



FINAL REPORT

FOUNDATION INVESTIGATION AND DESIGN REPORT New Patrol Yard Structure at MTO Jarvis Patrol Yard, Haldimand County

**Agreement No. 3015-E-0017
Assignment No. 6
GWP 3075-16-00
Geocres No. 40116-28**

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Foundation Investigation and Design Report

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1 FOUNDATION INVESTIGATION REPORT

1.1 Introduction

This report presents the results of a geotechnical investigation carried out by **exp** Services Inc. (**exp**) for the proposed new salt storage structure located at the MTO Jarvis Patrol Yard, located in Haldimand County, Southern Ontario. The work was undertaken under Agreement # 3015-E-0017, Assignment No. 6 (GWP 3075-16-00). The terms of reference (TOR) were as presented in the Ministry of Transportation (MTO) email received on July 27, 2017.

The purpose of this investigation is to establish existing subsurface conditions at the proposed location of the patrol yard structure within construction limits defined by MTO. The site specific geotechnical investigation consisted of field investigation including visual inspection, drilling, soil sampling, and laboratory testing. Factual results of the investigation and laboratory testing are included in this report. The report has been prepared specifically and solely for the project described in the report.

1.2 Site Description and Geological Setting

1.2.1 Site Description

The Jarvis Patrol Yard is located on Old Hwy 3, approximately 1.3 km west of the Hwy 3 and Hwy 6 junction in Jarvis, Haldimand County, Southern Ontario (see Key Map on Drawing 1, Appendix B). The site is bound by West Concession 7 Walpole to the north, Old Hwy 3 to the east, and by farm land to the south and west.

A paved roadway and parking area lead from the site entrance on Old Hwy 3 to an approximately 7x9 m steel shed, which is located approximately 60 m west of entrance gate, and to an approximately 18x32 m gambrel style building, which is located immediately west of the proposed structure.

The topography of the site is considered flat lying with borehole elevations ranging from 210.0 to 210.3 m. The ground surface of the proposed building site consists of gravel near the south end and transitions to tall grass to the north. The area beyond the north boundary of the proposed building consists of bush with mature trees. Photographs of the site are included in Appendix A.

1.2.2 Geological Setting

The Map P.2715 (Physiography of Southern Ontario, Third Edition, 1984) Bedrock Geology of Ontario, Southern Sheet, 1991) of the Ministry of Natural Resources indicates that the project area is located at the boundary of Sand Plain and Clay Plain. The Map 2556 (Quaternary Geology of Ontario, Southern Sheet, 1991) of the Ministry of Northern Development and Mines, indicates that the surface conditions consist of glaciolaustrine deposits including silt and clay, minor sand; basin and quiet water deposits. The Map 2544 (Bedrock Geology of Ontario, Southern Sheet, 1991) of the Ministry of Northern

Development and Mines, indicates that the bedrock formation of the project area consists of limestone, dolostone and shale, middle devonian.

1.3 Investigation Procedures

1.3.1 General

The field investigation was performed between August 23 and 25, 2017. The field program consisted of drilling five (5) sampled boreholes (BH-1 to BH-5). The boreholes were strategically located at the patrol yard to provide the subsurface information for the design of the proposed salt storage structure. The borehole locations are shown on Drawing 1 in Appendix B.

The borehole locations (referenced to the MTM NAD83 coordinate system) and their ground surface elevations were surveyed by **exp** personnel, with reference to a temporary benchmark (TBM) established on site. The TBM was set on top of concrete slab on grade located at the east side of the sliding garage door entrance to the large gambrel style building. The elevation of the TBM was assigned 210.0 m, and location of the TBM is shown on Drawing 1, in Appendix B.

The boreholes were advanced using a truck mounted CME-75 drill rig, equipped with a hollow stem augers and diamond bit NW casing. All borehole drilling and sampling operations were performed by a specialist drilling contractor, Elite Drilling Services. Boreholes BH-1, BH-3, and BH-5 were augered to refusal on bedrock then cored to depths ranging from 10.7 m to 11.0 m below grade and boreholes BH-2 and BH-4 were augered to refusal on bedrock at depths of 7.6 m and 7.7 m, respectively.

During the drilling of the boreholes, soil samples were obtained using a 51 mm outside diameter (O.D.) split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures (ASTM D 1586), at intervals shown on the attached borehole logs (Appendix C). The original field (uncorrected) SPT "N" values were recorded on the borehole logs as recommended in the Canadian Foundation Engineering Manual (CFEM pg. 40), and used to provide an assessment of in-situ consistency of cohesive soils or relative density of non-cohesive soils. Field vane testing was conducted in cohesive soil to measure the in-situ undrained shear strength of this soil. Field vane test was conducted in accordance with ASTM D2573-08. When a hard stratum was reached sampling of hard material was performed by diamond core drilling, using a 1.5 m long NQ double tube wireline core barrel.

Upon completion of the drilling operations, groundwater level measurements were carried out in the open holes. All boreholes remained dry upon completion of the drilling operations and the groundwater level at BH-1 was measured at 7.5 m below grade after remaining open for a period of four hours (see Section 1.5). The boreholes were decommissioned by bentonite/cement mixtures in accordance with the Ministry of the Environment Regulation 903, as amended by Regulation 128/03 (the well regulation under the Ontario Water Resources Act).

The fieldwork was supervised by a member of **exp's** engineering staff who directed the drilling and sampling operation, logged borehole data in accordance with MTO and/or ASTM standards for soils classification, and retrieved soil samples for subsequent laboratory testing and identification.

All the recovered soil samples were placed in labelled moisture-proof bags and returned to **exp's** Hamilton laboratory for additional visual, textual and olfactory examination, and sampling for laboratory testing.

1.3.2 Laboratory Testing

All samples returned to the laboratory were subjected to visual examination and classification. The laboratory testing program included the determination of natural moisture content, particle size distribution for approximately 25% of the collected soil samples. Atterberg Limits tests were carried out on select cohesive soil samples. Corrosivity package tests were performed on one soil sample. All the laboratory tests were carried out in accordance with MTO and/or ASTM standards as appropriate.

The laboratory test results are provided on the attached borehole log sheets in Appendix C. The results of the grain size analyses are presented graphically in Appendix D.

1.4 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes advanced during this investigation, together with the results of the laboratory tests carried out on selected soil samples, are presented on the borehole log sheets in Appendix C. Laboratory test results are provided in Appendix D. The "Explanation of Terms Used in Report" preceding the borehole logs in Appendix C forms an integral part of and should be read in conjunction with this report.

A borehole location plan and stratigraphic section along the proposed salt storage structure are provided in Appendix B. It should be noted that the stratigraphic boundaries indicated on the borehole logs and stratigraphic section are inferred from non-continuous sampling, observations of drilling progress and results of Standard Penetration Tests. These boundaries typically represent transitions from one soil type to another and should not be regarded as exact planes of geological change. Further, subsurface conditions may vary between and beyond the borehole locations.

In general, the stratigraphic sequence at the proposed structure site consists of top granular fill, underlain by native silty clay deposits followed by bedrock. A summary of the soil and groundwater conditions encountered in the boreholes is provided below.

1.4.1 Topsoil

Topsoil was encountered at the surface of boreholes BH-1, BH-2 and BH-5 and ranged in thickness from approximately 0.2 m to 0.3 m. Topsoil thicknesses may further vary beyond the borehole locations.

1.4.2 Asphalt

Asphalt was encountered at the surface of boreholes BH-3 and BH-4 and ranged in thickness from approximately 0.1 m to 0.2 m. Asphalt thicknesses may further vary beyond the borehole locations.

1.4.3 Fill: Sand and Gravel

A sand and gravel fill layer was encountered below the layer of top soil or asphalt in all drilled boreholes except in BH-2. The thickness of this fill layer is between 0.2 m and 0.8 m extending from Elev. 210 m to 209.2 m.

This layer consists of sand and gravel with trace to some silt size particles. The material is dark grey and brown in color, and damp. The SPT “N” values within this layer ranged from 13 to 30 blows per 300 mm penetration, corresponding to compact compactness condition.

Laboratory testing performed on selected samples consisted of six (6) moisture content tests. The test results are as follows:

Moisture Content:

- 3% to 4%

The results of the moisture content tests are provided on the record of borehole sheets in Appendix C.

1.4.4 Fill: Clayey Silt

A clayey silt fill layer was encountered below the layer of sand and gravel fill in BH-4. The thickness of this fill layer is about 0.3 m extending from Elev. 209.6 m to 209.3 m. This layer consists of clay and silt with trace of sand and gravel. The material is dark brown in color, and moist.

1.4.5 Silty Clay

A layer of native silty clay was encountered below the fill/topsoil in all boreholes. The silty clay extended to depths ranging between 7.6 m to 8.0 m below the ground surface corresponding to elevations between 202.6 m and 202.4 m. The explored thickness of this layer was between 6.8 m and 7.4 m. BH-2 was terminated in this layer due to auger refusal on assumed bedrock.

The composition of this layer is silt and clay, and trace sand and gravel. The material is brown in color and moist above the 4.6 m depth, while below that depth it became grey in colour and very moist. The plasticity of this cohesive soil was measured to be low to high, but typically moderate. The SPT “N” values within this layer ranged from 6 to 100 blows per 0.3 m penetration, typically 8 to 21 blows per 0.3 m penetration, suggesting stiff to very stiff material in consistency. In addition, one (1) in-situ shear vane test was performed and field result was about 110 kPa.

Laboratory testing performed on selected sample consisted of thirty-one (31) moisture content tests, nine (9) grain size distribution tests and nine (9) Atterberg Limit tests. The test results are as follow:

Moisture Content:

- 16% to 34%

Grain Size Distribution:

- 0% to 4% gravel;
- 0% to 7% sand;
- 27% to % 77silt; and
- 22% to 72% clay

Atterberg limits

- Liquid Limit: 33% to 56%
- Plasticity Index: 15% to 38%

The results of the moisture content, gain size distribution and Atterberg Limit tests are provided on the record of borehole sheets in Appendix C. The result of the grain size distribution test and Atterberg Limit tests performed by exp are also provided on Figure 1,2,4 and 5, respectively, in Appendix D.

1.4.6 Sandy Silty Clay Till

A layer of native sandy silty clay till was encountered below the silty clay in BH-3, BH-4 and BH-5. The till extended to depths ranging between 7.7 m to 7.8 m below the ground surface with elevations ranging between 202.3 m to 202.4 m. The explored thickness of this layer was between 0.1 m and 0.2 m. BH-4 was terminated in this layer due to auger refusal on assumed bedrock.

The composition of this till layer is sand, silt and clay with some gravel. The material is grey in color, moist and low plasticity. The SPT "N" values within this layer were 100 blows per 0.3 m penetration, suggesting hard in consistency.

Laboratory testing performed on selected sample consisted of three (3) moisture content tests, one (1) grain size distribution test and one (1) Atterberg Limit test. The test results are as follow:

Moisture Content:

- 9% to 12%

Grain Size Distribution:

- 16% gravel;
- 24% sand;
- 33% silt; and
- 27% clay

Atterberg limits

- Liquid Limit: 27%
- Plasticity Index: 13%

The results of the moisture content, grain size distribution and Atterberg Limit tests are provided on the record of borehole sheets in Appendix C. The result of the grain size distribution test and Atterberg Limit tests performed by exp are also provided on Figure 3 and 6, respectively, in Appendix D.

1.4.7 Bedrock

The presence of bedrock was found to be approximately between 7.6 m to 8 m below the ground surface. The bedrock was inferred from split spoon refusal in BH-2 and BH-4, or confirmed using coring depth of 3.0 m in BH-1, BH-3 and BH-5. The elevation of the inferred or actual bedrock surface below this site ranges from Elev. 202.4 m to 202.6 m. The inferred or actual bedrock surface depth and elevation encountered at these borehole locations are listed in Table 1.1.

Based on the bedrock cores recovered, the bedrock consists of limestone. In general, the bedrock samples are described as grey in colour and fine grained with nodular appearance, weathered. The Rock Quality Designation (RQD) measured on the core samples typically ranged from approximately 37% to 85%, indicating a rock mass of poor to good quality. Photographs of rock cores are included in Appendix E.

Table 1.1 Depth and elevation of bedrock or possible bedrock surface

Borehole	Depth Below Ground Surface (m)	Elevation (m)	Comments
BH-1	8.0	202.4	Bedrock Cored
BH-2	7.6	202.5	Inferred/ Spoon Refusal
BH-3	7.7	202.3	Bedrock Cored
BH-4	7.7	202.4	Inferred/ Spoon Refusal
BH-5	7.8	202.4	Bedrock Cored

1.5 Groundwater Conditions

Information regarding groundwater levels at the site was obtained by measuring the water levels in the open boreholes upon completion of drilling. Backfilling of Borehole BH-1 was delayed in obtaining a supplemental groundwater level measurement. All boreholes remained dry upon completion of the drilling operations. The subsequent groundwater level reading obtained at BH-1 after a period of four hours following completion was 7.5 m below grade. The water levels are not considered to have stabilized during the short term of the investigation.

1.6 Chemical Analyses

One soil sample was selected for chemical analyses and was sent via courier, in a secure cooler under chain of custody, to AGAT Laboratories., a CALA-certified and accredited laboratory in Mississauga, Ontario. The analytical laboratory results are presented in Appendix D, and are summarized in Table 1.2, below.

Table 1.2. Corrosivity chemical analysis

Sample Identification	pH (unitless)	Soluble Chloride (ppm)	Soluble Sulphate (ppm)	Resistivity (ohm-cm)	Conductivity (mS/cm)
BH5-SS2 Silty Clay	8.9	41	129	2,440	0.409

2 DISCUSSIONS AND ENGINEERING RECOMMENATIONS

2.1 General

This section of the report provides geotechnical design recommendations for the proposed salt building at the MTO Jarvis Patrol Yard, located in Haldimand County, Southern Ontario. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current investigation at the site and presented in **Part I-Foundation Investigation Report**. The interpretation and recommendations provided are intended solely to permit designers to assess foundation alternatives and design the proposed structure. Comments on construction are only provided to highlight issues that could affect the design. Contractors bidding on the works should make their own assessments of the factual data and how it might affect construction means and methods, scheduling and the like.

Based on information included in the TOR and correspondence with MTO it is understood that the new salt storage building will be constructed at the MTO Jarvis Patrol Yard at the location defined by MTO. The proposed salt building will have a footprint of about 36 m x 20 m in plan dimensions. At the time of writing this report the design of the building was not defined. However, it is understood that a building with a concrete reinforced push-wall with a minimum of 3 m above the finished floor elevation will be probably proposed. The building can then be erected with either steel or timber framing, at a height to accommodate indoor loading and delivery of road salt. The existing ground surface at the structure location varies between Elev. 210 m and 210.3 m. It is assumed that finished top of floor will be at the current ground level of about Elev. 210 m to tie-in to the adjacent exterior paved areas.

This report addresses the geotechnical design of the foundation for the proposed structure by providing geotechnical design parameters at the Ultimate Limit State (ULS) and Serviceability Limit States (SLS) as well as other geotechnical parameters that may be required in accordance with the latest edition of the *Canadian Highway Bridge Design Code (CHBDC)* (CAN/CSA-S6-14), the *Guideline for Professional Engineers Providing Geotechnical Engineering Service* (1992), the *Canadian Foundation Engineering Manual (CFEM)* (2006), the *provisions in the TOR* and good practice. It also provides discussion about the structure foundation type, stability and settlement analyses, frost protection, construction considerations and dewatering during construction, as requested in the TOR from MTO email dated July 27, 2017.

As further requested in the TOR, the settlement and stability analyses were completed for a scenario in which the new structure would be loaded to its full allowable capacity. This scenario consists of salt stacked to the maximum allowable height of the concrete walls with a stockpile area covering the entire footprint of the building. The angle of repose for road salt was assumed to be 33°.

2.2 Geotechnical Design Considerations for Foundations

The subsurface conditions at the site generally consist of a layer of granular fill underlain by stiff to very stiff silty clay, underlain by bedrock. The total overburden thickness ranged from 7.6 m (BH-2) to 8.0 m (BH-1) at the tested locations. The overburden soils are underlain by limestone bedrock of poor to good quality. It appears that the bedrock surface around the structure footprint is almost flat. Four hours after borehole drilling, the unstabilized groundwater level was measured within the stiff to very stiff silty clay deposit approximately 7.5 m below ground surface, suggesting a low groundwater level at the site as well as a low permeability of silty clay.

2.2.1 Evaluation of Foundation Alternatives

Considering the findings during the geotechnical investigation, shallow strip/spread footings founded on the native stiff to very stiff silty clay is recommended as the most preferable alternative from geotechnical/foundation perspectives. Deep foundations are considered as not necessary or practical at this site based on the subsurface conditions encountered.

Shallow foundations for the salt storage structure should consist of strip/spread footings which typically for this kind of structure have a width of 3 m. The footings founded at shallow depth on/within the native stiff to very stiff silty clay deposit can likely be constructed using conventional methods as such a founding depth is above the groundwater table as observed in the boreholes during the subsurface investigation.

2.2.2 Footing Elevation

Based on the results of the geotechnical investigation and a requirement for adequate protection against frost penetration in the project area (i.e. a minimum 1.2 m below the lowest surrounding area, see Section 2.2.5), the following founding elevations of strip/spread footings are recommended:

Table 2.1 Recommendations for footing elevation

Soil at Founding Level	Foundation Elevation (m)	Depth Below Existing Grade
Native Stiff to Very Stiff Silty Clay	208.8	1.2 m to 1.5 m

2.2.3 Geotechnical Resistances

In the context of the CHBDC, a satisfactory foundation design would require, in terms of Limit States Design, the factored geotechnical resistance of its foundation to withstand and not exceed the imposed Ultimate Limit State loads - (ULS) Design Approach, and its ability to deform acceptably under the Service Limit State loads - (SLS) Design Approach. These associated loads are typically known as

unfactored and factored loads, respectively. Therefore, strip/spread footings placed on the properly prepared subgrade at the design elevation given in Table 2.1, should be designed based on the factored resistances at ULS and geotechnical reactions at SLS for 25 mm of settlement given in Table 2.2 below. The footing width of 3 m is assumed. Settlement of the footings under the loading from the stockpile inside the structure which will occur after its construction is considered and discussed in Section 2.6.2. In determining the settlement characteristics of the proposed building (tolerable total and differential settlement), the unfactored loads are required to be provided by the Structural or Design Engineer.

Table 2.2 Geotechnical resistance at ULS and geotechnical reaction at SLS for a 3 m wide footing

Soil at Founding Level	Width of Footing (m)	Factored Geotechnical Resistance at ULS (kPa)	Geotechnical Reaction at SLS (kPa) (for 25 mm settlement)
Native Stiff to Very Stiff Silty Clay	3	450	300

Since the ULS resistance and the settlement depend on the footing size and depth of embedment, the geotechnical resistances given in Table 2.2 should be reviewed if the selected footing width or founding elevations differ from those given in the table. Similarly, if an inclined load is applied instead of a vertical load, which is used in these calculations, the values given in Table 2.2 should be reviewed to consider those inclinations.

Prior to placing footings, the exposed native subgrade should be inspected according with OPSS 902 and SP 109S12. A Qualified Geotechnical Engineer should check that the design foundation elevation is achieved and all unsuitable soils including fill and organics should be removed.

2.2.4 Resistance to Lateral Loads

Resistance to lateral forces/sliding resistance between the subgrade and concrete should be calculated in accordance with Section 6.7.5 of the CHBDC. The unfactored values of the coefficient of friction, $\tan \delta$, between the base of cast-in-place concrete footing and the native silty clay subgrade soils below the frost level are presented in Table 2.3.

Table 2.3 Recommendations for coefficient of friction

Interface	Coefficient of Friction, $\tan \delta^*$
Concrete and native stiff to very stiff silty clay	0.45

*- based on NAVFAC 1986, Table 1, pg. 7.2-63

A factor of 0.8 should be applied in calculation of the horizontal resistance in accordance with CHBDC.

In a case of the unbalanced lateral earth pressures caused by salt stockpiles being piled against the perimeter walls, these walls should be designed based on the following geotechnical parameters assuming a triangular lateral earth pressure distribution:

- Unit weight of salt stockpile material = 12 kN/m^3
- Friction angle of salt stockpile material = 33°
- Lateral earth pressure coefficient (K_o) = 0.5

2.2.5 Frost Protection

According to Ontario Provincial Standard Drawing (OPSD – 3090.101), the frost depth in Haldimand County is about 1.2 m. Consequently, all footings exposed to seasonal freezing conditions should be protected from frost action by at least 1.2 m of soil cover or equivalent insulation.

2.3 Earthquake Considerations

Recommendations for the geotechnical aspects to determine the earthquake loading are presented below.

Subsoil Conditions:

The subsoil and groundwater information at this site have been examined in relation to Section 4.1.8.4 A of the Ontario Building Code (OBC, 2012). The subsoil generally consists of granular fill and silty clay, underlain by bedrock located at the depth of approximately between 7.6 m to 8.0 m below the ground surface. It is expected that the foundations will be founded in the silty clay layer. The reported N-values for the soil below the founding level ranged from 6 to over 30 blows for 300 mm of penetration, with an average value being around 13 blows per 300 mm of penetration.

Corrected N-Values N_{60} :

The Average Standard Penetration Resistance shown in Table 4.1.8.4.A. Site Classification for Seismic Site Response in OBC 2012 refers to N_{60} which is defined as “Average Standard Penetration Resistance for the top 30 m, corrected to a rod energy efficiency of 60% of the theoretical maximum”. It should be noted that the drillers in the Jarvis area do not have their rod energy efficiencies measured and therefore, computed N_{60} values are not available for this site. In our opinion, the reported N-values could be considered as an approximate equivalent to the normalized N_{60} values as noted in the OBC 2012 for establishing the site classification.

Depth of Boreholes:

Table 4.1.8.4.A. Site Classification for Seismic Site Response in OBC 2012 indicated that the average properties in the top 30 m are to be used to determine the site classification. The five (5) boreholes advanced for building construction at this site were between 7.6 m and 11 m deep. The total overburden thickness was between 7.6 m and 8 m at the tested locations. The overburden soils are typically underlain by limestone bedrock of poor to good quality.

Site Classification:

Based on the above assumptions and interpretations, and the soil conditions, the Site Class for this site is estimated to be Class "D" as per Table 4.1.8.4.A, Site Classification for Seismic Site Response, OBC 2012.

These parameters should be reviewed by a Structural Engineer.

2.4 Liquefaction Considerations

Based on soils and groundwater condition encountered at the site, no liquefaction is expected due to the ground motion from an earthquake having 10% probability of exceedance in a 50-year period.

2.5 Perimeter Wall and Floor Construction

The perimeter wall of the proposed structures may be constructed as a cantilever retaining wall with an extended heel toward the inside of the structure and founded on native soils. Structural steel bars should be provided in the footings and in the walls. The asphalt floor could be designed inside the structure. The construction of spread footing and subgrade for the asphalt floor may be carried out in accordance with the following recommendations:

Prior to construction, all obviously unsuitable material should be fully removed from the entire underfooting and underfloor area (see Section 2.7). Following rough grading, the exposed subgrade should be proof-rolled with a roller under the full-time supervision of a qualified geotechnical personnel. Any soft spots detected during proof-rolling should be sub-excavated and replaced with Granular A or Granular B, Type I or Type II materials compacted to at least 98 % of the Standard Proctor Maximum Dry Density (SPMDD). The prepared subgrade should be covered with at least 200 mm thick layer of Granular A compacted to not less than 100% of the material's SPMDD, crowned slightly in the central area.

Around the perimeter of the building the ground surface should be sloped on a positive grade away from the structure to promote surface water run-off and reduce groundwater infiltration adjacent to the foundations. Permanent perimeter drains are not required if the interior base is set at least 200 mm above the exterior grade and the grade is sloped away from the structure. However, a permanent subfloor drainage system may be required to collect salt-bearing water. To minimize contamination into the native soils and subsequently into the groundwater, a barrier such as a compacted low-permeability clay liner or geomembrane usually should be installed below a salt storage area. In practice, the use of geomembrane shows advantage over the compacted clay liner in terms of improved performance of the barrier. The geomembrane should be installed on a minimum 75 mm thick sand layer (OPSS PROV 1004 or OPSS PROV 1002) and covered with a 300 mm thick layer of sand fill on top of the geomembrane to protect it from the overlying pavement structure. At this particular site, the presence of layer of natural stiff silty clay could be considered as a natural barrier system for contaminant transport.

2.6 Stability and Settlement Analyses

2.6.1 Stability

To assess the global stability of the storage structures and to check that a minimum Factor of Safety of 1.3 will be achieved for the maximum height salt stockpiles, a series of slope stability analyses were performed. The static slope stability analyses were performed using the Morgenstern-Price method developed based on limit equilibrium. The SLOPE/W computer program developed by GeoSlope International was employed for computation.

Stability assessments were performed for the proposed new structure of 36 m x 20 m dimensions assuming that the maximum salt stockpile height could be 9.5 m having the side slopes of 1.5H:1V as shown on Figure F1 in Appendix F. The stratigraphy and groundwater condition at the site were developed based on the results of the geotechnical investigation presented in Part I - Foundation Investigation Report.

Given the above, effective stress analyses for a long-term stability assessment was performed taking into consideration the subsoil conditions encountered directly beneath and adjacent the proposed structures.

Tabulated below in Table 2.4 are the soil parameters used for the slope stability analyses. The soil parameters were generally estimated based on the results of field and laboratory investigation.

Table 2.4 Soil properties used in slope stability analyses

Material Type	Effective Stress Parameters		
	ϕ (degrees)	c (kPa)	γ (kN/m ³)
Engineered Fill	35	0	22
Sand and Gravel Fill	32	0	20
Stiff to Very Stiff Silty Clay	28	5	19
Salt Stockpile Material	33	0	12

The graphical results of these analyses can be seen in Appendix F. As shown on Figures F1 and F2, the results of stability analyses for an approximately 9.5 m high salt stockpile (in the center, with the side slopes of 1.5H:1V) restrained with concrete walls on both sides in the building suggest that the factor of safety greater of 1.3 can be obtained for a deep-seated failure surface.

2.6.2 Settlement

To evaluate the maximum settlement and differential settlement values bellow the salt stockpile loadings in the proposed storage building, a 3D computer program; Settle3D (Rocscience) was employed. The

properties for the encountered soil layers used in the settlement model are evaluated based on the results of the SPT as per CHBDC. The parameters are listed in Table 2.5.

Table 2.5 Soil properties used in settlement analyses

Material Type	γ (kN/m ³)	E (MPa)	C _c	C _r	P _c (kPa)	e ₀
Stiff to Very Stiff Silty Clay Upper Layer	19	25	-	-	-	-
Stiff to Very Stiff Silty Clay Lower Layer	19	-	0.25	0.025	545	0.95
Salt Stockpile Material	12	-	-	-	-	-

The geometry of the stockpiles was assumed based on its maximum allowable capacity which is a maximum height of approximately 9.5 m at the center and 3 m along the sides at the wall. The model is illustrated on Figures G1 included in Appendix G.

The results of the settlement analyses are plotted on Figure G1 (Appendix G). The estimated settlements under the stockpile at the center and at the edges of the stockpile (i.e. location of footings) are presented in Table 2.6.

Table 2.6 Results of settlement analyses

Foundation Soil Type	Estimated Settlement (mm)			
	Elastic		Consolidation	
	Edge	Centre	Edge	Centre
Stiff to Very Stiff Silty Clay	5	11	13	24

The calculated elastic settlements are anticipated to occur immediately after the stockpile loadings are applied or within a period of about 14 days. However, the loadings and consequent consolidation settlement would be occurred after the footings have been constructed. Therefore, the footings for these structures should be design under the full allowable stockpile loadings. The geometries of stockpiles under the full allowable loadings including their maximum heights are recommended above. It is also recommended that the designer include detailed procedures in the contract drawings and note. It is estimated that the difference of total settlement at the edge and center is less than 20 mm, so preloading of the area is not required.

2.7 Site Preparation and Engineered Fill Construction

As mentioned previously, the areas within the limits of the buildings should be stripped and cleared of surface vegetation, topsoil and debris prior to construction. Any soils containing excessive organics or loose/disturbed materials are not suitable for the subgrade of building foundations, floor slabs or engineered fill. Therefore, areas with those soils should be excavated and replaced with engineered fill comprised of Granular A or Granular B, Type I or Type II.

Engineered fill could be placed after stripping all topsoil, organic matter, fill and other compressible, weak and deleterious materials within an area extending at least 1.0 meters beyond the outside edge of the founding level of any footings. After stripping, the entire area should be heavily proof-rolled inspected and approved by a Geotechnical Engineer. Engineered fill should be placed in accordance with OPSS 501 and SP SP105S21. The fill material should be placed in thin layers not exceeding approximately 300 mm when loose. Oversize particles larger than 120 mm should be discarded, and each fill layer should be uniformly compacted with heavy compactors, suitable for the type of fill used. The engineered fill below the footing and floor slab should be compacted to 100% of its SPMDD, while within outside/exterior paved areas, the fill should be compacted to 98% of its SPMDD.

Full-time geotechnical inspection and quality control (by means of frequent field density and laboratory testing) should be provided by the Geotechnical Engineer. Every lift should be evaluated by a sufficient number of tests to ensure that the level of compaction is constantly achieved and the compaction procedure is applied.

2.8 Excavation and Groundwater Control

For the construction of the proposed structure, excavations at least about 1.2 m depth will be required. The excavations are expected to encounter silty clay materials and above the groundwater level.

All excavations should be carried out in accordance with the latest version of the Occupational Health and Safety Act. For the act, the existing materials are considered as Type 3 soils above the groundwater table and Type 4 soils below the groundwater table. Temporary excavations (i.e. those that are open only for a short period) above the groundwater table may be made with side slopes not steeper than about 1H:1V, while the temporary slopes below the groundwater table must be formed at 3H:1V unless a suitable dewatering system is installed to lower the water level below the base of the excavation.

Excavations are expected to be shallow and above groundwater levels. Accordingly, no special groundwater control measures would be required. Any perched water during construction can be pumped. The exterior grade should be shaped to encourage runoff away from the structure.

A qualified geotechnical personnel should be on-site during the foundation installation and for fill material placement, to verify the design assumptions, and to verify the design recommendations.

2.9 Corrosion Protection

One soil sample was selected for chemical analyses and was sent via courier, in a secure cooler under chain of custody, to AGAT Laboratories., a CALA-certified and accredited laboratory in Mississauga, Ontario. The analytical laboratory results are summarized in Section 1.6 of this report and detailed results are included in Appendix D.

The chemical data indicates low resistivity of the tested soil, which indicates a medium potential for corrosion of buried metallic elements, particularly pipes and appurtenances (MTO Gravity Pipe Design Guidelines, Page 25). The maximum chloride content reported is 41ppm ($\mu\text{g/g}$) which indicates a low potential for additional corrosion.

The maximum water-soluble sulphate content of the soils tested is 129 ppm ($\mu\text{g/g}$), i.e. 0.13% and being between 0.10% to 0.20%, it indicates moderate potential to corrode normal Portland cement concrete. It is recommended to use Type II cement as recommended in Table 7.2 (MTO Gravity Pipe Design Guidelines, Page 59).

3 CLOSURE

The recommendations made in this report are in accordance with our present understanding of the project and are provided solely for the team responsible for the design of the works described herein.

We recommend that we be retained to review our recommendations as the design nears completion to ensure that the final design is in agreement with the assumptions on which our recommendations are based and that our recommendations have been interpreted as intended. If not accorded this review, exp will assume no responsibility for the interpretation and use of the recommendations in this report.


A subsurface investigation is a limited sampling of a site; the subsurface conditions have been established only at the test hole locations. Should conditions at the site be encountered which differ from those reported at the test locations, we require that we be notified immediately in order to assess this additional information and our recommendations, as appropriate. It may then be necessary to perform additional investigation and analysis.

Contractors bidding on or undertaking any proposed work at this site should, relative to the subsurface conditions, decide on their own investigations, if deemed necessary, as well as their own interpretations of the factual results provided herein, so they may draw their own conclusions as to how the subsurface conditions may affect them.


This Foundation Investigation and Design Report has been prepared by Silvana Micic, Ph.D., P.Eng. and Nimesh Tamrakar, M.Eng. and reviewed by TaeChul Kim, M.E.Sc., P.Eng. and Stan E. Gonsalves, M.Eng., P.Eng., Designated MTO Foundation Contact. The field investigation was conducted by Dilsher Bhargal, M.Eng.

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Encl.

4 LIMITATIONS AND USE OF REPORT

BASIS OF REPORT

This report ("Report") is based on site conditions known or inferred by the geotechnical investigation undertaken as of the date of the Report. Should changes occur which potentially impact the geotechnical condition of the site, or if construction is implemented more than one year following the date of the Report, the recommendations of exp may require re-evaluation.

The Report is provided solely for the guidance of design engineers and on the assumption that the design will be in accordance with applicable codes and standards. Any changes in the design features which potentially impact the geotechnical analyses or issues concerning the geotechnical aspects of applicable codes and standards will necessitate a review of the design by exp. Additional field work and reporting may also be required.

Where applicable, recommended field services are the minimum necessary to ascertain that construction is being carried out in general conformity with building code guidelines, generally accepted practices and exp's recommendations. Any reduction in the level of services recommended will result in exp providing qualified opinions regarding the adequacy of the work. exp can assist design professionals or contractors retained by the Client to review applicable plans, drawings, and specifications as they relate to the Report or to conduct field reviews during construction.

Contractors contemplating work on the site are responsible for conducting an independent investigation and interpretation of the borehole results contained in the Report. The number of boreholes necessary to determine the localized underground conditions as they impact construction costs, techniques, sequencing, equipment and scheduling may be greater than those carried out for the purpose of the Report.

Classification and identification of soils, rocks, geological units, contaminant materials, building envelopment assessments, and engineering estimates are based on investigations performed in accordance with the standard of care set out below and require the exercise of judgment. As a result, even comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations or building envelope descriptions involve an inherent risk that some conditions will not be detected. All documents or records summarizing investigations are based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated. Some conditions are subject to change over time. The Report presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, these should be disclosed to exp to allow for additional or special investigations to be undertaken not otherwise within the scope of investigation conducted for the purpose of the Report.

RELIANCE ON INFORMATION PROVIDED

The evaluation and conclusions contained in the Report are based on conditions in evidence at the time of site inspections and information provided to exp by the Client and others. The Report has been prepared for the specific site, development, building, design or building assessment objectives and purpose as communicated by the Client. exp has relied in good faith upon such representations,

information and instructions and accepts no responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of any misstatements, omissions, misrepresentation or fraudulent acts of persons providing information. Unless specifically stated otherwise, the applicability and reliability of the findings, recommendations, suggestions or opinions expressed in the Report are only valid to the extent that there has been no material alteration to or variation from any of the information provided to exp.

STANDARD OF CARE

The Report has been prepared in a manner consistent with the degree of care and skill exercised by engineering consultants currently practicing under similar circumstances and locale. No other warranty, expressed or implied, is made. Unless specifically stated otherwise, the Report does not contain environmental consulting advice.

COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment form part of the Report. This material includes, but is not limited to, the terms of reference given to exp by its client ("Client"), communications between exp and the Client, other reports, proposals or documents prepared by exp for the Client in connection with the site described in the Report. In order to properly understand the suggestions, recommendations and opinions expressed in the Report, reference must be made to the Report in its entirety. exp is not responsible for use by any party of portions of the Report.

USE OF REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. No other party may use or rely upon the Report in whole or in part without the written consent of exp. Any use of the Report, or any portion of the Report, by a third party are the sole responsibility of such third party. exp is not responsible for damages suffered by any third party resulting from unauthorised use of the Report.

REPORT FORMAT

Where exp has submitted both electronic file and a hard copy of the Report, or any document forming part of the Report, only the signed and sealed hard copy shall be the original documents for record and working purposes. In the event of a dispute or discrepancy, the hard copy shall govern. Electronic files transmitted by exp have utilize specific software and hardware systems. exp makes no representation about the compatibility of these files with the Client's current or future software and hardware systems. Regardless of format, the documents described herein are exp's instruments of professional service and shall not be altered without the written consent of exp.

Appendix A – Photographs



Photo 1: Jarvis Patrol Yard - the proposed new structure area, facing north



Photo 2: Jarvis Patrol Yard-existing Gambrel style shed, facing west



Photo 3: Jarvis Patrol Yard, facing south



Photo 4: Jarvis Patrol Yard, facing east



Photo 5: Facing north from location of BH-4 (Note the existing shed)



Photo 6: Facing west from location of BH-3

Appendix B – Drawings

HALDIMAND COUNTY W CONCESSION 7 WALPOLE

METRIC
DIMENSIONS ARE IN METERS AND/OR
MILLIMETERS UNLESS OTHERWISE SHOWN.
STATIONS ARE IN KILOMETERS +METERS

Agreement No. 3015-E-0017
Assignment No. 6
GWP 3075-16-00



NEW PATROL YARD STRUCTURE AT
MTO JARVIS PATROL YARD, HALDIMAND COUNTY
BOREHOLE LOCATION PLAN AND SOIL STRATA

SHEET

exp

exp Services Inc.

KEY PLAN



LEGEND

- Borehole
- N Standard Penetration Test (Blows/0.3 m)
- 73% Rock Quality Designation (RQD)
- Temporary Bench Mark (EL. 210.0m)

SOIL STRATA SYMBOLS

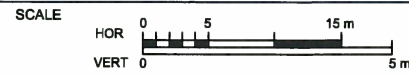
- ASPHALT
- GRANULAR FILL
- SILTY CLAY
- SANDY SILTY CLAY TILL
- BEDROCK

BH No.	APPROX. ELEV.	MTM CO-ORDINATES	
		NORTH	EAST
BH1	210.3	4748025.2	570948.8
BH2	210.1	4747996.7	570958.3
BH3	210.0	4748026.9	570957.4
BH4	210.1	4748015.6	570957.2
BH5	210.2	4747998.9	570965.3

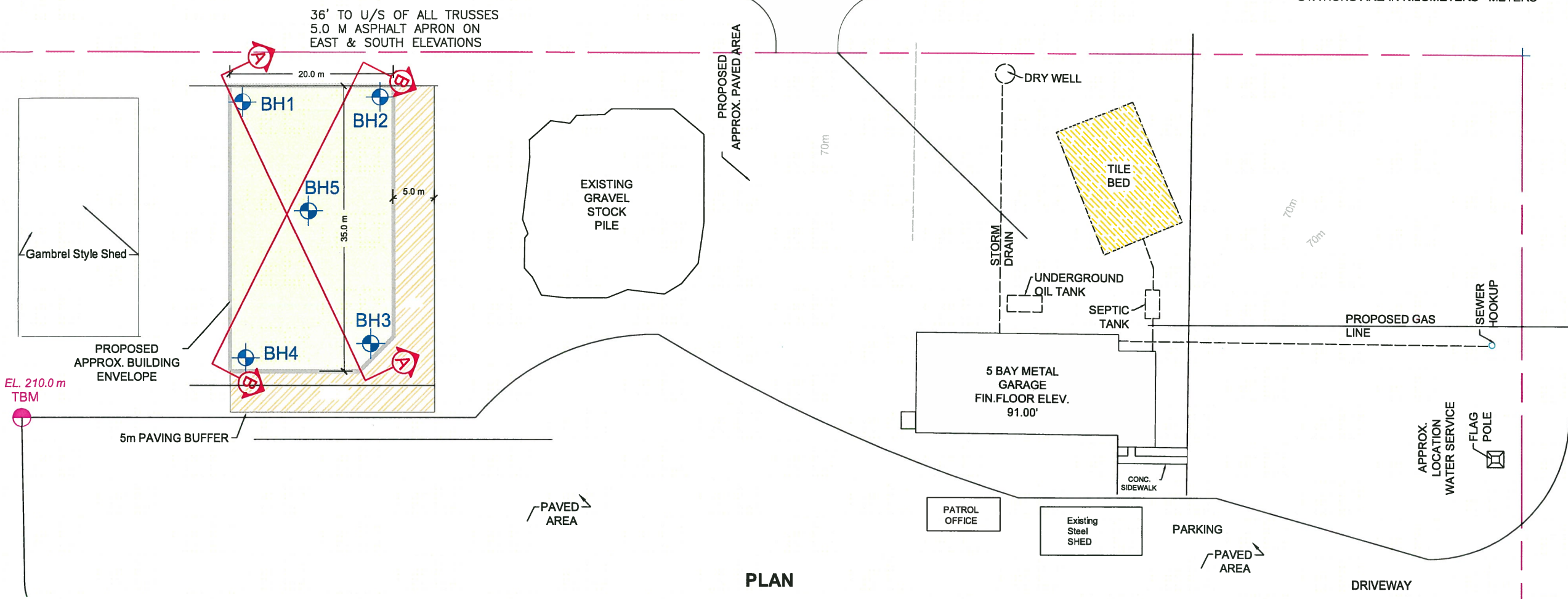
NOTE

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

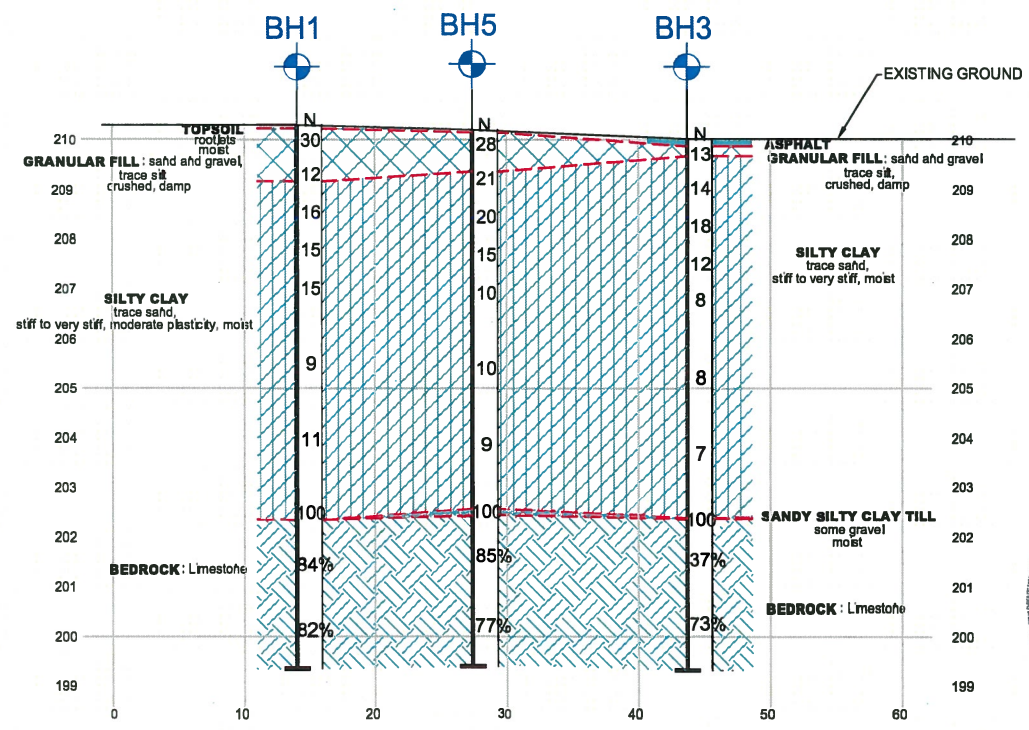
The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in the report and related documents are specifically excluded in accordance with the conditions of Section GC 2.01 of OPS Gen. Cond.



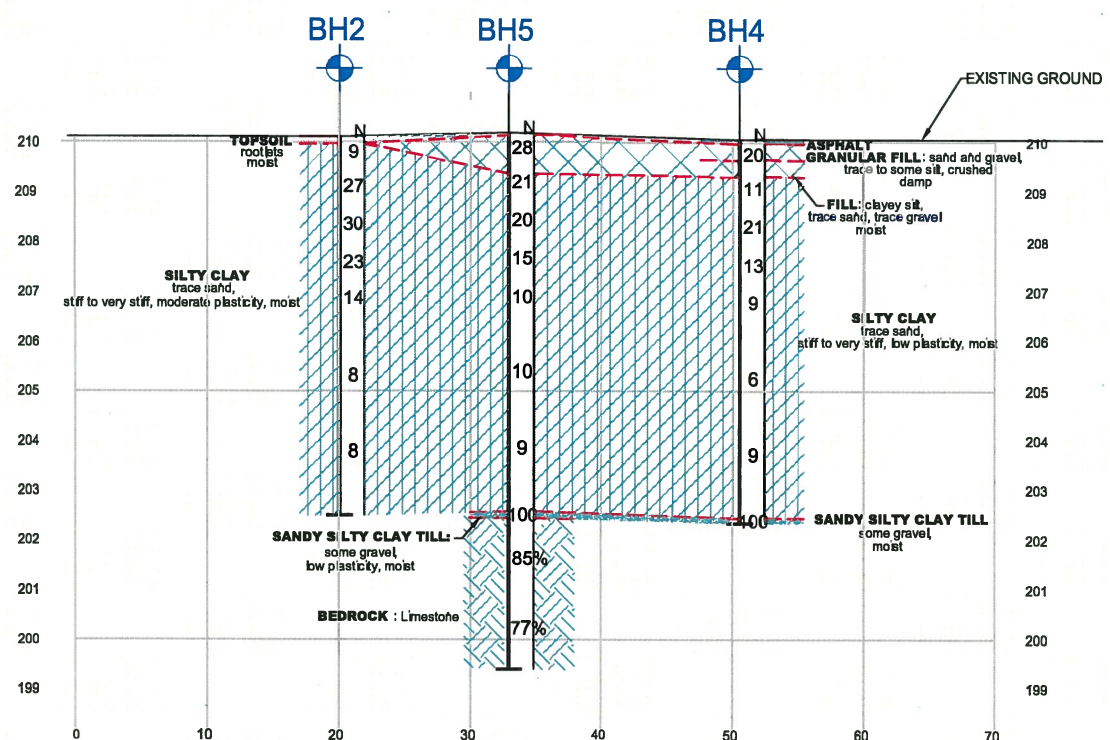
21/11/2017	-	SUBMISSION FOR MTO REVIEW	
DATE	BY	DESCRIPTION	
		GEOCRES NO. 40116-28	
		PROJECT NO. ADM-00235197-J0	
SUBM'D SM	CHECKED SM	DATE	21/11/2017
DRAWN SH	CHECKED SG	APPROVED SG	DWG. 1



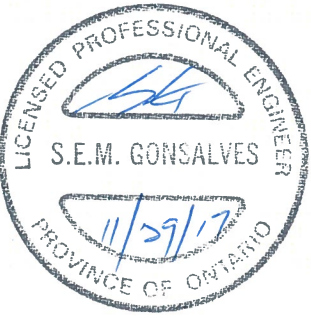
PLAN



SECTION A-A



SECTION B-B



Appendix C – Borehole Logs

Explanation of Terms Used on Borehole Records

SOIL DESCRIPTION

Terminology describing common soil genesis:

Topsoil: mixture of soil and humus capable of supporting good vegetative growth.

Peat: fibrous fragments of visible and invisible decayed organic matter.

Fill: where fill is designated on the borehole log it is defined as indicated by the sample recovered during the boring process. The reader is cautioned that fills are heterogeneous in nature and variable in density or degree of compaction. The borehole description may therefore not be applicable as a general description of site fill materials. All fills should be expected to contain obstruction such as wood, large concrete pieces or subsurface basements, floors, tanks, etc.; none of these may have been encountered in the boreholes. Since boreholes cannot accurately define the contents of the fill, test pits are recommended to provide supplementary information. Despite the use of test pits, the heterogeneous nature of fill will leave some ambiguity as to the exact composition of the fill. Most fills contain pockets, seams, or layers of organically contaminated soil. This organic material can result in the generation of methane gas and/or significant ongoing and future settlements. Fill at this site may have been monitored for the presence of methane gas and, if so, the results are given on the borehole logs. The monitoring process does not indicate the volume of gas that can be potentially generated nor does it pinpoint the source of the gas. These readings are to advise of the presence of gas only, and a detailed study is recommended for sites where any explosive gas/methane is detected. Some fill material may be contaminated by toxic/hazardous waste that renders it unacceptable for deposition in any but designated land fill sites; unless specifically stated the fill on this site has not been tested for contaminants that may be considered toxic or hazardous. This testing and a potential hazard study can be undertaken if requested. In most residential/commercial areas undergoing reconstruction, buried oil tanks are common and are generally not detected in a conventional geotechnical site investigation.

Till: the term till on the borehole logs indicates that the material originates from a geological process associated with glaciation. Because of this geological process the till must be considered heterogeneous in composition and as such may contain pockets and/or seams of material such as sand, gravel, silt or clay. Till often contains cobbles (60 to 200 mm) or boulders (over 200 mm). Contractors may therefore encounter cobbles and boulders during excavation, even if they are not indicated by the borings. It should be appreciated that normal sampling equipment cannot differentiate the size or type of any obstruction. Because of the horizontal and vertical variability of till, the sample description may be applicable to a very limited zone; caution is therefore essential when dealing with sensitive excavations or dewatering programs in till materials.

Terminology describing soil structure:

Desiccated: having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc.

Stratified: alternating layers of varying material or color with the layers greater than 6 mm thick.

Laminated: alternating layers of varying material or color with the layers less than 6 mm thick.

Fissured: material breaks along plane of fracture.

Varved: composed of regular alternating layers of silt and clay.

Slickensided: fracture planes appear polished or glossy, sometimes striated.

Blocky: cohesive soil that can be broken down into small angular lumps which resist further breakdown.

Lensed: inclusion of small pockets of different soil, such as small lenses of sand scattered through a mass of clay; not thickness.

Seam: a thin, confined layer of soil having different particle size, texture, or color from materials above and below.

Homogeneous: same color and appearance throughout.

Well Graded: having wide range in grain sized and substantial amounts of all predominantly on grain size.

Uniformly Graded: predominantly on grain size.

All soil sample descriptions included in this report follow generally the ASTM D2487-11 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) with some modification to reflect current MTO practices. The system divides soils into three major categories: (1) coarse grained, (2) fine-grained, and (3) highly organic. The soil is then subdivided based on either gradation or plasticity characteristics. The system provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification. The classification excludes particles larger than 76 mm. Please note that, with the exception of those samples where a grain size analysis has been made, all samples are classified visually in accordance with ASTM D2488-09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). Visual classification is not sufficiently accurate to provide exact grain sizing or precise differentiation between size classification systems. Others may use different classification systems; one such system is the ISSMFE Soil Classification.

ISSMFE SOIL CLASSIFICATION											
CLAY	SILT			SAND			GRAVEL			COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE		
<div><div>0.002</div><div>0.006</div><div>0.02</div><div>0.06</div><div>0.2</div><div>0.6</div><div>2.0</div><div>6.0</div><div>20</div><div>60</div><div>200</div></div>											
EQUIVALENT GRAIN DIAMETER IN MILLIMETRES											
CLAY (PLASTIC) TO				FINE		MEDIUM		CRS.		FINE COARSE	
SILT (NONPLASTIC)				SAND				GRAVEL			
UNIFIED SOIL CLASSIFICATION											

Terminology describing materials outside the USCS, (e.g. particles larger than 76 mm, visible organic matter, construction debris) is based upon the proportion of these materials present and as described below in accordance with Note 16 in ASTM D2488-09a:

Table a: Percent or Proportion of Soil, Pp

	Criteria
Trace	Particles are present but estimated to be less than 5%
Few	$5 \leq Pp \leq 10\%$
Little	$15 \leq Pp \leq 25\%$
Some	$30 \leq Pp \leq 45\%$
Mostly	$50 \leq Pp \leq 100\%$

The standard terminology to describe cohesionless soils includes the compactness as determined by the Standard Penetration Test 'N' value:

Table b: Apparent Density of Cohesionless Soil

	'N' Value (blows/0.3 m)
Very Loose	$N < 5$
Loose	$5 \leq N < 10$
Compact	$10 \leq N < 30$
Dense	$30 \leq N < 50$
Very Dense	$50 \leq N$

The standard terminology to describe cohesive soils includes consistency, which is based on undrained shear strength as measured by insitu vane tests, penetrometer tests, unconfined compression tests or similar field and laboratory analysis, Standard Penetration Test 'N' values can also be used to provide an approximate indication of the consistency and shear strength of fine grained, cohesive soils:

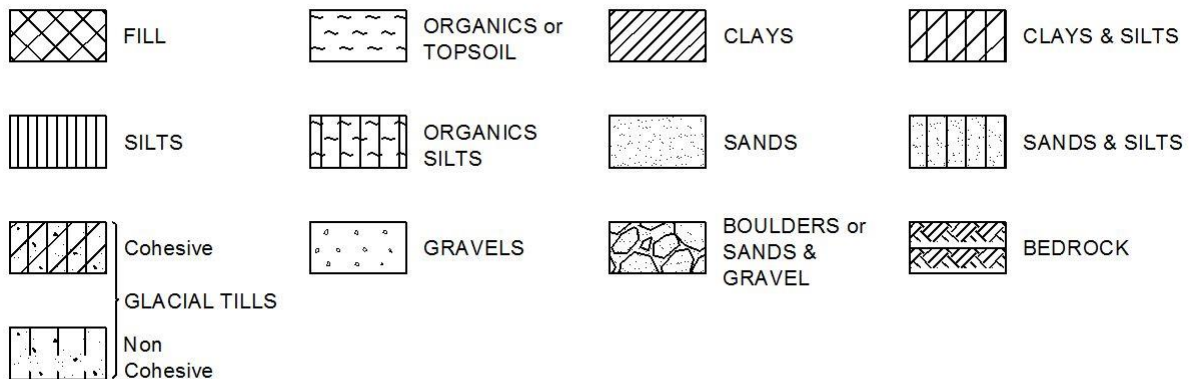
Table c: Consistency of Cohesive Soil

Consistency	Vane Shear Measurement (kPa)	'N' Value
Very Soft	<12.5	<2
Soft	12.5-25	2-4
Firm	25-50	4-8
Stiff	50-100	8-15
Very Stiff	100-200	15-30
Hard	>200	>30

Note: 'N' Value - The Standard Penetration Test records the number of blows of a 140 pound (64kg) hammer falling 30 inches (760mm), required to drive a 2 inch (50.8mm) O.D. split spoon sampler 1 foot (305mm). For split spoon samples where full penetration is not achieved, the number of blows is reported over the sampler penetration in meters (e.g. 50/0.15).

STRATA PLOT

Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols:



WATER LEVEL MEASUREMENT



Open Borehole or Test Pit



Monitoring Well, Piezometer or Standpipe

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

SS	Split spoon sample (obtained from the Standard Penetration Test)
WS	Wash sample
BS	Bulk sample
TW	Thin wall sample or Shelby tube
PS	Piston sample
AS	Auger sample
VT	Vane test
GS	Grab sample
HQ, NQ, etc.	Rock core samples obtained with the use of standard size diamond drilling bits

STRESS AND STRAIN

u_w	kPa	Pore water pressure
r_u	1	Pore pressure ratio
σ	kPa	Total normal stress
σ'	kPa	Effective normal stress
τ	kPa	Shear stress
$\sigma_1, \sigma_2, \sigma_3$	kPa	Principal stresses
ε	%	Linear strain
$\varepsilon_1, \varepsilon_2, \varepsilon_3$	%	Principal strains
E	kPa	Modulus of linear deformation
G	kPa	Modulus of shear deformation
μ	1	Coefficient of friction

MECHANICAL PROPERTIES OF SOIL

m_v	kPa^{-1}	Coefficient of volume change
c_c	1	Compression index
c_s	1	Swelling index
c_r	1	Recompression index
c_v	m^2/s	Coefficient of consolidation
H	m	Drainage path
T_v	1	Time factor
U	%	Degree of consolidation
σ'_{v0}	kPa	Effective overburden pressure
σ'_p	kPa	Preconsolidation pressure
τ_f	kPa	Shear strength
c'	kPa	Effective cohesion intercept
ϕ'	$^\circ$	Effective angle of internal friction
c_u	kPa	Apparent cohesion intercept
ϕ_u	$^\circ$	Apparent angle of internal friction
τ_R	kPa	Residual shear strength
τ_r	kPa	Remoulded shear strength
S_t	1	Sensitivity = c_u/τ_r

PHYSICAL PROPERTIES OF SOIL

P_s	kg/m^3	Density of solid particles
γ_s	kN/m^3	Unit weight of solid particles
ρ_w	kg/m^3	Density of water
γ_w	kN/m^3	Unit weight of water
ρ	kg/m^3	Density of soil
γ	kN/m^3	Unit weight of soil
ρ_d	kg/m^3	Density of dry soil
γ_d	kN/m^3	Unit weight of dry soil
ρ_{sat}	kg/m^3	Density of saturated soil
γ_{sat}	kN/m^3	Unit weight of saturated soil
ρ'	kg/m^3	Density of submerged soil
γ'	kN/m^3	Unit weight of submerged soil
e	1, %	Void ratio
n	1, %	Porosity
w	1, %	Water content
S_r	%	Degree of saturation
W_L	%	Liquid limit
W_P	%	Plastic limit
W_s	%	Shrinkage limit
I_p	%	Plasticity index = $(W_L - W_P)$
I_L	%	Liquidity index = $(W - W_P)/I_p$
I_C	%	Consistency index = $(W_L - W)/I_p$
e_{max}	1, %	Void ratio in loosest state
e_{min}	1, %	Void ratio in densest state
I_D	1	Density index = $(e_{max} - e)/(e_{max} - e_{min})$
D	mm	Grain diameter
D_n	mm	N percent - diameter
C_u	1	Uniformity coefficient
h	m	Hydraulic head or potential
q	m^3/s	Rate of discharge
v	m/s	Discharge velocity
i	1	Hydraulic gradient
k	m/s	Hydraulic conductivity
j	kN/m^3	Seepage force






Brampton, Ontario

RECORD OF BOREHOLE No BH-1

1 OF 1

METRIC

W.P. GWP 3075-16-00 LOCATION Old HWY 3, Jarvis, ON ORIGINATED BY DB
 DIST West HWY 3 BOREHOLE TYPE CME-55 Truck Mount, Continuous Flight Solid Stem Augers COMPILED BY JG
 DATUM Geodetic DATE 2017.08.23 - 2017.08.25 LATITUDE 42.881531 LONGITUDE -80.131222 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)			GR	SA	SI	CL
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL					× LAB VANE						
210.3	Ground Surface																				
210.2	TOPSOIL: brown, moist, rootlets		1	SS	30		210														
	GRANULAR FILL: sand and gravel, trace silt, grey, damp, crushed																				
209.2		2	SS	12																	
1.1	SILTY CLAY: trace sand, brown, moist, stiff to very stiff, moderate plasticity		3	SS	16																
			4	SS	15																
	trace gravel, high plasticity below 3.1 m depth		5	SS	15																
	grey, very moist below below 4.6 m depth		6	SS	9																
			7	SS	11																
202.4	BEDROCK: limestone, grey		8	SS	100																
8.0	RUN 1 (7.95 - 9.43 m): recovery 100%, RQD 84% (good) RUN 2 (9.43 - 10.95 m): recovery 100%, RQD 82% (good)						202														
								201													
								200													
199.4	End of Borehole at 11.0 m.																				
11.0	Notes: 1. This log is to be read with the subject report and project numbers as presented above. 2. Borehole remained dry upon completion of auger drilling. Four hours following completion, the groundwater level was measured at 7.5 m below grade. 3. Borehole open to 8.0 m below ground surface upon completion of auger drilling.																				

+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ONTARIO MTO ADM-00235197-J0 - SALT STORAGE DOME.GPJ ONTARIO MTO.GDT 20/9/17

Brampton, Ontario

RECORD OF BOREHOLE No BH-2

1 OF 1

METRIC

W.P. GWP 3075-16-00 LOCATION Old HWY 3, Jarvis, ON ORIGINATED BY DB
 DIST West HWY 3 BOREHOLE TYPE CME-55 Truck Mount, Continuous Flight Solid Stem Augers COMPILED BY JG
 DATUM Geodetic DATE 2017.08.23 - 2017.08.23 LATITUDE 42.881273 LONGITUDE -80.131108 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							W _P W W _L			
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							WATER CONTENT (%)			
210.1	Ground Surface							20	40	60	80	100						
210.0	TOPSOIL: brown, moist, rootlets		1	SS	9		210							○				
0.2	SILTY CLAY: brown, moist, stiff to very stiff, moderate plasticity		2	SS	27		209							○				
			3	SS	30		208							○				
	trace sand at 2.3 m depth		4	SS	23		207							○				
	grey below 3.1 m depth		5	SS	14		206							○				
			6	SS	8		205							○				
	very moist, high plasticity below 4.6 m depth		7	SS	8		204							○				
							203											
202.5	End of Borehole at 7.6 m due to auger refusal on assumed bedrock.																	
7.6	Notes: 1. This log is to be read with the subject report and project numbers as presented above. 2. Borehole remained dry upon completion of drilling. 3. Borehole open to 7.6 m below ground surface upon completion of drilling.																	

+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ONTARIO MTO ADM-00235197-J0 - SALT STORAGE DOME.GPJ ONTARIO MTO.GDT 20/9/17

Brampton, Ontario

RECORD OF BOREHOLE No BH-3

1 OF 1

METRIC

W.P. GWP 3075-16-00 LOCATION Old HWY 3, Jarvis, ON ORIGINATED BY DB
 DIST West HWY 3 BOREHOLE TYPE CME-55 Truck Mount, Continuous Flight Solid Stem Augers COMPILED BY JG
 DATUM Geodetic DATE 2017.08.23 - 2017.08.25 LATITUDE 42.881546 LONGITUDE -80.131116 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
210.0	Ground Surface							20	40	60	80	100		
209.0	ASPHALT (~150 mm thick)							20	40	60	80	100		
209.2	GRANULAR FILL: sand and gravel, trace silt, grey, damp, crushed		1	SS	13									
0.4	SILTY CLAY: trace sand, brown, moist, stiff to very stiff		2	SS	14									
			3	SS	18									
			4	SS	12									
	very moist, high plasticity below 3.1 m depth		5	SS	8									
	grey below below 4.6 m depth		6	SS	8									
	firm below 6.1 m depth		7	SS	7									
202.4														
202.6	SANDY SILTY CLAY TILL: some gravel, grey, moist		8	SS	100									
7.7	BEDROCK: limestone, grey													
	RUN 1 (7.65 - 9.12 m): recovery 98%, RQD 37% (poor)													
	RUN 2 (9.12 - 10.70 m): recovery 100%, RQD 73% (fair)													
199.3														
10.7	End of Borehole at 10.7 m.													
	Notes: 1. This log is to be read with the subject report and project numbers as presented above. 2. Borehole remained dry upon completion of auger drilling. 3. Borehole open to 7.7 m below ground surface upon completion of auger drilling.													

+ 3, × 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ONTARIO MTO ADM-00235197-J0 - SALT STORAGE DOME.GPJ ONTARIO MTO.GDT 20/9/17

Brampton, Ontario

RECORD OF BOREHOLE No BH-4

1 OF 1

METRIC

W.P. GWP 3075-16-00 LOCATION Old HWY 3, Jarvis, ON ORIGINATED BY DB
 DIST West HWY 3 BOREHOLE TYPE CME-55 Truck Mount, Continuous Flight Solid Stem Augers COMPILED BY JG
 DATUM Geodetic DATE 2017.08.23 - 2017.08.23 LATITUDE 42.881444 LONGITUDE -80.13112 CHECKED BY SM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE						
210.1	Ground Surface														
210.0	ASPHALT: (~90 mm thick)														
209.6	GRANULAR FILL: sand and gravel, trace to some silt, dark grey and brown, damp, crushed		1	SS	20										
0.4															
209.3	FILL: clayey silt, dark brown, moist, trace sand, trace gravel		2	SS	11										
0.8	SILTY CLAY: trace sand, brown, moist, stiff to very stiff, low plasticity														
			3	SS	21										
			4	SS	13										
	very moist below 3.1 m depth		5	SS	9										
	occasional silt seam, very moist, grey below 4.6 m depth		6	SS	6										
			7	SS	9										
202.4															
202.8	SANDY SILTY CLAY TILL: some gravel, grey, moist		8	SS	100										
7.7	End of Borehole at 7.7 m due to auger refusal on assumed bedrock.														
	Notes: 1. This log is to be read with the subject report and project numbers as presented above. 2. Borehole remained dry upon completion of drilling. 3. Borehole open to 7.7 m below ground surface upon completion drilling.														

+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ONTARIO MTO ADM-00235197-J0 - SALT STORAGE DOME.GPJ ONTARIO MTO.GDT 20/9/17

Brampton, Ontario

RECORD OF BOREHOLE No BH-5

1 OF 1

METRIC

W.P. GWP 3075-16-00 LOCATION Old HWY 3, Jarvis, ON ORIGINATED BY DB
 DIST West HWY 3 BOREHOLE TYPE CME-55 Truck Mount, Continuous Flight Solid Stem Augers COMPILED BY JG
 DATUM Geodetic DATE 2017.08.23 - 2017.08.25 LATITUDE 42.881292 LONGITUDE -80.131023 CHECKED BY SM

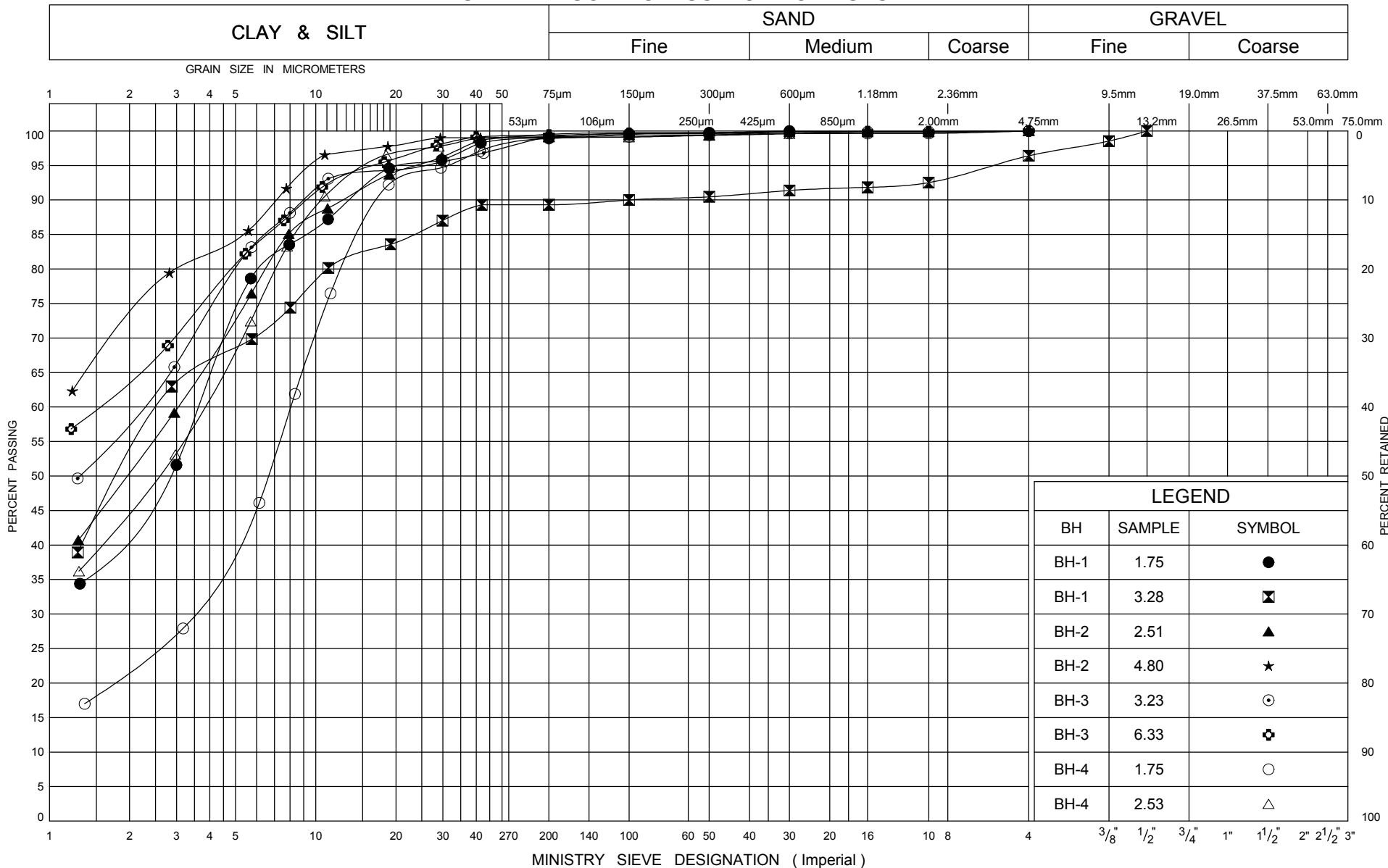
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)	
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE							
210.2	Ground Surface						20 40 60 80 100	20 40 60								
210.2	TOPSOIL: brown, moist, rootlets		1	SS	28											
	GRANULAR FILL: sand and gravel, trace silt, grey, damp, crushed															
209.4	SILTY CLAY: trace sand, trace gravel, brown, moist, stiff to very stiff, moderate plasticity		2	SS	21											
0.8			3	SS	20											
			4	SS	15											
			5	SS	10											
			6	SS	10											
			7	SS	9											
	grey, very moist below 4.6 m depth															
202.6	SANDY SILTY CLAY TILL: some gravel, grey, moist, low plasticity		8	SS	100											
202.6	BEDROCK: limestone, grey															
7.8	<u>RUN 1 (7.75 - 9.27 m):</u> recovery 100%, RQD 85% (good)															
	<u>RUN 2 (9.27 - 10.80 m):</u> recovery 100%, RQD 77% (good)															
199.4	End of Borehole at 10.8 m.															
10.8	Notes: 1. This log is to be read with the subject report and project numbers as presented above. 2. Borehole remained dry upon completion of auger drilling. 3. Borehole open to 7.8 m below ground surface upon completion of auger drilling.															

+³, ×³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

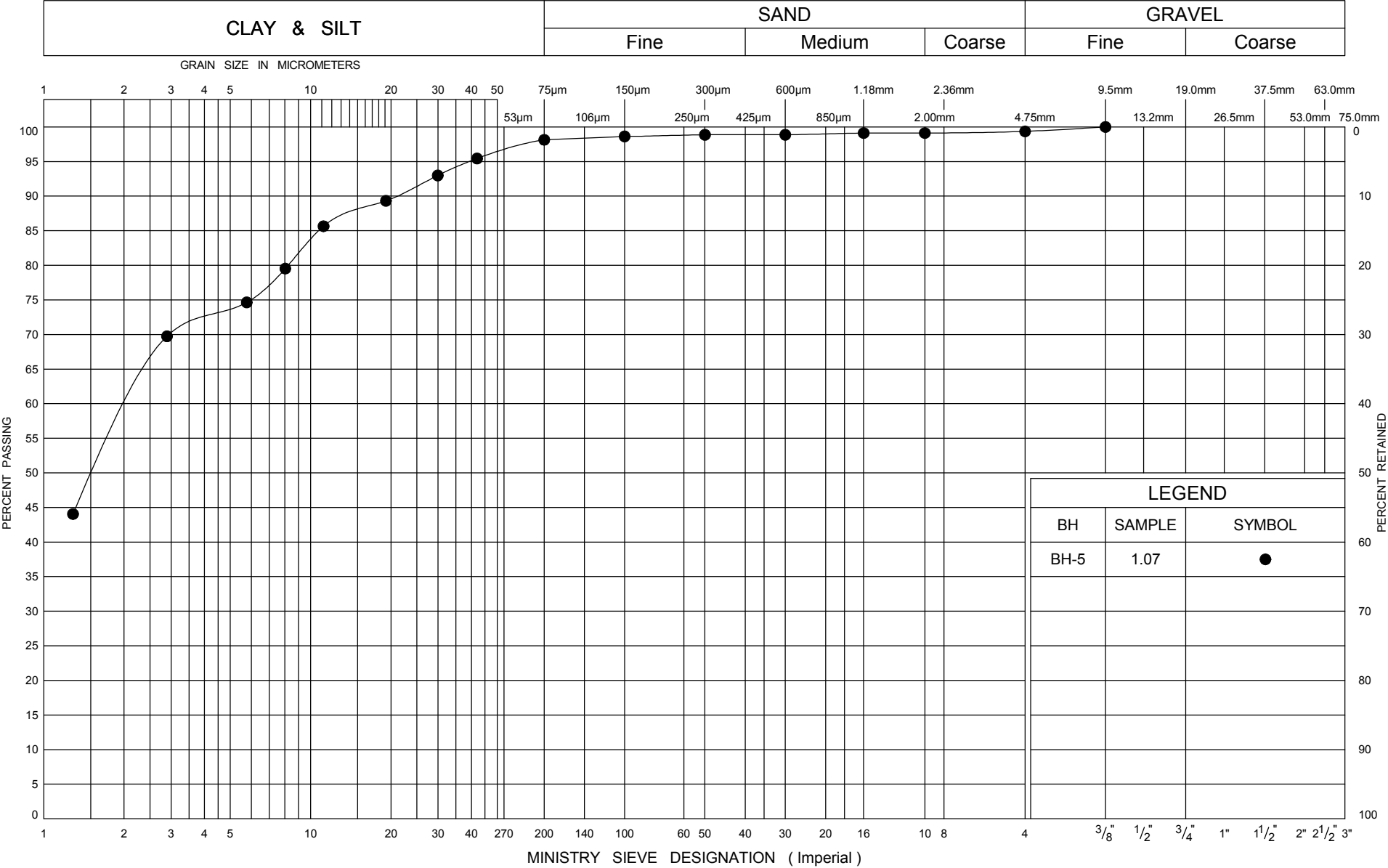
ONTARIO MTO ADM-00235197-J0 - SALT STORAGE DOME.GPJ ONTARIO MTO.GDT 20/9/17

Appendix D – Laboratory Data

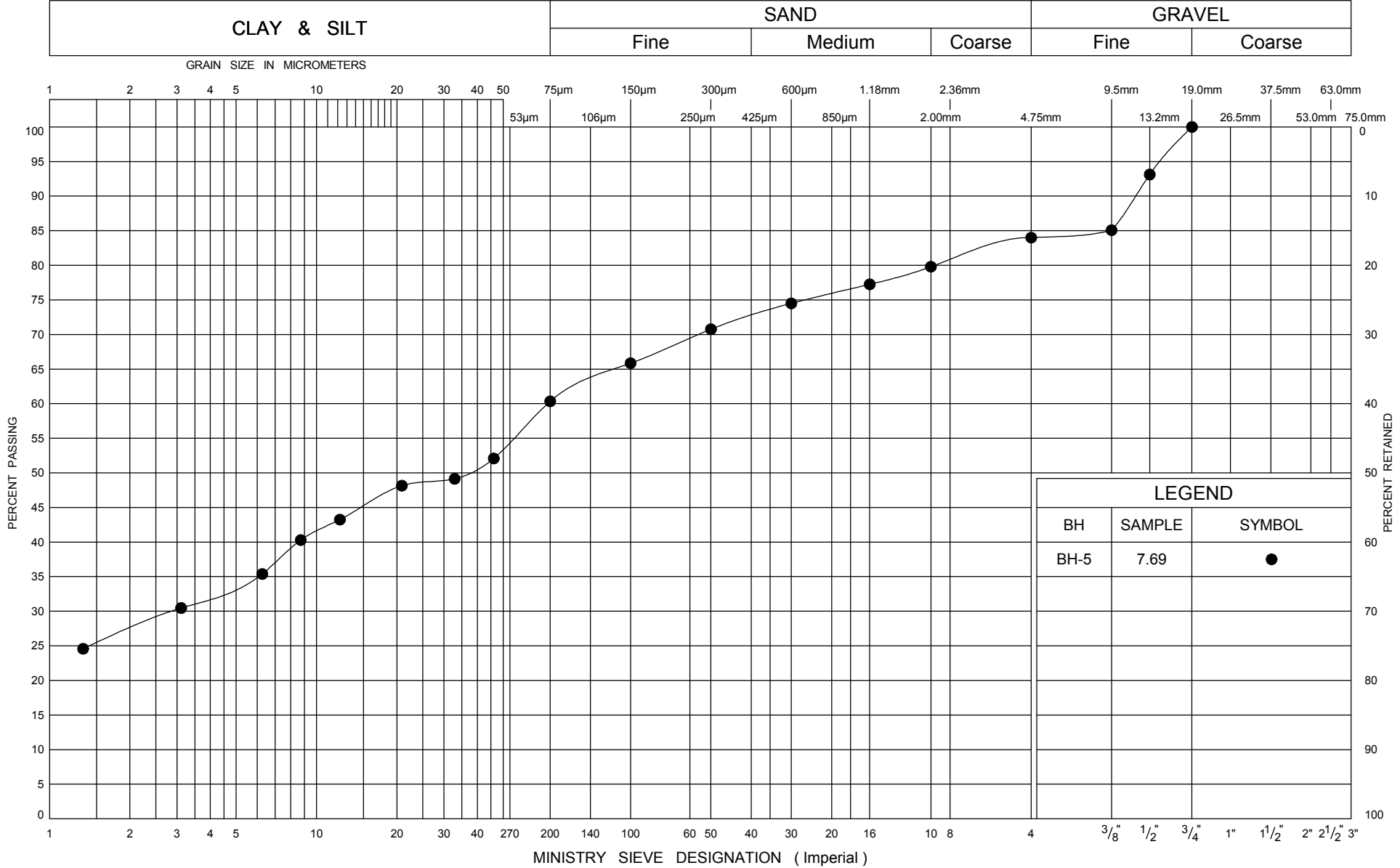
UNIFIED SOIL CLASSIFICATION SYSTEM

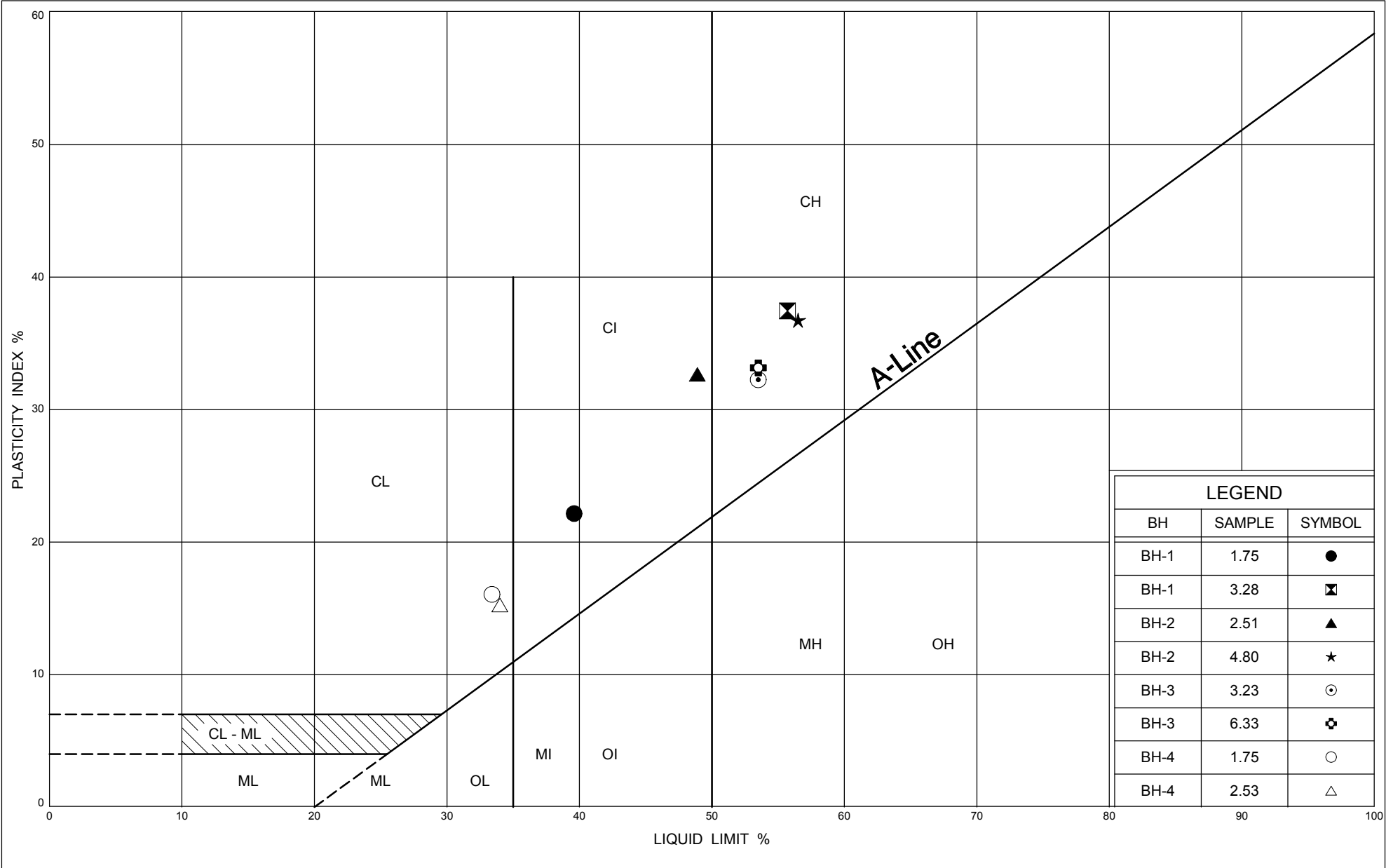


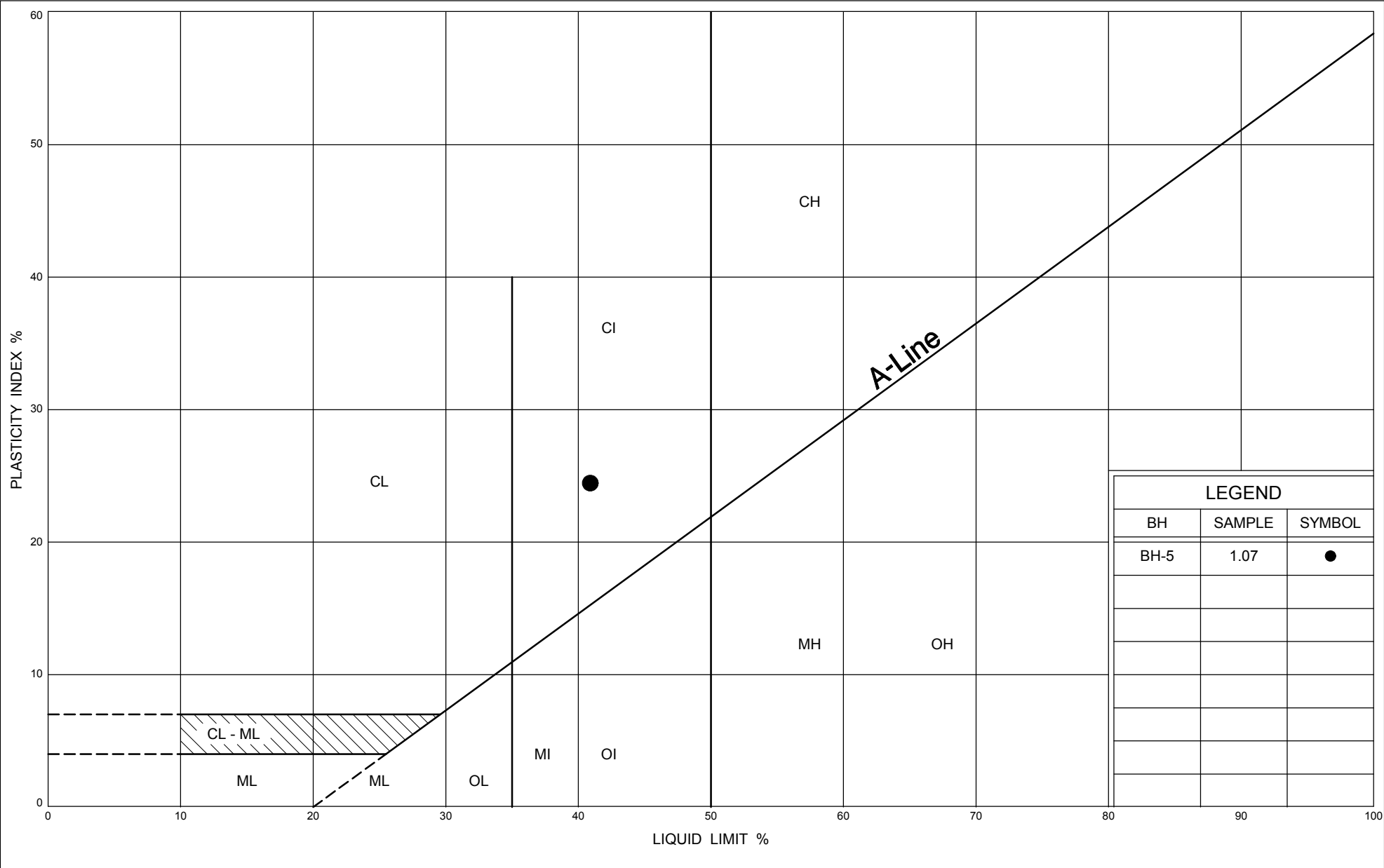
UNIFIED SOIL CLASSIFICATION SYSTEM

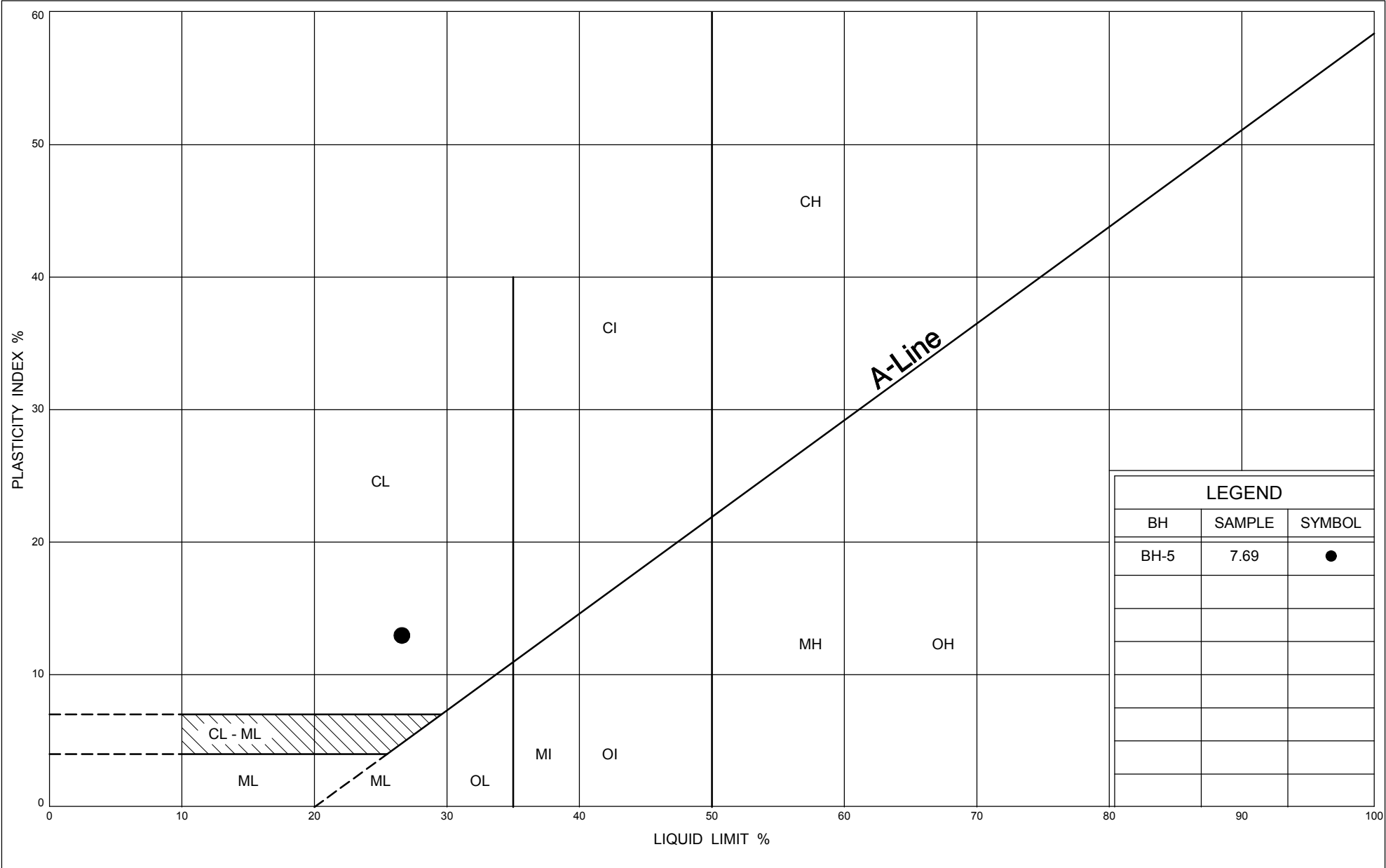


UNIFIED SOIL CLASSIFICATION SYSTEM









**CLIENT NAME: EXP. SERVICES INC.
80 BANCROFT STREET
HAMILTON, ON L8E2W5
(905) 573-4000**

ATTENTION TO: Jeff Golder

PROJECT: Borehole Investigation

AGAT WORK ORDER: 17H254496

SOIL ANALYSIS REVIEWED BY: Amanjot Bhela, Inorganic Coordinator

DATE REPORTED: Sep 07, 2017

PAGES (INCLUDING COVER): 5

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.



AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 17H254496

PROJECT: Borehole Investigation

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

CLIENT NAME: EXP. SERVICES INC.

ATTENTION TO: Jeff Golder

SAMPLING SITE:

SAMPLED BY:

Corrosivity Package

DATE RECEIVED: 2017-08-29

DATE REPORTED: 2017-09-07

SAMPLE DESCRIPTION: BH-5 SS2

SAMPLE TYPE: Soil

DATE SAMPLED: 2017-08-23

Parameter	Unit	G / S	RDL	8676073
Sulfide (S2-)	%		0.05	<0.05
Chloride (2:1)	µg/g		2	41
Sulphate (2:1)	µg/g		2	129
pH (2:1)	pH Units		NA	8.90
Electrical Conductivity (2:1)	mS/cm		0.005	0.409
Resistivity (2:1)	ohm.cm		1	2440

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

8676073 EC, pH, Chloride, Sulphate and Redox Potential were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil).

*Sulphide analyzed at AGAT 5623 McAdam

Certified By:

Amanjot Bhela

Quality Assurance

CLIENT NAME: EXP. SERVICES INC.

PROJECT: Borehole Investigation

SAMPLING SITE:

AGAT WORK ORDER: 17H254496

ATTENTION TO: Jeff Golder

SAMPLED BY:

Soil Analysis

RPT Date: Sep 07, 2017

DUPLICATE

REFERENCE MATERIAL

METHOD BLANK SPIKE

MATRIX SPIKE

PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD	Method Blank	Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper

Corrosivity Package

Sulfide (S2-)	8676073	8676073	< 0.05	< 0.05	NA	< 0.05	97%	80%	120%	NA			NA		
Chloride (2:1)	8676073	8676073	41	44	7.1%	< 2	97%	80%	120%	98%	80%	120%	102%	70%	130%
Sulphate (2:1)	8676073	8676073	129	139	7.5%	< 2	94%	80%	120%	97%	80%	120%	99%	70%	130%
pH (2:1)	8676073	8676073	8.90	8.93	0.3%	NA	101%	90%	110%	NA			NA		
Electrical Conductivity (2:1)	8676073	8676073	0.409	0.427	4.3%	< 0.005	95%	90%	110%	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.

Certified By:

Amanjot Bhela

Method Summary

CLIENT NAME: EXP. SERVICES INC.

AGAT WORK ORDER: 17H254496

PROJECT: Borehole Investigation

ATTENTION TO: Jeff Golder

SAMPLING SITE:

SAMPLED BY:

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
Sulfide (S ²⁻)	MIN-200-12025	ASTM E1915-09	GRAVIMETRIC
Chloride (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
Sulphate (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
pH (2:1)	INOR 93-6031	MSA part 3 & SM 4500-H+ B	PH METER
Electrical Conductivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B	EC METER
Resistivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B, SSA #5 Part 3	CALCULATION



Laboratories

LARGE BL

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

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)

Company:	exp Services Inc.	
Contact:	Jeffrey Golder	
Address:	80 Bancroft Street	
	Hamilton, ON L8E 2W5	
Phone:	905.573.4000 x5022	Fax: _____
Reports to be sent to:	jeffrey.golder@exp.com	
1. Email:	_____	
2. Email:	_____	

<input type="checkbox"/> Regulation 153/04	<input type="checkbox"/> Sewer Use	<input type="checkbox"/> Regulation 558
Table _____ <i>Indicate One</i>	<input type="checkbox"/> Sanitary	<input type="checkbox"/> CCME
<input type="checkbox"/> Ind./Comm	<input type="checkbox"/> Storm	<input type="checkbox"/> Prov. Water Quality Objectives (PWQO)
<input type="checkbox"/> Res./Park		<input type="checkbox"/> Other
<input type="checkbox"/> Agriculture		
Soil Texture (<i>Check One</i>)	Region _____ <i>Indicate One</i>	
<input type="checkbox"/> Coarse		
<input type="checkbox"/> Fine		

Project: Borehole Investigation
 Site Location: MTO Storage Dome, Jorvis, ON
 Sampled By: Dilsher
 AGAT Quote #: 159061 PO: ADM-235197-J0

Please note: if quotation number is not provided, clients will be billed full price for analysis.

Company: _____
Contact: _____
Address: _____
Email: _____

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

[illegible]

Samples Returned By (Print Name and Sign): <i>J. H. Gable</i> <i>Jeff Gable</i>		Date <i>Aug 29/17</i>	Time <i>7:00</i>	Samples Received By (Print Name and Sign): <i>Daniella Jalc</i> <i>John</i>		Date <i>8/29/17</i>	Time <i>2:50pm</i>	Page <u>1</u> of <u>1</u>
Samples Returned By (Print Name and Sign): <i>Daniella Jalc</i>		Date <i>8/30/17</i>	Time <i>1:15</i>	Samples Received By (Print Name and Sign): <i>Daniella Jalc</i>		Date <i>8/30/17</i>	Time <i>7:30</i>	
Samples Returned By (Print Name and Sign): <i>[Signature]</i>		Date <i>8/30/17</i>	Time <i>2:45</i>	Samples Received By (Print Name and Sign): <i>[Signature]</i>		Date <i>8/30/17</i>	Time <i>2:45</i>	

Laboratory Use Only

Work Order #: 17H25496

Cooler Quantity: 5m cooler

Arrival Temperatures: 7.6 | 7.3 | 7.2

Custody Seal Intact: 7-3716

Notes: ☒ Yes ☐ No ☐ N/A

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

Appendix E – Rock Core Photographs

Project No: ADM 00235197-J0
BH No: 1 Run No: 1 & 2
Sample Depth: 8.0 m to 11.0 m
Elevation: 202.4 m to 199.4 m
Description: Limestone
Date: August 23 to 25, 2017



Figure E1. Rock cores from BH-1

Project No: ADM 00235197-J0
BH No: 3 Run No: 1 & 2
Sample Depth: 7.7 m to 10.7 m
Elevation: 202.3 m to 199.3 m
Description: Limestone
Date: August 23 to 25, 2017



Figure E2. Rock cores from BH-3

Project No: ADM 00235197-J0
BH No: 5 Run No: 1 & 2
Sample Depth: 7.8 m to 10.8 m
Elevation: 202.4 m to 199.4 m
Description: Limestone
Date: August 23 to 25, 2017



Figure E3. Rock cores from BH-5

Appendix F – Results of Stability Analyses

November 29, 2017

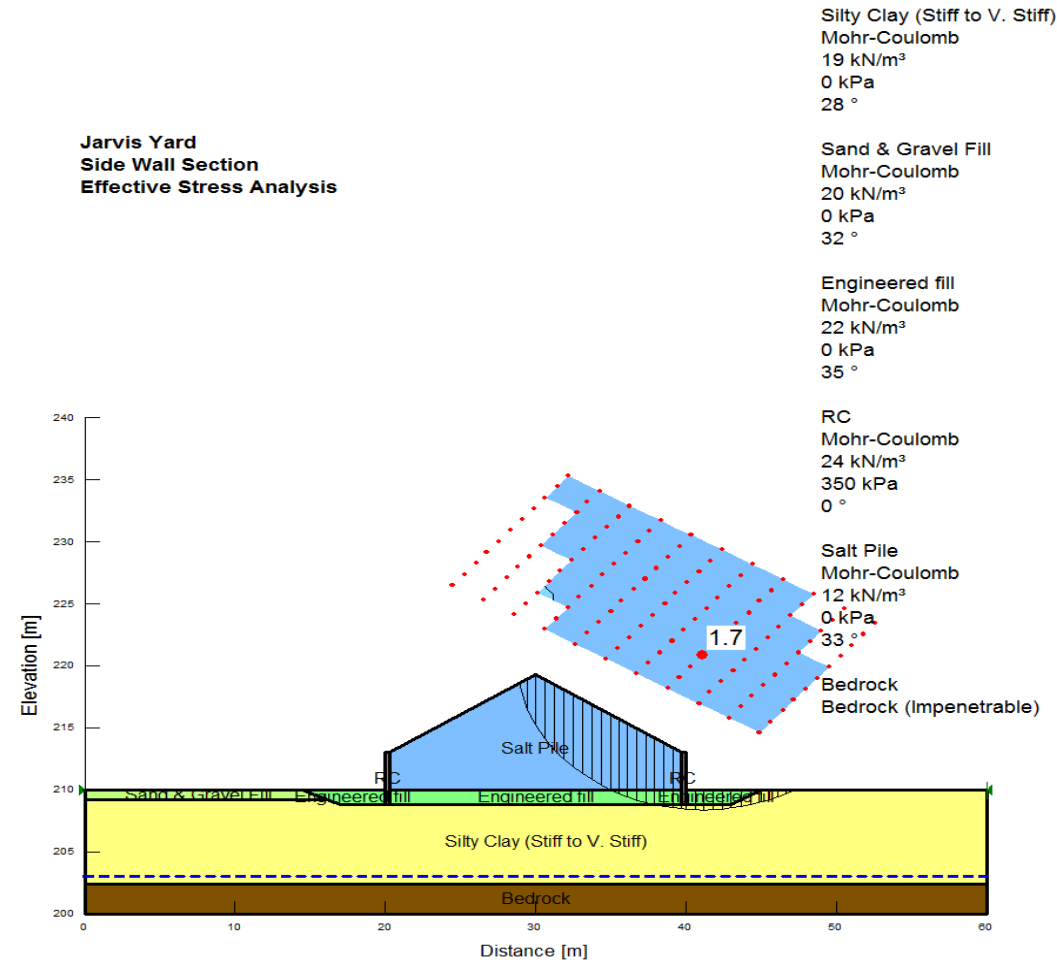


Figure F1. Results of global stability analyses along the side wall for the proposed salt storage structure

November 29, 2017

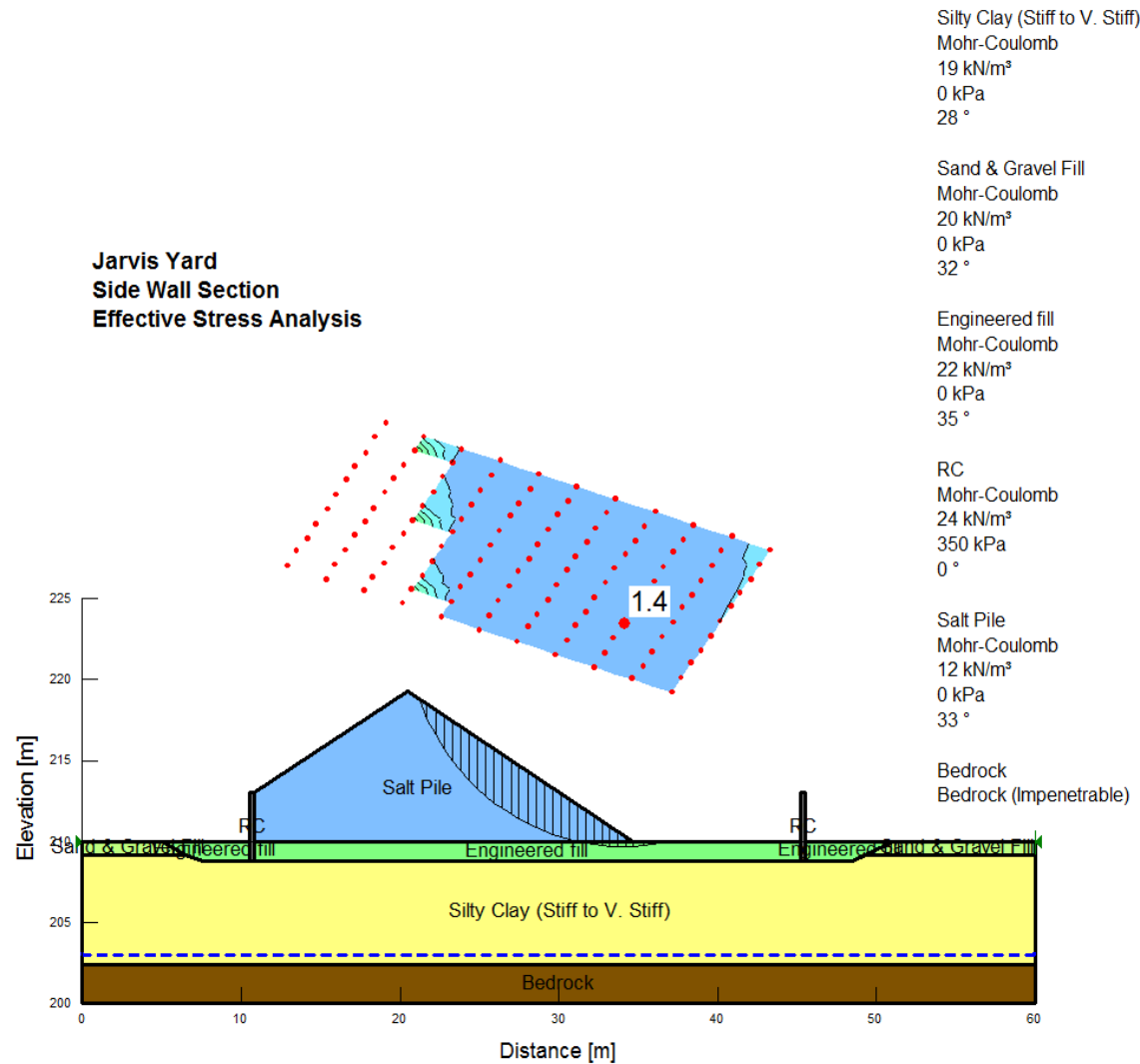
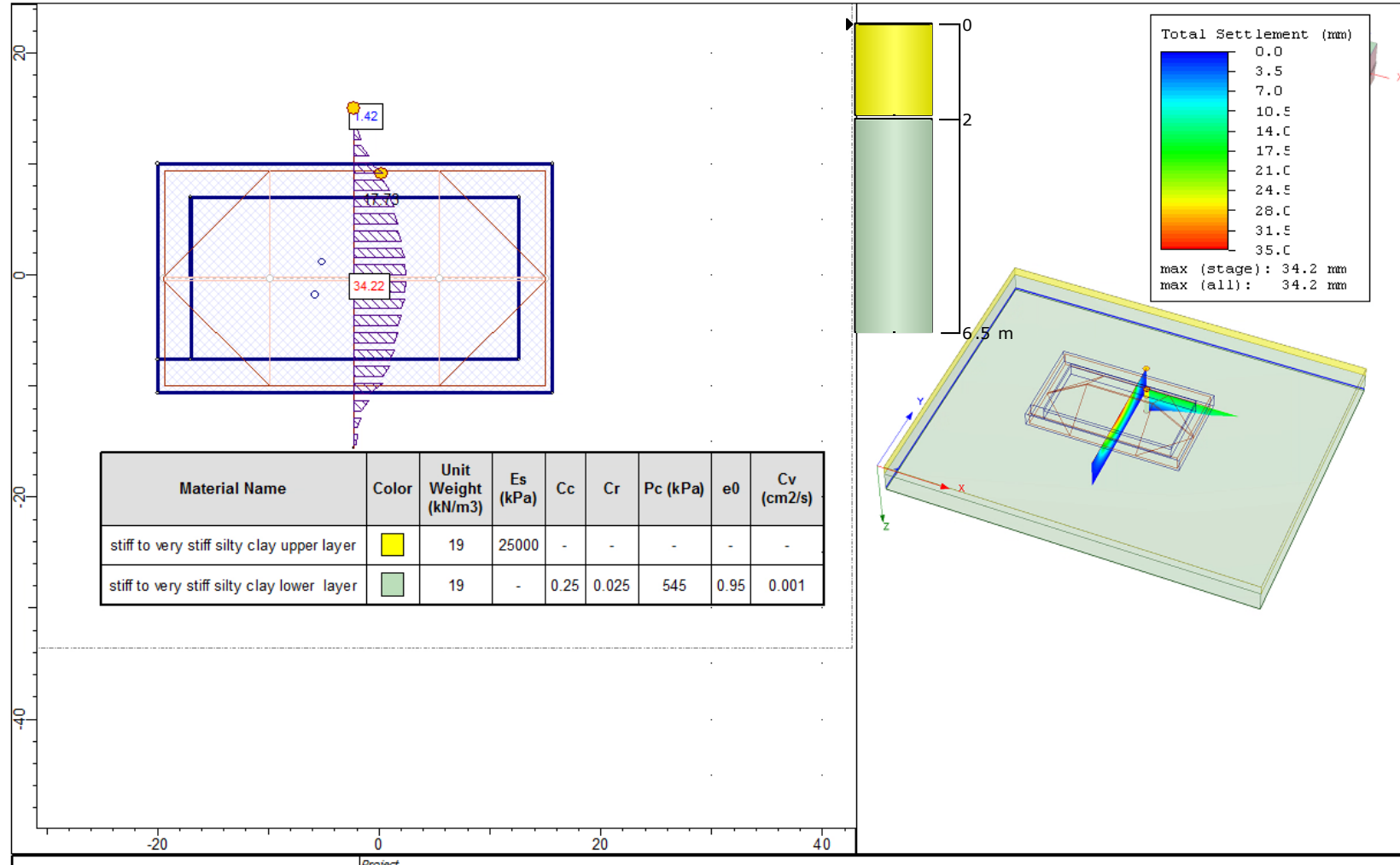


Figure F2. Results of global stability analyses along N-S section for the proposed salt storage structure

Appendix G – Results of Settlement Analyses



Project: FIDR for New Patrol Yard, Haldimand County

Analysis Description: Full loading – Total Settlement

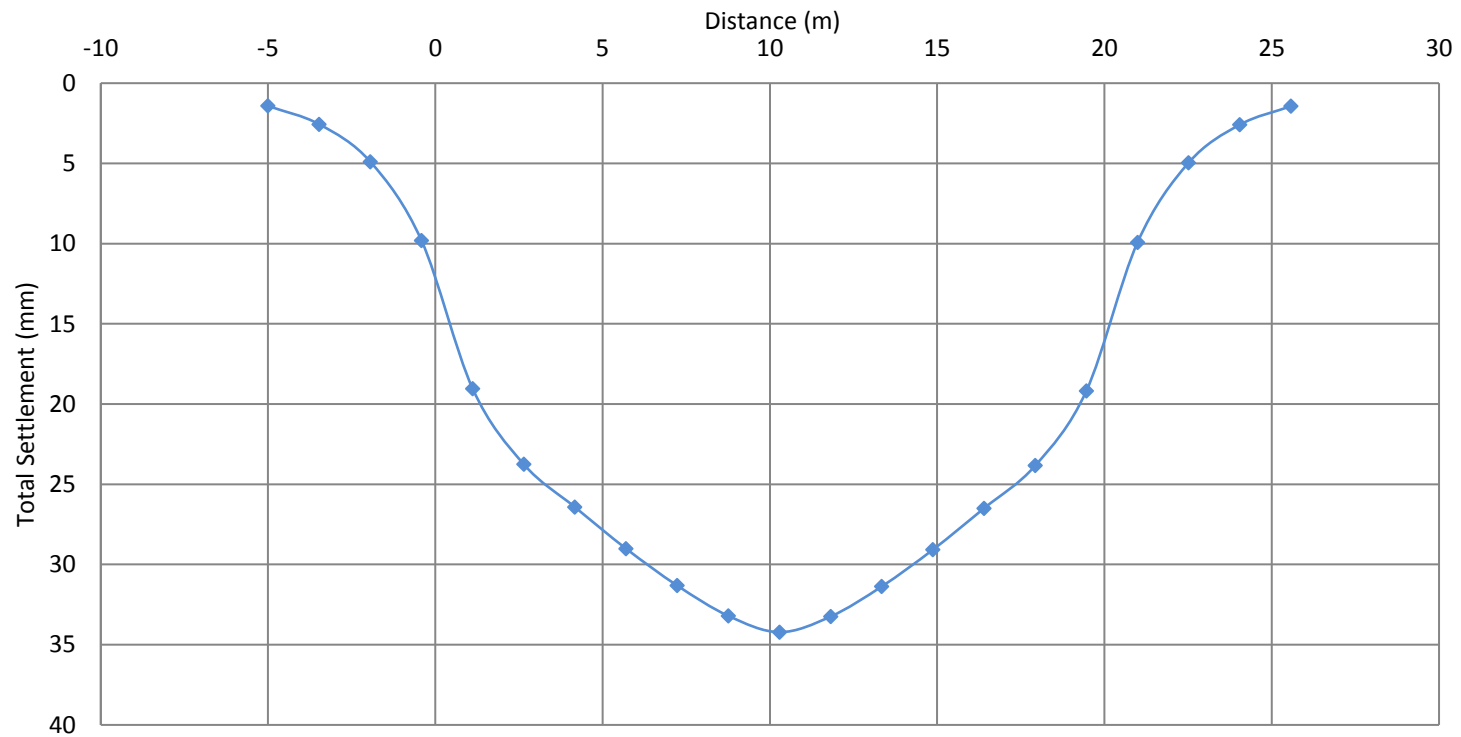
Figure No: G1

Date: September, 2017

Company: exp Services Inc.

File Name: Settlement Analysis – Assignment 6

Distance vs. Total Settlement



Project: FIDR for New Patrol Yard, Haldimand County

Analysis Description: Full loading – **Total Settlement Graph**

Figure No: G2

Date: September, 2017

Company: **exp** Services Inc.

File Name: Settlement Analysis – Assignment 6