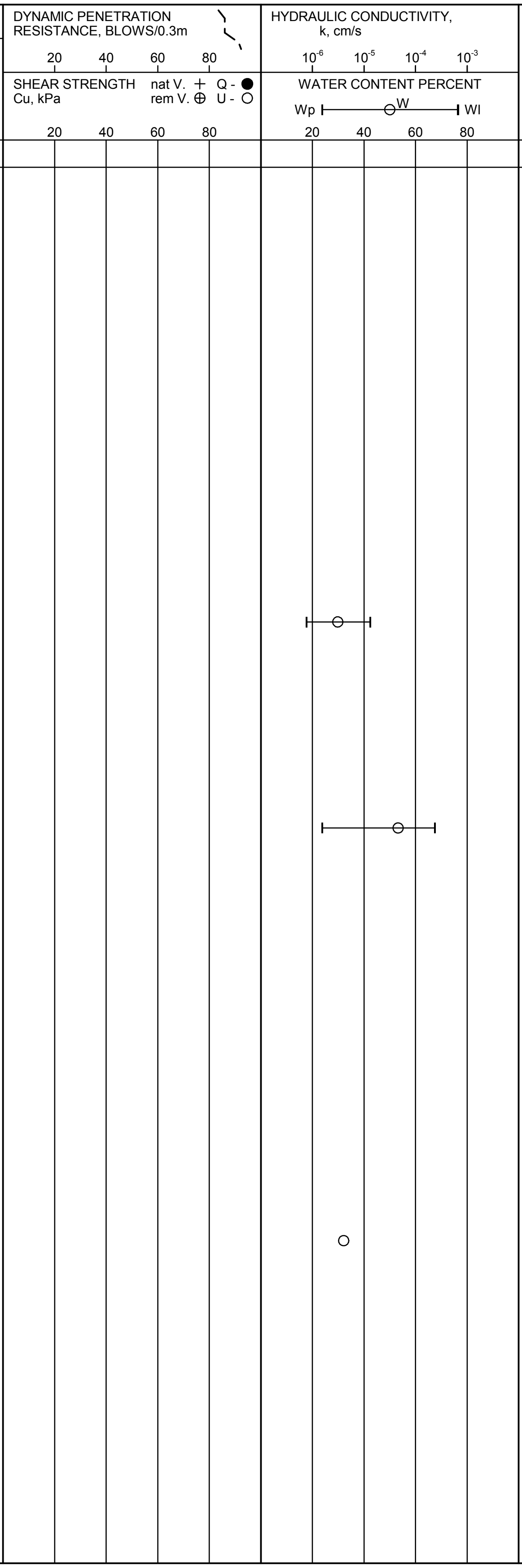
DATUM: Geodetic

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	ADDITIONAL LAB. TESTING
GROUND SURFACE	86.87				
(ML) sandy SILT; brown; non-cohesive, moist, loose	0.00	1	SS	8	
(CI/CH) SILTY CLAY to CLAY; grey brown, contains silty sand seams (WEATHERED CRUST); cohesive, w>PL, very stiff	86.26 0.61	2	SS	8	
		3	SS	8	CHEM
		4	SS	5	
		5	SS	6	
		6	SS	5	
		7	SS	3	
		8	SS	4	
(CI/CH) SILTY CLAY to CLAY; grey; cohesive, w>PL, stiff	80.77 6.10	9	SS	1	
		10	SS	3	
		11	SS	5	
End of Borehole	78.59 8.28				



PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE 1 : 50

GOLDER

LOGGED: JD

CHECKED: SAT

MIS-BHS 001 1534482.GPJ GAL-MIS.GDT 6/18/19 ZS

PROJECT: 1534482

RECORD OF BOREHOLE: 16-4

SHEET 1 OF 1

LOCATION: See Site Plan

BORING DATE: July 20, 2016

DATUM: Geodetic

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	86.57			
TOPSOIL - (SM) SILTY SAND, trace gravel; dark brown; non-cohesive, moist, loose	0.00			
(CI/CH) SILTY CLAY to CLAY; grey brown, contains silty sand seams (WEATHERED CRUST); cohesive, w>PL, very stiff	86.34 0.23	1	SS	7
		2	SS	9
		3	SS	5
		4	SS	5
		5	SS	6
		6	SS	4
		7	SS	4
(SP/GP) SAND and GRAVEL; grey brown; non-cohesive	80.93 5.66	8	SS	10
(CI/CH) SILTY CLAY to CLAY; grey brown, contains silty sand seams (WEATHERED CRUST); cohesive, w>PL, very stiff				
(CI/CH) SILTY CLAY to CLAY; grey; cohesive, w>PL, stiff	80.47 6.10	9	SS	2
End of Borehole	79.25 7.32			

SHEAR STRENGTH Cu, kPa (nat V. + Q - ● ; rem V. ⊕ U - ○):

DEPTH (m)	rem V.	nat V.
7.0	⊕	+
7.3		>96+

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m: 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

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

MIS-BHS 001 1534482.GPJ GAL-MIS.GDT 6/18/19 ZS

DEPTH SCALE

1 : 50

GOLDER

LOGGED: JD

CHECKED: SAT

PROJECT: 1534482

RECORD OF BOREHOLE: 16-5

SHEET 1 OF 1

LOCATION: See Site Plan

BORING DATE: July 20, 2016

DATUM: Geodetic

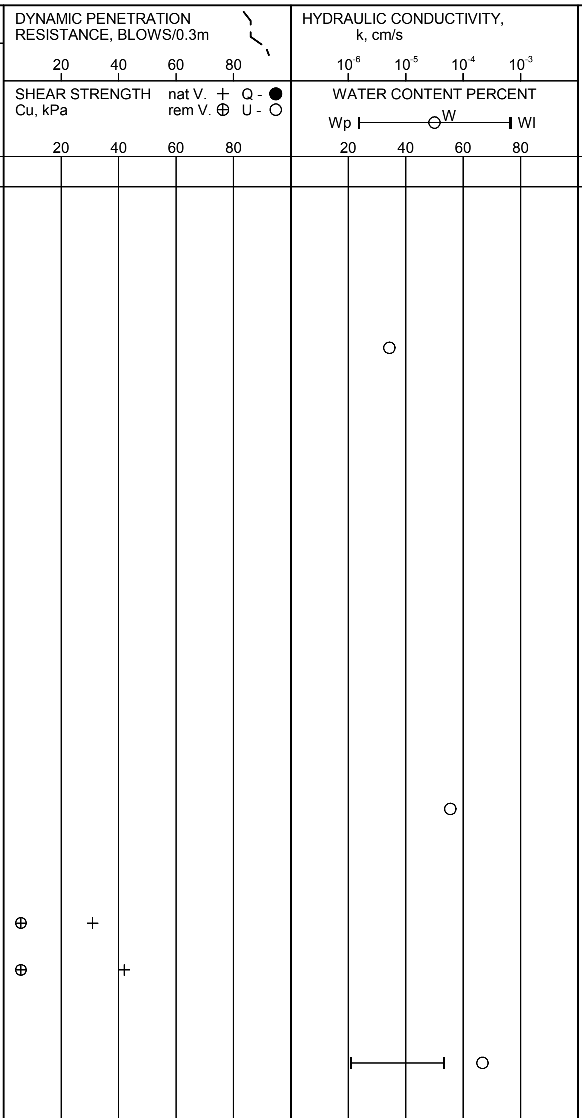
SAMPLER HAMMER, 64kg; DROP, 760mm

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

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

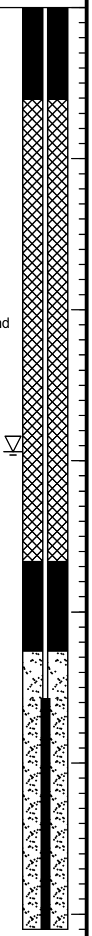
SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)
GROUND SURFACE		86.71
(SM) SILTY SAND, trace clay; grey brown; non-cohesive, moist, loose	▨	0.00
(CI/CH) SILTY CLAY to CLAY; grey brown, contains silty sand seams (WEATHERED CRUST); cohesive, w>PL, very stiff to stiff	▨	86.10 0.61
(CI/CH) SILTY CLAY to CLAY, trace sand; grey; cohesive, w>PL, firm	▨	82.90 3.81
End of Borehole		80.61 6.10

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



ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION



WL in Standpipe at Elev. 83.77 m on Aug. 2, 2016

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

DEPTH SCALE
1 : 50

GOLDER

LOGGED: JD
CHECKED: SAT

PROJECT: 1534482

RECORD OF BOREHOLE: 16-6

SHEET 1 OF 1

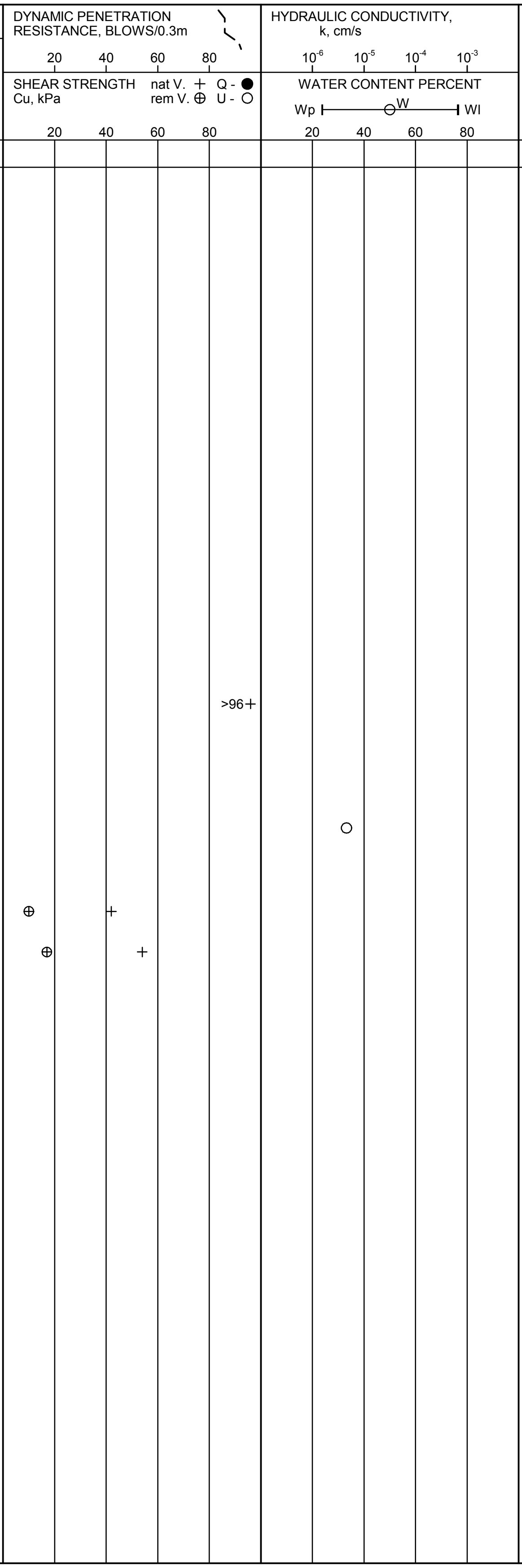
LOCATION: See Site Plan
BORING DATE: July 21, 2016
DATUM: Geodetic

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)
	GROUND SURFACE	88.42
0	TOPSOIL - (ML) sandy SILT; dark brown; non-cohesive, moist	0.00
	(ML) sandy SILT; brown; non-cohesive, moist, loose	88.12 0.30
	(CI/CH) SILTY CLAY to CLAY; grey brown, contains silty sand seams (WEATHERED CRUST); cohesive, w>PL, very stiff to stiff	87.81 0.61
4	(CI/CH) SILTY CLAY to CLAY; grey; cohesive, w>PL, firm to stiff	84.46 3.96
	End of Borehole	82.62 5.80

NUMBER	TYPE	BLOWS/0.30m
1	SS	10
2	SS	8
3	SS	4
4	SS	3
5	SS	2
6	SS	1



ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE
1 : 50

GOLDER

LOGGED: JD
CHECKED: SAT

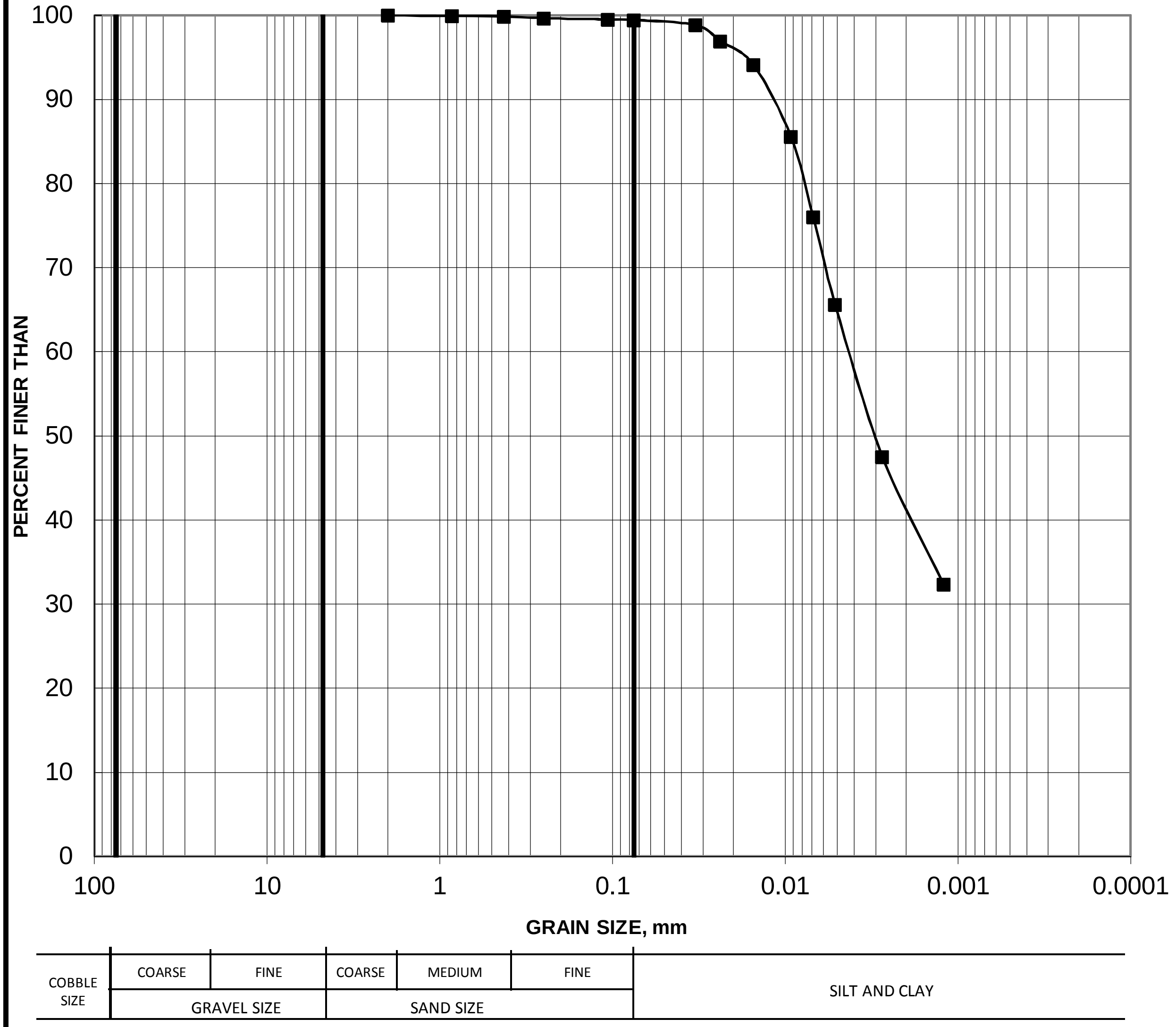
APPENDIX B

Results of Laboratory Testing

GRAIN SIZE DISTRIBUTION

B-1

SILTY CLAY



Borehole	Sample	Depth (m)	Constituents (%) Gravel	Sand	Silt	Clay
—■— 19-01	8	7.62-8.23	0	1	59	40

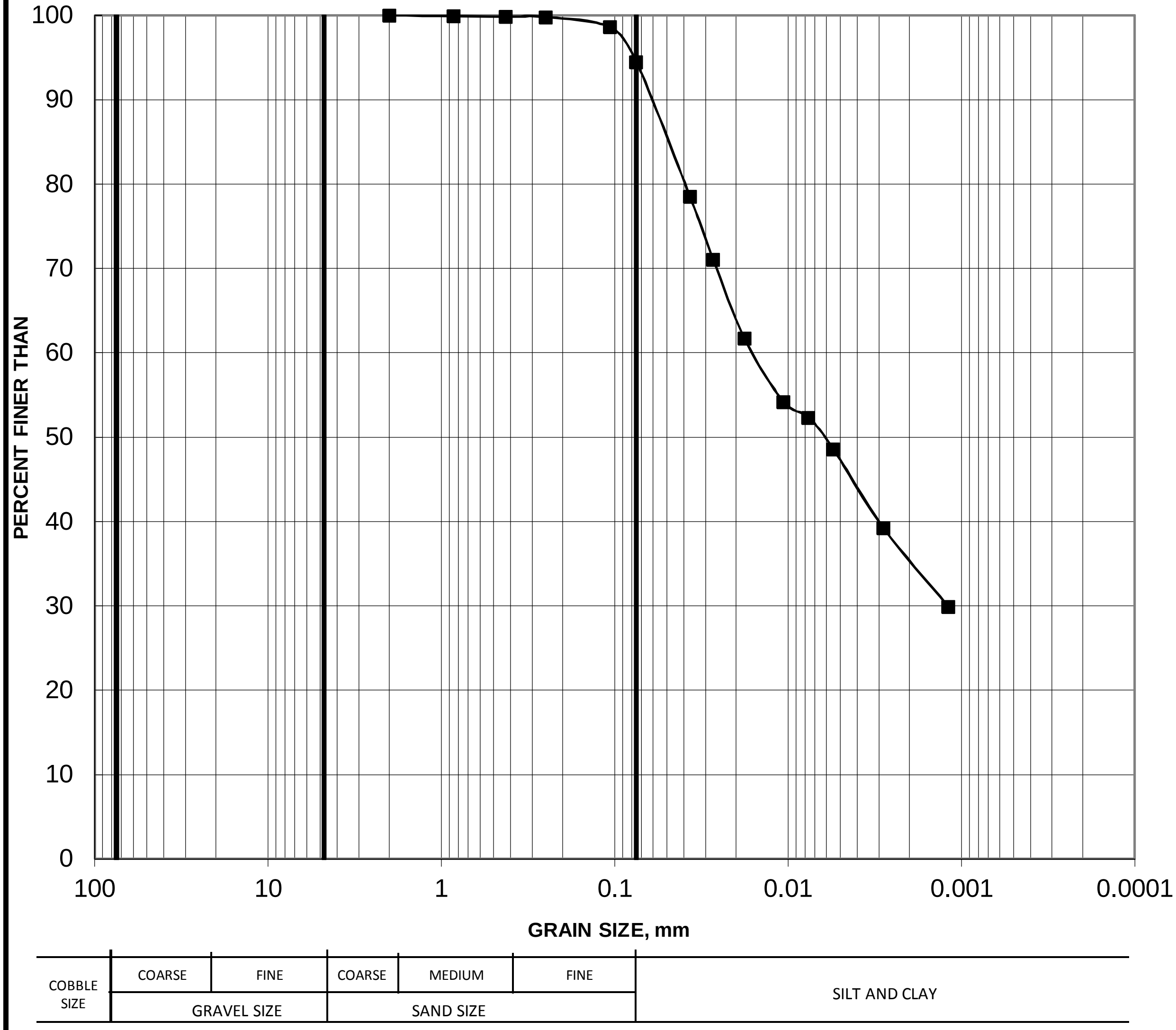
Created by: PJ
Checked by: MI

Project: 1534482

Golder Associates

GRAIN SIZE DISTRIBUTION

SILTY CLAY



Borehole	Sample	Depth (m)	Constituents (%) Gravel	Sand	Silt	Clay
■ 19-05	2	1.98-2.59	0	6	60	35

Project: 1534482

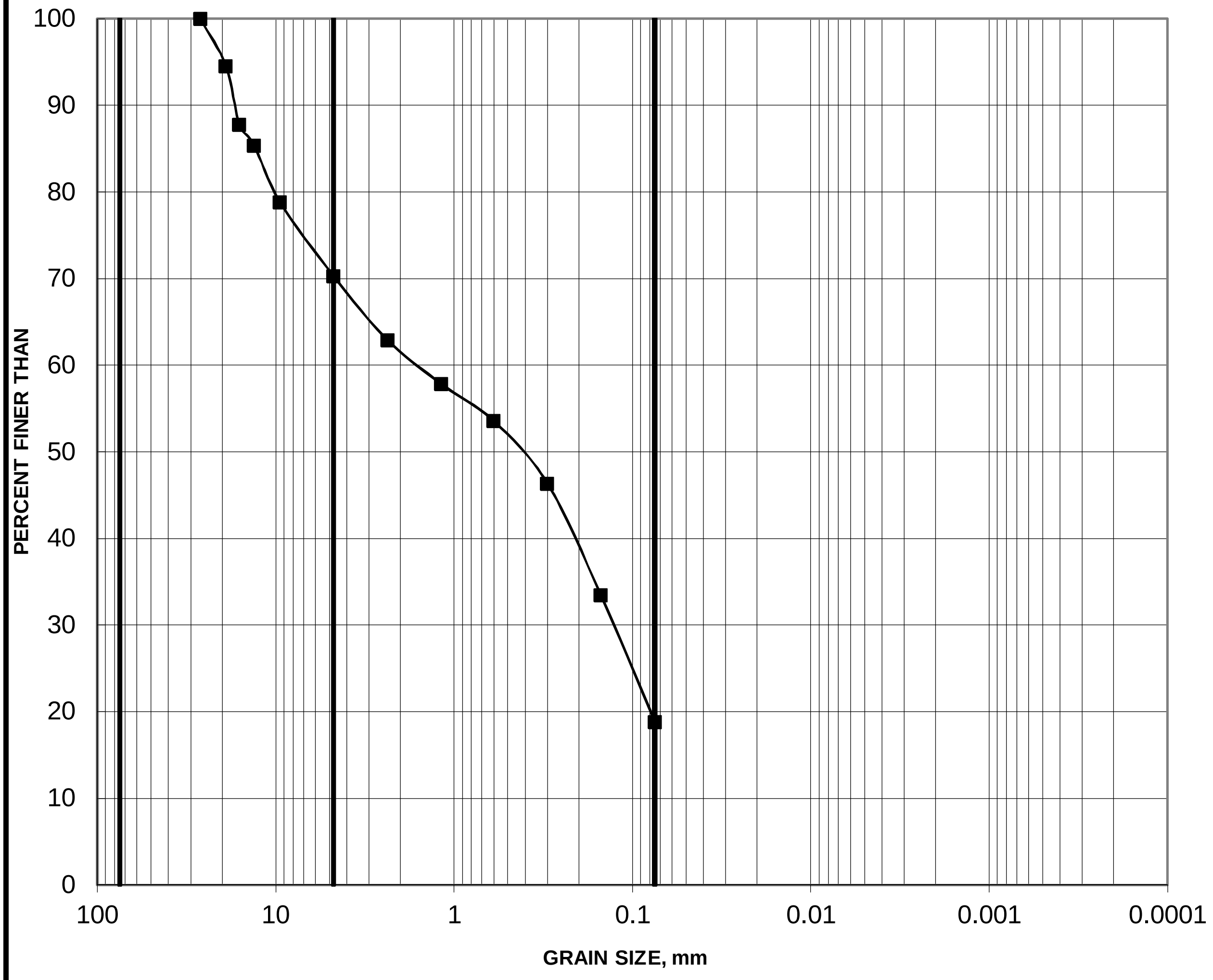
Golder Associates

Created by: PJ
Checked by: MI

GRAIN SIZE DISTRIBUTION

B-3

GLACILA TILL



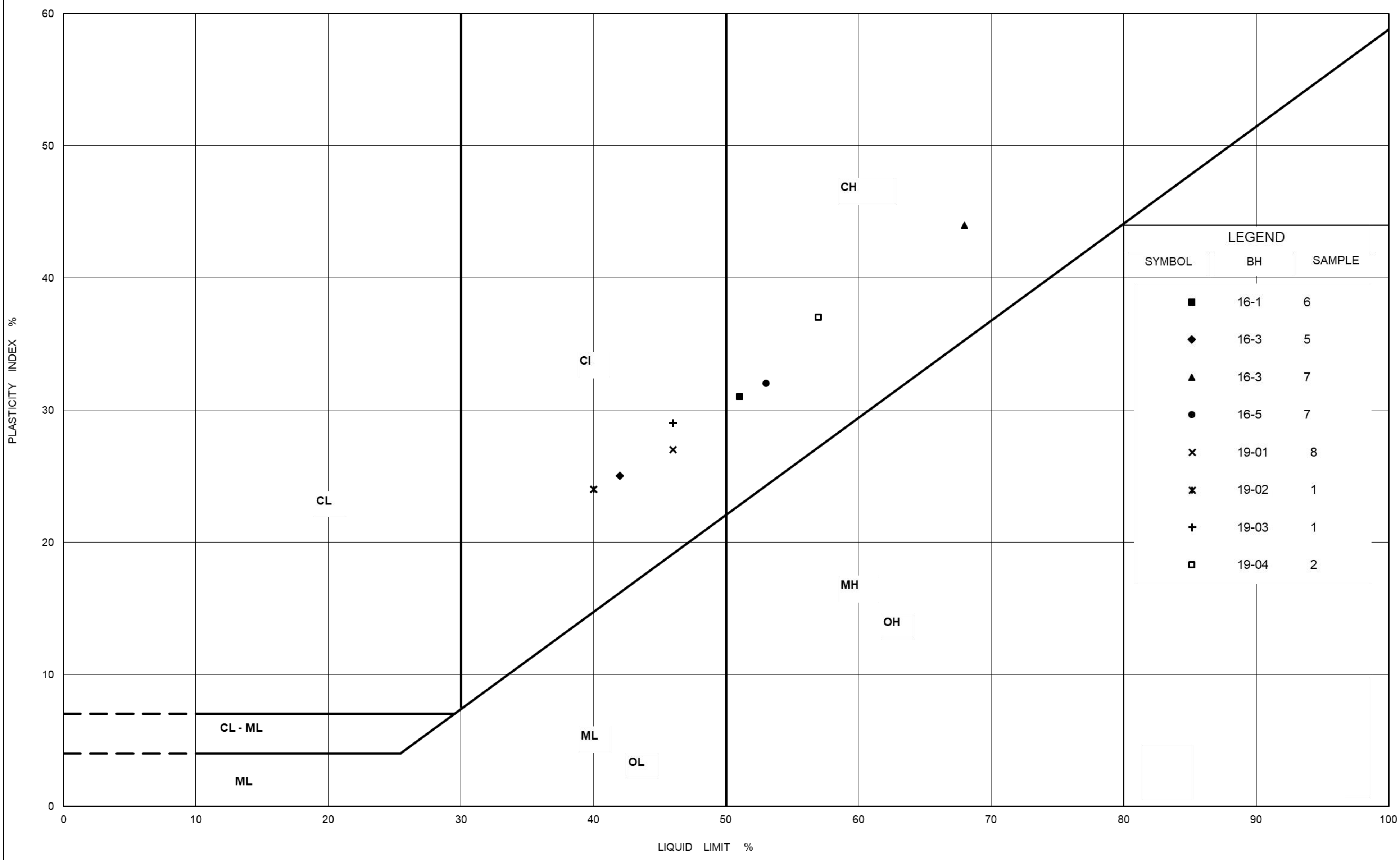
COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY
	GRAVEL SIZE		SAND SIZE			

Borehole	Sample	Depth (m)	Constituents (%) Gravel	Sand	Fines
■ 19-01	11	10.67-11.28	30	52	19

Project: 1534482

Golder Associates

Created by: PJ
Checked by: MI



GOLDER

PLASTICITY CHART

Figure : B-4

Project No.: 1534482

Compiled By : ____ Checked By :_AG__

GOLDER

SHRINKAGE LIMIT DETERMINATIONS
ASTM D4943

Borehole Number	19-05	
Sample Number	2	
Depth, m	1.98-2.59	
Shrinkage Dish Number	1	2
Mass of the dry soil pat, g	18.09	18.24
Mass of dry soil pat + shrinkage dish, g	41.27	40.49
Mass of shrinkage dish, g	23.18	22.25
Volume of shrinkage dish, cm^3	13.40	13.33
Mass of wet soil + shrinkage dish, g	48.01	47.28
Moisture content of the soil	37.26	37.23
Mass of dry soil pat before waxing, g	18.09	18.24
Volume of dry soil pat + wax, cm^3	13.21	13.68
Mass of dry soil pat + wax in air, g	21.64	22.26
Mass of dry soil pat + wax in water, g	8.43	8.58
Mass of wax, g	3.55	4.02
Volume of wax, cm^3	3.84	4.35
Specific gravity of wax	0.925	0.925
Volume of dry soil pat, cm^3	9.37	9.33
SHRINKAGE LIMIT, SL	**14.99**	**15.32**
SHRINKAGE RATIO, R	**1.93**	**1.95**

Project Number:	1534482	Date Tested:	June 25, 2019
Project Name:	Regional/Nichols Lock Prop/Ontario	Tested By:	XM

Notes:

Test carried out using wax method (Microsere Wax 5214)

Checked By:

APPENDIX C

Results of Chemical Analysis

Certificate of Analysis

Client: Golder Associates Ltd. (Ottawa)
1931 Robertson Road
Ottawa, ON
K2H 5B7
Attention: Ms. Susan Trickey
PO#:
Invoice to: Golder Associates Ltd. (Ottawa)

Report Number: 1614317
Date Submitted: 2016-08-15
Date Reported: 2016-08-19
Project: 1534482
COC #: 810923

				Lab I.D.	1255695
				Sample Matrix	Soil
				Sample Type	
				Sampling Date	2016-07-20
				Sample I.D.	BH 16-3 SA 3
Group	**Analyte**	**MRL**	**Units**	**Guideline**	
Agri. - Soil	pH	2.0			7.6
General Chemistry	Cl	0.002	%		0.002
	Electrical Conductivity	0.05	mS/cm		0.12
	Resistivity	1	ohm-cm		8330
	SO4	0.01	%		<0.01

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

EXOVA ENVIRONMENTAL ONTARIO

Certificate of Analysis

Client: Golder Associates Ltd. (Ottawa)
1931 Robertson Road
Ottawa, ON
K2H 5B7
Attention: Ms. Susan Trickey
PO#:
Invoice to: Golder Associates Ltd. (Ottawa)

Report Number: 1614317
Date Submitted: 2016-08-15
Date Reported: 2016-08-19
Project: 1534482
COC #: 810923

				Lab I.D.	1255695
				Sample Matrix	Soil
				Sample Type	
				Sampling Date	2016-07-20
				Sample I.D.	BH 16-3 SA 3
Group	**Analyte**	**MRL**	**Units**	**Guideline**	
Agri. - Soil	pH	2.0			7.6
General Chemistry	Cl	0.002	%		0.002
	Electrical Conductivity	0.05	mS/cm		0.12
	Resistivity	1	ohm-cm		8330
	SO4	0.01	%		<0.01

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

APPENDIX D

Site Reconnaissance Photographs

Photo D-1: Northern Slopes; cross-section A-A'; looking toward northwest

Photo D-2: Northern Slopes; cross-section B-B'; looking toward north

Photo D-3: Northern Slopes; cross-section C-C’; looking toward southeast

Photo D-4: Northern Slopes; cross-section D-D’; looking toward northwest

Photo D-5: Northern Slopes; gully connection to the creek; looking toward southeast

Photo D-6: Northern Slopes; cross-section E-E’; looking toward east

Photo D-7: Northern Slopes; cross-section F-F’; looking toward east

Photo D-8: Northern Slopes; cross-section G-G’; looking toward northeast

Photo D-9: Western Slopes; cross-section H-H’; looking toward northeast

Photo D-10: Western Slopes; cross-section I-I’; looking toward northeast

Photo D-11: Western Slopes; cross-section J-J'; looking toward northeast

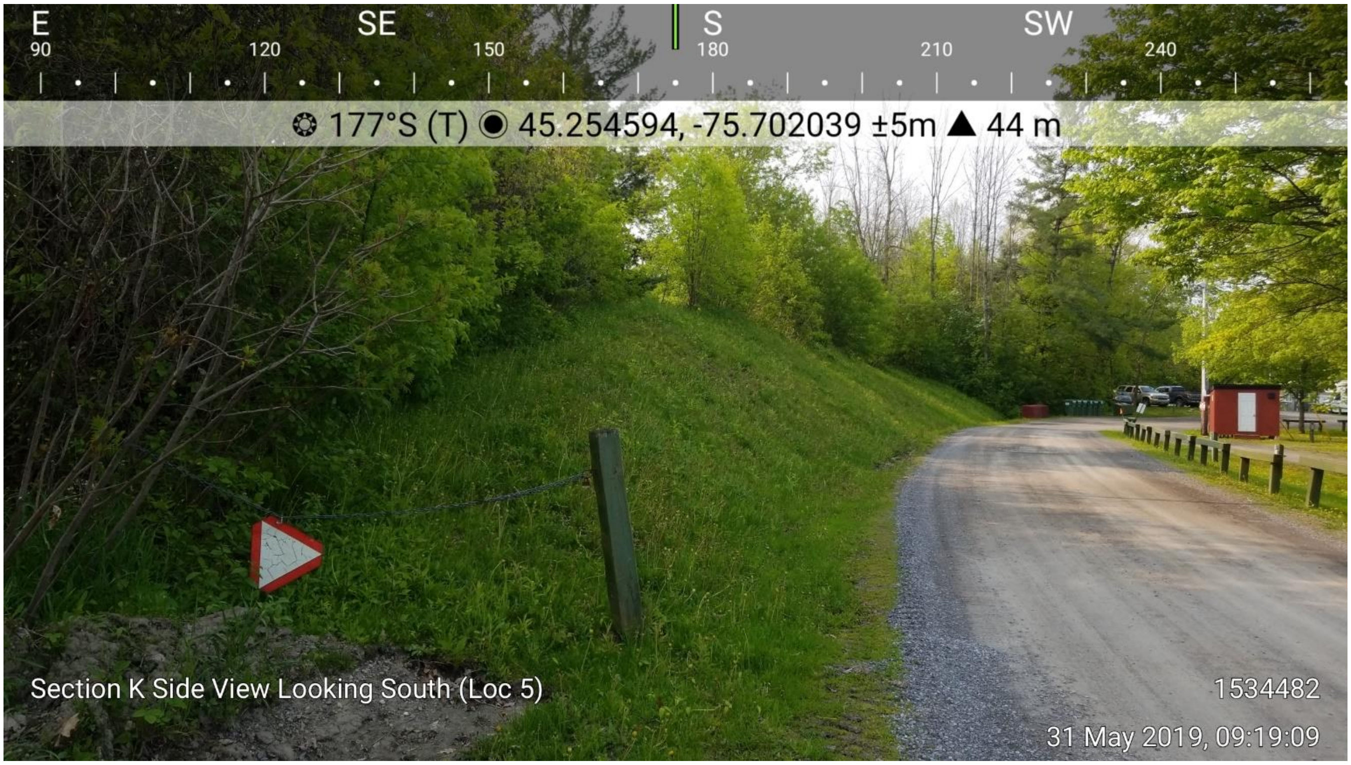
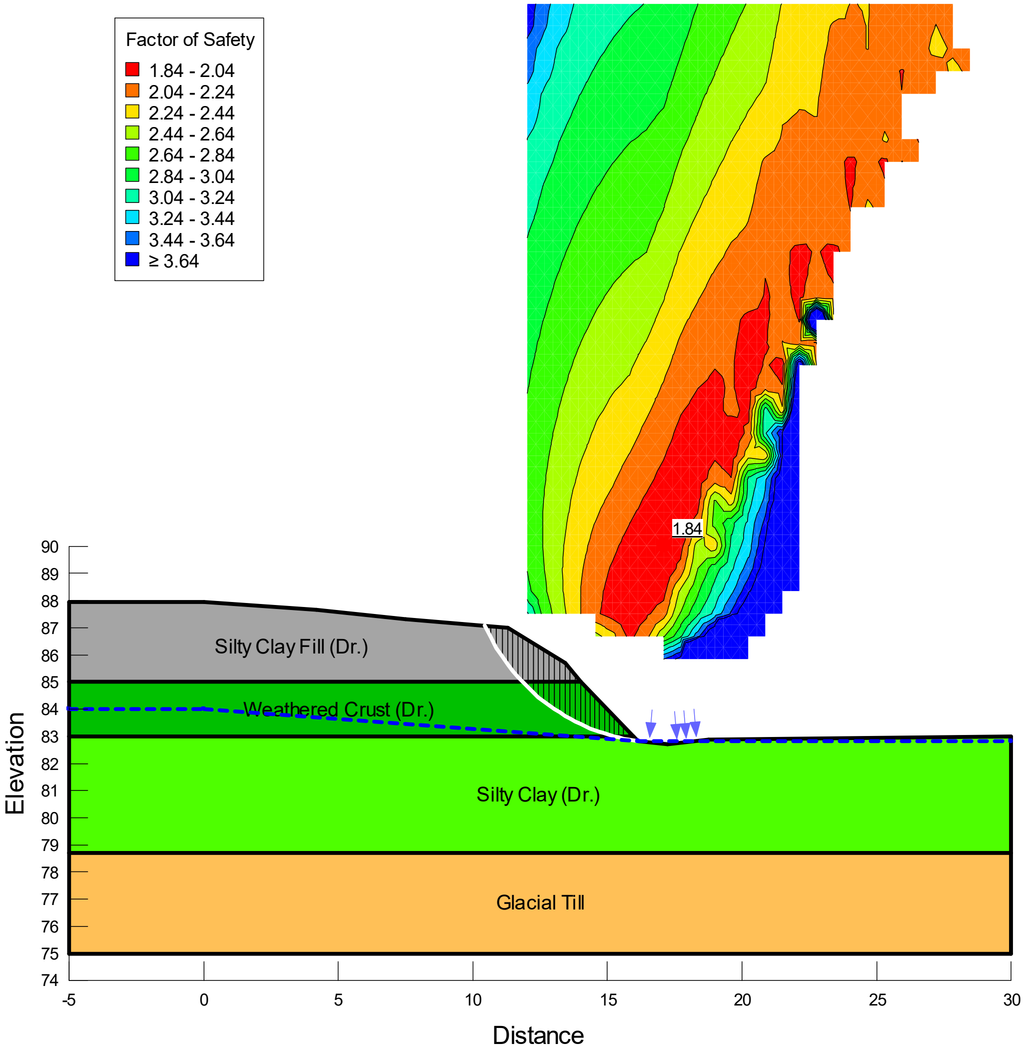


Photo D-12: Western Slopes; cross-section K-K'; looking toward south

APPENDIX E

Slope Stability Results



File Name: 1534482_2019_SectionAA_AG.gsz
Title: 1534482 Slope Analyses
Name: Section AA - Drained Flat Radius
Method: Morgenstern-Price
Direction of movement: Left to Right
Horz Seismic Load:

Groundwater Elevation of 84.0 Metres Down to Creek
Minimum Slip Surface Depth of 1.0 Metres

Color	**Name**	**Model**	**Unit Weight (kN/m³)**	**Cohesion' (kPa)**	**Phi' (°)**
🟧	Glacial Till	Mohr-Coulomb	21	0	36
🟩	Silty Clay (Dr.)	Mohr-Coulomb	16.5	7.5	32
⬜	Silty Clay Fill (Dr.)	Mohr-Coulomb	17.5	7.5	28
🟩	Weathered Crust (Dr.)	Mohr-Coulomb	17.5	7.5	36

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Slope Stability Assessment - Drained (cross-section A-A')

Wright Lands - Northern Slopes

Ottawa, Ontario

Project No.	1534482
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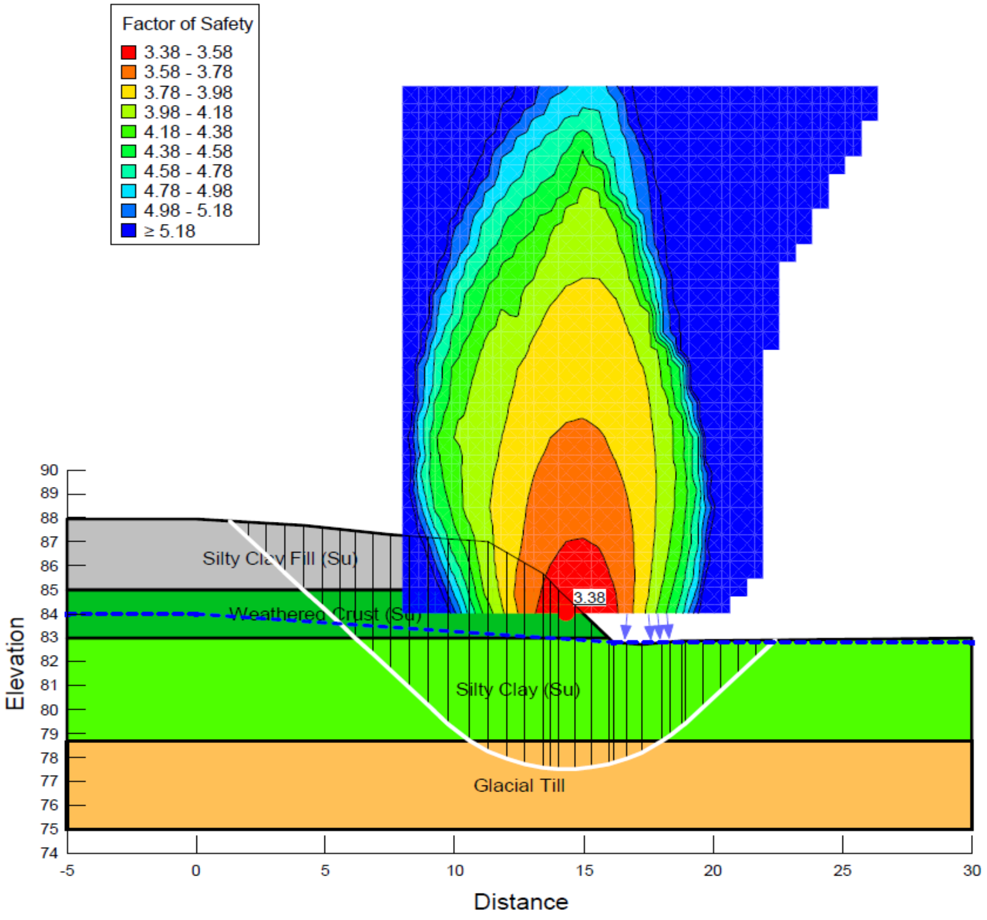
Date:	2020-02-27
Checked:	AG
Review:	MSS

Figure E-1



File Name: 1534482_2019_SectionAA_AG.gsz
Title: 1534482 Slope Analyses
Name: Section AA - Undrained
Method: Morgenstern-Price
Direction of movement: Left to Right
Horz Seismic Load:

Groundwater Elevation of 84.0 Metres Down to Creek
Minimum Slip Surface Depth of 1.0 Metres

Color	**Name**	**Model**	**Unit Weight (kN/m³)**	**Cohesion (kPa)**	**Cohesion' (kPa)**	**Phi' (°)**
🟧	Glacial Till	Mohr-Coulomb	21		0	36
🟩	Silty Clay (Su)	Undrained (Phi=0)	16.5	55		
⬜	Silty Clay Fill (Su)	Undrained (Phi=0)	17.5	70		
🟩	Weathered Crust (Su)	Undrained (Phi=0)	17.5	80		

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Slope Stability Assessment - Undrained (cross-section A-A')

Wright Lands - Northern Slopes

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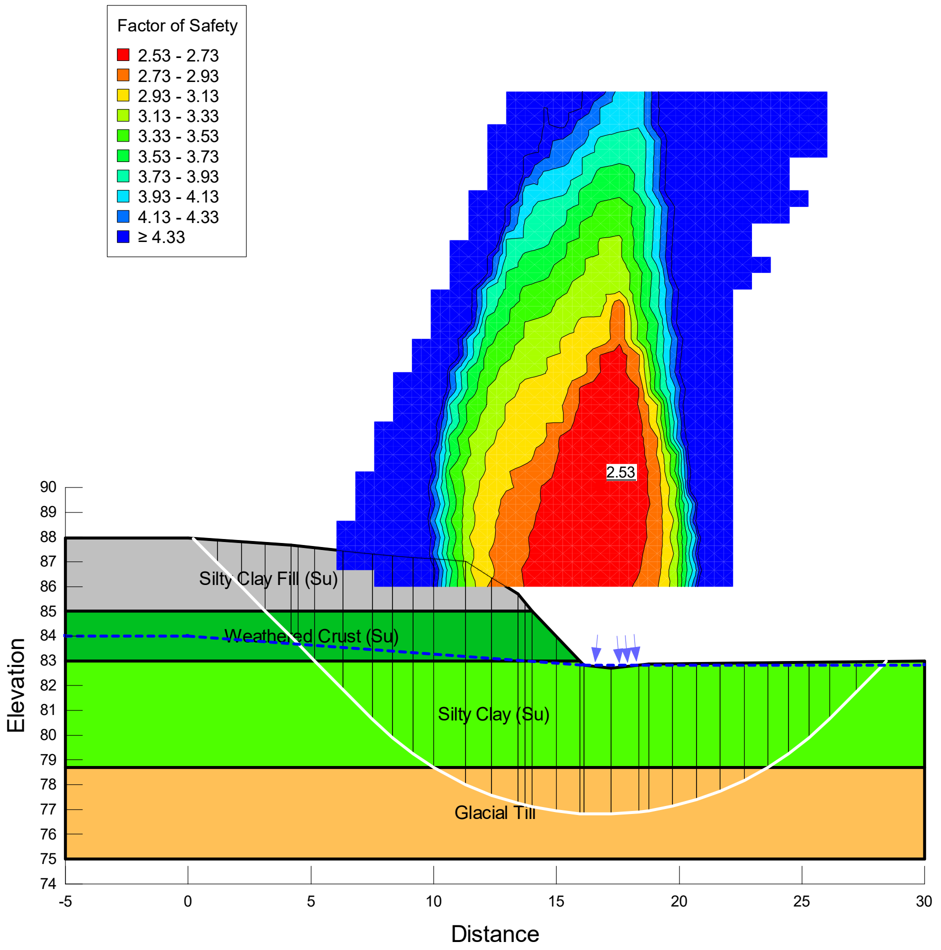
Figure E-2



File Name: 1534482_2019_SectionAA_AG.gsz
Title: 1534482 Slope Analyses
Name: Section AA - Undrained Seismic
Method: Morgenstern-Price
Direction of movement: Left to Right
Horz Seismic Load: 0.14

Groundwater Elevation of 84.0 Metres Down to Creek
Minimum Slip Surface Depth of 1.0 Metres

Color	Name	Model	Unit Weight (kN/m³)	Cohesion (kPa)	Cohesion' (kPa)	Phi' (°)
🟧	Glacial Till	Mohr-Coulomb	21		0	36
🟩	Silty Clay (Su)	Undrained (Phi=0)	16.5	55		
⬜	Silty Clay Fill (Su)	Undrained (Phi=0)	17.5	70		
🟩	Weathered Crust (Su)	Undrained (Phi=0)	17.5	80		

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Slope Stability Assessment - Seismic (cross-section A-A')

Wright Lands - Northern Slopes

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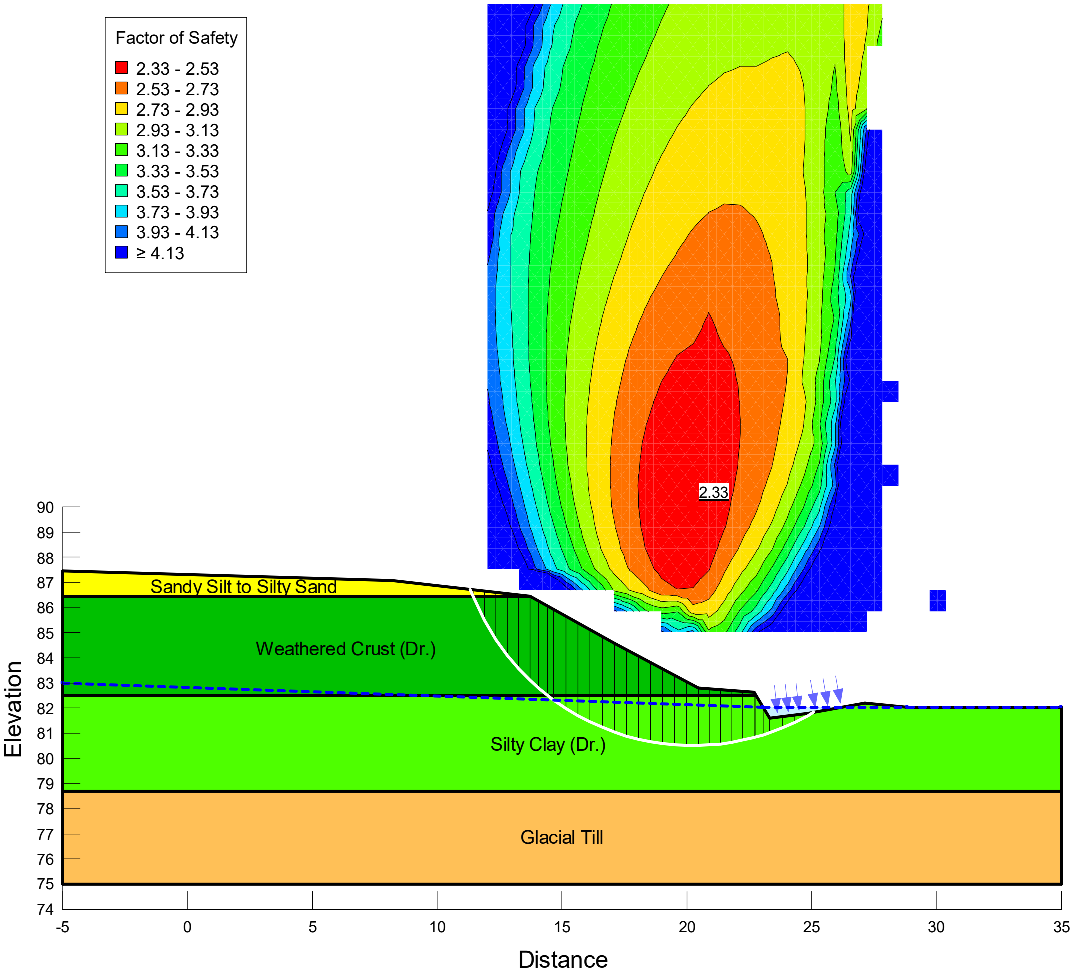
Figure E-3



File Name: 1534482_2019_SectionCC_AG.gsz
Title: 1534482 Slope Analyses
Name: Section CC - Drained Flat Radius
Method: Morgenstern-Price
Direction of movement: Left to Right
Horz Seismic Load:

Groundwater Elevation of 83.0 Metres Down to Creek
Minimum Slip Surface Depth of 1.0 Metres

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟧	Glacial Till	Mohr-Coulomb	21	0	36
🟨	Sandy Silt to Silty Sand	Mohr-Coulomb	17.5	0	34
🟩	Silty Clay (Dr.)	Mohr-Coulomb	16.5	7.5	32
🟩	Weathered Crust (Dr.)	Mohr-Coulomb	17.5	7.5	36

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Slope Stability Assessment - Drained (cross-section C-C')

Wright Lands - Northern Slopes

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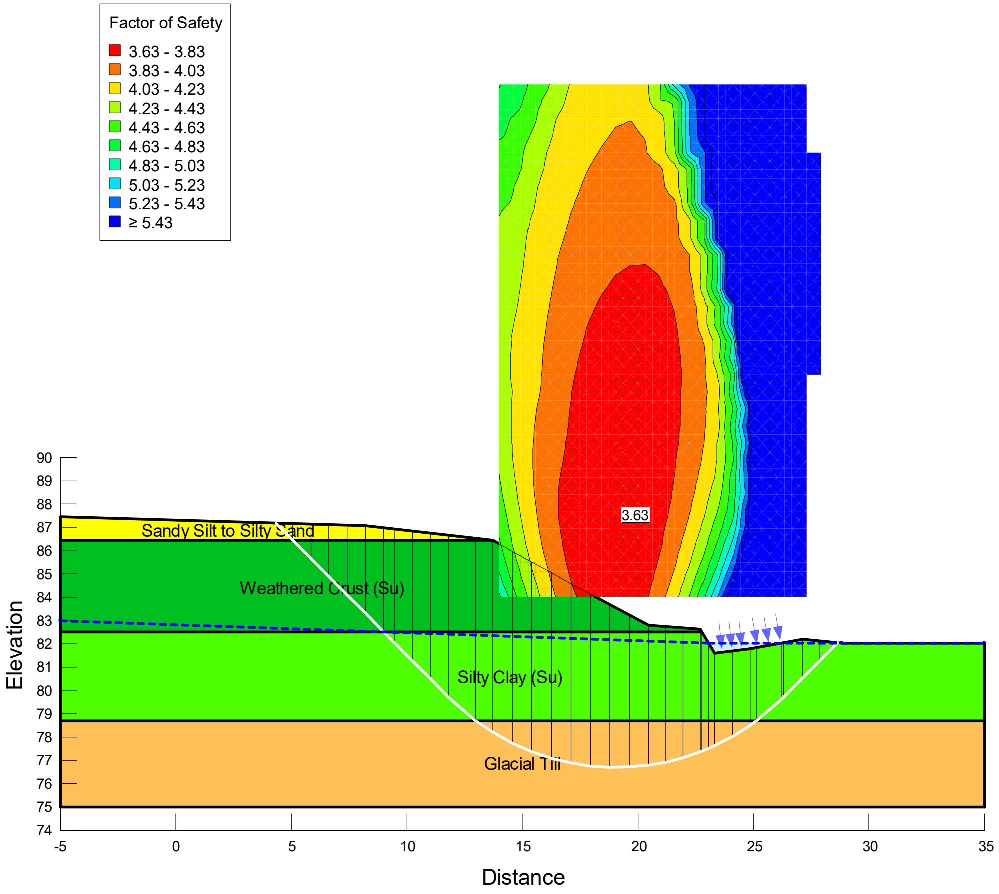
Figure E-4



File Name: 1534482_2019_SectionCC_AG.gsz
Title: 1534482 Slope Analyses
Name: Section CC - Undrained
Method: Morgenstern-Price
Direction of movement: Left to Right
Horz Seismic Load:

Groundwater Elevation of 83.0 Metres Down to Creek
Minimum Slip Surface Depth of 1.0 Metres

Color	Name	Model	Unit Weight (kN/m³)	Cohesion (kPa)	Cohesion' (kPa)	Phi' (°)
🟧	Glacial Till	Mohr-Coulomb	21		0	36
🟨	Sandy Silt to Silty Sand	Mohr-Coulomb	17.5		0	34
🟩	Silty Clay (Su)	Undrained (Phi=0)	16.5	55		
🟩	Weathered Crust (Su)	Undrained (Phi=0)	17.5	80		

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Slope Stability Assessment - Undrained (cross-section C-C')

Wright Lands - Northern Slopes

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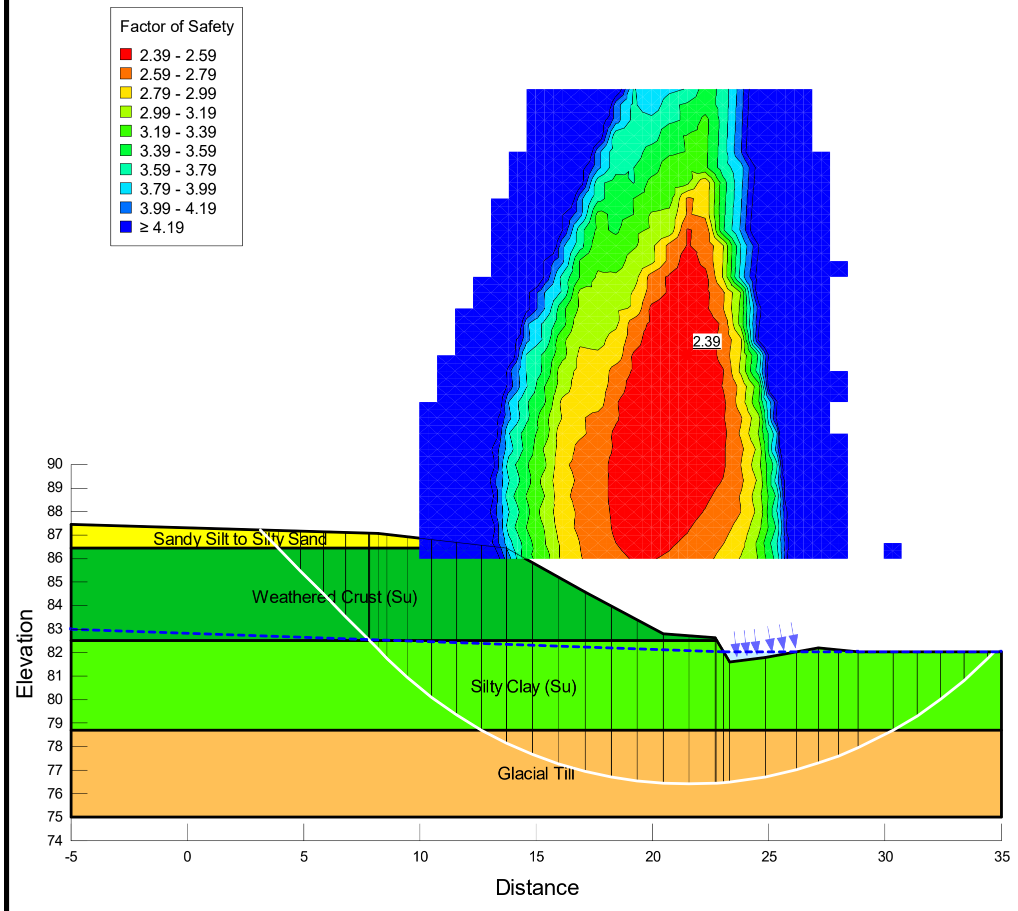
Review:	MSS

Figure E-5



File Name: 1534482_2019_SectionCC_AG.gsz
Title: 1534482 Slope Analyses
Name: Section CC - Undrained Seismic
Method: Morgenstern-Price
Direction of movement: Left to Right
Horz Seismic Load: 0.14

Groundwater Elevation of 83.0 Metres Down to Creek
Minimum Slip Surface Depth of 1.0 Metres

Color	Name	Model	Unit Weight (kN/m³)	Cohesion (kPa)	Cohesion' (kPa)	Phi' (°)
🟧	Glacial Till	Mohr-Coulomb	21		0	36
🟨	Sandy Silt to Silty Sand	Mohr-Coulomb	17.5		0	34
🟩	Silty Clay (Su)	Undrained (Phi=0)	16.5	55		
🟩	Weathered Crust (Su)	Undrained (Phi=0)	17.5	80		

Slope Stability Assessment - Seismic (cross-section C-C')

Wright Lands - Northern Slopes

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Project No.	1534482
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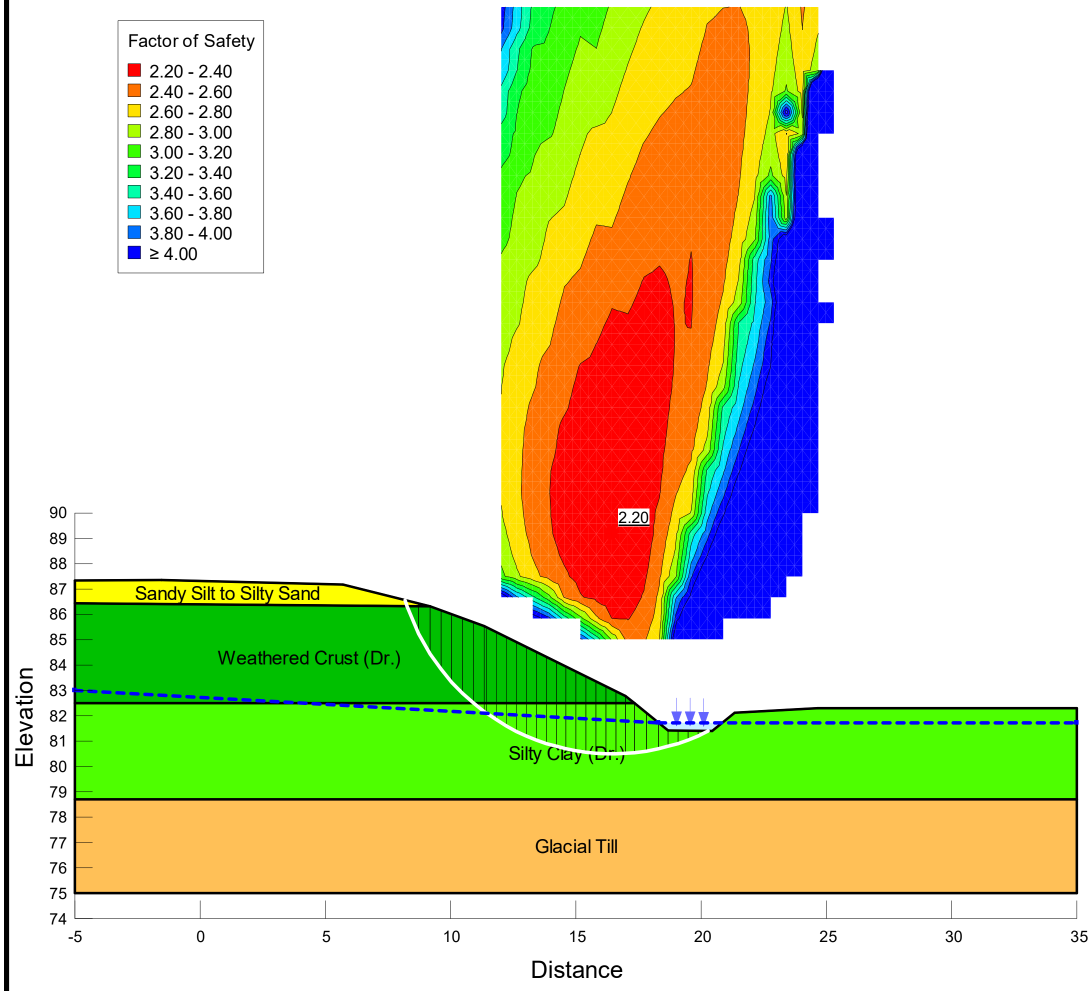
Date:	2020-02-27
Checked:	AG
Review:	MSS

Figure E-6



File Name: 1534482_2019_SectionDD_AG.gsz
Title: 1534482 Slope Analyses
Name: Section DD - Drained Flat Radius
Method: Morgenstern-Price
Direction of movement: Left to Right
Horz Seismic Load:

Groundwater Elevation of 83.0 Metres Down to Creek
Minimum Slip Surface Depth of 1.0 Metres

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟧	Glacial Till	Mohr-Coulomb	21	0	36
🟨	Sandy Silt to Silty Sand	Mohr-Coulomb	17.5	0	34
🟩	Silty Clay (Dr.)	Mohr-Coulomb	16.5	7.5	32
🟩	Weathered Crust (Dr.)	Mohr-Coulomb	17.5	7.5	36

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Slope Stability Assessment - Drained (cross-section D-D')

Wright Lands - Northern Slopes

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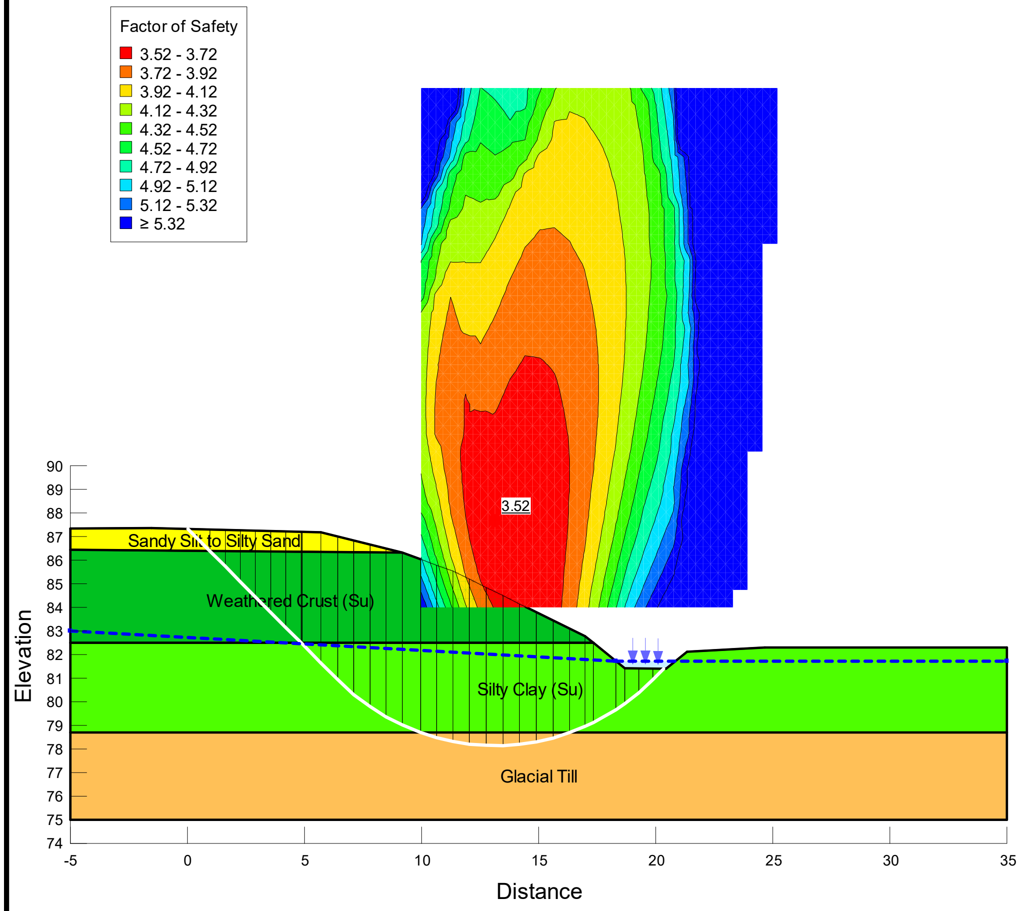
Date:	2020-02-27
Checked:	AG
Review:	MSS

Figure E-7



File Name: 1534482_2019_SectionDD_AG.gsz
Title: 1534482 Slope Analyses
Name: Section DD - Undrained
Method: Morgenstern-Price
Direction of movement: Left to Right
Horz Seismic Load:

Groundwater Elevation of 83.0 Metres Down to Creek
Minimum Slip Surface Depth of 1.0 Metres

Color	Name	Model	Unit Weight (kN/m³)	Cohesion (kPa)	Cohesion' (kPa)	Phi' (°)
🟧	Glacial Till	Mohr-Coulomb	21		0	36
🟨	Sandy Silt to Silty Sand	Mohr-Coulomb	17.5		0	34
🟩	Silty Clay (Su)	Undrained (Phi=0)	16.5	55		
🟩	Weathered Crust (Su)	Undrained (Phi=0)	17.5	80		

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Slope Stability Assessment - Undrained (cross-section D-D')

Wright Lands - Northern Slopes

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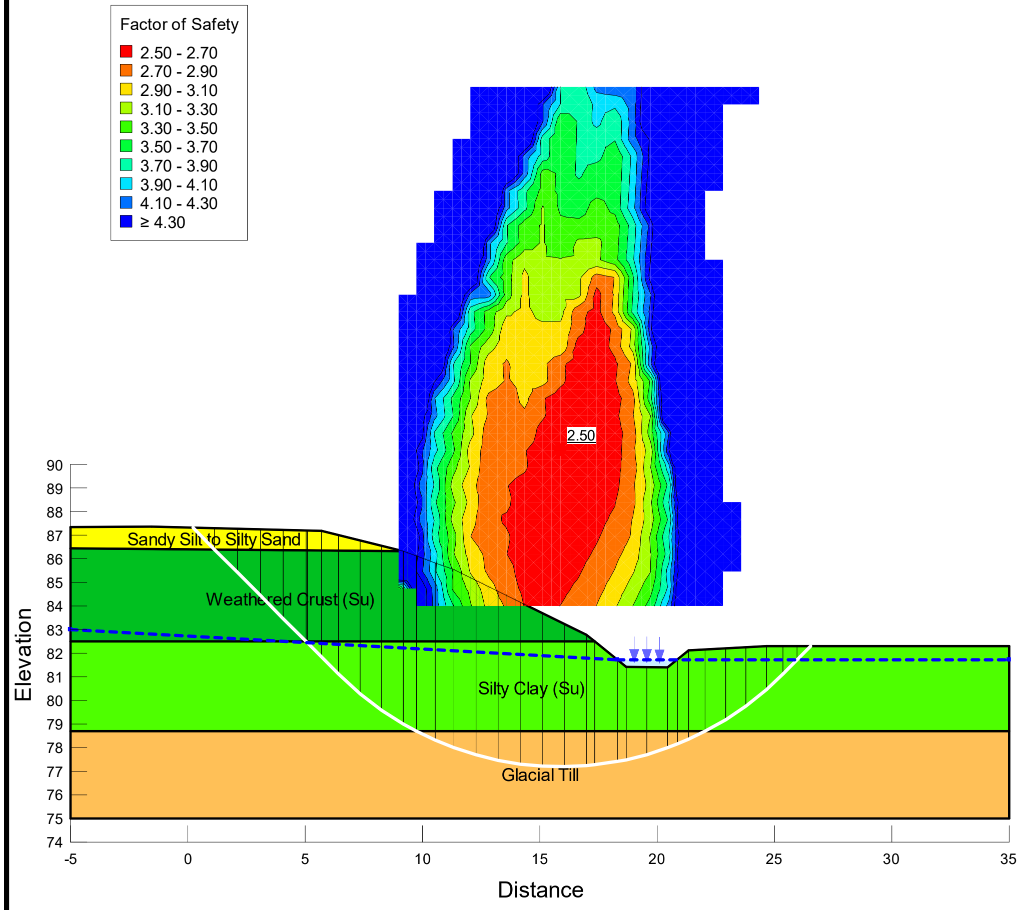
Date:	2020-02-27
Checked:	AG
Review:	MSS

Figure E-8



File Name: 1534482_2019_SectionDD_AG.gsz
Title: 1534482 Slope Analyses
Name: Section DD - Undrained Seismic
Method: Morgenstern-Price
Direction of movement: Left to Right
Horz Seismic Load: 0.14

Groundwater Elevation of 83.0 Metres Down to Creek
Minimum Slip Surface Depth of 1.0 Metres

Color	Name	Model	Unit Weight (kN/m³)	Cohesion (kPa)	Cohesion' (kPa)	Phi' (°)
🟧	Glacial Till	Mohr-Coulomb	21		0	36
🟨	Sandy Silt to Silty Sand	Mohr-Coulomb	17.5		0	34
🟩	Silty Clay (Su)	Undrained (Phi=0)	16.5	55		
🟩	Weathered Crust (Su)	Undrained (Phi=0)	17.5	80		

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Slope Stability Assessment - Seismic (cross-section D-D')

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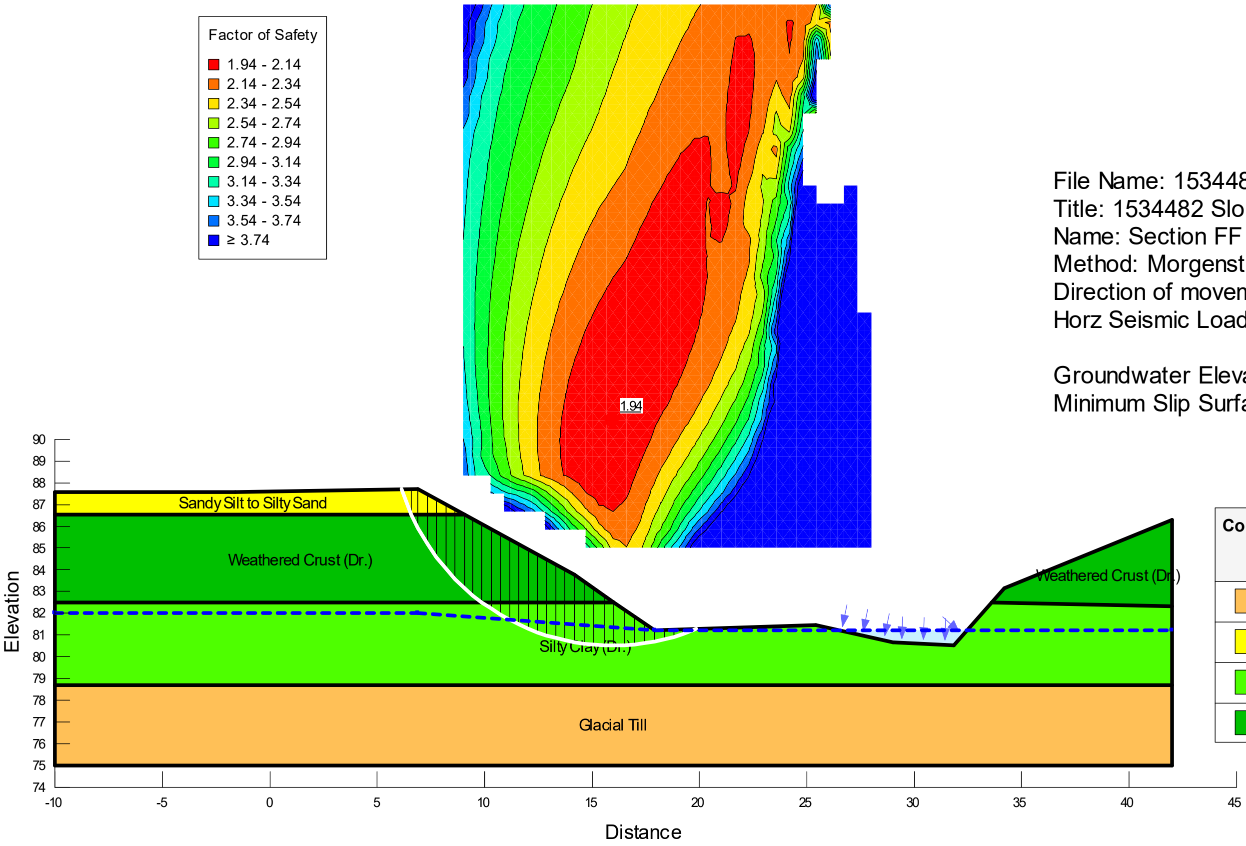
Checked:	AG
Review:	MSS

Figure E-9



File Name: 1534482_2019_SectionFF_AG.gsz
Title: 1534482 Slope Analyses
Name: Section FF - Drained Flat Radius
Method: Morgenstern-Price
Direction of movement: Left to Right
Horz Seismic Load:

Groundwater Elevation of 82.0 Metres Down to Creek
Minimum Slip Surface Depth of 1.0 Metres

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟧	Glacial Till	Mohr-Coulomb	21	0	36
🟨	Sandy Silt to Silty Sand	Mohr-Coulomb	17.5	0	34
🟩	Silty Clay (Dr.)	Mohr-Coulomb	16.5	7.5	32
🟩	Weathered Crust (Dr.)	Mohr-Coulomb	17.5	7.5	36

Slope Stability Assessment - Drained (cross-section F-F')

Wright Lands - Northern Slopes

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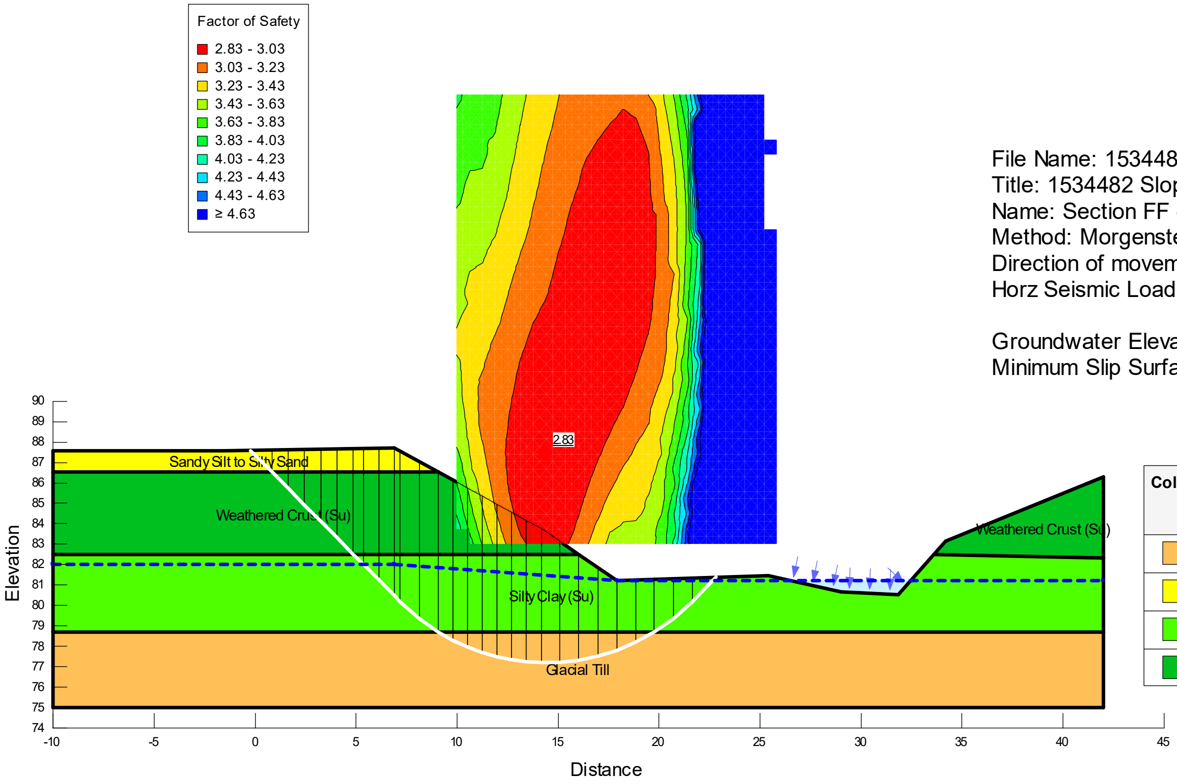
Project No.	1534482
Drawn:	RK
Date:	2020-02-27
Checked:	AG
Review:	MSS

Figure E-10



File Name: 1534482_2019_SectionFF_AG.gsz
Title: 1534482 Slope Analyses
Name: Section FF - Undrained
Method: Morgenstern-Price
Direction of movement: Left to Right
Horz Seismic Load:

Groundwater Elevation of 82.0 Metres Down to Creek
Minimum Slip Surface Depth of 1.0 Metres

Color	Name	Model	Unit Weight (kN/m³)	Cohesion (kPa)	Cohesion' (kPa)	Phi' (°)
🟧	Glacial Till	Mohr-Coulomb	21		0	36
🟨	Sandy Silt to Silty Sand	Mohr-Coulomb	17.5		0	34
🟩	Silty Clay (Su)	Undrained (Phi=0)	16.5	55		
🟩	Weathered Crust (Su)	Undrained (Phi=0)	17.5	80		

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Slope Stability Assessment - Undrained (cross-section F-F')

Wright Lands - Northern Slopes

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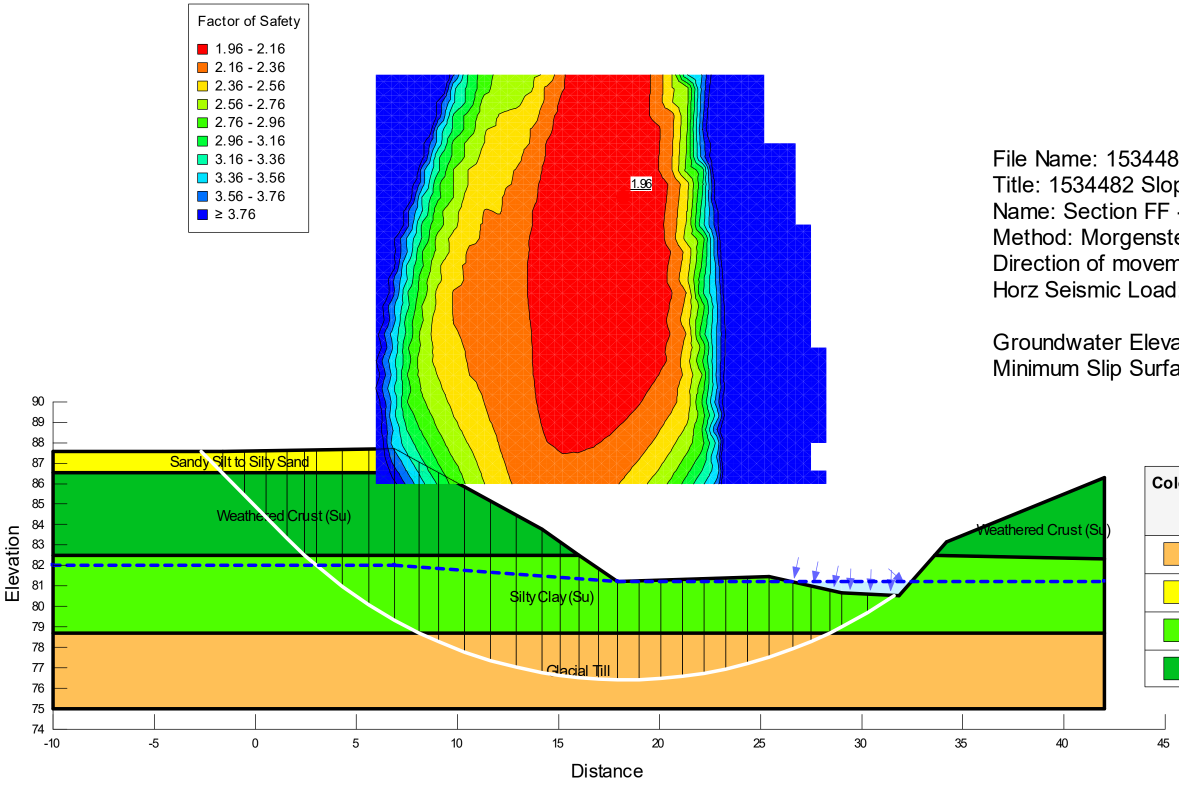
Review:	MSS

Figure E-11



File Name: 1534482_2019_SectionFF_AG.gsz
Title: 1534482 Slope Analyses
Name: Section FF - Undrained Seismic
Method: Morgenstern-Price
Direction of movement: Left to Right
Horz Seismic Load: 0.14

Groundwater Elevation of 82.0 Metres Down to Creek
Minimum Slip Surface Depth of 1.0 Metres

Color	Name	Model	Unit Weight (kN/m³)	Cohesion (kPa)	Cohesion' (kPa)	Phi' (°)
🟧	Glacial Till	Mohr-Coulomb	21		0	36
🟨	Sandy Silt to Silty Sand	Mohr-Coulomb	17.5		0	34
🟩	Silty Clay (Su)	Undrained (Phi=0)	16.5	55		
🟩	Weathered Crust (Su)	Undrained (Phi=0)	17.5	80		

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Slope Stability Assessment - Seismic (cross-section F-F')

Wright Lands - Northern Slopes

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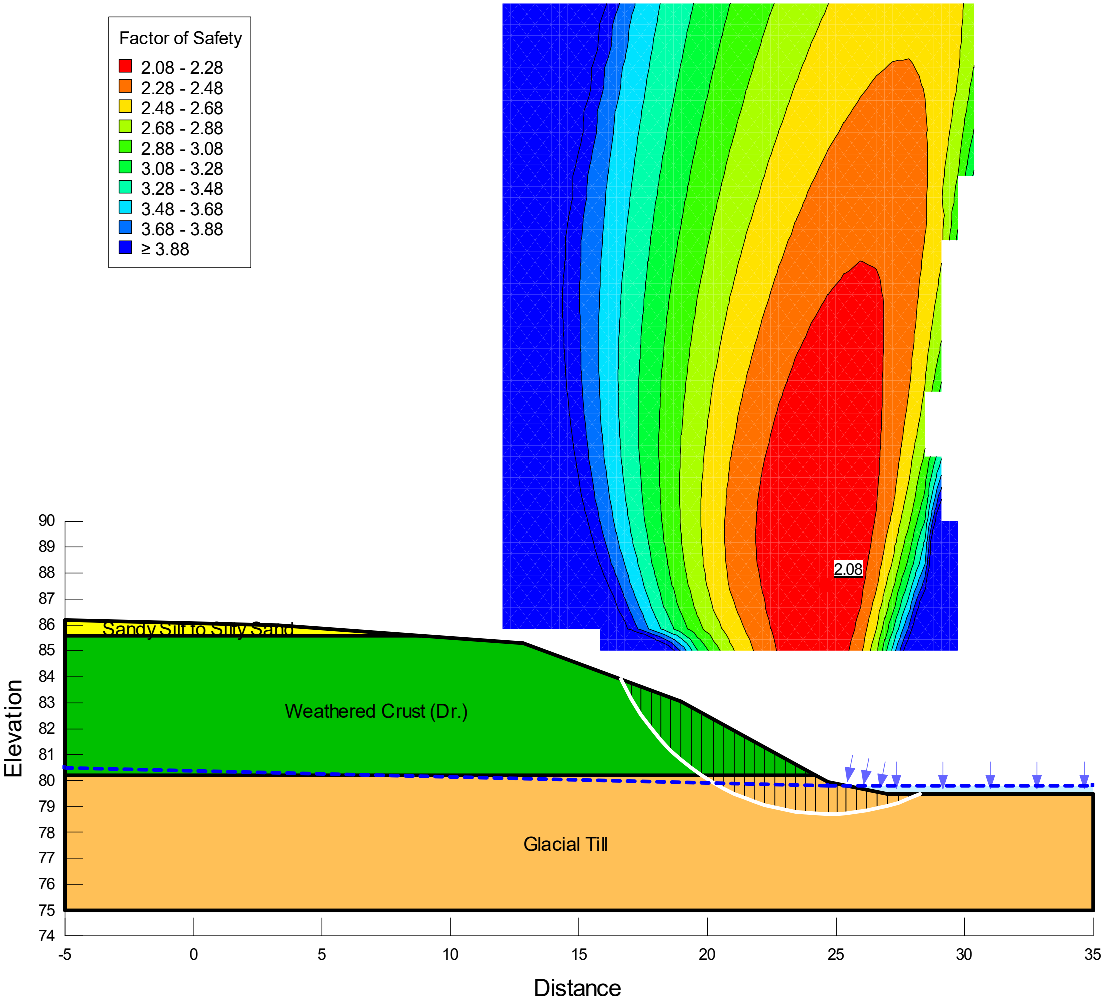
Review:	MSS

Figure E-12



File Name: 1534482_2019_SectionGG_AG.gsz
Title: 1534482 Slope Analyses
Name: Section GG - Drained Flat Radius
Method: Morgenstern-Price
Direction of movement: Left to Right
Horz Seismic Load:

Groundwater Elevation of 80.5 Metres Down to Creek
Minimum Slip Surface Depth of 1.0 Metres

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟧	Glacial Till	Mohr-Coulomb	21	0	36
🟨	Sandy Silt to Silty Sand	Mohr-Coulomb	17.5	0	34
🟩	Weathered Crust (Dr.)	Mohr-Coulomb	17.5	7.5	36

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Slope Stability Assessment - Drained (cross-section G-G')

Wright Lands - Northern Slopes

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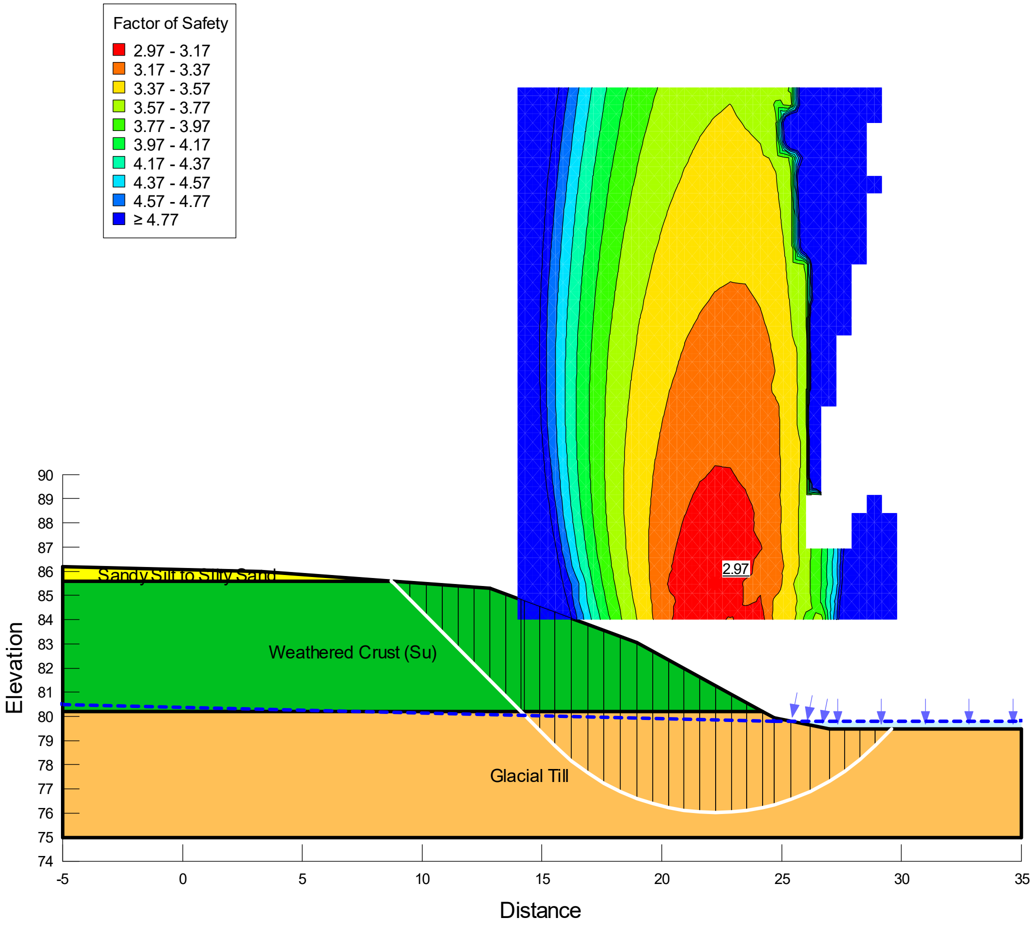
Drawn:	RK
Date:	2020-02-27
Checked:	AG
Review:	MSS

Figure E-13



File Name: 1534482_2019_SectionGG_AG.gsz
Title: 1534482 Slope Analyses
Name: Section GG - Undrained
Method: Morgenstern-Price
Direction of movement: Left to Right
Horz Seismic Load:

Groundwater Elevation of 80.5 Metres Down to Creek
Minimum Slip Surface Depth of 1.0 Metres

Color	Name	Model	Unit Weight (kN/m³)	Cohesion (kPa)	Cohesion' (kPa)	Phi' (°)
🟧	Glacial Till	Mohr-Coulomb	21		0	36
🟨	Sandy Silt to Silty Sand	Mohr-Coulomb	17.5		0	34
🟩	Weathered Crust (Su)	Undrained (Phi=0)	17.5	80		

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Slope Stability Assessment - Undrained (cross-section G-G')

Wright Lands - Northern Slopes

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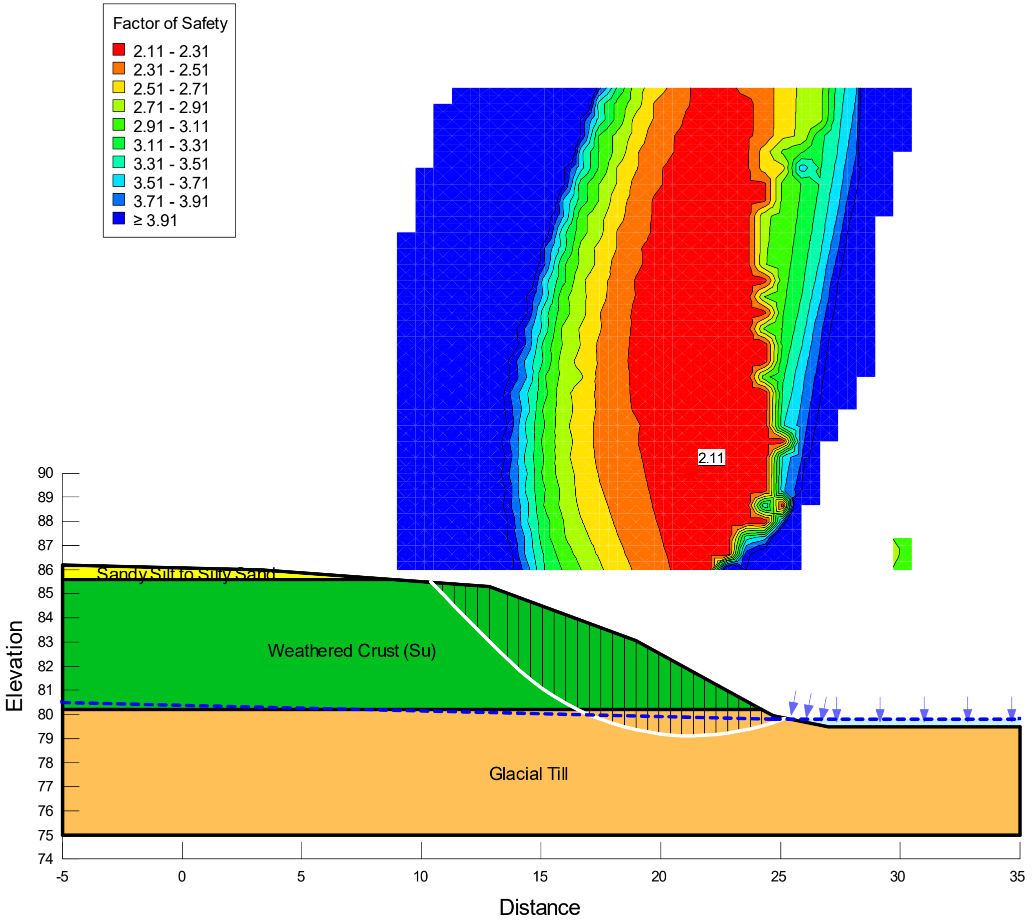
Checked:	AG
Review:	MSS

Figure E-14



File Name: 1534482_2019_SectionGG_AG.gsz
Title: 1534482 Slope Analyses
Name: Section GG - Undrained Seismic
Method: Morgenstern-Price
Direction of movement: Left to Right
Horz Seismic Load: 0.14

Groundwater Elevation of 80.5 Metres Down to Creek
Minimum Slip Surface Depth of 1.0 Metres

Color	**Name**	**Model**	**Unit Weight (kN/m³)**	**Cohesion (kPa)**	**Cohesion' (kPa)**	**Phi' (°)**
🟧	Glacial Till	Mohr-Coulomb	21		0	36
🟨	Sandy Silt to Silty Sand	Mohr-Coulomb	17.5		0	34
🟩	Weathered Crust (Su)	Undrained (Phi=0)	17.5	80		

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Slope Stability Assessment - Seismic (cross-section G-G')

Wright Lands - Northern Slopes

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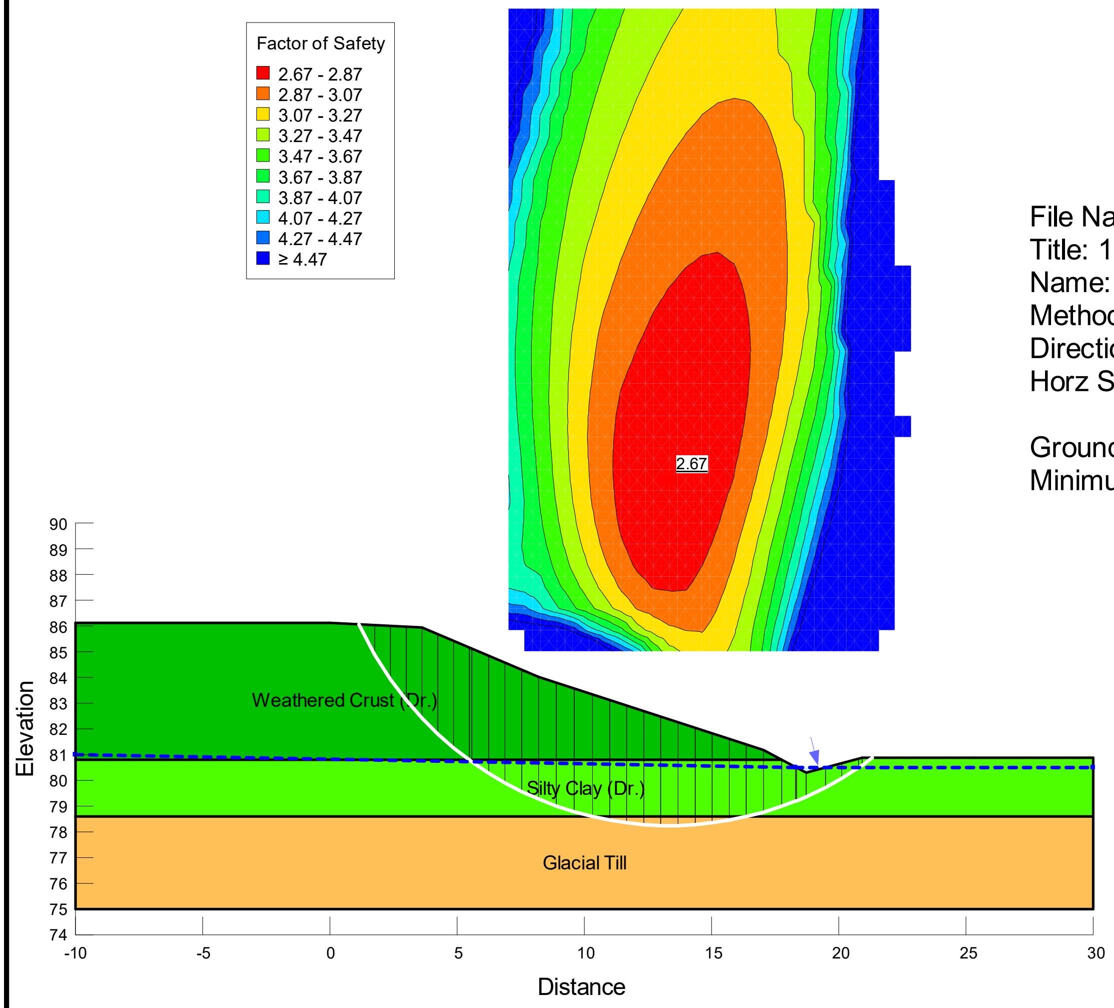
Review:	MSS

Figure E-15



File Name: 1534482_2019_SectionII_AG.gsz
Title: 1534482 Slope Analyses
Name: Section II - Drained Flat Radius
Method: Morgenstern-Price
Direction of movement: Left to Right
Horz Seismic Load:

Groundwater Elevation of 81.0 Metres Down to Roadside Ditch
Minimum Slip Surface Depth of 1.0 Metres

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟧	Glacial Till	Mohr-Coulomb	21	0	36
🟩	Silty Clay (Dr.)	Mohr-Coulomb	16.5	7.5	32
🟩	Weathered Crust (Dr.)	Mohr-Coulomb	17.5	7.5	36

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Slope Stability Assessment - Drained (cross-section I-I')

Wright Lands - Northern Slopes

Ottawa, Ontario

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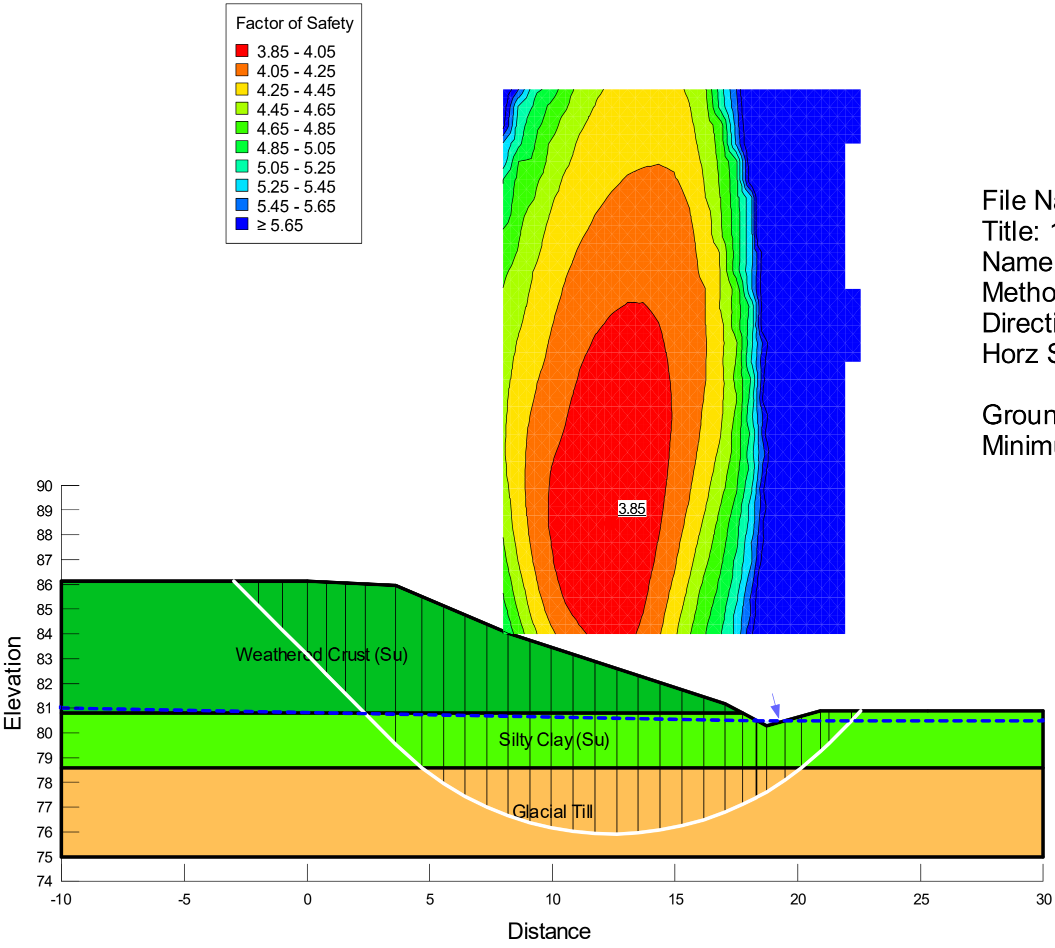
Review:	MSS

Figure E-16



File Name: 1534482_2019_SectionII_AG.gsz
Title: 1534482 Slope Analyses
Name: Section II - Undrained
Method: Morgenstern-Price
Direction of movement: Left to Right
Horz Seismic Load:

Groundwater Elevation of 81.0 Metres Down to Roadside Ditch
Minimum Slip Surface Depth of 1.0 Metres

Color	Name	Model	Unit Weight (kN/m³)	Cohesion (kPa)	Cohesion' (kPa)	Phi' (°)
🟧	Glacial Till	Mohr-Coulomb	21		0	36
🟩	Silty Clay (Su)	Undrained (Phi=0)	16.5	55		
🟩	Weathered Crust (Su)	Undrained (Phi=0)	17.5	80		

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Slope Stability Assessment - Undrained (cross-section I-I')

Wright Lands - Northern Slopes

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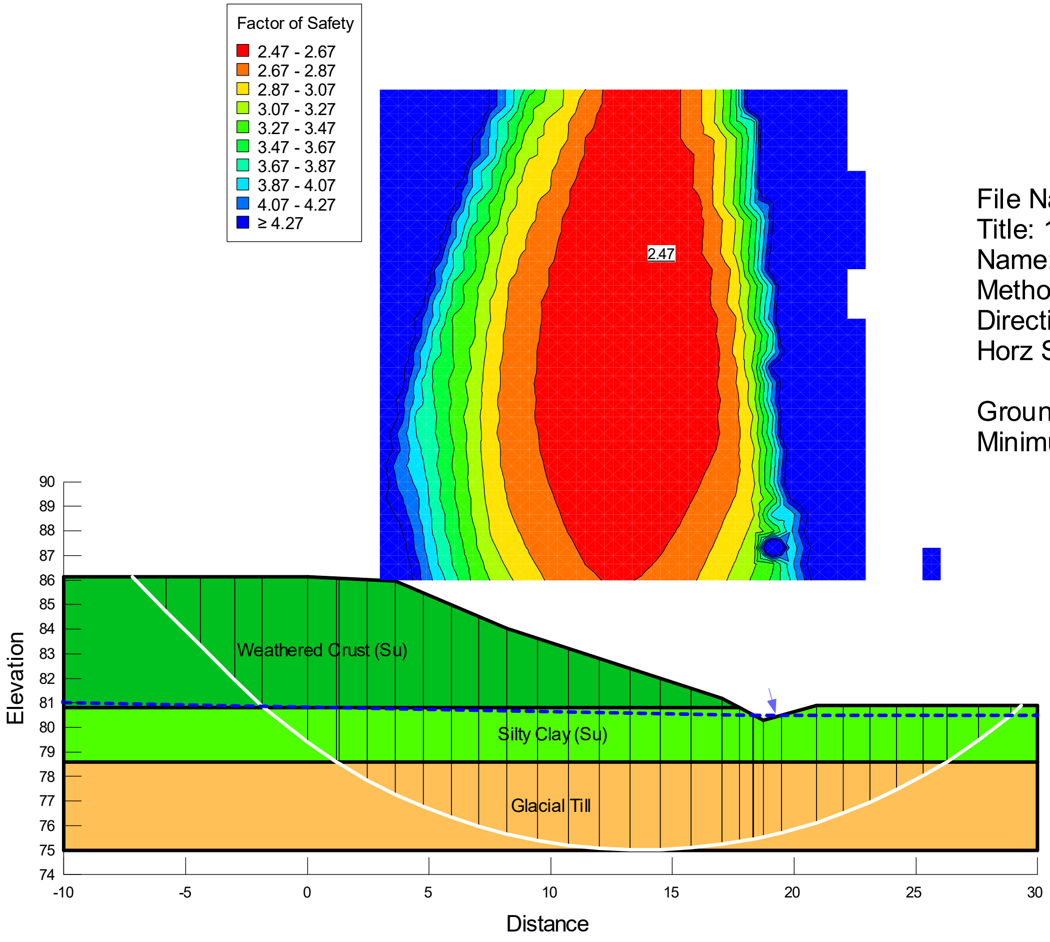
Drawn:	RK
Date:	2020-02-27
Checked:	AG
Review:	MSS

Figure E-17



File Name: 1534482_2019_SectionII_AG.gsz
Title: 1534482 Slope Analyses
Name: Section II - Undrained Seismic
Method: Morgenstern-Price
Direction of movement: Left to Right
Horz Seismic Load: 0.14

Groundwater Elevation of 81.0 Metres Down to Roadside Ditch
Minimum Slip Surface Depth of 1.0 Metres

Color	Name	Model	Unit Weight (kN/m³)	Cohesion (kPa)	Cohesion' (kPa)	Phi' (°)
🟧	Glacial Till	Mohr-Coulomb	21		0	36
🟩	Silty Clay (Su)	Undrained (Phi=0)	16.5	55		
🟩	Weathered Crust (Su)	Undrained (Phi=0)	17.5	80		

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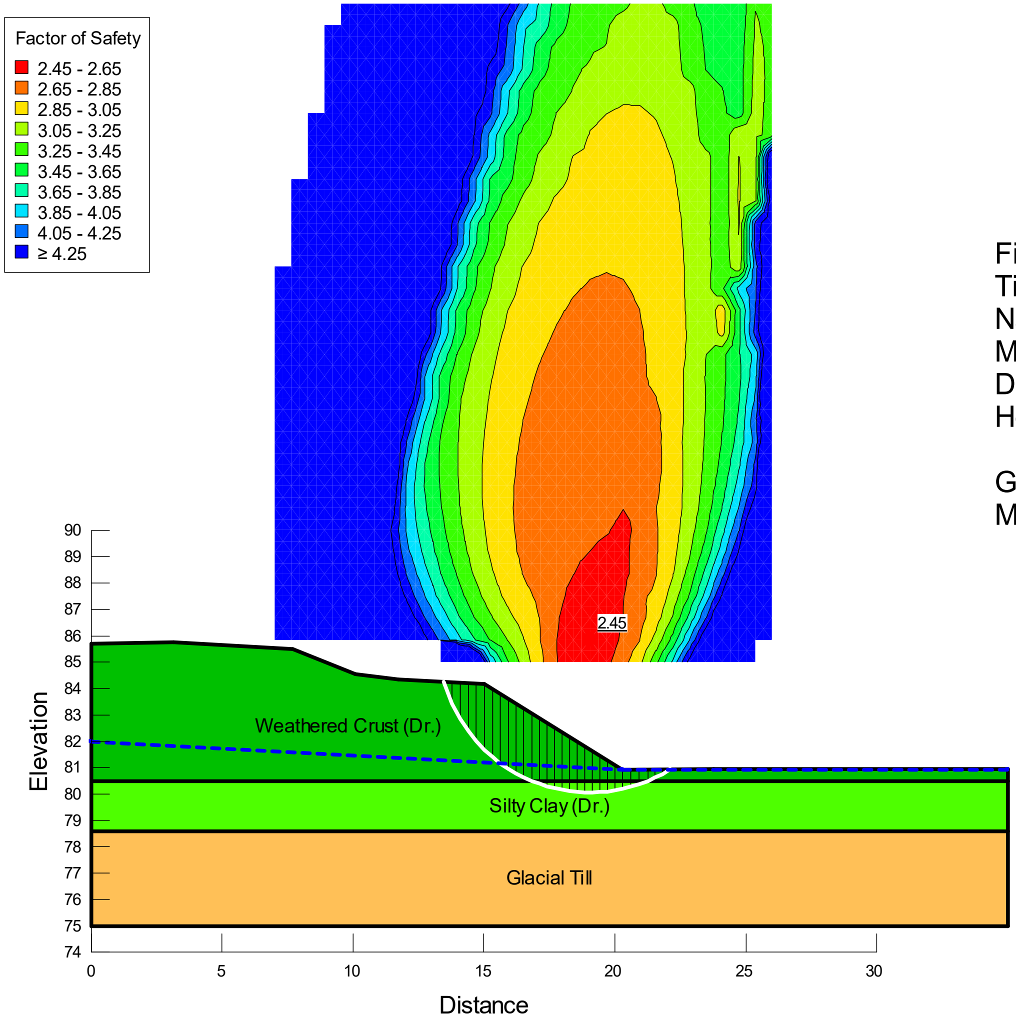
Slope Stability Assessment - Seismic (cross-section I-I')

Wright Lands - Northern Slopes

Ottawa, Ontario

Project No.	1534482
Drawn:	RK
Date:	2020-02-27
Checked:	AG
Review:	MSS

Figure E-18



File Name: 1534482_2019_SectionKK_AG.gsz
Title: 1534482 Slope Analyses
Name: Section KK - Drained Flat Radius
Method: Morgenstern-Price
Direction of movement: Left to Right
Horz Seismic Load:

Groundwater Elevation of 82.0 Metres Down to Roadside Ditch
Minimum Slip Surface Depth of 1.0 Metres

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟧	Glacial Till	Mohr-Coulomb	21	0	36
🟩	Silty Clay (Dr.)	Mohr-Coulomb	16.5	7.5	32
🟩	Weathered Crust (Dr.)	Mohr-Coulomb	17.5	7.5	34

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Slope Stability Assessment - Drained (cross-section K-K')

Wright Lands - Northern Slopes

Ottawa, Ontario

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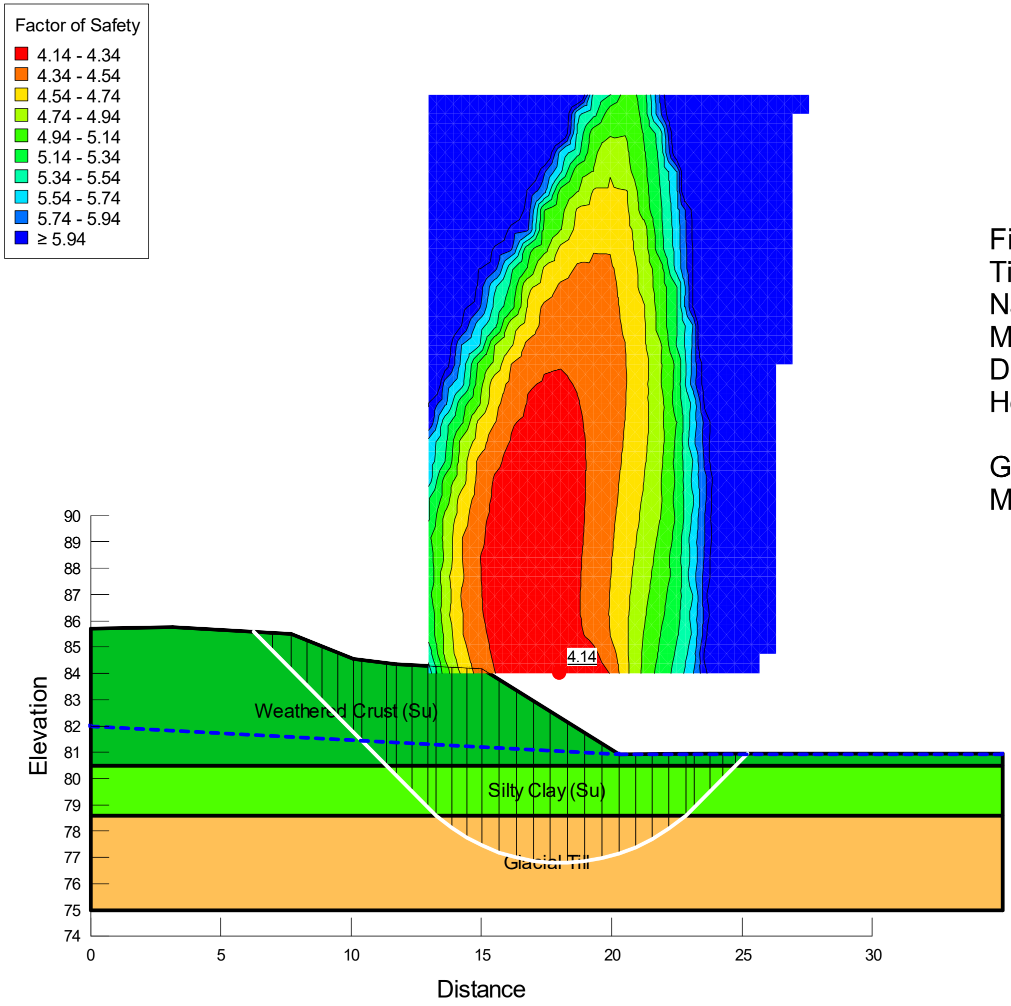
Checked:	AG
Review:	MSS

Figure E-19



File Name: 1534482_2019_SectionKK_AG.gsz
Title: 1534482 Slope Analyses
Name: Section KK - Undrained
Method: Morgenstern-Price
Direction of movement: Left to Right
Horz Seismic Load:

Groundwater Elevation of 82.0 Metres Down to Roadside Ditch
Minimum Slip Surface Depth of 1.0 Metres

Color	Name	Model	Unit Weight (kN/m³)	Cohesion (kPa)	Cohesion' (kPa)	Phi' (°)
🟧	Glacial Till	Mohr-Coulomb	21		0	36
🟩	Silty Clay (Su)	Undrained (Phi=0)	16.5	55		
🟩	Weathered Crust (Su)	Undrained (Phi=0)	17.5	80		

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Slope Stability Assessment - Undrained (cross-section K-K')

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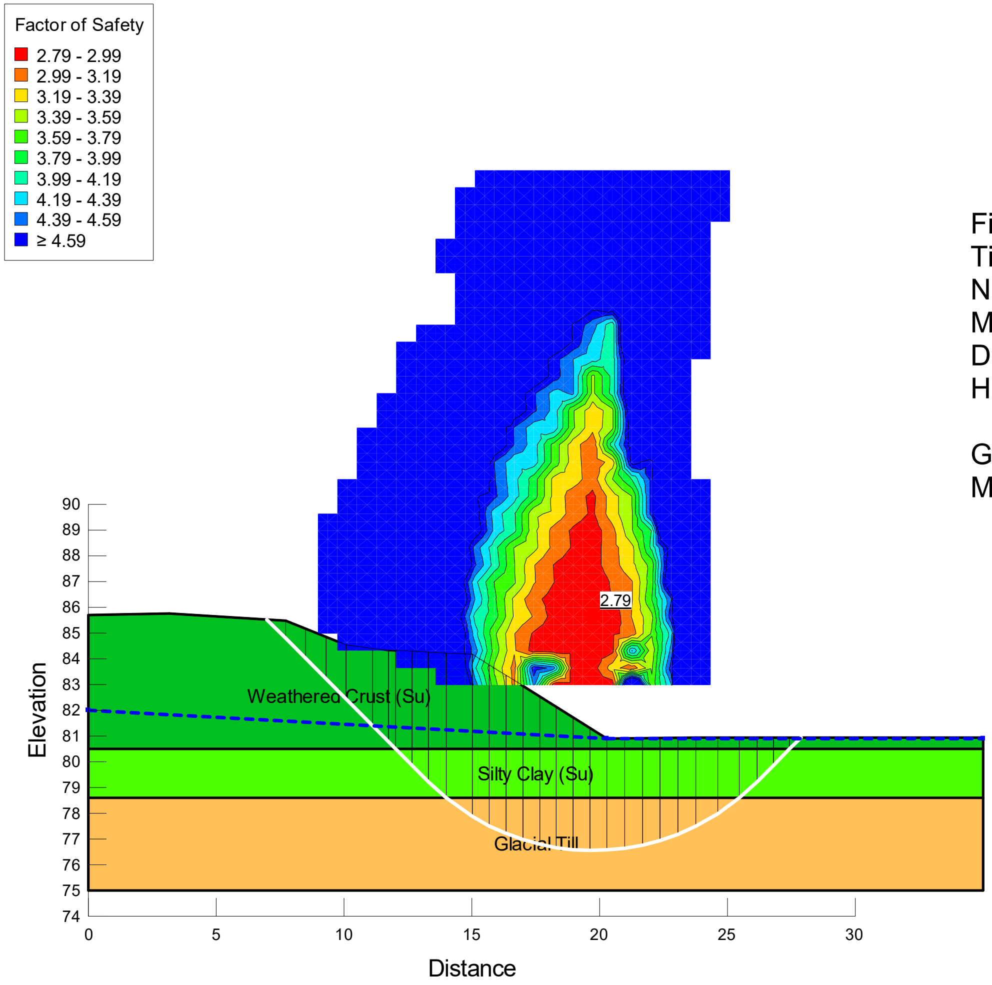
Review:	MSS

Figure E-20



File Name: 1534482_2019_SectionKK_AG.gsz
Title: 1534482 Slope Analyses
Name: Section KK - Undrained Seismic
Method: Morgenstern-Price
Direction of movement: Left to Right
Horz Seismic Load: 0.14

Groundwater Elevation of 82.0 Metres Down to Roadside Ditch
Minimum Slip Surface Depth of 1.0 Metres

Color	Name	Model	Unit Weight (kN/m³)	Cohesion (kPa)	Cohesion' (kPa)	Phi' (°)
🟧	Glacial Till	Mohr-Coulomb	21		0	36
🟩	Silty Clay (Su)	Undrained (Phi=0)	16.5	55		
🟩	Weathered Crust (Su)	Undrained (Phi=0)	17.5	80		

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Slope Stability Assessment - Seismic (cross-section K-K')

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Figure E-21

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