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REPORT

PRELIMINARY GEOTECHNICAL INVESTIGATION

Proposed Water Tank and Booster Station, Warkworth Institute, Campbellford, Ontario

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ATTACHMENTS

APPENDICES

1.0 INTRODUCTION

Golder Associates Ltd. ("Golder") was retained by CIMA+ to carry out a preliminary geotechnical investigation for a proposed new water tank and booster station facility at the Warkworth Institute located at 15847 County Road 29, Campbellford, Ontario (see Figure 1).

The purpose of the investigation was to obtain information on the subsurface soil and shallow groundwater conditions at the site by means of two (2) boreholes. Based on our interpretation of the borehole data, this report provides geotechnical information for the preliminary design of the proposed water tank and booster station.

The factual data, interpretations and preliminary recommendations contained in this report pertain to a specific project as described in the report and are not applicable to any other project or site location. If the project is modified in concept, location or elevation, or if the project is not initiated within eighteen months of the date of the report, Golder should be given an opportunity to confirm that the geotechnical recommendations are still valid.

This report should be read in conjunction with the "Important Information and Limitations of This Report" attached in Appendix A. The reader's attention is specifically drawn to this information, as it is essential for the proper use and interpretation of this report.

2.0 SITE AND PROJECT DESCRIPTION

We understand that CIMA+ (on behalf of Public Works and Government Services Canada (PWGSC)) are to design a new water tank and associated booster station facility to be located at a site east of the existing prison complex (hereafter referred to as the "Site" – see Figure 1). The site is currently grass-covered and flat-lying, and is bounded to the west by an access roadway, the east by a swampy area, the north by an existing underground storage tank, and to the south by a sewage facility.

Based on correspondence with CIMA+, two options for the preliminary design of the new water tank facility are being considered as follows.

Option 1) A single elevated water tank (approximate storage capacity of 1900 m^3) supported on 7.5 m diameter concrete pedestal (supported on raft foundation) and associated booster station on conventional spread footings or caissons; and

Option 2) Two at-grade water tanks (approximate storage capacity of 950 m^3 each) supported on 8.5 m diameter concrete ring foundation and associated (slightly larger) booster station on conventional spread footings or caissons.

3.0 GEOTECHNICAL INVESTIGATION

The field work for this geotechnical investigation was carried out from December 21 to 22, 2015, during which time two (2) boreholes (Boreholes 15-1 and 15-2) were advanced at the locations shown on the Borehole Location Plan - Figure 2. The boreholes were drilled using a track mounted drillrig supplied and operated by a specialist drilling contractor subcontracted to Golder. Standard penetration testing (SPT) and sampling were carried out at regular intervals of depth in the boreholes using conventional 35 mm internal diameter split spoon sampling equipment and an automatic hammer. Field Vane shear tests using an 'N'-size vane were carried out in the cohesive soils. Bedrock coring was carried out in each borehole using NQ size coring equipment. The shallow groundwater conditions were noted in the open boreholes during drilling and each borehole was equipped with a 50 mm diameter monitoring well following completion of the drilling. Details of the monitoring well installations are shown on the Record of Borehole sheets that follow the text of this report.

The field work for this investigation was monitored by a member of our engineering staff who also logged the boreholes and cared for the recovered soil and bedrock samples. All of the soil / bedrock samples obtained during this investigation were brought to our Whitby laboratory for further examination and classification testing, including water contents, Atterberg limits and grain size distributions on the soil samples.

The borehole locations and ground surface elevations shown on Figure 2 and the Record of Boreholes were interpolated from site features and the topographic plan for the Site prepared by PWGSC and provided to Golder by CIMA+, entitled "*Base Plan*" and dated December 2015. As such, the borehole locations and elevations are considered to be approximate.

4.0 SUBSURFACE CONDITIONS

4.1 General

The subsurface soil and shallow groundwater conditions encountered in the boreholes, as well as the results of the field and laboratory testing, are shown in detail on the Record of Borehole Sheets and on Figures 3 to 6 following the text of this report. Preceding the Record of Borehole sheets, "Method of Soil Classification and Symbols" and "Terms Used on Records of Boreholes and Test Pits" sheets are provided to assist in the interpretation of the Record of Borehole Sheets. The results of the in-situ field tests (i.e., SPT 'N'-values and undrained shear strengths measured from the field vanes) as presented on the Record of Borehole sheets and in Section 4.0 are uncorrected.

It should be noted that the boundaries between the soil strata have been inferred from drilling observations and non-continuous sampling. The boundaries generally represent a transition from one soil type to another and should not be inferred to represent an exact plane of geological change. Further, the subsurface conditions will vary between and beyond the borehole locations and caution should be used when extrapolating subsurface conditions between the boreholes. The following provides an overview of the subsurface conditions encountered in the boreholes advanced during this investigation, followed by more detailed descriptions of the major soil strata and shallow groundwater conditions.

In general, the subsurface soils generally consist of a surficial layer of topsoil underlain by silty clay fill containing organics. The fill is underlain by a varved silty clay to clayey silt deposit, underlain by interbedded silts, sands and silty sand till to sandy silt till. Cobbles/boulders are inferred within the silty sand till to sandy silt till due to grinding of the augers during drilling operations. Limestone bedrock was encountered below the silty sand till to sandy silt till in both boreholes.

The monitoring wells installed in Boreholes 15-1 and 15-2 measured groundwater levels at depths of 4.2 m and 4.5 m below the existing ground surface respectively on January 25, 2016.

4.2 Topsoil

Topsoil was encountered at the ground surface of both boreholes and was measured to be approximately 90 mm thick at both locations.

4.3 Fill

Cohesive silty clay fill was encountered below the topsoil at both borehole locations and extended to a depth of approximately 0.7 m below ground surface. The fill materials generally contain organic inclusions and rootlets. The SPT 'N'-values measured within the silty clay fill gave 'N' values of 9 blows per 0.3 m of penetration, suggesting a stiff consistency. The laboratory natural water contents measured on two selected silty clay fill samples were 20 and 23 percent.

4.4 Varved Silty Clay to Clayey Silt

A deposit of varved silty clay to clayey silt was encountered beneath the fill in both boreholes. The deposit typically consisted of alternating silty clay and clayey silt layers (each layer being about 3 mm to 20 mm thick). The silty clay to clayey silt was encountered at a depth of about 0.7 m below ground surface and extended to depths of 2.4 m and 5.6 m below ground surface (Elevation 123.8 m to 121.2 m) in Boreholes 15-1 and 15-2 respectively. The SPT ‘N’-values measured within the varved silty clay to clayey silt range from 5 blows to 10 blows per 0.3 m of penetration. Three in-situ field vane tests performed within the varved silty clay to clayey silt measured undrained shear strengths greater than 100 kPa. The results of the field tests suggest the varved silty clay to clayey silt matrix has a firm to stiff consistency. The natural water content of selected silty clay to clayey silt samples ranged from 27 percent to 40 percent. A plasticity chart showing the results of Atterberg limits testing performed on a selected sample of the varved silty clay to clayey silt is shown on Figure 3. The results measure a plastic limit of 20 percent, a liquid limit of 37 percent and a plasticity index of 17 percent, classifying the sample as silty clay of intermediate plasticity. A grain size distribution curve for a selected sample of the varved silty clay to clayey silt is shown on Figure 4.

4.5 Sand, Silty Sand and Sandy Silt

A deposit of sand, silty sand and sandy silt was encountered underlying the varved silty clay to clayey silt deposit in Borehole 15-1. The sand, silty sand and sandy silt was encountered at a depth of 2.4 m below ground surface and extended to a depth of 4.1 m below ground surface (Elevation 122.1 m). Two SPT ‘N’-values measured within the sand, silty sand and sandy silt were 29 blows and 36 blows per 0.3 m of penetration, indicating a compact to dense state of compactness. The water content measured on two samples of the sand, silty sand and sandy silt were 9 percent and 12 percent.

4.6 Silty Sand Till to Sandy Silt Till

A deposit of silty sand till to sandy silt till was encountered below the silty sand to sandy silt in Borehole 15-1 and underlying the varved silty clay to clayey silt in Borehole 15-2. The till was encountered at depths of 4.1 m and 5.6 m below ground surface (Elevation 122.1 m and 121.2 m) and extended to depths of 7.8 m and 9.8 m below ground surface (Elevation 118.4 m and 117.1 m) in Boreholes 15-1 and 15-2 respectively. The presence of cobbles and possibly boulders is inferred from grinding of the augers at various depths within the silty sand till during drilling operations. An interbed of sandy silt was encountered within the silty sand till in Borehole 15-1 from a depth of 5.6 m to 6.7 m. The SPT ‘N’-values measured within the silty sand till to sandy silt till range from 45 blows per 0.3 m of penetration to 50 blows per 0.03 m of penetration, indicating a dense to very dense state of compactness. The water content measured on the till samples generally ranged from approximately 7 percent to 12 percent, although a water content of 18 percent was measured on a wet sand seam near the contact with the underlying bedrock in Borehole 15-2. A grain size distribution curve for a selected sample of the sandy silt interbed within the till is shown on Figure 5. A grain size distribution for a selected sample of the sandy silt till is shown on Figure 6.

4.7 Bedrock

Bedrock was encountered below the silty sand till to sandy silt till at depths of 7.8 m and 9.8 m below ground surface (Elevation 118.4 m to 117.1 m) in Boreholes 15-1 and 15-2 respectively. Weathered bedrock is inferred from continuous grinding of the augers from a depth of 7.8 m to 9 m in Borehole 15-1 and from a depth of 9.8 m to 10.5 m in Borehole 15-2. After auger refusal was achieved, bedrock was confirmed by coring 3.7 m (Elevation 117.2 m to 113.6 m) into the rock in Borehole 15-1 and 3.8 m into the bedrock (Elevation 116.4 m to 112.6 m) in Borehole 15-2. The cored bedrock is classified as slightly weathered, strong to very strong, medium grey limestone. The Total Core Recovery (TCR) values ranged from 90 percent to 100 percent and the Rock Quality Designation (RQD) values on the recovered core samples ranged from approximately 74 percent to 100 percent, with one outlier value of 41 percent near the surface of the bedrock in Borehole 15-2.

4.8 Groundwater Conditions

Groundwater observations and measurements are shown in detail on the Record of Borehole sheets following the text of this report. Groundwater was evident in the boreholes at the conclusion of drilling and was measured at depths of 7.6 m and 8.8 m below ground surface in Boreholes 15-1 and 15-2 respectively on December 21, 2015. Monitoring wells were installed and the screened portion was sealed within the upper portion of the bedrock in both boreholes. The groundwater level in the monitoring wells was measured at depths of 4.2 m and 4.5 m below ground surface (corresponding to Elevation 122.0 m and 122.3 m) in Boreholes 15-1 and 15-2 respectively on January 25, 2016. Pressurized groundwater (i.e. artesian conditions) may be present within or immediately above the bedrock at the Site. Further investigation of the groundwater condition may be required during detailed design.

It should be noted that the observations and groundwater levels measured in the boreholes during the time of the field investigation are not representative of the stabilized groundwater level at this site. In addition, the subsequent groundwater levels measured in the monitoring wells should be expected to fluctuate seasonally in response to changes in precipitation and snow melt, and should be expected to be higher during the spring season and during any period of heavy precipitation.

5.0 GEO-ENVIRONMENTAL SOIL CHARACTERIZATION

5.1 Soil Submission

In order to provide preliminary information regarding the chemical quality of the subsurface soils at the Site for disposal purposes during construction, the following two soil samples were submitted to AGAT Laboratories Ltd. ("AGAT') for metals and inorganic, volatile organic compounds ("VOCs"), and petroleum hydrocarbons ("PHCs") parameter analyses. Each sample was composed of discrete samples collected from each borehole, which was inferred to represent the fill and/or native soils at the Site, as follows:

Sample ID	Fill/Native	Soil Sample Depth (m below ground surface)	Parameters
15-1 SA1	Fill	0.0 - 0.6	Metals and inorganics, VOCs, and PHCs
15-2 SA4	Native	2.3 – 2.9	Metals and inorganics, VOCs, and PHCs

At the time of the sampling, no obvious visual or olfactory evidence of environmental impact (i.e. staining or odours) was observed at the sampling locations.

For a summary of subsurface conditions observed, please refer to the Record of Borehole Sheets.

5.2 Soil Analytical Results

The soil sample analytical results were compared to the Ontario Ministry of the Environment ("MOECC") "Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act", April 15, 2011, Table 1 Full Depth Background Site Condition Standards for Residential / Parkland / Institutional / Commercial / Community Property Use ("MOECC Table 1 Standards")

A summary of the soil analytical results and the MOECC Table 1 Standards is provided on the Laboratory Certificates of Analysis, included in Appendix B.

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides preliminary geotechnical comments / recommendations regarding the proposed water tank and booster station at the Site. The geotechnical recommendations are based on our interpretation of the borehole information and on our understanding of the project requirements. The information in this portion of the report is provided for the guidance of the design engineers and professionals. Where comments are made on construction, they are provided only in order to highlight aspects of construction that could affect the design of the project. Contractors bidding on or undertaking any work at the Site should examine the factual results of the investigation, satisfy themselves as to the adequacy of the information for construction and make their own interpretation of the factual data as it affects their proposed construction techniques, schedule, equipment capabilities, costs, sequencing and the like.

Our professional services for this assignment address the geotechnical (physical) aspects with limited geo-environmental (chemical) aspects of the subsurface conditions at this Site for the purposes of soil disposal. A detailed geo-environmental (chemical) investigation, including the consequences of possible surface and/or subsurface contamination resulting from previous activities or uses of the Site are beyond the scope of this report.

Based on correspondence with CIMA+, two options for the preliminary design of the new water tank facility are being considered as follows.

Option 1) A single elevated water tank (approximate storage capacity of 1900 m^3) supported on 7.5 m diameter concrete pedestal (supported on raft foundation) and associated booster station on conventional spread footings or deep foundations; and

Option 2) Two at-grade water tanks (approximate storage capacity of 950 m^3 each) supported on 8.5 m diameter concrete ring foundation and associated (slightly larger) booster station on conventional spread footings or deep foundations.

The proposed site grade and/or new base slab elevation for the water tanks / booster station are not known at this time and proposed founding elevations and/or site servicing depths are not known. As such, the following preliminary recommendations should be used for planning purposes and should be reviewed, revised and supplemented as necessary during detailed design.

6.1 Site Preparation and Grading

It is assumed that the proposed site grade will match the exiting grade (i.e. no significant cut or fill required). Based on the boreholes, topsoil and fill materials containing organic inclusions are present at the proposed water tank and booster station site. The topsoil and existing fill materials are not considered suitable to provide subgrade support for the proposed water tanks, booster station or associated access roads and should be completely stripped / removed from these areas. Depending on the chosen foundation option, subexcavation of the varved silty clay to clayey silt deposit may also be required within the footprint of foundations, tanks and/or any engineered fill placement.

6.2 Foundations

Based on our understanding, the foundations for the proposed water tank and booster station will be located in the vicinity of Borehole 15-1 and/or 15-2. Based on the results of the boreholes, the varved silty clay to clayey silt extends to a depth of 2.4 m below ground surface (Elevation 123.8 m) in Borehole 15-1 and a depth of 5.6 m (Elevation 121.2 m) in Borehole 15-2 and is generally firm to stiff. Given the variability in the thickness and presence of varves in the silty clay to clayey silt layer, compressible nature of the clayey soils, and non-uniform loading at the tank centre and edges, the native varved silty clay to clayey silt soil is not considered suitable for support of the tank foundation. The underlying compact to dense sands, silty sand to sandy silt and dense to very dense silty sand till to sandy silt till deposits are considered suitable for the water tank and booster station foundations.

The following foundation recommendations can be used for planning and preliminary design purposes. Where geotechnical resistance values are provided, the values are considered to be net bearing capacities for preliminary design.

6.2.1 Option 1 – Elevated Water Tank with Concrete Raft Foundation

Consideration may be given to founding the proposed tank on a concrete pedestal supported on a circular raft foundation (approximately 7.5 m in diameter) bearing on the native undisturbed dense to very dense silty sand till at a depth of approximately 4.1 m and 5.6 m below the existing ground surface (Elevation 122.1 m and 121.2 m) in Boreholes 15-1 and 15-2 respectively. Consideration could be given to supporting the raft foundation on the compact to dense sand, silty sand to sandy silt layers in Borehole 15-1; however, differential settlement could occur if the relative density and thickness of the sandy / silty layers is not consistent across the footprint of the tank foundation.

A rigid concrete raft bearing on the dense to very dense sand, silty sand to sandy silt, and silty sand till to sandy silt till soils at the elevations described above (i.e. modelled as a circular shallow footing with a 7.5 m diameter) may be designed using a geotechnical reaction at Serviceability Limit States (SLS) of 400 kPa, for 25 mm of settlement and a factored geotechnical resistance at Ultimate Limit States (ULS) of 600 kPa for preliminary purposes.

Consideration could be given to raising the founding design elevation and supporting the concrete raft on granular engineered fill (see Section 6.5). The granular engineered fill would need to be properly placed and compacted to 100% Standard Proctor Maximum Dry Density (SPMDD) after subexcavating to the surface of the native silty sand till to sandy silt till stratum. For a rigid concrete raft (7.5 m diameter) founded on properly placed and compacted Granular ‘A’ engineered fill supported on the native dense to very dense till soils, a geotechnical reaction at SLS of 350 kPa (for 25 mm of settlement) and factored geotechnical resistance at ULS of 600 kPa can be used for preliminary design.

Alternatively, deep foundations (i.e. caissons) founded on the very dense tills or limestone bedrock could be considered to support the water tank pedestal. For planning / preliminary design, an axial geotechnical resistance of about 3,300 kN at ULS can be used assuming 750 mm diameter drilled caisson piles founded on the sound limestone bedrock (i.e. about Elevation 117 m in 15-1 and Elevation 116 m in 15-2). For 900 mm diameter caissons founded on sound limestone bedrock, a preliminary geotechnical resistance of 4,800 kN at ULS can be used. The geotechnical resistances are based mainly on end-bearing (with limited rock strength information) and the recommendations for deep foundations should be reassessed during detailed design, when the strength of the bedrock is confirmed. The actual capacity of caissons will also depend on whether they are designed as end-bearing or shaft resistance (or combination thereof) and will depend on whether or not the base of the caissons can be effectively augered/cored into the bedrock, "cleaned" and verified in the field. Typically, higher resistances can be obtained for the caisson option socketed into the bedrock, although installation effort will increase. Driven piles could also be considered during detail design but may get "hung up" in the till containing cobbles and boulders and may not reach bedrock without predrilling.

The design founding elevation and/or subexcavation elevation to reach the dense to very dense silty sand till to sandy silt till or bedrock within the foundation footprint should be investigated further during detail design and confirmed by inspection of a geotechnical engineer during construction. In this regard, once the proposed location of the tank and foundation type is finalized, additional boreholes may be advanced within the tank/foundation footprint to determine the variability and excavation depths required to reach the competent silty sand till and/or bedrock bearing stratum.

6.2.2 Option 2 - At-grade Water Tank(s) Supported on Concrete Ring Foundation

Consideration may be given to founding the proposed at-grade tank edges on ring footings bearing on the sandy silt till to silty sand till at a depth of approximately 4.1 m to 5.6 m below the existing ground surface in Boreholes 15-1 and 15-2 respectively (Elevation 122.1 m to 121.2 m). Consideration could be given to supporting the ring foundation on the compact to dense sand, silty sand to sandy silt layers in Borehole 15-1; however, differential settlement could occur if the relative density and thickness of the sandy / silty layers is not consistent across the footprint of the tank foundation.

As previously discussed, the firm to stiff varved silty clay to clayey silt is not considered suitable for support of the tank foundations or interior base of a typical steel tank (see Section 6.3).

As a result, subexcavation of the firm to stiff varved silty clay to clayey silt deposit is recommended beneath the entire tank footprint (in addition to the ring foundation) consistent with the subexcavation recommendations for the ring foundation discussed previously. In order for the tanks to be constructed at-grade, either the surrounding grade would need to be lowered or the foundation subgrade raised using properly placed and compacted granular engineered fill similar to the requirements in Section 6.2.1 (e.g. Granular 'A' compacted to 100 percent SPMDD).

Strip footings bearing on the dense to very dense sand, silty sand to sandy silt, and silty sand till to sandy silt till soils with a minimum width of 1 m may be designed using a geotechnical reaction at Serviceability Limit States (SLS) of 400 kPa, for 25 mm of settlement and a factored geotechnical resistance at Ultimate Limit States (ULS) of 600 kPa for preliminary purposes.

Alternatively, for strip footings (1 m wide) founded on properly placed and compacted Granular 'A' engineered fill supported on the native dense to very dense till soils, a geotechnical reaction at SLS of 350 kPa (for 25 mm of settlement) and factored geotechnical resistance at ULS of 600 kPa can be used for preliminary design.

Similarly to Option 1, deep foundations (i.e. caissons or piles) founded on the very dense tills or limestone bedrock could be considered to support the water tank foundations; however, consideration should be given to supporting the entire tank base (as opposed to just the ring foundation) on the same foundation type to reduce the potential for intolerable differential settlements.

The design founding elevation and/or subexcavation elevation to reach the dense to very dense silty sand till to sandy silt till or bedrock within the foundation footprint should be investigated further during detail design and confirmed by inspection of a geotechnical engineer during construction. In this regard, once the proposed location of the tank and foundation type is finalized, additional boreholes may be advanced within the tank/foundation footprint to determine the variability and excavation depths required to reach the competent silty sand till and/or bedrock bearing stratum.

6.2.3 Booster Station - Conventional Spread Footings

It is understood that a proposed booster station will be constructed on site and supported on conventional shallow footings. No details of the booster station were provided at this preliminary stage.

Provided the booster station pad is located outside the zone of influence of the water tank foundation and there is no grade raise, lightly loaded shallow foundations (i.e. spread/strip footings) founded on an engineered granular fill pad within the varved silty clay to clayey silt deposit can be considered. For preliminary design, it is assumed that the surficial soils, fills and varved silty clay stratum are subexcavated and replaced with a minimum 2 m thick granular pad. For shallow foundations (minimum 1 m wide) founded on a properly placed and compacted Granular 'A' engineered fill pad supported on the firm to stiff varved silty clay, a geotechnical reaction at SLS of 100 kPa (for 25 mm of settlement) and factored geotechnical resistance at ULS of 200 kPa can be used for preliminary design.

Alternatively, if higher geotechnical resistances are required, full subexcavation of the varved silty clay deposit and replacement with Granular 'A' engineered fill could be performed and similar geotechnical resistance values given for the ring foundation in Section 6.2.2 can be used. Deep foundations could also be considered as discussed in Section 6.2.1.

6.2.4 General Foundation Comments / Soil-Structure Interaction

All exterior footings and pile/caisson caps, and footings in unheated areas should be provided with at least 1.6 m of soil cover after final grading, in order to reduce the potential for damage due to frost action.

All foundation excavations at the site should be carried out in accordance with the Occupational Health and Safety Act and Regulations for Construction Projects. The subgrade / founding soils are susceptible to disturbance by construction activity especially during wet weather and care should be taken to preserve the integrity of the materials as bearing strata. Prior to pouring concrete for the footings or placing engineered fill on subgrade soils, the bottom of the excavations should be inspected by Golder to confirm that the subgrade is undisturbed and a competent bearing stratum that has been cleaned of ponded water and all disturbed, softened, loosened, organic and other deleterious material. Continuous monitoring of engineered fill placement to support foundations or any settlement sensitive structures is required to be performed by qualified geotechnical personnel.

Based on the borehole investigation, the major soil layers and estimated unit weights are provided below for preliminary design.

Idealized Soil Layer	Unit Weight (kN/m^3)
Varved Silty Clay to Clayey Silt	18
Compact to Very Dense Silty Sand and Sandy Silt	20
Silty Sand Till and Sandy Silt Till	21

Consideration could be given to designing the footings/rafts using the modulus of subgrade reaction for the supporting soil. The vertical modulus of subgrade value (k) depends on many factors, including size and shape footing(raft), soil type and layering within zone of influence, relative stiffness of footing and soil, duration of loading, etc. The value of modulus of subgrade reaction also varies from one point to another beneath a footing or raft (e.g. centre, edge, or corner) and can change with time.

Considering the modulus value changes with the size of the footing, for preliminary design purposes, a modulus of subgrade reaction value, k_{v1} (for a one-foot square plate), of 50 MPa/m be used for the dense to very dense silty sand to sandy silt, and silty sand till layers. A k_{v1} value of 40 MPa/m can be used for footings supported on the properly compacted granular engineered fill pad supported on the native cohesionless layers. Higher modulus of sugrade values could be considered for raft footings founded at greater depths within the "100-blow" till soils and/or bedrock.

It is noted that the actual vertical modulus of subgrade value (k) decreases with the size of the footing/raft. Considering the footing/raft dimensions currently being considered range from about 1 m to 7.5 m in width/diameter, the modulus of subgrade (k) for the actual footing dimensions are anticipated to be about 40% to 25% of the estimated k_{v1} values provided above. Care should be exercised when using these values and a more detailed settlement analysis should be considered during detail design.

6.3 Settlement

Settlement of the foundation soils due to loading from the tanks will depend on many factors including site location (i.e. subsoils conditions vary considerably in the two boreholes advanced at the site), actual external loading condition at edge or centre of tank, subexcavation limits and type of engineered fill (if being used for foundation support), etc.

Preliminary assessment indicates that, if the tanks were placed above the varved silty clay deposit, the settlement of the varved silty clay soil (assuming 5 m thickness) due to a surcharge pressure of about 170 kPa would result in about 100 mm of consolidation settlement. Due to the variable thickness of the varved clayey deposit and unbalanced loading at the centre and edge of the tank, differential settlement is expected. The majority of the settlement (90%) is expected to occur within about 4 months and the remaining consolidation settlement expected to occur within the first year assuming a constant load. Preliminary tank base and edge stability assessment indicates a low factor of safety against bearing capacity failure given the inherent variability and complex nature of the underlying varved silty clay soils. Further investigation and laboratory testing would be required to confirm settlement / stability and it is likely that soil improvement would be required to consider supporting ring foundations and/or the steel tank bottom of at-grade tanks on the cohesive deposit.

If the varved silty clay to clayey silt deposit is subexcavated and replaced with properly placed and compacted engineered fill, settlements are expected to reduce significantly. The engineered fill will be subject to settlement induced by self-weight of the material following completion of filling, in addition to settlements of the underlying silty sand till to sandy silt till soils.

If Select Subgrade Material or Granular A or B soils are used for the engineered fill, the maximum settlement due to self-weight of the fill is anticipated to be less than 50 mm assuming the fill thickness will be less than 5 m. The anticipated self-weight settlements of the granular engineered fill soils are estimated to be less than 1% of the fill thickness considered for this project. The settlement of these granular soils is expected to occur rapidly during, or immediately following placement and compaction of the engineered fill (within 24 hours).

If cohesive material is used for the engineered fill, self-weight settlements are estimated to be up to 2% of the fill thickness (i.e. up to 100 mm) and is expected to occur over a period of months. Design specific criteria including magnitude and duration of settlement should be further assessed during detail design. A preload period may be required to allow the cohesive soils to consolidate. For these reasons, it is not recommended to use cohesive material as engineered fill.

In summary, if properly placed and compacted granular engineered fill is used, the total settlement at existing ground surface (below loaded tank) is expected to be less than 100 mm and consist of: 50 mm or less in the engineered fill (due to self-weight of up to 5 m of engineered fill); 25 mm or less in the silty sand till (from weight of engineered fill and 170 kPa surcharge); and 25 mm or less in engineered fill from the 170 kPa surcharge. The majority of this settlement is expected to occur shortly after initial placement and/or surcharge loading (within about 24 hours).

6.4 Temporary Excavations

It is anticipated that temporary excavations up to 5.6 m below the existing ground surface may be required for subexcavation, engineered fill placement, and/or placement of foundations. Based on the groundwater conditions encountered in the boreholes, excavations could be below (up to 1.1 m) the local groundwater table when measured on January 25, 2016. Groundwater control during excavation within the excavations can likely be handled, as required, by pumping from properly constructed and filtered sumps located within the excavations.

It is anticipated that the excavations will consist of conventional temporary open cuts with side slopes not steeper than 1H: 1V. However, depending upon the construction procedures adopted by the contractor, groundwater seepage conditions and weather conditions at the time of construction, some local flattening of the slopes may be required, especially if any looser/softer zones are encountered (i.e. in the native varved silty clay to clayey silt deposits) or where localized seepage is encountered. Care should be taken to direct surface runoff away from the open excavations and all excavations should be carried out in accordance with the Occupational Health and Safety Act and Regulations for Construction Projects. According to the Act, the existing fill and firm to stiff varved silty clay to clayey silt would be classified as Type 3 soils. In addition, care must be taken during excavation to ensure that adequate support is provided for any existing structures and underground services located adjacent to the excavations.

6.5 Engineered Fill

Based on the results of the boreholes, the existing clayey fill soils containing organics are not considered suitable for reuse as engineered fill. Also, the native varved silty clay to clayey silt soil is not recommended for use as engineered fill below foundations or settlement sensitive structures, but could be suitable for reuse as general fill

/ backfill provided that the placement water content of the fill does not exceed the optimum water content for compaction by more than about 2 percent. Based on the measured in situ water contents, the majority of the native varved silty clay soils are generally above their estimated laboratory optimum water contents for compaction; and may require drying or mixing prior to placement and compaction. The actual decision on reuse of materials will need to be made as the materials are excavated and inspected in the field. It should also be noted that due to the fine-grained nature of the predominant silty/clayey subsoils, their workability is sensitive to moisture conditions and difficulty would be expected in achieving adequate compaction during wet weather.

Imported materials may be used for engineered fill and should be approved by geotechnical personnel at the source(s), prior to hauling to the site. In this regard, imported sandy (granular) materials which meet the requirements for OPSS Select Subgrade Material (SSM) would be suitable for use as engineered fill. In areas where settlement sensitive structures are to be placed on engineered fill, OPSS Granular B or Granular A is recommended for use as engineered fill to further limit potential differential settlements.

The approved materials should be placed in maximum 300 mm loose lifts and uniformly compacted to at least 100 percent of the materials Standard Proctor Maximum Dry Density throughout.

Engineered fill should not be placed or compacted during freezing conditions (i.e. winter months) such that frozen lumps of material, snow and ice are not present in the fill.

Care will be required to ensure that the prepared area extends far enough to encompass the limits of the engineered fill. Where appropriate, the engineered fill limits are defined such that the fill extends to at least one metre beyond the outside edge of the founding level of any footing or other settlement sensitive area and then downward and outward at a slope of one horizontal to one vertical down to the subgrade level.

Full-time monitoring and in situ density testing should be carried out by a qualified geotechnical engineering firm during placement of all engineered fill beneath the structures and settlement sensitive areas.

The final surface of the engineered fill should be protected as necessary from construction and foot traffic, and should be sloped to provide positive drainage for surface water during the construction period. If the engineered fill materials will be left exposed (i.e. uncovered) during periods of freezing weather, consideration should be given to placing an additional soil cover above final subgrade to provide for frost protection. Prior to constructing any foundations, the surface of the engineered fill should be inspected by the geotechnical engineer.

6.6 Underground Services

It is anticipated that the trench excavations for underground servicing would typically extend to just below frost depth and consist of conventional temporary open cuts with side slopes not steeper than 1 horizontal to 1 vertical. However, some local flattening of side slopes may be required in some areas in looser soil zones or where significant water seepage is encountered. The bedding for buried pipes should be compatible with the type and class of pipe, the surrounding subsoil and anticipated loading conditions and should be designed in accordance with Northumberland County and National/Provincial Standards. Where granular bedding is deemed to be acceptable, it should consist of at least 150 mm of OPSS.PROV 1010 (Aggregates) Granular ‘A’ or 19 mm crusher run limestone material. A thicker bedding layer (i.e. 300 to 450 mm in total) may be required where the bottom of the excavation/bedding is on the native varved silty clay to clayey silt. From the springline to 300 mm above the obvert of the pipe, sand cover may be used as appropriate. All bedding and cover materials should be placed in maximum 150 mm loose lifts and should be uniformly compacted to at least 98 percent of standard Proctor maximum dry density. If grades are to be raised or surcharge loadings applied above utilities, the settlement of the pipe and any connections should be assessed. Special connection details to allow for differential settlement near the loaded tanks will likely be required.

6.7 Hydraulic Conductivity Estimates

Single-Well Response Testing

Monitoring wells were installed within the limestone bedrock encountered at boreholes BH15-1 and BH15-2. To estimate the hydraulic conductivity (K) of the bedrock adjacent to the screened intervals, single-well response testing was carried out on January 25, 2016. Single-well response testing at both wells was conducted by rapidly lowering the water levels, by purging with a dedicated Waterra footvalve and tubing. The resulting water level recovery was monitored manually with an electronic level tape.

The Hvorslev (1951) method was applied to water level recovery data from the monitoring wells. The results are presented in Table 1, below. A record of the single-well response test data and the data analyses are attached in Appendix C.

Grain Size Distribution - Hazen

Selected soil samples from various soil units obtained during the borehole investigation program were submitted to our Whitby laboratory for grain size distribution analysis. The hydraulic conductivity of one selected non-cohesive soil sample was approximated using the Hazen method (Freeze and Cherry, 1979) as follows:

$$K = A\, d_{10}^2$$

where K is in cm/s, A = 1.0 and d_{10} is the grain size (in mm) at which 90% is coarser and 10% is finer.

The result is presented in Table 1, below. It is noted that the Hazen method is most applicable to well sorted fine-grained sand soils, and may not necessarily be applicable to other soils types. Nevertheless, the results are presented below for discussion purposes.

Summary

The estimated hydraulic conductivity values obtained from the single-well response testing and by the Hazen method are summarized in the following Table 1:

Table 1: Summary of Hydraulic Conductivity Estimates

Monitoring Well / Borehole ID	Soil Sample Number	Screened / Tested Unit	Method	Estimated Hydraulic Conductivity (cm/s)
BH15-1	-	Limestone Bedrock	Hvorslev (1951)	1 x 10-5
BH15-1	7	(ML) Sandy Silt	Hazen (1910)	3 x 10-6
BH15-2	-	Limestone Bedrock	Hvorslev (1951)	6 x 10-5

6.8 Groundwater Control and Permit To Take Water

A Permit To Take Water ("PTTW") from the Ontario Ministry of the Environment and Climate Change ("MOECC") is required when dewatering activities result in groundwater abstraction in excess of 50 m^3/day. A Category 2 PTTW allows for a short term, non-recurring taking less than 30 consecutive days and less than 400 m^3/day. A

Category 3 PTTW is required where the proposed water taking is expected to exceed 30 consecutive days, and/or for abstraction rates of greater than 400 m^3/day.

Temporary construction dewatering rates were estimated on the basis of the subsurface conditions encountered at boreholes BH15-1 and BH15-2, and on the proposed water tank foundation options. The average approximate ground surface elevation at the two boreholes was 126.5 m asl. On January 25, 2016, the groundwater level was measured at BH15-1 and BH15-2 at depths of 4.2 m bgs (122.0 m asl) and 4.5 m bgs (122.3 m asl), respectively. Seasonal fluctuations in groundwater levels should be expected. As discussed in Section 6.4, the installation of the water tank foundations (including subexcavation and replacement with engineered fill option) may require excavations up to 5.6 m bgs (approximately Elevation 121.3 m asl, depending on location). Depending on the native soil type(s) encountered at the base of the excavation, groundwater levels may require lowering by an additional one metre below the depth of excavation (to approximately Elevation 120.3 m asl). Accordingly groundwater level lowering in the order of 2 m (122.3 m - 120.3 m) may be required. Additional groundwater level lowering should be expected at times of seasonally higher groundwater levels.

Based on groundwater conditions at the time of construction, groundwater inflow may expected mainly from the non-cohesive sand to sandy silt unit encountered between overlying silty clay unit and the underlying silty sand till unit at BH15-1, depending on the lateral extent of this unit which was not assessed as part of this investigation. It is noted that i) this unit was not saturated at the time of drilling, but may be at least partly saturated at times of seasonally higher groundwater levels; and, ii) this unit was not encountered at the second borehole location. Additional groundwater inflow may also be expected from sandy silt interbeds within the glacial till unit, although the lateral extent of these units was not assessed as part of this investigation.

It is understood that the design options and construction methods for the water tank(s) have not yet been determined. Based on the hydrogeological conditions encountered at the borehole locations, steady state groundwater inflow rates to the excavation(s) are expected to be less than 50 m^3/day. However, the rate of groundwater inflow will vary during construction. Initially, higher inflow rates will occur as groundwater is removed from storage within the zone of influence. With time, rates will decrease toward a steady-state condition. Incident precipitation into the excavation(s) may also need to be managed with the groundwater, and factored into the total daily pumping rate estimates.

Depending on groundwater conditions at the time of construction, the founding depth of the excavation(s), the number of excavations, and the lateral extent of saturated, non-cohesive sand to sandy silt units encountered, the combined dewatering rates may initially exceed the 50 m^3/day threshold for which a PTTW is required. Given the anticipated dewatering length of greater than 30 days, the need to obtain a Category 3 PTTW could conservatively be anticipated at this time. This recommendation should be reviewed on the basis of detailed design information, additional information on construction methods, and any amended PTTW requirements that are in effect at that time. To provide additional information on seasonal groundwater fluctuations, additional monitoring could be carried out at the monitoring well locations during the spring season.

6.9 Seismic Consideration

The 2012 Ontario Building Code (2012 OBC) came into effect on January 1, 2014 and contains updated seismic analysis and design methodology. Seismic hazard is defined for an earthquake with a 2% probability of exceedance in 50 years (i.e. a return period of 2,400 years) which encompasses a larger earthquake hazard than in prior editions of the OBC. Design earthquakes are commonly defined by an earthquake magnitude, distance, and peak ground acceleration (PGA). The 2012 OBC uses the uniform hazard spectra (UHS) to define the response of the structure to the design earthquake and also considers the effects of the localized site conditions on the structural response. The 2012 OBC also uses a refined site classification system defined by the average soil/bedrock properties in the top 30 metres of the subsurface profile beneath the structure(s). There are 6 site classes designated as A to F related to decreasing ground stiffness from A for hard rock to E for soft soil and site class F for problematic soils (e.g. sites underlain by thick peat deposits and/or liquefiable soils). The site class is then used to obtain acceleration and velocity-based site coefficients, Fa and Fv, respectively, used to modify the reference UHS to account for the effects of site-specific soil conditions in design.

It has been our experience, that depending on the structural design requirements for structures that fall under the OBC jurisdiction, significant structural design and construction costs are frequently associated with the seismic design aspects. Significant cost savings may, therefore, be realized by adopting a more accurate site classification method which can only be determined based on actual physical testing extending to a depth of at least 30 m below the ground surface. We strongly recommend that the methodology for the seismic testing of the Site soils be selected in conjunction with discussions with the structural engineer for the project.

Conservative Approach

The conservative site classification is based on physical borehole information obtained at depths of less than 30 m and based on general knowledge of the local geology. In this regard, Golder's drilling program includes a borehole drilled to a depth of 14.3 m below existing ground surface. Based on the results of the boreholes, the subsurface soil conditions at the Site generally consist of fill, underlain by a varved silty clay deposit, underlain by silty sand till to sandy silt till deposits with sand beds. Limestone bedrock was encountered at depths of 7.8 m and 9.8 m below ground surface (Elevation 118.4 m and 117.1 m). Based on the borehole information and our local experience, a preliminary Site Class D may be used for the site. If the varved silty clay to clayey silt soils are to be subexcavated and replaced with engineered fill, a preliminary Site Class C may be used for the site. When the details of the foundation system are finalized, the site classification should be reassessed by Golder.

Geophysical Method

To determine the actual site classification based on physical on-site measurements of shear wave velocity as required by OBC 2012, the Multichannel Analysis of Surface Waves ("MASW") should be considered. Should it be required by the structural engineer to optimize the Site Class for the development, MASW testing should be carried out at the Site. The existing monitoring wells (screened in the bedrock) installed as part of this investigation may be used to carry out this testing.

6.10 Discussion of Environmental Analytical Results

Based on the limited soil sample analytical testing and results, no exceedances were reported when compared to and the MOE Table 1 Standards. As a result, there are no anticipated environmental suitability restrictions for excess soil at the locations sampled on Site for reuse onsite or offsite disposal.

Further, Ontario Regulation ("O.Reg.") 153/04 requires that specific testing protocols are followed and that the material satisfy the applicable MOECC standards if soil is moved to a site that is the subject of a Record of Site Condition. Please note that the level of testing outlined herein is meant to provide a broad indication of soil quality based on the soil samples tested. It is not intended to be fully compliant with the excess soil characterization provisions contained in O.Reg 153/04. If full compliance with O.Reg. 153/04 is desired, a much higher sampling frequency and other site assessment work will be required.

If excess soil materials generated during construction vary in composition from the samples tested by Golder, additional testing is recommended to determine their suitability for disposal/reuse. Note that the excess soil reuse options as discussed herein are limited to the environmental quality of the soil.

7.0 ADDITIONAL WORK, QUALITY CONTROL AND TESTING

Once the actual site location, design details and elevations are known, the preliminary geotechnical information contained in this report should be checked against the design drawings/specifications and the proposed construction methodology should be reviewed by this office to confirm that the intent of this report has been met.

Additional geotechnical investigation and/or testing (especially for the bedrock) may be recommended depending on the final design. During construction, sufficient foundation and subgrade inspections, in situ density tests and materials testing should be carried out to confirm that the conditions present are consistent with those encountered in the boreholes advanced during preliminary and detail design, and to observe conformance with the pertinent project specifications. Golder should be present at the Site on a full-time basis during subexcavation, engineered fill placement, and foundation construction.

It is noted that the monitoring wells installed as part of this investigation should be decommissioned during construction in accordance with the requirements of Ontario Regulation 903 (as amended).

8.0 CLOSURE

We trust that this report provides sufficient geotechnical engineering information to proceed with the preliminary design of this project. If you have any questions regarding the contents of this report or require additional information, please do not hesitate to contact this office.

Yours truly,

GOLDER ASSOCIATES LTD.

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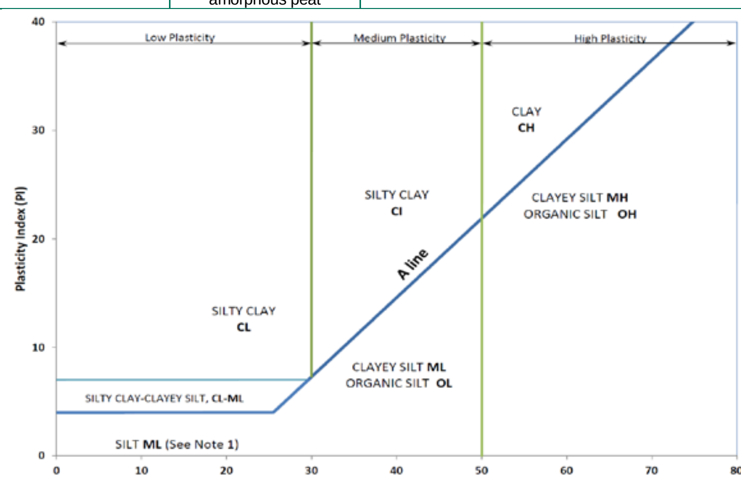
The Golder Associates Ltd. Soil Classification System is based on the Unified Soil Classification System (USCS)

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 ~~or~~ indicate~~s~~ a range of similar soil types within a stratum.

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

PARTICLE SIZES OF CONSTITUENTS

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

MODIFIERS FOR SECONDARY AND MINOR CONSTITUENTS

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

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Cone Penetration Test (CPT)

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

Dynamic Cone Penetration Resistance (DCPT); N_d:

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

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

SAMPLES

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

SOIL TESTS

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

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

NON-COHESIVE (COHESIONLESS) SOILS

Compactness[2]

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

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

Field Moisture Condition

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

COHESIVE SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N'[1] (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.

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
σ_1, σ_2, σ_3	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

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

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan\delta$
c′	effective cohesion
c_u, s_u	undrained shear strength (ϕ = 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

RECORD OF BOREHOLE: 15-1

PROJECT: 1531866
LOCATION: SEE FIGURE 2
BORING DATE: December 21, 2015
SHEET 1 OF 2
DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 762mm

BORING METHOD: POWER AUGER CME 55 TRACK MOUNTED, 200 mm O.D. Hollow Stem Augers

Column headings: DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE (DESCRIPTION, STRATA PLOT, ELEV. DEPTH (m)) | SAMPLES (NUMBER, TYPE, BLOWS/0.3m) | 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 (10, 20, 30, 40) | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION

DESCRIPTION	ELEV. / DEPTH (m)
GROUND SURFACE	126.20
TOPSOIL	0.00
FILL - (CL) SILTY CLAY, trace sand, organic inclusions; brown; w>PL, stiff	0.09
(CL-ML) SILTY CLAY to CLAYEY SILT; brown to light brown, varved; w>PL firm to stiff	125.51 / 0.69
(SP) SAND, fine to medium grained, trace silt, trace gravel; brown; dry to moist, dense	123.76 / 2.44
(ML-SM) SILTY SAND to SANDY SILT; brown, oxidation staining; moist, compact	123.23 / 2.97
(SM) SILTY SAND, some gravel, some clay; brown, oxidation staining, (TILL); moist, very dense	122.09 / 4.11
(ML) sandy SILT, some clay; brown; moist, very dense	120.56 / 5.64
(SM) SILTY SAND, some gravel, some clay; grey, (TILL); moist, very dense	119.49 / 6.71
INFERRED BEDROCK - Auger grinding on inferred bedrock from depths of 7.8 m to 9.0 m	118.40 / 7.80
BEDROCK Bedrock cored from about of 8.99 m to 12.65 m depth For bedrock coring details refer to Record of Drillhole BH15-1.	117.21 / 8.99

NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING
1	SS	9	
2	SS	8	
3	SS	10	
4A			
4B	SS	36	
5	SS	29	
6	SS	57	
7	SS	50/ 0.10	MH
8	SS	50/ 0.03	

Piezometer/standpipe installation: Bentonite; Sand; Screen

CONTINUED NEXT PAGE

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: EW
CHECKED: KJB

RECORD OF BOREHOLE: 15-1

BORING DATE: December 21, 2015

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 762mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	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 (10, 20, 30, 40)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- CONTINUED FROM PREVIOUS PAGE ---									
10–12.65	POWER AUGER CME 55 TRACK MOUNTED; 200 mm O.D. Hollow Stem Augers	BEDROCK Bedrock cored from about of 8.99 m to 12.65 m depth For bedrock coring details refer to Record of Drillhole BH15-1.		113.55 12.65							Screen

1. Groundwater encountered during drilling at a depth of 7.9 m below ground surface, Dec. 21/15
2. Groundwater measured inside augers at a depth of 7.6 m below ground surface upon completion of augering, Dec. 21/15
3. Groundwater measured in monitoring well at a depth of 4.17 m below ground surface, Jan. 25/16

Depth scale marks: 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20

RECORD OF DRILLHOLE: 15-1

PROJECT: 1531866
SHEET 1 OF 1

LOCATION: SEE FIGURE 2
DRILLING DATE:
DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---
DRILL RIG: CME55 Trackmount
DRILLING CONTRACTOR: Davis

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate, BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Cleavage, PL - Planar, CU - Curved, UN - Undulating, ST - Stepped, IR - Irregular, PO - Polished, K - Slickensided, SM - Smooth, RO - Rough, VR - Very Rough, MB - Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	DISCONTINUITY DATA TYPE AND SURFACE DESCRIPTION	NOTES
		TOP OF DRILLHOLE	117.21			
9	CME55 TRACK MOUNTED NQ CORE ROTARY DIAMOND CONE	Slightly weathered, strong to very strong, thin to very thinly bedded, non-porous, medium grained, crystaline, medium grey limestone	8.99	1	BD,UN,SM BD,UN,SM BD,UN,SM	Bentonite Sand
				2	BD,UN,SM BD,UN,SM BD,UN,SM BD,UN,SM BD,UN,SM BD,UN,SM BD,UN,SM BD,UN,SM BD,UN,SM BD,UN,SM	
10						
11				3	BD,UN,SM BD,UN,SM BD,UN,SM BD,UN,SM BD,UN,SM	Screen
12			113.55			
		END OF DRILLHOLE	12.65			
13						
14						
15						
16						
17						
18						

Column headings: COLOUR % RETURN; FLUSH; RECOVERY (TOTAL CORE %, SOLID CORE %); R.Q.D. %; FRACT. INDEX PER 0.25 m; B Angle; DIP w.r.t. CORE AXIS; Jr; Ja; Jn; HYDRAULIC CONDUCTIVITY K, cm/sec; Diametral Point Load Index (MPa); RMC -Q' AVG.

GTA-RCK 018 S:\CLIENTS\CIMA\CAMPBELLFORD_WORKWORTH_INSTITUTE\02_DATA\GINT\1531866.GPJ GAL-MISS.GDT 4/26/16

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: EW
CHECKED: KJB

PROJECT: 1531866

LOCATION: SEE FIGURE 2

RECORD OF BOREHOLE: 15-2

BORING DATE: December 21-22, 2015

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 762mm

Boring method: Power Auger, 200 mm O.D. Hollow Stem Augers

DEPTH SCALE METRES	DESCRIPTION	ELEV. / DEPTH (m)	SAMPLE NUMBER	TYPE	BLOWS/0.3m	SHEAR STRENGTH Cu, kPa	WATER CONTENT	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
	GROUND SURFACE	126.85							
0	TOPSOIL	0.00							
	FILL - (CL) SILTY CLAY, trace sand, organic inclusions and rootlets; dark brown; w>PL, stiff	0.09	1	SS	9				
	(CL) SILTY CLAY; dark brown, varved, oxidation staining; w>PL, firm	126.16 / 0.69							
1			2	SS	6				
	(CI-ML) SILTY CLAY to CLAYEY SILT; brown, verved, oxidation staining; w>PL, firm to stiff	125.40 / 1.45	3	SS	5				
2						>100kPa			
			4	SS	6			SEE NOTE 1	
3						>100kPa			
			5	SS	5			MH SEE NOTE 1	
4						>100kPa			
5			6	SS	6			SEE NOTE 1	Bentonite
	(SM-ML) SILTY SAND to SANDY SILT, some clay, trace gravel, contains cobbles and boulders, contains sand seams; brown, (TILL); moist, dense to very dense	121.21 / 5.64							
6			7	SS	58				
7	- Becomes grey at a depth of 7.1 m								
8			8	SS	45			MH	
	- Auger grinding on inferred cobbles and boulders from a depth of 8.7 m to 9.1 m								
9			9A	SS	88				
	- Wet silty sand seam from depths of 9.3 m to 9.4 m		9B						
		117.10 / 9.75							
10									

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 : 10 20 30 40

CONTINUED NEXT PAGE

DEPTH SCALE 1 : 50

Golder Associates

LOGGED: EW

CHECKED: KJB

PROJECT: 1531866

LOCATION: SEE FIGURE 2

RECORD OF BOREHOLE: 15-2

BORING DATE: December 21-22, 2015

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 762mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m; SHEAR STRENGTH Cu, kPa	HYDRAULIC CONDUCTIVITY, k, cm/s; WATER CONTENT PERCENT	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		--- *CONTINUED FROM PREVIOUS PAGE* ---									
10	Power Auger; 200 mm O.D. Hollow Stem Augers	INFERRED BEDROCK - Auger grinding on inferred bedrock from a depth of 9.8 m to 10.5 m		116.39 10.46							Bentonite
11		BEDROCK Bedrock cored from about 10.46 m to 14.25 m depth For bedrock coring details refer to Record of Drillhole BH15-2.									Sand
12–14				112.60 14.25							Screen
		END OF BOREHOLE NOTES: 1. On Dec. 22, 2015 another borehole was drilled about 2 m away from 15-2 and in-situ dhear vane tests were performed at the depths shown. In addition, a thin wall Shelby Tube was hydraulically pushed from a depth of 3.0 m to 3.4 m. The borehole was terminated at a depth of 3.4 m and backfilled with bentonite to the ground surface.									1. Groundwater encountered during drilling at a depth of 7.3 m below ground surface, Dec. 21/15 2. Groundwater measured inside augers at a depth of 8.8 m below ground surface upon completion of augering, Dec. 21/15 3. Groundwater measured in monitoring well at a depth of 4.54 m below ground surface, Jan. 25/16
15–20											

Dynamic penetration scale: 20 40 60 80; Shear strength: nat V. + Q - ● rem V. ⊕ U - ○; 20 40 60 80

Hydraulic conductivity: 10^{-6} 10^{-5} 10^{-4} 10^{-3}; Water content: Wp —○W— Wl; 10 20 30 40

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: EW

CHECKED: KJB

PROJECT: 1531866

RECORD OF DRILLHOLE: 15-2

SHEET 1 OF 1

LOCATION: SEE FIGURE 2

DRILLING DATE:

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: ---

DRILL RIG: CME55 Trackmount

DRILLING CONTRACTOR: Davis

JN - Joint, FLT - Fault, SH - Shear, VN - Vein, CJ - Conjugate; BD - Bedding, FO - Foliation, CO - Contact, OR - Orthogonal, CL - Cleavage; PL - Planar, CU - Curved, UN - Undulating, ST - Stepped, IR - Irregular; PO - Polished, K - Slickensided, SM - Smooth, RO - Rough, VR - Very Rough; MB - Mechanical Break, BR - Broken Rock

NOTE: For additional abbreviations refer to list of abbreviations & symbols.

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	RUN No.	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	NOTES
		TOP OF DRILLHOLE	116.39			
	CME55 TRACK MOUNTED; NQ CORE ROTARY DIAMOND CONE	Slightly weathered, strong to very strong, thin to very thinly bedded, non-porous, medium grained, crystaline, medium grey limestone	10.46	1	BD,UN,SM	Bentonite; Sand
11						
				2	BD,UN,SM	
					BD,UN,SM	
12					BD,UN,SM	
					BD,UN,SM	
					BD,UN,SM	Screen
					BD,UN,SM	
13				3		
					BD,UN,SM	
14			112.60		BD,UN,SM	
		END OF DRILLHOLE	14.25			
15						
16						
17						
18						
19						
20						

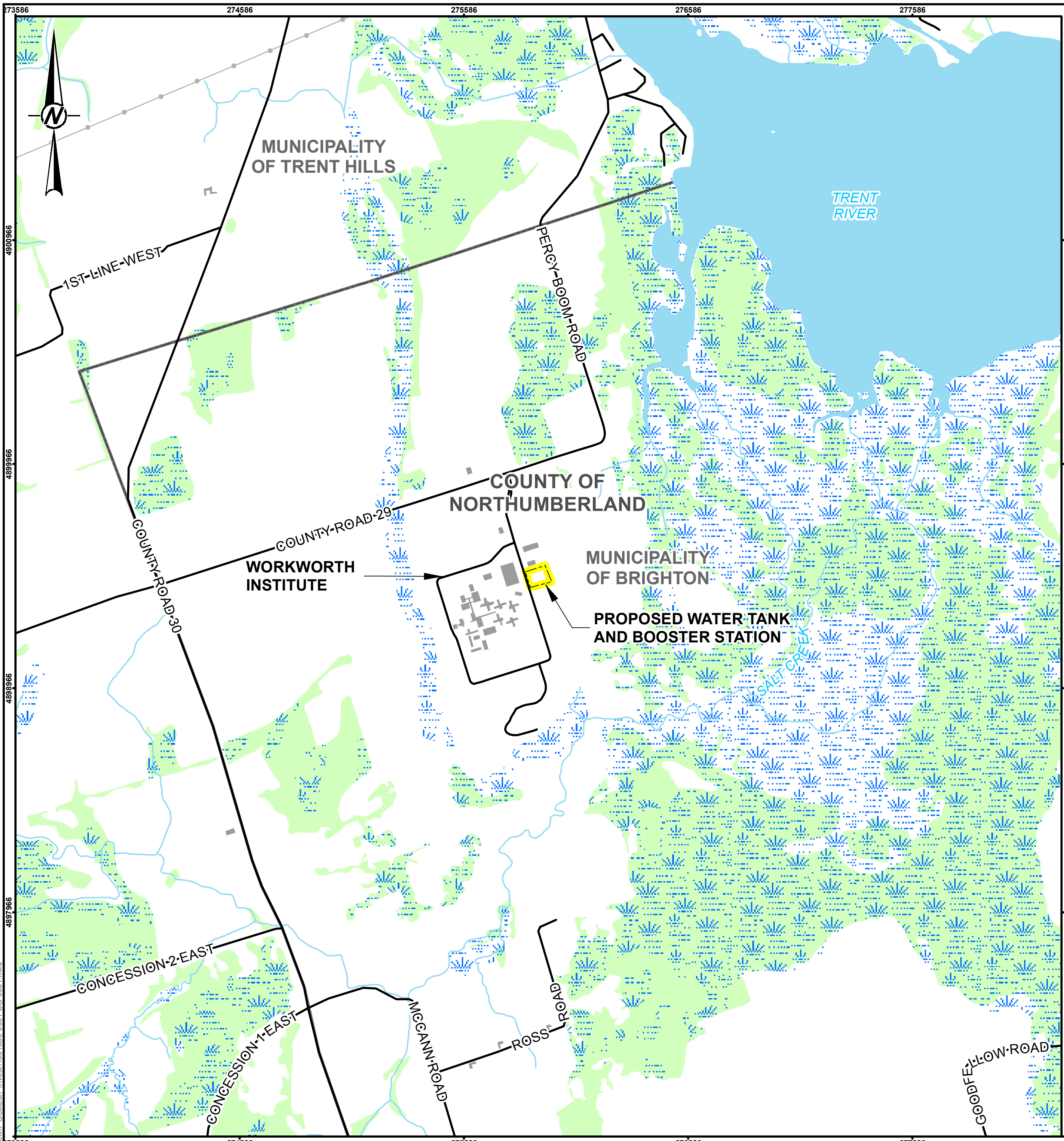
DEPTH SCALE

1 : 50

Golder Associates

LOGGED: EW

CHECKED: KJB



LEGEND

- ROAD
- UTILITY LINE
- WATERCOURSE
- APPROXIMATE SITE BOUNDARY
- BUILDING
- MUNICIPAL BOUNDARY
- WATERBODY
- WETLAND
- WOODED AREA

0 500 1,000

1:25,000 METRES

REFERENCE(S)

BASE DATA - MNR LIO, OBTAINED 2016
PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2016
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 18N

CLIENT
CIMA +

PROJECT
PRELIMINARY GEOTECHNICAL INVESTIGATION
PROPOSED WATER TANK AND BOOSTER STATION
WARKWORTH INSTITUTE, CAMPELLFORD, ONTARIO

TITLE
KEY PLAN

CONSULTANT

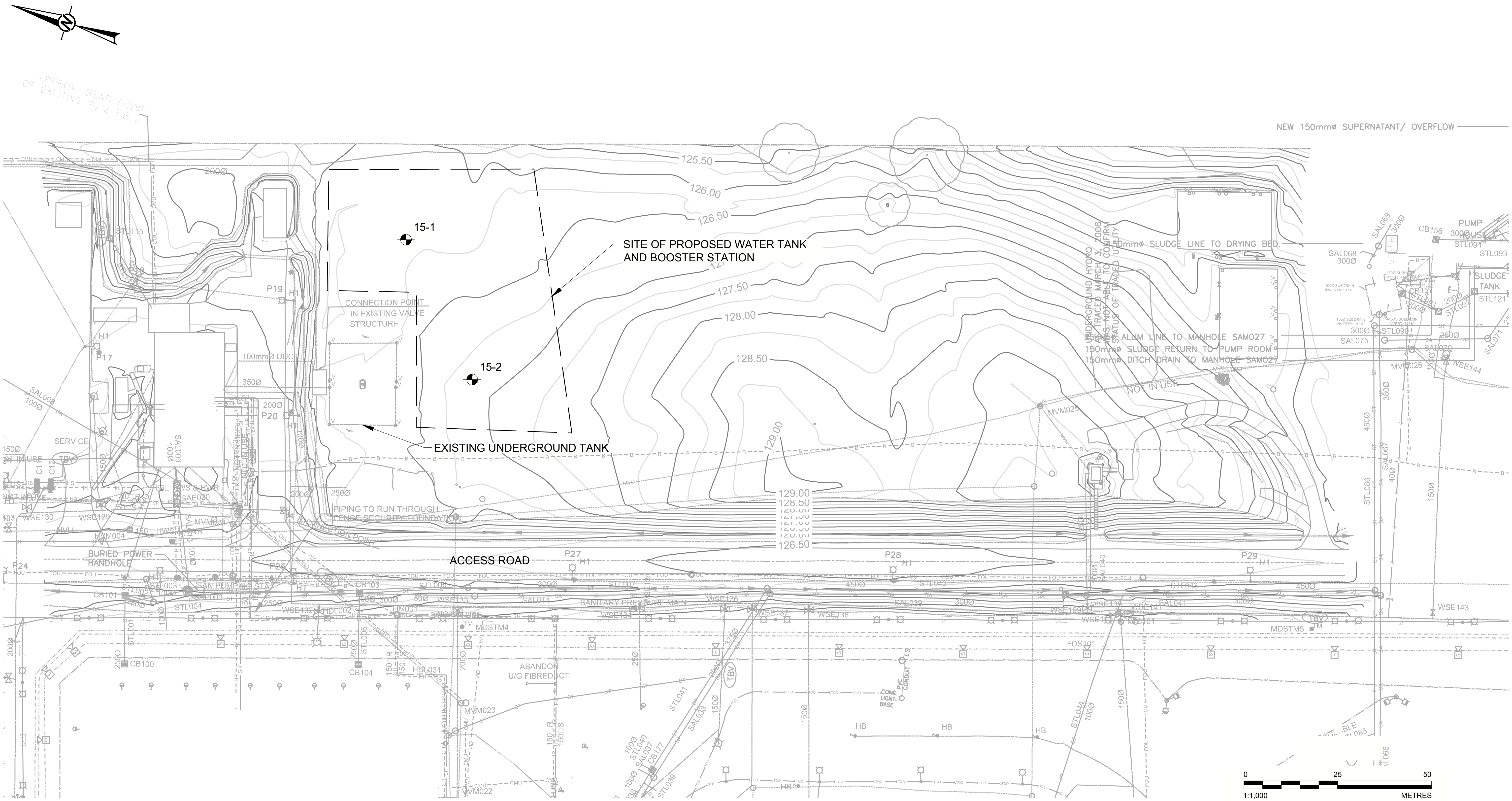
Golder Associates

YYYY-MM-DD	2016-02-21
DESIGNED	JT
PREPARED	JT
REVIEWED	EW
APPROVED	KJB

PROJECT NO.	CONTROL	REV.	FIGURE
1531866			1

Path: S:\Clients\CIMA\Campbellford_Workworth_Institute\99_PROJ\1531866\40_PROD\0001_Prelim_Geotech_Invest\1531866-0001-BG-0001.mxd

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



LEGEND

APPROXIMATE BOREHOLE LOCATION

REFERENCE

1. BASE PLAN PROVIDED BY PUBLIC WORKS AND GOVERNMENT SERVICES CANADA, ENTITLED "BASE PLAN", PROJECT NO. T000517A, DRAWING NO. SK-001, DATED DECEMBER 3, 2015.

CLIENT
CIMA+

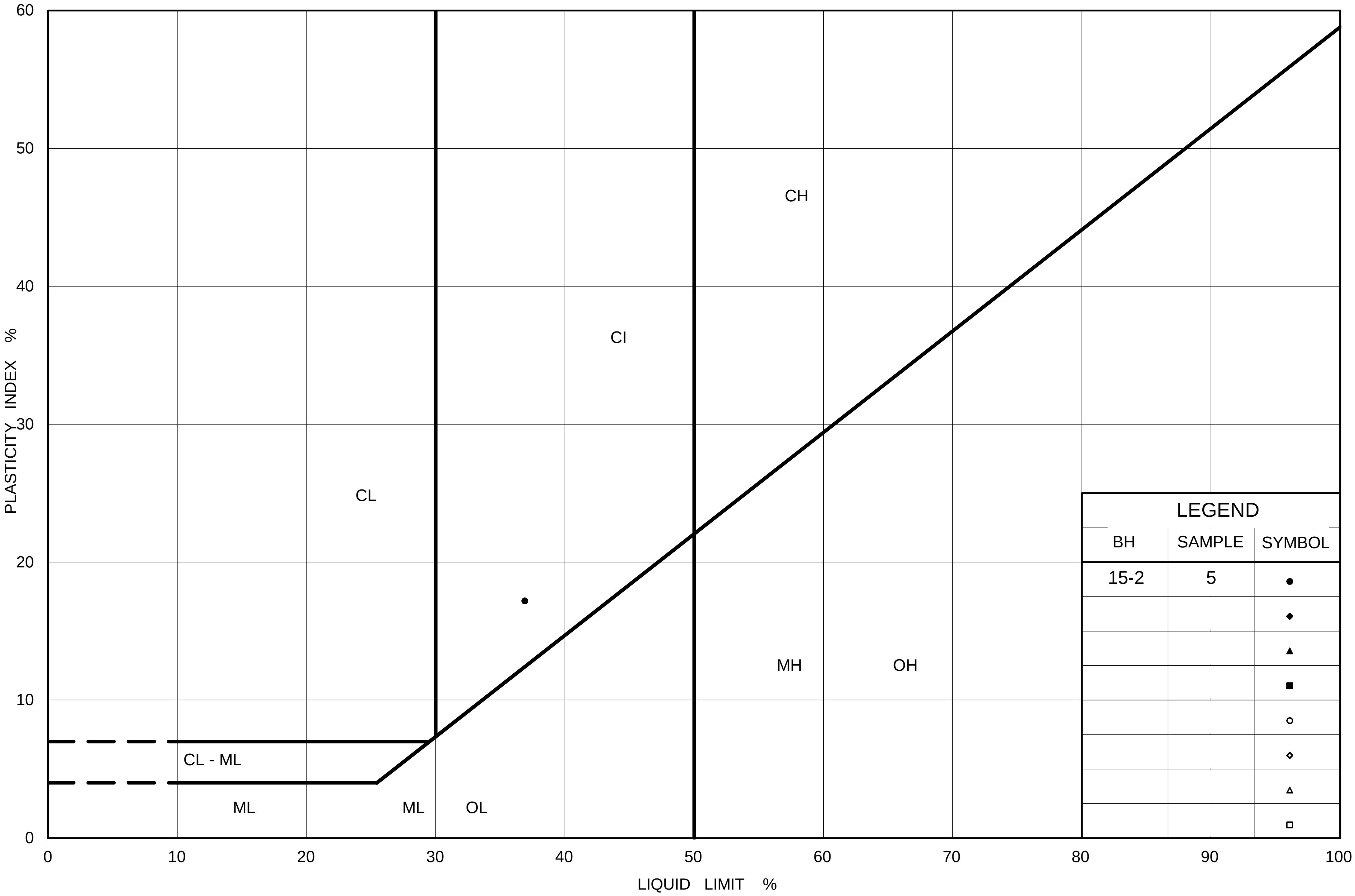
CONSULTANT
Golder Associates

YYYY-MM-DD	2016-02-19
DESIGNED	
PREPARED	MK
REVIEWED	EW
APPROVED	KJB

PROJECT
PRELIMINARY GEOTECHNICAL INVESTIGATION
PROPOSED WATER TANK AND BOOSTER STATION
WARKWORTH INSTITUTE, CAMPELLFORD, ONTARIO

TITLE
BOREHOLE LOCATION PLAN

PROJECT NO.	CONTROL	REV.	FIGURE
1531866		----	2



LEGEND

BH	SAMPLE	SYMBOL
15-2	5	●
		◆
		▲
		■
		○
		◇
		△
		□

Golder Associates

PLASTICITY CHART
(CI) SILTY CLAY

Figure No 3

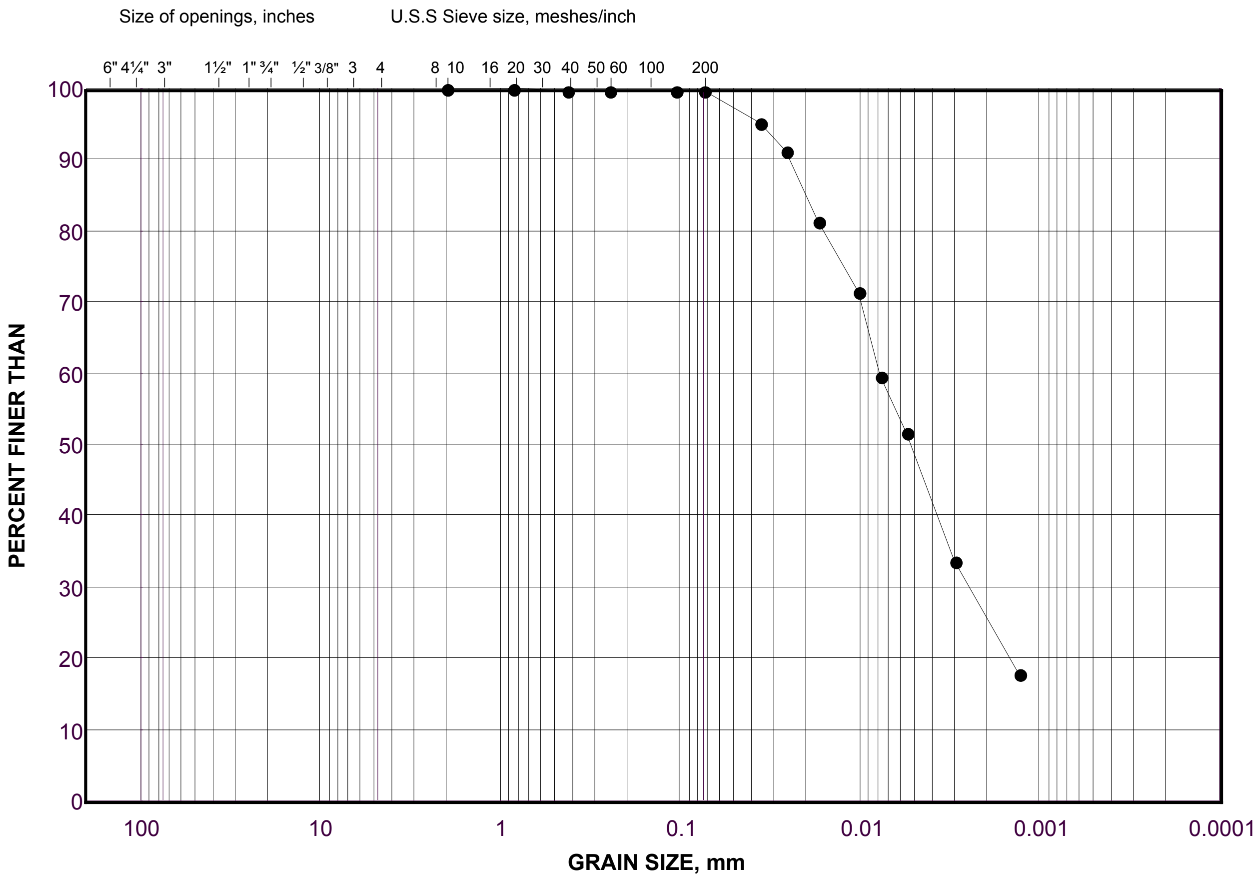
Project No. 15-31866

Checked By: EW

GRAIN SIZE DISTRIBUTION

(CI) SILTY CLAY

FIGURE 4



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	15-2	5	3.0 - 3.7

Project Number: 15-31866

Checked By: EW

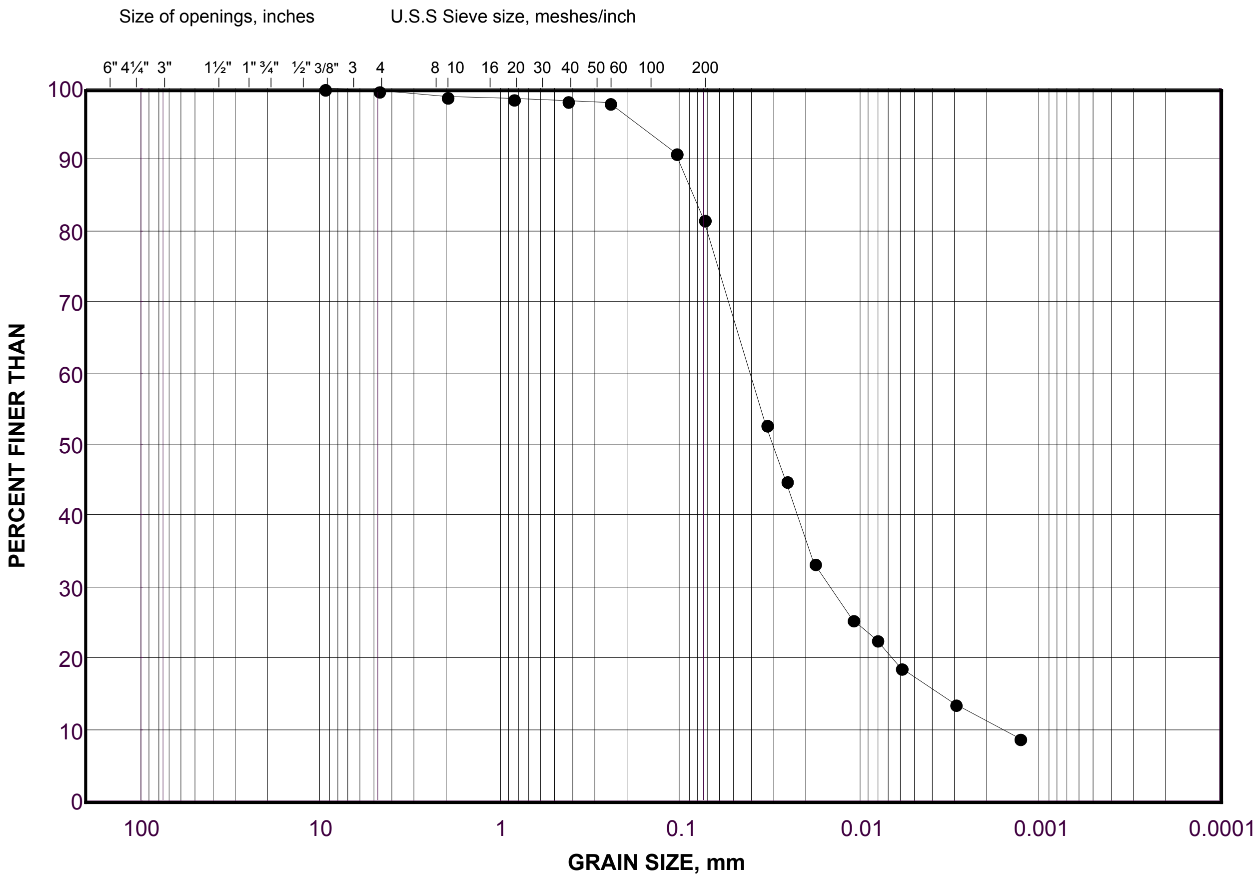
Golder Associates

Date: 09-Feb-16

GRAIN SIZE DISTRIBUTION

(ML) sandy SILT

FIGURE 5



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	15-1	7	6.1 - 6.4

Project Number: 15-31866

Checked By: EW

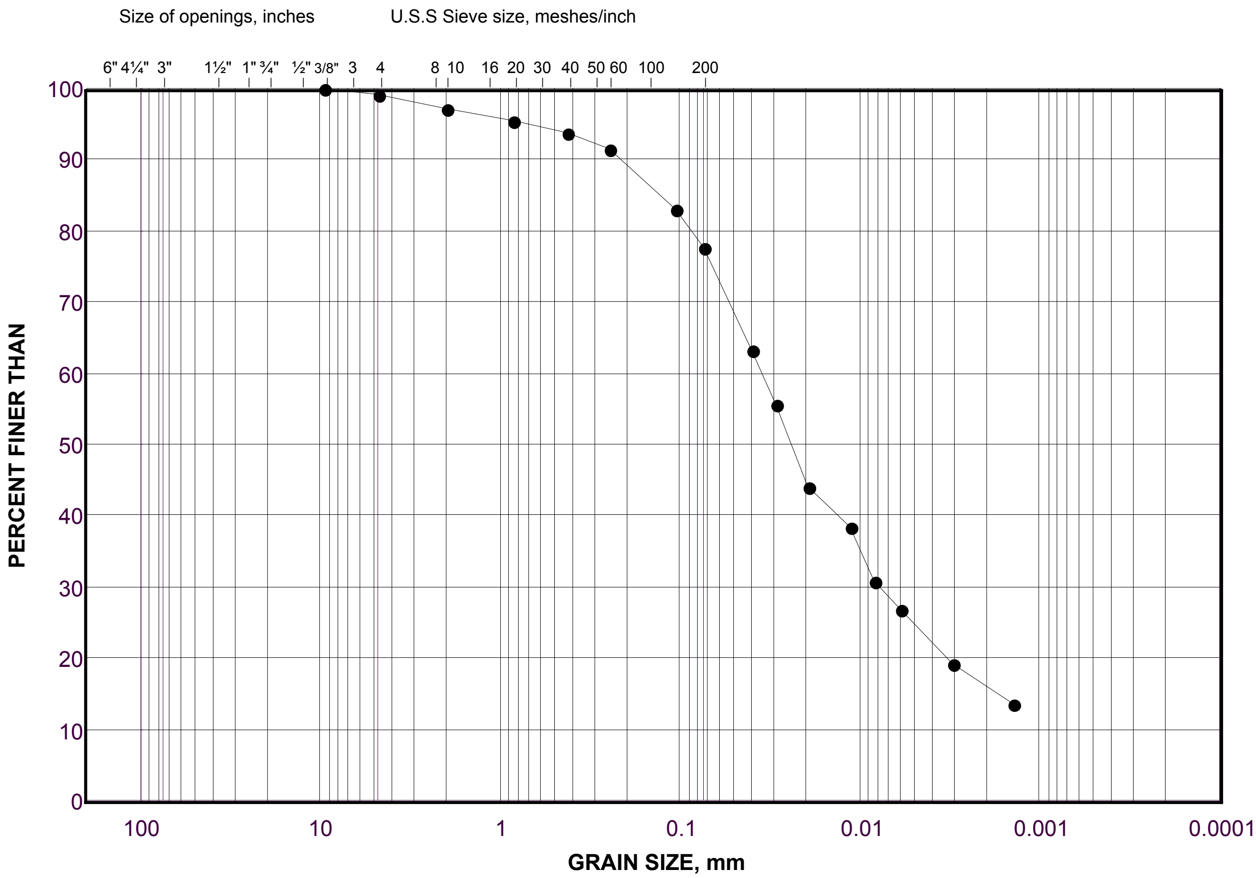
Golder Associates

Date: 09-Feb-16

GRAIN SIZE DISTRIBUTION

(ML) sandy SILT (TILL)

FIGURE 6



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	15-2	8	7.6 - 8.1

Project Number: 15-31866

Checked By: EW

Golder Associates

Date: 09-Feb-16

APPENDIX A

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 practising 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. 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 can not 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 upon the reasonable request of the client, Golder may authorize in writing the use of this report by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process. 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 can not 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 can not 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 Ground water 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.

APPENDIX B

Laboratory Certificates of Analysis

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

CLIENT NAME: GOLDER ASSOCIATES LTD.
100 SCOTIA COURT
WHITBY, ON L1N8Y6
(905) 723-2727

ATTENTION TO: Eric Wolinsky

PROJECT: 15-31866

AGAT WORK ORDER: 15T056346

SOIL ANALYSIS REVIEWED BY: Anthony Dapaah, PhD (Chem), Inorganic Lab Manager

TRACE ORGANICS REVIEWED BY: Oksana Gushyla, Trace Organics Lab Supervisor

DATE REPORTED: Jan 05, 2016

PAGES (INCLUDING COVER): 12

VERSION*: 1

Should you require any information regarding this analysis please contact your client services representative at (905) 712-5100

*NOTES

All samples will be disposed of within 30 days following analysis. Please contact the lab if you require additional sample storage time.

Certificate of Analysis

AGAT WORK ORDER: 15T056346
PROJECT: 15-31866

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

CLIENT NAME: GOLDER ASSOCIATES LTD.
ATTENTION TO: Eric Wolinsky
SAMPLING SITE:
SAMPLED BY:Eric Wolinsky

O. Reg. 153(511) - Metals & Inorganics (Soil)

DATE RECEIVED: 2015-12-24 **DATE REPORTED: 2016-01-05**

			SAMPLE DESCRIPTION:	15-1 SA1	15-2 SA4
			SAMPLE TYPE:	Soil	Soil
			DATE SAMPLED:	12/21/2015	12/21/2015
Parameter	**Unit**	**G / S**	**RDL**	**7312438**	**7312441**
Antimony	µg/g	1.3	0.8	<0.8	<0.8
Arsenic	µg/g	18	1	2	2
Barium	µg/g	220	2	123	156
Beryllium	µg/g	2.5	0.5	0.9	0.6
Boron	µg/g	36	5	<5	8
Boron (Hot Water Soluble)	µg/g	NA	0.10	0.12	<0.10
Cadmium	µg/g	1.2	0.5	<0.5	<0.5
Chromium	µg/g	70	2	32	30
Cobalt	µg/g	21	0.5	10.9	10.8
Copper	µg/g	92	1	18	22
Lead	µg/g	120	1	16	7
Molybdenum	µg/g	2	0.5	<0.5	<0.5
Nickel	µg/g	82	1	18	19
Selenium	µg/g	1.5	0.4	<0.4	<0.4
Silver	µg/g	0.5	0.2	<0.2	<0.2
Thallium	µg/g	1	0.4	<0.4	<0.4
Uranium	µg/g	2.5	0.5	0.6	0.5
Vanadium	µg/g	86	1	48	53
Zinc	µg/g	290	5	69	63
Chromium VI	µg/g	0.66	0.2	<0.2	<0.2
Cyanide	µg/g	0.051	0.040	<0.040	<0.040
Mercury	µg/g	0.27	0.10	<0.10	<0.10
Electrical Conductivity	mS/cm	0.57	0.005	0.113	0.135
Sodium Adsorption Ratio	NA	2.4	NA	0.177	0.190
pH, 2:1 CaCl2 Extraction	pH Units		NA	7.60	7.70

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard: Refers to Table 1: Full Depth Background Site Condition Standards - Soil - Residential/Parkland/Institutional/Industrial/Commercial/Community Property Use

7312438-7312441 EC & SAR were determined on the DI water extract obtained from the 2:1 leaching procedure (2 parts DI water:1 part soil). pH was determined on the 0.01M CaCl2 extract prepared at 2:1 ratio.

Certified By:

AGAT Laboratories

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

Certificate of Analysis

AGAT WORK ORDER: 15T056346

PROJECT: 15-31866

CLIENT NAME: GOLDER ASSOCIATES LTD.

ATTENTION TO: Eric Wolinsky

SAMPLING SITE:

SAMPLED BY:Eric Wolinsky

O. Reg. 153(511) - PHCs F1 - F4 (-BTEX) (Soil)

DATE RECEIVED: 2015-12-24

DATE REPORTED: 2016-01-05

			SAMPLE DESCRIPTION:	15-1 SA1	15-2 SA4
			SAMPLE TYPE:	Soil	Soil
			DATE SAMPLED:	12/21/2015	12/21/2015
Parameter	**Unit**	**G / S**	**RDL**	**7312438**	**7312441**
F1 (C6 to C10)	µg/g		5	<5	<5
F1 (C6 to C10) minus BTEX	µg/g	25	5	<5	<5
F2 (C10 to C16)	µg/g	10	10	<10	<10
F3 (C16 to C34)	µg/g	240	50	<50	<50
F4 (C34 to C50)	µg/g	120	50	<50	<50
Gravimetric Heavy Hydrocarbons	µg/g	120	50	NA	NA
Moisture Content	%		0.1	13.9	21.4
Surrogate	**Unit**	**Acceptable Limits**			
Terphenyl	%	60-140		99	100

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard: Refers to Table 1: Full Depth Background Site Condition Standards - Soil - Residential/Parkland/Institutional/Industrial/Commercial/Community Property Use

7312438-7312441 Due to high moisture content of the sample the reporting detection limit has been raised.
Results are based on sample dry weight.
The C6-C10 fraction is calculated using toluene response factor.
The C10 - C16, C16 - C34, and C34 - C50 fractions are calculated using the average response factor for n-C10, n-C16, and n-C34.
Gravimetric Heavy Hydrocarbons are not included in the Total C16-C50 and are only determined if the chromatogram of the C34 - C50 hydrocarbons indicates that hydrocarbons >C50 are present.
The chromatogram has returned to baseline by the retention time of nC50.
Total C6 - C50 results are corrected for BTEX contributions.
This method complies with the Reference Method for the CWS PHC and is validated for use in the laboratory.
nC6 and nC10 response factors are within 30% of Toluene response factor.
nC10, nC16 and nC34 response factors are within 10% of their average.
C50 response factor is within 70% of nC10 + nC16 + nC34 average.
Linearity is within 15%.
Extraction and holding times were met for this sample.
Fractions 1-4 are quantified without the contribution of PAHs. Under Ontario Regulation 153, results are considered valid without determining the PAH contribution if not requested by the client.

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CLIENT NAME: GOLDER ASSOCIATES LTD.

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SAMPLING SITE:

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O. Reg. 153(511) - VOCs (Soil)

DATE RECEIVED: 2015-12-24

DATE REPORTED: 2016-01-05

Parameter	Unit	G / S	RDL	15-1 SA1	15-2 SA4
			SAMPLE DESCRIPTION:	15-1 SA1	15-2 SA4
			SAMPLE TYPE:	Soil	Soil
			DATE SAMPLED:	12/21/2015	12/21/2015
				7312438	7312441
Dichlorodifluoromethane	µg/g	0.05	0.05	<0.05	<0.05
Vinyl Chloride	ug/g	0.02	0.02	<0.02	<0.02
Bromomethane	ug/g	0.05	0.05	<0.05	<0.05
Trichlorofluoromethane	ug/g	0.25	0.05	<0.05	<0.05
Acetone	ug/g	0.5	0.50	<0.50	<0.50
1,1-Dichloroethylene	ug/g	0.05	0.05	<0.05	<0.05
Methylene Chloride	ug/g	0.05	0.05	<0.05	<0.05
Trans- 1,2-Dichloroethylene	ug/g	0.05	0.05	<0.05	<0.05
Methyl tert-butyl Ether	ug/g	0.05	0.05	<0.05	<0.05
1,1-Dichloroethane	ug/g	0.05	0.02	<0.02	<0.02
Methyl Ethyl Ketone	ug/g	0.5	0.50	<0.50	<0.50
Cis- 1,2-Dichloroethylene	ug/g	0.05	0.02	<0.02	<0.02
Chloroform	ug/g	0.05	0.04	<0.04	<0.04
1,2-Dichloroethane	ug/g	0.05	0.03	<0.03	<0.03
1,1,1-Trichloroethane	ug/g	0.05	0.05	<0.05	<0.05
Carbon Tetrachloride	ug/g	0.05	0.05	<0.05	<0.05
Benzene	ug/g	0.02	0.02	<0.02	<0.02
1,2-Dichloropropane	ug/g	0.05	0.03	<0.03	<0.03
Trichloroethylene	ug/g	0.05	0.03	<0.03	<0.03
Bromodichloromethane	ug/g	0.05	0.05	<0.05	<0.05
Methyl Isobutyl Ketone	ug/g	0.5	0.50	<0.50	<0.50
1,1,2-Trichloroethane	ug/g	0.05	0.04	<0.04	<0.04
Toluene	ug/g	0.2	0.05	<0.05	<0.05
Dibromochloromethane	ug/g	0.05	0.05	<0.05	<0.05
Ethylene Dibromide	ug/g	0.05	0.04	<0.04	<0.04
Tetrachloroethylene	ug/g	0.05	0.05	<0.05	<0.05
1,1,1,2-Tetrachloroethane	ug/g	0.05	0.04	<0.04	<0.04
Chlorobenzene	ug/g	0.05	0.05	<0.05	<0.05
Ethylbenzene	ug/g	0.05	0.05	<0.05	<0.05
m & p-Xylene	ug/g		0.05	<0.05	<0.05

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PROJECT: 15-31866

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SAMPLING SITE:
ATTENTION TO: Eric Wolinsky
SAMPLED BY:Eric Wolinsky

O. Reg. 153(511) - VOCs (Soil)

DATE RECEIVED: 2015-12-24
DATE REPORTED: 2016-01-05

			SAMPLE DESCRIPTION:	15-1 SA1	15-2 SA4
			SAMPLE TYPE:	Soil	Soil
			DATE SAMPLED:	12/21/2015	12/21/2015
Parameter	**Unit**	**G / S**	**RDL**	**7312438**	**7312441**
Bromoform	ug/g	0.05	0.05	<0.05	<0.05
Styrene	ug/g	0.05	0.05	<0.05	<0.05
1,1,2,2-Tetrachloroethane	ug/g	0.05	0.05	<0.05	<0.05
o-Xylene	ug/g		0.05	<0.05	<0.05
1,3-Dichlorobenzene	ug/g	0.05	0.05	<0.05	<0.05
1,4-Dichlorobenzene	ug/g	0.05	0.05	<0.05	<0.05
1,2-Dichlorobenzene	ug/g	0.05	0.05	<0.05	<0.05
Xylene Mixture	ug/g	0.05	0.05	<0.05	<0.05
1,3-Dichloropropene	µg/g	0.05	0.04	<0.04	<0.04
n-Hexane	µg/g	0.05	0.05	<0.05	<0.05
Surrogate	**Unit**	**Acceptable Limits**			
Toluene-d8	% Recovery	50-140		97	98
4-Bromofluorobenzene	% Recovery	50-140		93	89

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard: Refers to Table 1: Full Depth Background Site Condition Standards - Soil - Residential/Parkland/Institutional/Industrial/Commercial/Community Property Use

7312438-7312441 The sample was analysed using the high level technique. The sample was extracted using methanol, a small amount of the methanol extract was diluted in water and the purge & trap GC/MS analysis was performed. Results are based on the dry weight of the soil.

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Quality Assurance

CLIENT NAME: GOLDER ASSOCIATES LTD.
PROJECT: 15-31866
SAMPLING SITE:

AGAT WORK ORDER: 15T056346
ATTENTION TO: Eric Wolinsky
SAMPLED BY:Eric Wolinsky

Soil Analysis

RPT Date: Jan 05, 2016			DUPLICATE			Method Blank	REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper
O. Reg. 153(511) - Metals & Inorganics (Soil)															
Antimony	7312735		<0.8	<0.8	NA	< 0.8	101%	70%	130%	103%	80%	120%	102%	70%	130%
Arsenic	7312735		6	6	0.0%	< 1	112%	70%	130%	98%	80%	120%	102%	70%	130%
Barium	7312735		82	80	2.5%	< 2	103%	70%	130%	100%	80%	120%	101%	70%	130%
Beryllium	7312735		0.7	0.7	NA	< 0.5	98%	70%	130%	105%	80%	120%	95%	70%	130%
Boron	7312735		8	9	NA	< 5	75%	70%	130%	102%	80%	120%	96%	70%	130%
Boron (Hot Water Soluble)	7310735		3.31	3.06	7.8%	< 0.10	116%	60%	140%	95%	70%	130%	93%	60%	140%
Cadmium	7312735		<0.5	<0.5	NA	< 0.5	103%	70%	130%	100%	80%	120%	96%	70%	130%
Chromium	7312735		21	22	4.7%	< 2	93%	70%	130%	106%	80%	120%	101%	70%	130%
Cobalt	7312735		12.7	12.9	1.6%	< 0.5	93%	70%	130%	97%	80%	120%	93%	70%	130%
Copper	7312735		32	31	3.2%	< 1	99%	70%	130%	109%	80%	120%	98%	70%	130%
Lead	7312735		11	11	0.0%	< 1	105%	70%	130%	109%	80%	120%	104%	70%	130%
Molybdenum	7312735		<0.5	<0.5	NA	< 0.5	98%	70%	130%	99%	80%	120%	103%	70%	130%
Nickel	7312735		24	24	0.0%	< 1	94%	70%	130%	98%	80%	120%	92%	70%	130%
Selenium	7312735		<0.4	<0.4	NA	< 0.4	107%	70%	130%	98%	80%	120%	99%	70%	130%
Silver	7312735		<0.2	<0.2	NA	< 0.2	79%	70%	130%	101%	80%	120%	96%	70%	130%
Thallium	7312735		<0.4	<0.4	NA	< 0.4	109%	70%	130%	98%	80%	120%	95%	70%	130%
Uranium	7312735		0.5	0.5	NA	< 0.5	102%	70%	130%	97%	80%	120%	93%	70%	130%
Vanadium	7312735		26	27	3.8%	< 1	92%	70%	130%	97%	80%	120%	97%	70%	130%
Zinc	7312735		64	64	0.0%	< 5	103%	70%	130%	103%	80%	120%	96%	70%	130%
Chromium VI	7312747		<0.2	<0.2	NA	< 0.2	98%	70%	130%	98%	80%	120%	99%	70%	130%
Cyanide	7312470		<0.040	<0.040	NA	< 0.040	102%	70%	130%	103%	80%	120%	99%	70%	130%
Mercury	7312735		<0.10	<0.10	NA	< 0.10	115%	70%	130%	88%	80%	120%	85%	70%	130%
Electrical Conductivity	7311824		0.726	0.711	2.1%	< 0.005	93%	90%	110%	NA			NA		
Sodium Adsorption Ratio	7311824		5.98	6.08	1.7%	NA	NA			NA			NA		
pH, 2:1 CaCl2 Extraction	7311154		7.63	7.66	0.4%	NA	101%	80%	120%	NA			NA		

Comments: NA signifies Not Applicable.
Duplicate Qualifier: As the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

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Quality Assurance

CLIENT NAME: GOLDER ASSOCIATES LTD. **AGAT WORK ORDER: 15T056346**
PROJECT: 15-31866 **ATTENTION TO: Eric Wolinsky**
SAMPLING SITE: **SAMPLED BY:Eric Wolinsky**

Trace Organics Analysis

RPT Date: Jan 05, 2016			DUPLICATE			Method Blank	REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper
O. Reg. 153(511) - VOCs (Soil)															
Dichlorodifluoromethane	7311672		< 0.05	< 0.05	NA	< 0.05	94%	50%	140%	74%	50%	140%	110%	50%	140%
Vinyl Chloride	7311672		< 0.02	< 0.02	NA	< 0.02	89%	50%	140%	75%	50%	140%	90%	50%	140%
Bromomethane	7311672		< 0.05	< 0.05	NA	< 0.05	81%	50%	140%	85%	50%	140%	86%	50%	140%
Trichlorofluoromethane	7311672		< 0.05	< 0.05	NA	< 0.05	86%	50%	140%	101%	50%	140%	99%	50%	140%
Acetone	7311672		< 0.50	< 0.50	NA	< 0.50	104%	50%	140%	124%	50%	140%	104%	50%	140%
1,1-Dichloroethylene	7311672		< 0.05	< 0.05	NA	< 0.05	93%	50%	140%	96%	60%	130%	101%	50%	140%
Methylene Chloride	7311672		< 0.05	< 0.05	NA	< 0.05	126%	50%	140%	113%	60%	130%	115%	50%	140%
Trans- 1,2-Dichloroethylene	7311672		< 0.05	< 0.05	NA	< 0.05	78%	50%	140%	70%	60%	130%	95%	50%	140%
Methyl tert-butyl Ether	7311672		< 0.05	< 0.05	NA	< 0.05	77%	50%	140%	87%	60%	130%	110%	50%	140%
1,1-Dichloroethane	7311672		< 0.02	< 0.02	NA	< 0.02	75%	50%	140%	85%	60%	130%	98%	50%	140%
Methyl Ethyl Ketone	7311672		< 0.50	< 0.50	NA	< 0.50	130%	50%	140%	130%	50%	140%	114%	50%	140%
Cis- 1,2-Dichloroethylene	7311672		< 0.02	< 0.02	NA	< 0.02	112%	50%	140%	126%	60%	130%	102%	50%	140%
Chloroform	7311672		< 0.04	< 0.04	NA	< 0.04	120%	50%	140%	122%	60%	130%	94%	50%	140%
1,2-Dichloroethane	7311672		< 0.03	< 0.03	NA	< 0.03	130%	50%	140%	128%	60%	130%	108%	50%	140%
1,1,1-Trichloroethane	7311672		< 0.05	< 0.05	NA	< 0.05	113%	50%	140%	121%	60%	130%	107%	50%	140%
Carbon Tetrachloride	7311672		< 0.05	< 0.05	NA	< 0.05	80%	50%	140%	115%	60%	130%	102%	50%	140%
Benzene	7311672		< 0.02	< 0.02	NA	< 0.02	128%	50%	140%	116%	60%	130%	116%	50%	140%
1,2-Dichloropropane	7311672		< 0.03	< 0.03	NA	< 0.03	118%	50%	140%	111%	60%	130%	108%	50%	140%
Trichloroethylene	7311672		< 0.03	< 0.03	NA	< 0.03	113%	50%	140%	94%	60%	130%	102%	50%	140%
Bromodichloromethane	7311672		< 0.05	< 0.05	NA	< 0.05	106%	50%	140%	126%	60%	130%	107%	50%	140%
Methyl Isobutyl Ketone	7311672		< 0.50	< 0.50	NA	< 0.50	96%	50%	140%	108%	50%	140%	103%	50%	140%
1,1,2-Trichloroethane	7311672		< 0.04	< 0.04	NA	< 0.04	100%	50%	140%	101%	60%	130%	104%	50%	140%
Toluene	7311672		< 0.05	< 0.05	NA	< 0.05	92%	50%	140%	84%	60%	130%	94%	50%	140%
Dibromochloromethane	7311672		< 0.05	< 0.05	NA	< 0.05	75%	50%	140%	120%	60%	130%	99%	50%	140%
Ethylene Dibromide	7311672		< 0.04	< 0.04	NA	< 0.04	97%	50%	140%	106%	60%	130%	104%	50%	140%
Tetrachloroethylene	7311672		< 0.05	< 0.05	NA	< 0.05	86%	50%	140%	76%	60%	130%	91%	50%	140%
1,1,1,2-Tetrachloroethane	7311672		< 0.04	< 0.04	NA	< 0.04	70%	50%	140%	102%	60%	130%	92%	50%	140%
Chlorobenzene	7311672		< 0.05	< 0.05	NA	< 0.05	91%	50%	140%	85%	60%	130%	92%	50%	140%
Ethylbenzene	7311672		< 0.05	< 0.05	NA	< 0.05	90%	50%	140%	80%	60%	130%	90%	50%	140%
m & p-Xylene	7311672		< 0.05	< 0.05	NA	< 0.05	93%	50%	140%	81%	60%	130%	92%	50%	140%
Bromoform	7311672		< 0.05	< 0.05	NA	< 0.05	73%	50%	140%	107%	60%	130%	96%	50%	140%
Styrene	7311672		< 0.05	< 0.05	NA	< 0.05	87%	50%	140%	82%	60%	130%	87%	50%	140%
1,1,2,2-Tetrachloroethane	7311672		< 0.05	< 0.05	NA	< 0.05	93%	50%	140%	105%	60%	130%	102%	50%	140%
o-Xylene	7311672		< 0.05	< 0.05	NA	< 0.05	93%	50%	140%	82%	60%	130%	90%	50%	140%
1,3-Dichlorobenzene	7311672		< 0.05	< 0.05	NA	< 0.05	87%	50%	140%	80%	60%	130%	86%	50%	140%
1,4-Dichlorobenzene	7311672		< 0.05	< 0.05	NA	< 0.05	91%	50%	140%	83%	60%	130%	89%	50%	140%
1,2-Dichlorobenzene	7311672		< 0.05	< 0.05	NA	< 0.05	91%	50%	140%	85%	60%	130%	90%	50%	140%
1,3-Dichloropropene	7311672		< 0.04	< 0.04	NA	< 0.04	86%	50%	140%	109%	60%	130%	103%	50%	140%
n-Hexane	7311672		0.58	0.47	21.0%	< 0.05	95%	50%	140%	105%	60%	130%	120%	50%	140%

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Quality Assurance

CLIENT NAME: GOLDER ASSOCIATES LTD.
PROJECT: 15-31866
SAMPLING SITE:

AGAT WORK ORDER: 15T056346
ATTENTION TO: Eric Wolinsky
SAMPLED BY:Eric Wolinsky

Trace Organics Analysis (Continued)

RPT Date: Jan 05, 2016			DUPLICATE				REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD	Method Blank	Measured Value	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper
O. Reg. 153(511) - PHCs F1 - F4 (-BTEX) (Soil)															
F1 (C6 to C10)	7312534		< 5	< 5	NA	< 5	110%	60%	130%	91%	85%	115%	85%	70%	130%
F2 (C10 to C16)	7312463		< 10	< 10	NA	< 10	98%	60%	130%	102%	80%	120%	84%	70%	130%
F3 (C16 to C34)	7312463		< 50	< 50	NA	< 50	98%	60%	130%	105%	80%	120%	91%	70%	130%
F4 (C34 to C50)	7312463		< 50	< 50	NA	< 50	83%	60%	130%	109%	80%	120%	85%	70%	130%

Comments: When the average of the sample and duplicate results is less than 5x the RDL, the Relative Percent Difference (RPD) will be indicated as Not Applicable(NA).

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Method Summary

CLIENT NAME: GOLDER ASSOCIATES LTD.

AGAT WORK ORDER: 15T056346

PROJECT: 15-31866

ATTENTION TO: Eric Wolinsky

SAMPLING SITE:

SAMPLED BY:Eric Wolinsky

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
Antimony	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Arsenic	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Barium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Beryllium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Boron	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Boron (Hot Water Soluble)	MET-93-6104	EPA SW 846 6010C; MSA, Part 3, Ch.21	ICP/OES
Cadmium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Chromium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Cobalt	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Copper	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Lead	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Molybdenum	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Nickel	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Selenium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Silver	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Thallium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Uranium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Vanadium	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Zinc	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Chromium VI	INOR-93-6029	SM 3500 B; MSA Part 3, Ch. 25	SPECTROPHOTOMETER
Cyanide	INOR-93-6052	MOE CN-3015 & E 3009 A;SM 4500 CN	TECHNICON AUTO ANALYZER
Mercury	MET-93-6103	EPA SW-846 3050B & 6020A	ICP-MS
Electrical Conductivity	INOR-93-6036	McKeague 4.12, SM 2510 B	EC METER
Sodium Adsorption Ratio	INOR-93-6007	McKeague 4.12 & 3.26 & EPA SW-846 6010B	ICP/OES
pH, 2:1 CaCl2 Extraction	INOR-93-6031	MSA part 3 & SM 4500-H+ B	PH METER

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Method Summary

CLIENT NAME: GOLDER ASSOCIATES LTD.
PROJECT: 15-31866
SAMPLING SITE:
AGAT WORK ORDER: 15T056346
ATTENTION TO: Eric Wolinsky
SAMPLED BY:Eric Wolinsky

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Trace Organics Analysis			
F1 (C6 to C10)	VOL-91-5009	CCME Tier 1 Method, SW846 5035	P &T GC / FID
F1 (C6 to C10) minus BTEX	VOL-91-5009	CCME Tier 1 Method, SW846 5035	P & T GC / FID
F2 (C10 to C16)	VOL-91-5009	CCME Tier 1 Method	GC / FID
F3 (C16 to C34)	VOL-91-5009	CCME Tier 1 Method	GC / FID
F4 (C34 to C50)	VOL-91-5009	CCME Tier 1 Method	GC / FID
Gravimetric Heavy Hydrocarbons	VOL-91-5009	CCME Tier 1 Method	GRAVIMETRIC ANALYSIS
Moisture Content	VOL-91-5009	CCME Tier 1 Method, SW846 5035,8015	BALANCE
Terphenyl	VOL-91-5009		GC/FID
Dichlorodifluoromethane	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Vinyl Chloride	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Bromomethane	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Trichlorofluoromethane	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Acetone	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
1,1-Dichloroethylene	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Methylene Chloride	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Trans- 1,2-Dichloroethylene	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Methyl tert-butyl Ether	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
1,1-Dichloroethane	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Methyl Ethyl Ketone	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Cis- 1,2-Dichloroethylene	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Chloroform	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
1,2-Dichloroethane	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
1,1,1-Trichloroethane	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Carbon Tetrachloride	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Benzene	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
1,2-Dichloropropane	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Trichloroethylene	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Bromodichloromethane	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Methyl Isobutyl Ketone	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
1,1,2-Trichloroethane	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Toluene	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Dibromochloromethane	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Ethylene Dibromide	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Tetrachloroethylene	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
1,1,1,2-Tetrachloroethane	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Chlorobenzene	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Ethylbenzene	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
m & p-Xylene	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Bromoform	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Styrene	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
1,1,2,2-Tetrachloroethane	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
o-Xylene	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
1,3-Dichlorobenzene	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
1,4-Dichlorobenzene	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
1,2-Dichlorobenzene	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
Xylene Mixture	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
1,3-Dichloropropene	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
n-Hexane	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS

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Method Summary

CLIENT NAME: GOLDER ASSOCIATES LTD.
PROJECT: 15-31866
SAMPLING SITE:

AGAT WORK ORDER: 15T056346
ATTENTION TO: Eric Wolinsky
SAMPLED BY:Eric Wolinsky

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Toluene-d8	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS
4-Bromofluorobenzene	VOL-91-5002	EPA SW-846 5035 & 8260	(P&T)GC/MS

AGAT Laboratories

5835 Coopers Avenue
Mississauga, Ontario L4Z 1Y2
Ph: 905.712.5100 Fax: 905.712.5122
webearth.agatlabs.com

Laboratory Use Only

Work Order #: 15T 056346
Cooler Quantity: 1 ea
Arrival Temperatures: 3.9 | 3.4 | 3.3 / 3 | 2.6 | 2.4 (Ice)
Custody Seal Intact: ☐ Yes ☐ No ☐ N/A
Notes:

Chain of Custody Record

If this is a Drinking Water sample, please use Drinking Water Chain of Custody Form (potable water intended for human consumption)

Report Information:
Company: Golder Associates
Contact: Eric Wolinsky
Address: 100 Scotia Ct
Whitby ON L1N 8Y6
Phone: 905-723-2727 Fax:
Reports to be sent to:
1. Email: ewolinsky@golder.com
2. Email:

Regulatory Requirements: ☐ No Regulatory Requirement
(Please check all applicable boxes)

☒ Regulation 153/04 — Table 1 (Indicate One)
☒ Ind/Com
☒ Res/Park
☐ Agriculture
Soil Texture (Check One)
☐ Coarse
☒ Fine

☐ Sewer Use
☐ Sanitary
☐ Storm
Region ____ (Indicate One)

☐ Regulation 558
☐ CCME
☐ Prov. Water Quality Objectives (PWQO)
☐ Other ____ (Indicate One)

Is this submission for a Record of Site Condition? ☐ Yes ☒ No

Report Guideline on Certificate of Analysis ☒ Yes ☐ No

Turnaround Time (TAT) Required:
Regular TAT ☒ 5 to 7 Business Days
Rush TAT (Rush Surcharges Apply)
☐ 3 Business Days ☐ 2 Business Days ☐ 1 Business Day
OR Date Required (Rush Surcharges May Apply):
Please provide prior notification for rush TAT
**TAT is exclusive of weekends and statutory holidays*

Project Information:
Project: 15-31866
Site Location: Warkworth
Sampled By: Eric Wolinsky
AGAT Quote #: Golder PO:
Please note: If quotation number is not provided, client will be billed full price for analysis.

Invoice Information: Bill To Same: Yes ☒ No ☐
Company: Golder Associates
Contact:
Address:
Email:

Sample Matrix Legend
B Biota
GW Ground Water
O Oil
P Paint
S Soil
SD Sediment
SW Surface Water

(Check Applicable)
ORPs: ☐ B-HWS ☐ Cl⁻ ☐ CN⁻ ☐ Cr⁶⁺ ☐ EC ☐ FOC ☐ NO_3/NO_2 ☐ Total N ☐ Hg ☐ pH ☐ SAR
Nutrients: ☐ TP ☐ NH_3 ☐ TKN ☐ NO_3 ☐ NO_2 ☐ NO_3/NO_2
Volatiles: ☒ VOC ☐ BTEX ☐ THM

Sample Identification	Date Sampled	Time Sampled	# of Containers	Sample Matrix	Comments/ Special Instructions	Metals and Inorganics	Metal Scan	Hydride Forming Metals	Client Custom Metals	ORPs	Nutrients	Volatiles	CCME Fractions 1 to 4	ABNs	PAHs	Chlorophenols	PCBs	Organochlorine Pesticides	TCLP Metals/Inorganics	Sewer Use
15-1 SA1	Dec 21	10 am	3	S		X						X	X							
15-2 SA7	Dec 21	1 pm	3	S		X						X	X							

Samples Relinquished By (Print Name and Sign):	Date	Time	Samples Received By (Print Name and Sign):	Date	Time
Eric Wolinsky [signature]	Dec 23/15	1:00pm	[signature]	2015-12-24	8:29
[signature]	2015-12-24	9:42			

Page 1 of 1

Nº: T 019672

Document ID: DIV-78 1511.010

Pink Copy - Client | Yellow Copy - AGAT | White Copy- AGAT

Date Issued: November 2, 2015

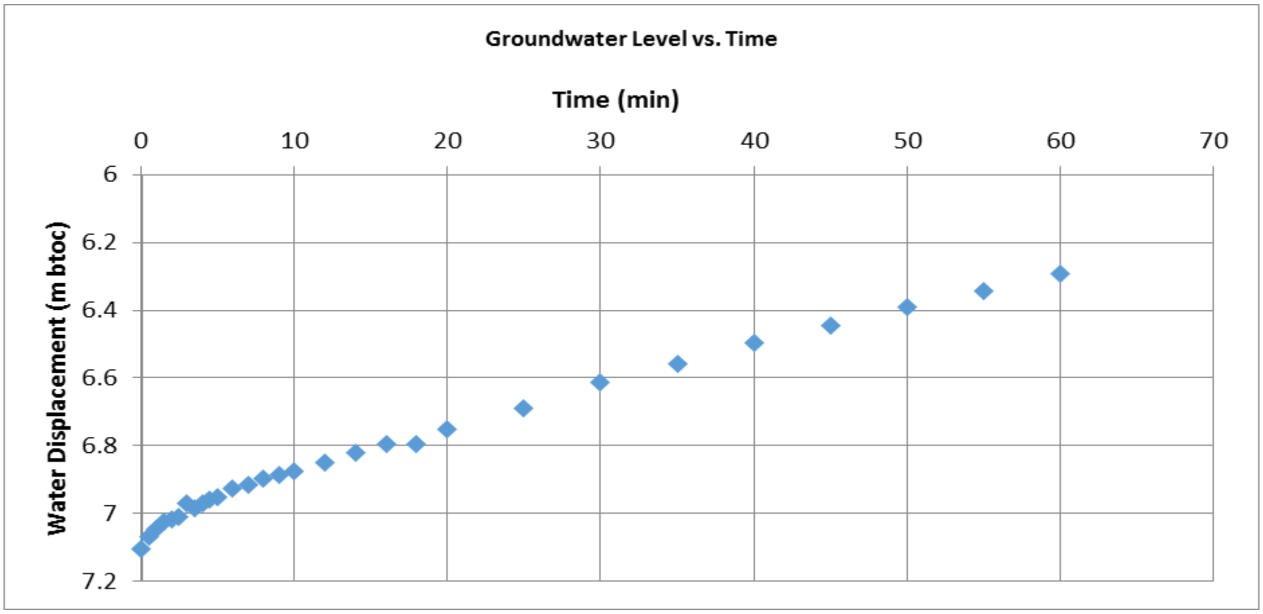
APPENDIX C

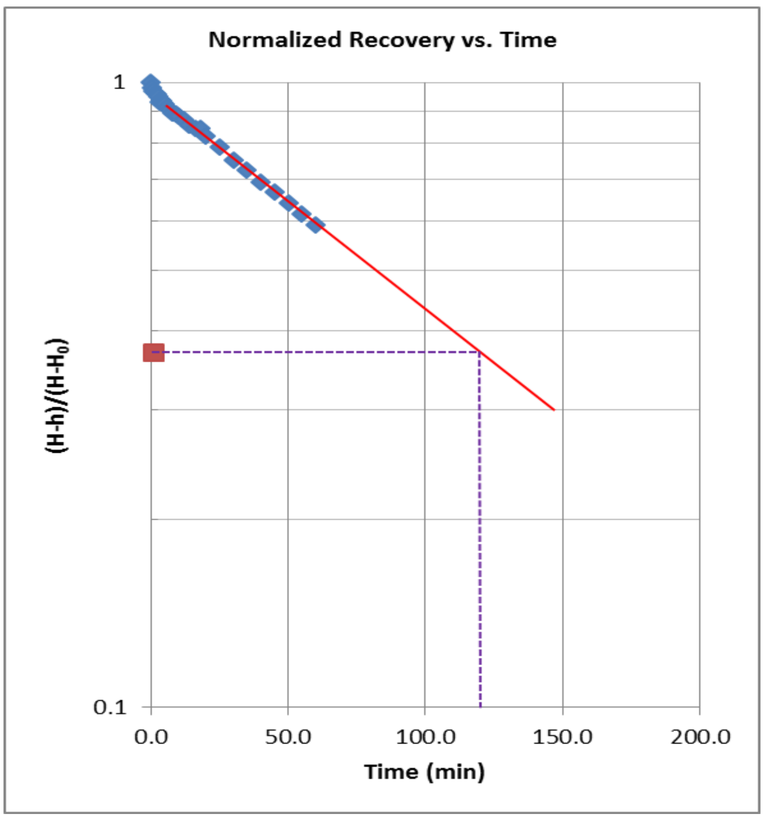
Single-Well Response Test Data

In Situ Hydraulic Conductivity Test Report of BH15-1

Proposed Water Tank and Booster Station, Warkworth Institute, Campbellford, Ontario

Figure C1





Screened Interval

9.12 to 12.65 m btoc

Bedrock

Time Lag (T_0) =	120 min
Screen Length (L) =	3.53 m
Well Radius (r) =	0.0508 m
Hole Radius (R) =	0.203 m

Hvorslev Analysis

$$K = \frac{(r^2)\ln(^L/_R)}{2T_0L} = 1 \times 10^{-5} \text{ cm/s}$$

DATE: April 2016

PROJECT: 1531866

Golder Associates

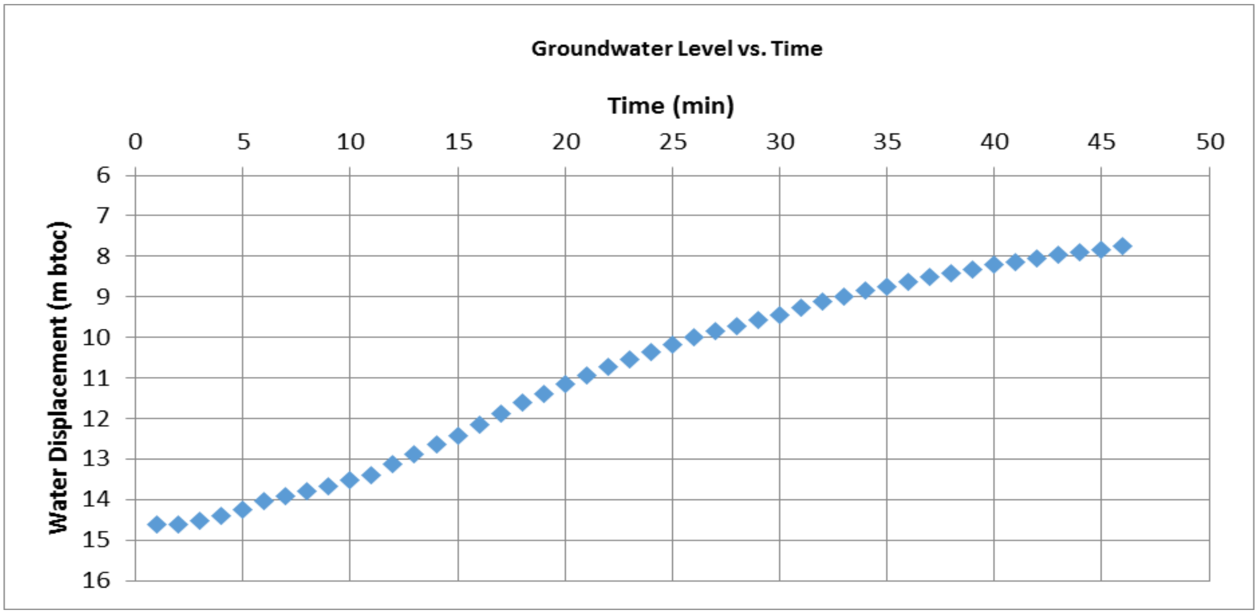
Prepared By EW

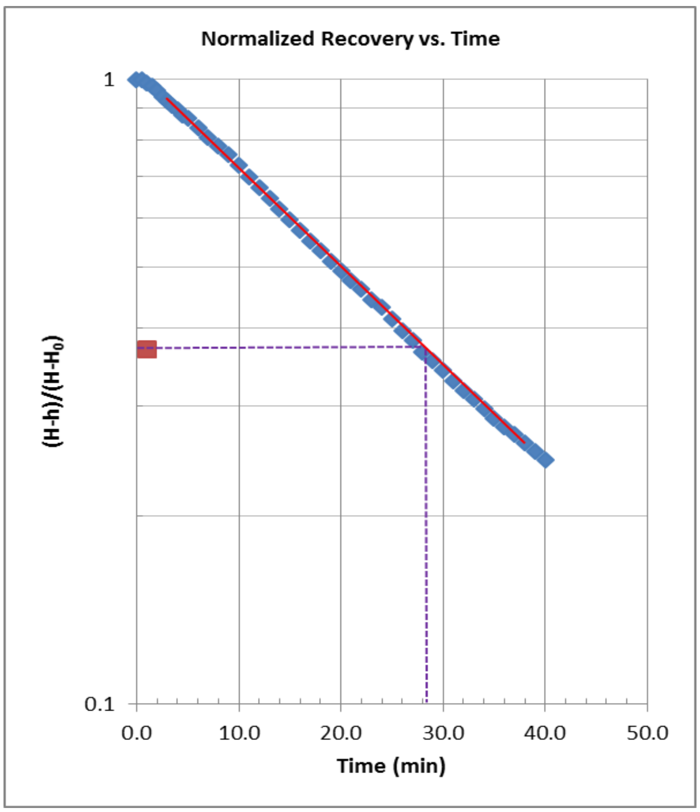
Checked By: CMK

In Situ Hydraulic Conductivity Test Report of BH15-2

Proposed Water Tank and Booster Station, Warkworth Institute, Campbellford, Ontario

Figure C2





Screened Interval

10.5 to 14.1 m btoc

Bedrock

Time Lag (T_0) =	28 min
Screen Length (L) =	3.60 m
Well Radius (r) =	0.0508 m
Hole Radius (R) =	0.203 m

Hvorslev Analysis

$$K = \frac{(r^2)\ln(^L/_R)}{2T_0L} = 6 \times 10^{-5} \text{ cm/s}$$

DATE:	April 2016	Prepared By	EW
PROJECT:	1531866	Checked By:	CMK

Golder Associates

At Golder Associates we strive to be the most respected global company providing consulting, design, and construction services in earth, environment, and related areas of energy. Employee owned since our formation in 1960, our focus, unique culture and operating environment offer opportunities and the freedom to excel, which attracts the leading specialists in our fields. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees who operate from offices located throughout Africa, Asia, Australasia, Europe, North America, and South America.

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