



## **FINAL REPORT**

### **FOUNDATION INVESTIGATION AND DESIGN REPORT**

**New Salt Storage Facility at Kakabeka patrol Yard, Highway 11/17, Kakabeka Falls, District of Thunder Bay, Ontario**

**Agreement No. 6014-E-0017**

**Assignment No. 13**

**WO 2016-11029**

**Geocres No. 52A-221**

**Prepared for:**

**Ontario Ministry of Transportation**  
Regional Director's Office -NW Region  
615 James Street South  
Thunder Bay, ON P7E 6P6  
Attn: Mike Satten

**Ontario Ministry of Transportation**  
Pavements and Foundations Section  
Foundations Group  
Building 'C', Room 223  
1201 Wilson Avenue  
Downsview, ON M3M 1J8  
Attn: K.Ahmad

**exp Services Inc.**

July 06, 2016

# Ministry of Transportation

## Foundation Investigation and Design Report

Agreement No. 6014-E-0017

Assignment No. 13

WO 2016-11029

Geocres No. 52A-221

### Type of Document:

FINAL

### Project Name:

New Salt Storage Facility at Kakabeka Patrol Yard, Highway 11/17, Kakabeka Falls, District of Thunder Bay

### Project Number:

ADM-00223648-L0

### Prepared By:

Ahileas Mitsopoulos, P.Eng.

Nimesh Tamrakar, M.Eng, EIT.

Demetri N. Georgiou, MAsc. P.Eng.

Silvana Micic, Ph.D., P.Eng.

### Reviewed By:

TaeChul Kim, M.E.Sc., P.Eng.

Stan E. Gonsalves, M.Eng., P.Eng.

### exp Services Inc.

56 Queen St, East, Suite 301

Brampton, ON L6V 4M8

Canada



---

Silvana Micic, Ph.D., P.Eng.  
Senior Geotechnical Engineer



---

Stan E. Gonsalves, M.Eng., P.Eng.  
Principal Engineer  
Designated MTO Foundation Contact

### Date Submitted:

07/06/2016

## Table of Contents

<b>Appendices .....</b>	<b>iii</b>
<b>1 FOUNDATION INVESTIGATION REPORT .....</b>	<b>1</b>
1.1 Introduction .....	1
1.2 Site Description and Geological Setting .....	1
1.2.1 Site Description.....	1
1.2.2 Geological Setting.....	1
1.3 Investigation Procedures .....	2
1.3.1 Field Work.....	2
1.3.2 Laboratory Testing.....	3
1.4 Subsurface Conditions .....	3
1.4.1 Fill: Poorly Graded Sand with Silt and Gravel .....	3
1.4.2 Sand .....	4
1.4.3 Silt.....	5
1.4.4 Silty Clay to Silt Till .....	5
1.5 Groundwater Conditions.....	6
<b>2 DISCUSSIONS AND ENGINEERING RECOMMENATIONS .....</b>	<b>8</b>
2.1 General .....	8
2.2 Geotechnical Design Considerations for Foundations .....	9
2.2.1 Evaluation of Foundation Alternatives.....	9
2.2.2 Footing Elevation .....	11
2.2.3 Geotechnical Resistances .....	11
2.2.4 Resistance to Lateral Loads .....	12
2.2.5 Frost Protection .....	12
2.3 Earthquake Considerations .....	12
2.4 Perimeter Wall and Floor Construction .....	13
2.5 Stability and Settlement Analyses .....	14
2.5.1 Stability .....	14
2.5.2 Settlement.....	15
2.6 Site Preparation and Engineered Fill Construction .....	16
2.7 Excavation and Groundwater Control .....	17
<b>3 CLOSURE .....</b>	<b>18</b>
<b>Part IV: LIMITATIONS AND USE OF REPORT .....</b>	<b>19</b>

## **Appendices**

**APPENDIX A: PHOTOGRAPHS**

**APPENDIX B: DRAWINGS**

**APPENDIX B: BOREHOLE LOGS**

**APPENDIX D: LABORATORY DATA**

**APPENDIX E: RESULTS OF STABILITY ANALYSES**

**APPENDIX F: RESULTS OF SETTLEMENT ANALYSES**

# 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 facility located at the Kakabeka Patrol Yard, which is located on Highway 11/17, about 1 km south of Kakabeka Falls, in the Municipality of Oliver Paipoonge, in the District of Thunder Bay. The work was undertaken under Agreement # 6014-E-0017, Assignment No. 13. The terms of reference (TOR) were presented in the Ministry of Transportation (MTO) letter received on May 27, 2016. The location of the new salt storage building with dimensions of about 18.3 m x 24.4 m (60 ft x 80 ft) was laid out in the field by the MTO.

The purpose of the investigation is to establish the existing subsurface conditions at the proposed location of the patrol yard structure near the proposed building. The site specific geotechnical investigation consisted of field investigation including visual inspection, drilling, soil sampling, and laboratory testing. Factual results of the geotechnical investigation and laboratory testing are included in this report. The report has been prepared specifically and solely for the projects described in the report. A hydrogeological assessment at the site was not in a scope of this investigation.

## 1.2 Site Description and Geological Setting

### 1.2.1 Site Description

The Kakabeka Patrol Yard is located on Highway 11/17, about 1 km south of Kakabeka Falls, within the Municipality of Oliver Paipoonge, in the District of Thunder Bay; see Key Map on Drawing 1 in Appendix B. The topography of the site is relatively flat with a slight slope to the northwest and a steep drop in grade of about 1.4 m to 1.5 m bordering the northwest wall of the proposed structure. A partial retaining wall was also observed at the steep drop; see photographs in Appendix A and Drawings 1 and 2, in Appendix B.

At the time of the investigation, the area within the building footprint contained five (5) large salt solution, above ground storage tanks. To the south of the proposed building are two rectangular salt storage structures, to the east is a round salt storage dome, and further to the south is a garage and administrative building. The site plan is provided on Drawing 1 in Appendix B.

During the fieldwork, the general site conditions were assessed. Select photographs are provided in Appendix A.

### 1.2.2 Geological Setting

According to the MNR Northern Ontario Engineering Geology Terrain Data Base Map, Ontario Geological Survey Map 5047, Scale 1:100,000, dated 1981, the underlying native soil at the site predominantly consists of gravel and sand glaciolacustrine delta deposits. The local relief is mainly a low plain with terraced sections and dry surface conditions.

According to the Ontario Geological Survey, Precambrian Geology Compilation Series, Map No. 2664, Thunder Bay Sheet, Scale 1:250,000, issued 2001, the bedrock at the site is described as from the Paleoproterozoic Era (1.6 to 2.5 Ga) and in particular part of the Animike Group (1.6 to 2.2 Ga). The rock is of sedimentary composition and consists of mudstone (argillite), limestone, iron formation, and basalt from the Upper Gunflint formation (1878 Ma).

## 1.3 Investigation Procedures

### 1.3.1 Field Work

The field investigation was carried out during June 13, 14, and 17, 2016. The field program consisted of drilling four (4) sampled boreholes (BH101, BH102, BH103 and BH104) located just outside the perimeter of the structure, at all four corners (see Drawing 1 in Appendix B). BH101 was advanced to a depth of about 15.5 m below ground surface, and the remaining boreholes were advanced to depths ranging between about 10.5 m and 10.6 m below ground surface.

The borehole locations were referenced to the MTM NAD83 (ON-15) coordinate system and the ground surface elevations were surveyed by **exp** personnel, with reference to a benchmark provided by the client (the designed finished floor elevation of the garage and administrative building). The benchmark was located at the most southern point of the concrete apron outside the Bay 5 door, with a geodetic elevation of 285.29 m (936.0 ft).

The boreholes were advanced using a truck-mounted CME 55 drill rig, equipped with continuous flight hollow stem augers. All borehole drilling/sampling were operated by a specialist drilling contractor, Cartwright Drilling Inc.

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 D1586), and were generally performed at intervals of about 0.75 m, in the upper 6 m, and 1.5 m intervals thereafter. The original field (uncorrected) SPT "N" values were recorded on the borehole logs as recommended in the Canadian Foundation Engineering Manual and used to provide an assessment of *in-situ* compactness (cohesionless) or consistency (cohesive) soils.

At boreholes BH101, BH102 and BH104, the groundwater level depths could not be measured as the boreholes caved/collapsed at depths less than that of the groundwater table. A temporary standpipe was installed at BH103 on June 14, 2016, and the groundwater depth was measured on June 17, 2016. The standpipe was removed from the ground at that time. The measured groundwater level and details of the standpipe construction are provided on the borehole log, in Appendix C. All boreholes were backfilled with a mixture of bentonite and auger cuttings. The borehole decommissioning was in general 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. All of the recovered soil samples were placed in labelled

moisture-proof bags which were brought to **exp's** Thunder Bay laboratory for additional visual, textual and olfactory examination, and for subsequent examination by a geotechnical engineer and 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 and particle size distribution for approximately 25% of the collected soil samples. Atterberg Limits tests were carried out on select cohesive soil samples. All of the laboratory tests were carried out in accordance with MTO and/or ASTM standards as appropriate, at the **exp** laboratory in Thunder Bay, Ontario.

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 select 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 sections 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 a layer of fill material consisting of sand with silt and gravel, overlying sand deposits, overlying silt, and overlying silty clay to silt till deposits. A brief summary of the soil and groundwater conditions encountered in the boreholes is provided below.

### 1.4.1 Fill: Poorly Graded Sand with Silt and Gravel

Poorly graded sand with silt and gravel fill was encountered surfacing boreholes BH103 and BH104, and beneath the asphalt at BH101 and BH102. The asphalt thickness was about 150 mm at both boreholes. The fill was generally described as loose to dense, brown, and damp to moist. The SPT "N" values ranged between about 9 and 31 blows per 300 mm penetration, with an average "N" value of about 19. The fill extended to depths ranging between about 0.8 m and 1.5 m below ground surface, with elevations ranging between about 283.9 m and 284.3 m.

Laboratory testing performed on selected samples of the fill consisted of moisture content and grain size distribution tests. The test results are as follows:

Moisture content:

2.1% to 3.8%

Grain size distribution:

23% gravel;

66% sand; and

11% silt and clay size.

The results of the moisture content and grain size distribution tests are provided on the record of borehole sheets in Appendix C. The results of the grain size distribution tests are also provided on Figure 1, in Appendix D.

#### **1.4.2 Sand**

Sand was encountered underlying the fill. The sand was generally described as poorly graded, loose to compact, brown, and moist to wet at depth. The SPT "N" values ranged between 7 and 20 blows per 300 mm penetration, with an average "N" value of about 12. The sand extended to depths ranging between about 5.5 m and 7.6 m below ground surface, with elevations ranging between about 277.8 m and 279.5 m.

Laboratory testing performed on selected samples consisted of moisture content and grain size distribution tests. The test results are as follows:

Moisture content:

2.6% to 18.2%

Grain size distribution:

0% to 8% gravel;

71% to 97% sand; and

3% to 29% silt and clay size.

Total saturated unit weights have been calculated based on the moisture contents at and below the estimated groundwater table (about 6 m below ground surface). Moisture content was tested for only one sample below 6 m depth, and the result was about 15.1%; the total saturated unit weight is about 21.7 kN/m<sup>3</sup>.



The results of the moisture content and grain size distribution tests are provided on the record of borehole sheets in Appendix C. The results of the grain size distribution tests are also provided on Figure 2, in Appendix D.

### **1.4.3 Silt**

Silt was generally encountered beneath the sand. The silt was generally described as sandy silt to clayey silt with sand, loose to compact (firm to stiff), brown to grey, and wet. The SPT “N” values ranged between 7 and 24 blows per 300 mm penetration, with an average “N” value of about 12. The silt extended to depths ranging between about 7.6 m and about 9.2 m below ground surface, and elevations ranging between 275.9 m and 277.4 m.

Laboratory testing performed on selected samples consisted of moisture content and grain size distribution tests. The test results are as follows:

Moisture content:

21.8% to 30.3%

Grain size distribution:

0% gravel;

5% to 39% sand;

49% to 79% silt; and

12% to 16% clay sizes.

Total saturated unit weights have been calculated based on the moisture contents and are estimated to range from about 19.0 to 20.3 kN/m<sup>3</sup>. Two (2) Atterberg Limits test were performed on representative samples of the silt (BH101-S10 and BH103-S9). The results indicated that the samples are of low plasticity. The data is shown on the plasticity chart, Figure 6. The liquid limit, plastic limit and plasticity index ranged between about 20 and 25, 14 and 17, and 5 and 8, respectively.

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

### **1.4.4 Silty Clay to Silt Till**

Silty clay to silt till was encountered at underlying the silt to sandy silt, and sand. The till consisted of deposits of silty clay, clayey silt, silt with sand, and silt. The till was generally described as compact to very dense, grey, and moist. Occasional cobbles and boulders were encountered at BH102. The SPT “N” values ranged between 10 and 100 (i.e. SPT refusal) blows per 300 mm penetration, with an average “N” value of about 65. The till extended to the termination depth of all boreholes, with depths

ranging between about 10.5 m and about 15.5 m below ground surface, and elevations ranging between 269.9 m and 275.0 m.

Laboratory testing performed on selected samples consisted of moisture content and grain size distribution tests. The test results are as follows:

Moisture content:

14.4% to 32.1%

Grain size distribution:

0% to 6% gravel;

5% to 20% sand;

46% to 62% silt; and

17% to 49% clay sizes.

Total saturated unit weights have been calculated based on the moisture contents and are estimated to range from about 18.7 to 21.8 kN/m<sup>3</sup>. Four (4) Atterberg Limits test were performed on representative samples of the till (BH101-S12, BH102-S10, BH103-S10 and BH104-S12). The results indicated that the samples are of low to medium plasticity. The data is shown on the plasticity chart, Figure 6. The liquid limit, plastic limit and plasticity index ranged between about 25 and 47, 13 and 20 and 12 and 27, respectively.

The results of the moisture content, grain size distribution and Atterberg Limits test are provided on the record of borehole sheets in Appendix C. The results of the grain size distribution are also provided on Figures 4 and 5 in Appendix D, and Atterberg Limits test are provided on Figure 6 in Appendix D.

## **1.5 Groundwater Conditions**

Information on groundwater levels at the site was obtained by measuring the water levels in the open boreholes after completion of drilling. A temporary standpipe was installed at BH103. The groundwater levels encountered in the boreholes are shown on the borehole logs and presented below in Table 1.1.

Seasonal variations in the water table should be expected, or after periods of extended precipitation or drought, and, as such, may differ at other times.

**Table 1.1. Groundwater data**

Borehole	Date Completed	Date Measured	Ground Surface Elevation <sup>2</sup>	Depth to Water <sup>3</sup>	Groundwater Elevation
BH101	Jun. 13/16	Jun. 13/16	285.39	dry <sup>4</sup>	--
BH102	Jun. 13/16	Jun. 13/16	285.47	dry <sup>4</sup>	--
BH103 <sup>5</sup>	Jun. 14/16	Jun. 17/16	284.97	6.52	278.45
BH104	Jun. 14/16	Jun. 14/16	285.04	dry <sup>4</sup>	--
Notes: 1) All units in metres. 2) Elevations surveyed are referenced to the client provided benchmark (the designed finished floor elevation of the garage and administrative building). The benchmark was located at the most southern point of the concrete apron outside the Bay 5 door, with a geodetic elevation of 285.29 m (936.0 ft). 3) Depths are relative to ground surface. 4) Indicates no groundwater encountered in open boreholes. 5) Temporary standpipe installed.					

At BH101, BH102 and BH104, the boreholes caved/collapsed at depths of about 4.5 m (280.9 m elevation), 5.1 (280.4 m elevation) and 3.1 m (281.9 m elevation), respectively; no groundwater was encountered at these boreholes.

## 2 DISCUSSIONS AND ENGINEERING RECOMMENATIONS

### 2.1 General

This section of the report provides geotechnical design recommendations for the proposed MTO Kakabeka Patrol Yard structure located approximately 1 km south of Kakabeka Falls, off Hwy 11/17, Thunder Bay area. 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.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. The design-build contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

Based on information included in the TOR and correspondence with MTO it is understood that the new storage structures will be built at the site. The proposed building will consist of a conventional building for storage of road salt, and will allow for inside loading and dumping. Based on information presented in Special Provision provided by MTO and attached in Appendix E, the proposed salt storage building will have a footprint of about 24.38 m x 18.28 m in plan dimensions. It will have a maximum height of about 11.0 m to the bottom of the trusses (underside of roof truss) and it will be encompassed with a 2.5 m high, cast-in-place concrete foundation walls around the perimeter. The building will have a steel roof and timber wall cladding, and an asphalt floor slab within the plan area of the storage. The assumed finished top of the asphalt floor will be approximately at Elev. 285.5 m to tie-in to the existing 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 Ontario Building Code (OBC), 2012, O.Reg. 332/12, Building Code Act, 1992, Ministry of Municipal Affairs and Housing; the *Guideline for Professional Engineers Providing Geotechnical Engineering Service* (1992); the *Canadian Foundation Engineering Manual (CFEM)* (2006) and the *provisions in the TOR* and good practice. It also provides discussion about stability and settlement analyses, frost protection, drainage, backfilling material, construction considerations and dewatering during construction, as requested in the TOR from MTO letter dated May 27, 2016.

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 winter salt stacked to the maximum allowable height of the concrete wall with a stockpile area covering the entire footprint of the building.

## **2.2 Geotechnical Design Considerations for Foundations**

The geotechnical investigation and its findings pertaining to the subsurface soil characteristics have been covered in Part I - Foundation Investigation Report 1 which contains details of the field and laboratory aspects of the investigation. In general, the subsurface conditions encountered at the site consist of up to 1.5 m of compact to dense sand (with silt and gravel) fill underlain by a non-cohesive deposit of loose to compact sand extended to depths ranging between about 5.5 m and about 7.6 m below ground surface (measured 'N' values between 7 and 20; average 'N' value of about 12 blows per 300 mm of penetration) followed by a deposit of loose to compact silt extended to depths ranging between about 7.6 m and about 9.2 m below ground surface (measured 'N' values between 7 and 24; average 'N' value of about 12 blows per 300 mm of penetration). The silty layer is underlain by compact to very dense silty clay to silt till (measured 'N' values between 10 and 100; average 'N' value is 65 blows per 300 mm of penetration). The groundwater level measured in the temporary standpipe was approximately 6.5 m below the ground surface (Elev. 278.45 m).

### **2.2.1 Evaluation of Foundation Alternatives**

Considering that very dense material was encountered at the approximately 10-12 m depth, as well as the high cost of pile foundations and the structure's operating life it is unlikely that deep foundations can be considered practical for this patrol yard structure. It appears that shallow foundations are more practicable. However, an evaluation of these two foundation alternatives is included in this report. Advantages and disadvantages of shallow foundations such as strip/spread footings and deep foundations such as driven steel H-piles are presented in Table 2.1.

Given the subsurface conditions at the site the impact on settlement at the foundations of the structure will be influenced by the operating/stockpiling practices. It is our understanding that the structure will accommodate stockpiles of road salt at strategic locations within the structure. Based on the information mentioned in Section 2.1, the maximum loading condition is likely to be salt stockpiled to at least the level of the concrete wall over the full footprint. Mounding in the centre at the angle of repose material of 33% beyond the height of the concrete wall is also a possibility. As noted in the Special Provision, the design should account for entire surface area of the interior asphalt pad to be loaded. It is recommended that minimum bulk density of 20 kN/m<sup>3</sup> (127.4 pcf).

These types of structures generally have service lives of about 20 years. Typically, in settings of poor soil conditions, the approach would be to mitigate potential distress for a shallow foundation supported on it rather than employ expensive deep foundations for building support. Mitigation to create stable foundation soils can include vibrocompaction to densify loose sands, preloading of the footprint area before construction, structure support on engineered fill and/or stockpiling constrains in order to enhance serviceability.

Table 2.1 Evaluation of foundation alternatives

Options	Rank	Advantages	Disadvantages	Relative Costs	Risks/Consequences
<b>Shallow Foundation</b>  (Strip/Spread Footings on Native Compact Sand Material)	1*	<ul style="list-style-type: none"> <li>▪ Straightforward construction</li> </ul>	<ul style="list-style-type: none"> <li>▪ Fairly low geotechnical resistance available</li> <li>▪ Foundation on engineered fill may be necessary</li> <li>▪ Depending on conditions, some stockpiling constraints may be necessary</li> </ul>	<ul style="list-style-type: none"> <li>▪ Significantly lower relative cost compare to piles</li> </ul>	<ul style="list-style-type: none"> <li>▪ Risk of differential settlements due to loading patterns in the past and during operations</li> <li>▪ Possible constraints on a storage volume</li> </ul>
<b>Deep Foundation</b>  (Driven Steel H-Piles )	2	<ul style="list-style-type: none"> <li>▪ Straightforward construction</li> </ul>	<ul style="list-style-type: none"> <li>▪ Not typical for this type of structure</li> <li>▪ Could be very long piles, not warranted for this type of structure</li> </ul>	<ul style="list-style-type: none"> <li>▪ Higher relative costs compared with shallow foundations</li> <li>▪ Unlikely to be economically feasible at the site</li> </ul>	<ul style="list-style-type: none"> <li>▪ Deep firm ground</li> <li>▪ Not viable due to cost</li> </ul>

\* If geotechnical resistance is adequate, otherwise vibrocompaction and/or preloading and/or founding on engineered fill and/or stockpiling constraints may be necessary.

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 will be founded on/within the native compact sand deposit.

## 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 2.2 m below the lowest surrounding area, see Section 2.2.5), the following founding elevations of strip/spread footings are recommended:

*Table 2.2 Recommendations for footing elevation*

Soil at Founding Level	Foundation Elevation (m)	Depth Below Existing Grade
Native Compact Sand	282.8	2.2 m

## 2.2.3 Geotechnical Resistances

In the context of the Ontario Building Code (OBC), 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 2.2, should be designed based on the factored resistances at ULS and geotechnical reactions at SLS for 25 mm of settlement given in Table 2.3 below. The footing width of 3 m is assumed. Settlement of the footings under the loading from the stockpiles 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 2.3 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 Compact Sand	3	500	225

Since the ULS resistance and the settlement depend on the footing size and depth of embedment, the geotechnical resistances given in Table 2.3 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 are used in these calculations, the values given in Table 2.3 has to be reviewed to take into account those inclinations.

Prior to placing footings, the exposed native subgrade should be inspected according with OPSS 902. A Qualified Geotechnical Engineer should check that the design foundation elevation is achieved and all unsuitable soils including fill, organics and those soils with the USCS classification of CH, OH, MH, OL or PT have been removed.

## 2.2.4 Resistance to Lateral Loads

The unfactored values of the coefficient of friction,  $\tan \delta$ , between the base of cast-in-place concrete footing and the granular subgrade soils below the frost level are presented in Table 2.4.

Table 2.4 Recommendations for coefficient of friction

Soil at Founding Level	Coefficient of Friction, $\tan \delta^*$
Native Compact Sand	0.40

\*- 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 Table 8.1, CFEM.

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 = 20 kN/m<sup>3</sup>
- 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 the Thunder Bay area is about 2.2 m. Consequently, all footings exposed to seasonal freezing conditions should be protected from frost action by at least 2.2 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 sand and silt layers underlain by very dense silt till. It is expected that the foundations will be founded in the sand layer underlain by the silt layer. The reported N-values for the soil below the founding level ranged from 7 to 100, with an average value about 30.



#### 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 Thunder Bay 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 the purpose of 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 four (4) boreholes advanced for building construction at this site were maximum 15.5 m deep.

#### Site Classification:

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

These parameters should be reviewed by the Structural Engineer.

## **2.4 Perimeter Wall and Floor Construction**

The perimeter wall of the proposed structure may be constructed as a cantilever retaining wall with an extended heel toward the inside of the structure and founded on native soils or engineered fill. Structural steel bars should be provided in the footings and in the walls. The asphalt floor will 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 qualified geotechnical personnel. Any soft spots detected during proof-rolling should be sub-excavated and replaced with approved materials compacted to 100 % of the Standard Proctor Maximum Dry Density (SPMDD). The prepared subgrade should be covered with at least 400 mm compacted OPS Granular A, crowned slightly in the central area. As stated in the Special Provision, the placing of 50 mm of Super Pave 12.5 asphalt is required

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. In order to minimize contamination into the native soils and subsequently into the groundwater, a barrier such as a compacted low-permeability clay liner or geomembrane should be installed below the 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 and covered with a 300 mm thick layer of sand fill on top of the geomembrane in order to protect it from the overlying pavement structure. In addition, asphalt used for the floor of the structure should be sealed to minimize infiltration, since it is somewhat permeable. However, sulphate resistant concrete should be used for structure foundations.

## 2.5 Stability and Settlement Analyses

### 2.5.1 Stability

To assess the global stability of the storage structure and to check that a minimum Factor of Safety of 1.3 will be achieved for the maximum height salt stockpile of approximately 8.6 m, a series of slope stability analyses were performed. The static slope stability analyses were performed using the Morgenstern-Price method developed on the basis of limit equilibrium. The SLOPE/W computer program developed by GeoSlope International was employed for computation.

Stability assessments were performed for two cases: (i) an approximately 8.6 m high stockpile (assumed slopes of 1.5H:1V) restrained with both sides by concrete side walls as shown on Figure E1, and (ii) an approximately 8.6 m high stockpile with the restrained back side with the concrete wall and an unrestrained front side with assumed slope of 1.5H:1V as shown on Figure E2. It should be noted that the side stability of the stockpile will be governed by the angle of repose of the stockpile material, which value of 33 degrees is provided in the Special Provision. 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 were performed taking into consideration the subsoil conditions encountered directly beneath and adjacent the proposed structure. The asphalt floor was not included in the analyses, but it is expected that it will provide additional stability support to the system.

Tabulated below in Table 2.5 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 2.5 Soil properties used in slope stability analyses

Material Type	Effective Stress Parameters		
	$\phi$ (degrees)	c (kPa)	$\gamma$ (kN/m <sup>3</sup> )
Engineered Fill	35	0	22
Sand and Gravel Fill	30	0	21

Material Type	Effective Stress Parameters		
	$\phi$ (degrees)	c (kPa)	$\gamma$ (kN/m <sup>3</sup> )
Compact Sand	29	0	20
Geomembrane	16	0	19
Salt Stockpile Material	33	0	20

The graphical results of these analyses can be seen in Appendix E. As shown on Figure E1, the results of stability analyses for an approximately 8.6 m high salt stockpile restrained with concrete walls on both sides suggest that the factor of safety of 1.7 can be obtained for a deep-seated failure surface. The same results (i.e. min FOS =1.5) were obtained for the approximately 8.6 m high stockpile with the restrained back side and an unrestrained front slope as shown on Figure E2.

## 2.5.2 Settlement

To evaluate the maximum settlement and differential settlement values bellow the salt stockpile loading in the proposed storage building, a 3D computer program; Settle3D (Rocscience) was employed. Considering the cohesionless nature of the soil material encountered at the site it is anticipated that only an immediate settlement would be occurred under the loading. The elastic moduli of deformation 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 2.6.

Table 2.6 Soil properties used in settlement analyses

Material Type	$\gamma$ (kN/m <sup>3</sup> )	E (MPa)	Poisson's Ratio
Engineered Fill	22	40	0.3
Sand (Loose)	18	25	0.3
Sand (Compact)	20	30	0.3
Sandy Silt (Compact)	20	25	0.3
Silt Till (Dense to Very Dense)	21	70	0.3

The geometry of the stockpile was assumed based on its maximum allowable capacity; a maximum height of approximately 8.6 m at the center (with side slopes of 1.5H:1V) and 2.5 m along the sides at the concrete wall. The settlement computed under the maximum capacity of stockpile is presented graphically in Appendix F.

The estimated settlement under the stockpile at the center and at the edge of the stockpile (i.e. location of footings) is presented in Table 2.7.

*Table 2.7 Results of settlement analyses for the proposed structure*

Foundation Soil Type	Estimated Settlement (mm)		
	At Center	At Edge	Differential
Loose to Compact Sand	41	12	29

As it is mentioned, the calculated settlement is considered immediate after the stockpile loading. However, the loading and consequent settlement would be occurred after the footings have been constructed. Therefore, the footing for this structure has to be design under the full allowable stockpile loading. The geometry of stockpile under the full allowable loading including its maximum height is recommended above. It is also recommended that the designer includes detailed procedures in the contract drawings and note.

If the footprint area is preloaded by a gravel/sand stockpile prior of construction, the post-construction settlement can be significantly reduced. The settlement analyses for different height of the stockpile preloading were performed and the results are presented in Table 2.8 and attached Figures F3 and F4, appendix F. The results show that the immediate settlement of approximately 20 mm and 26 mm at the center could be achieved by placing a 4 m and 5 m high stockpile, respectively. The settlement of 5 mm to 6 mm can be produced at the proposed location of the storage footings. Therefore, these analyses demonstrate that preloading can significantly reduce the post construction settlement. It is anticipated that these predicted immediate settlements will take place as the load is applied or within a time period of about 14 days.

*Table 2.8 Results of settlement analyses for preloading*

Height of Stockpile Preloading (m)	Estimated Settlement at Centre (mm)	Estimated Settlement at Location of Proposed Footing (mm)
4	20	5
5	26	6

## 2.6 Site Preparation and Engineered Fill Construction

As mentioned previously, the area within the limits of the building 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. Considering the high groundwater table at the site the preferred engineered fill should be Granular B, Type II. However, in order to prevent migration of fine soil particles a geotextile can be used underneath Granular B, 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.

## **2.7 Excavation and Groundwater Control**

For the construction of the proposed structure, excavations at least about 2.2 m depth will be required. The excavations are expected to encounter mostly sandy 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 purpose of 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 have to be formed at 3H:1V unless a suitable dewatering system is installed to lower the water level below the base of the excavation.

Considering the subsurface conditions at the site (i.e. sandy soils and the groundwater table approximately 6.5 m below the ground surface) and the depth of the excavations, it is expected that excavations will not encounter groundwater seepage. Perimeter ditches should be incorporated into the surface water drainage plan to promote run-off away from the structures.

It should be noted that the water levels in this area may fluctuate depending on the time of year. It is recommended that excavations for the footings be carried out in late summer when the water levels are anticipated to be lower.

July 6, 2016

### 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 Ahileas Mitsopoulos, P.Eng., Nimesh Tamrakar, M.Eng, EIT., Demetri N. Georgiou, M.A.Sc. P.Eng., and Silvana Micic, Ph.D., P.Eng. It was reviewed by TaeChul Kim, P.Eng. and by Stan E. Gonsalves, M.Eng., P.Eng., Designated MTO Foundation Contact. The field investigation was conducted by Robert Moen. B.Eng, EIT.

Yours truly,

**exp Services Inc.**



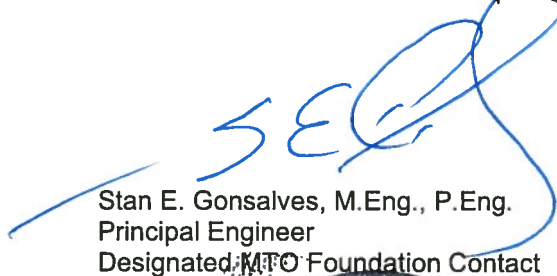
Nimesh Tamrakar, M.Eng.EIT.  
Technical Specialist



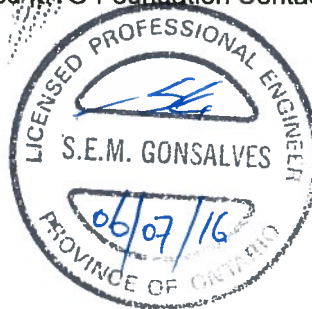
TaeChul Kim, M.E.Sc., P.Eng.  
Senior Geotechnical/Foundation Specialist



Silvana Micic, Ph.D, P.Eng.  
Senior Geotechnical Engineer



Stan E. Gonsalves, M.Eng., P.Eng.  
Principal Engineer  
Designated MTO Foundation Contact



Encl.



## **Part IV: 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. Facing southeast towards BH101 location and the garage/administration building



Photo 2. Facing southwest along the proposed south building footprint. The existing salt storage buildings are observed



Photo 3. Facing northwest along the proposed west building footprint. The salt storage solutions in the ASTs is observed on the right



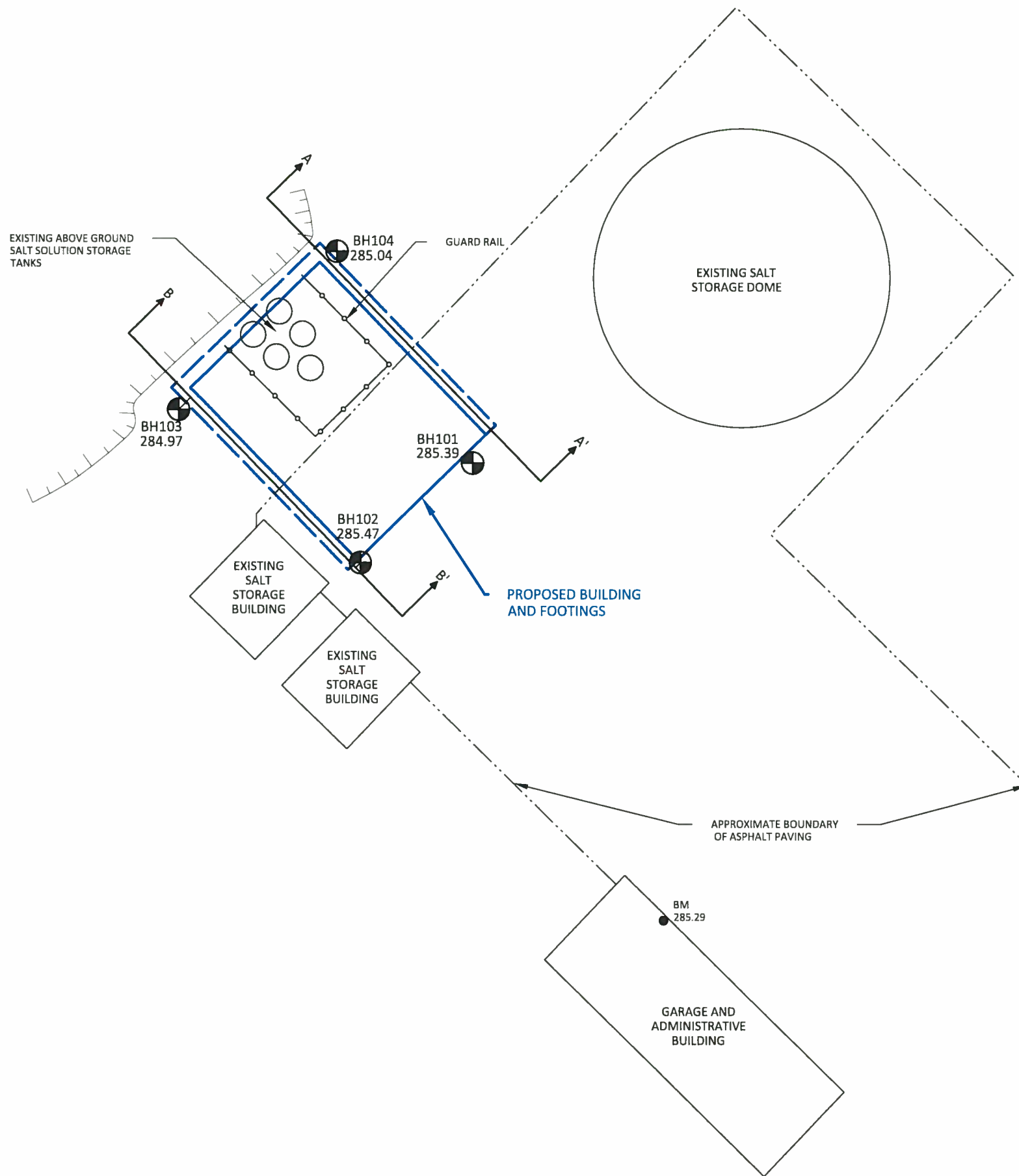
Photo 4. Facing south along the proposed north building footprint. Steep slope, including retaining wall is noted on the right and the salt solution ASTs are noted on the left.





Photo 5. Facing south towards location of BM (south corner of Bay 5) at the garage / administration building

## **Appendix B – Drawings**



Agreement No. 6014-E-0017  
Assignment No. 13  
WO 2016-11029

KAKABEKA PATROL YARD  
(Highway 11/17, Kakabeka Falls, ON)  
PLAN

DWG  
1

\*exp.

exp Services Inc.

KEY PLAN

LEGEND

BH101  
285.39

BOREHOLE LOCATION  
GROUND SURFACE ELEVATION IN METRES

BM  
285.29

BENCHMARK LOCATION  
LOCAL ELEVATION IN METRES

BH No.	APPROX. ELEV. (m)	MTM COORDINATES	
		NORTH	EAST
BH101	285.39	5,362,008	334,118
BH102	285.47	5,361,993	334,108
BH103	284.97	5,362,001	334,080
BH104	285.04	5,362,026	334,104

NOTES

1. ALL DIMENSIONS ARE IN METRES.

2. BASE MAP PROVIDED BY CLIENT.

3. MTM COORDINATES BASE ON MTM ZONE ON-15 PROJECTION.

4. THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. THE PROPOSED AND EXISTING STRUCTURE DETAILS/WORKS ARE SHOWN FOR ILLUSTRATION PURPOSES ONLY.

5. BENCHMARK LOCATED ON CONCRETE APRON AT SOUTHERN MOST POINT OF OUTSIDE OF BAY 5 DOOR, AT ONSITE GARAGE/ADMINISTRATIVE BUILDING.

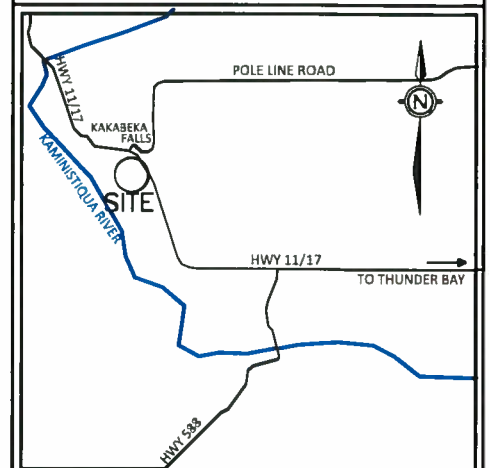
REVISIONS

DATE	BY	DESCRIPTION

GEOCREs No. 52A-221  
Date: June 27, 2016  
Drawn By: RM

Project No. ADM-00223648-LO  
Scale : 1:500  
Checked By: AM  
Checked By: DG

KEY PLAN



LEGEND

- N STANDARD PENETRATION TEST (BLOWS/0.3 m)  
▽ MEASURED WATER LEVEL

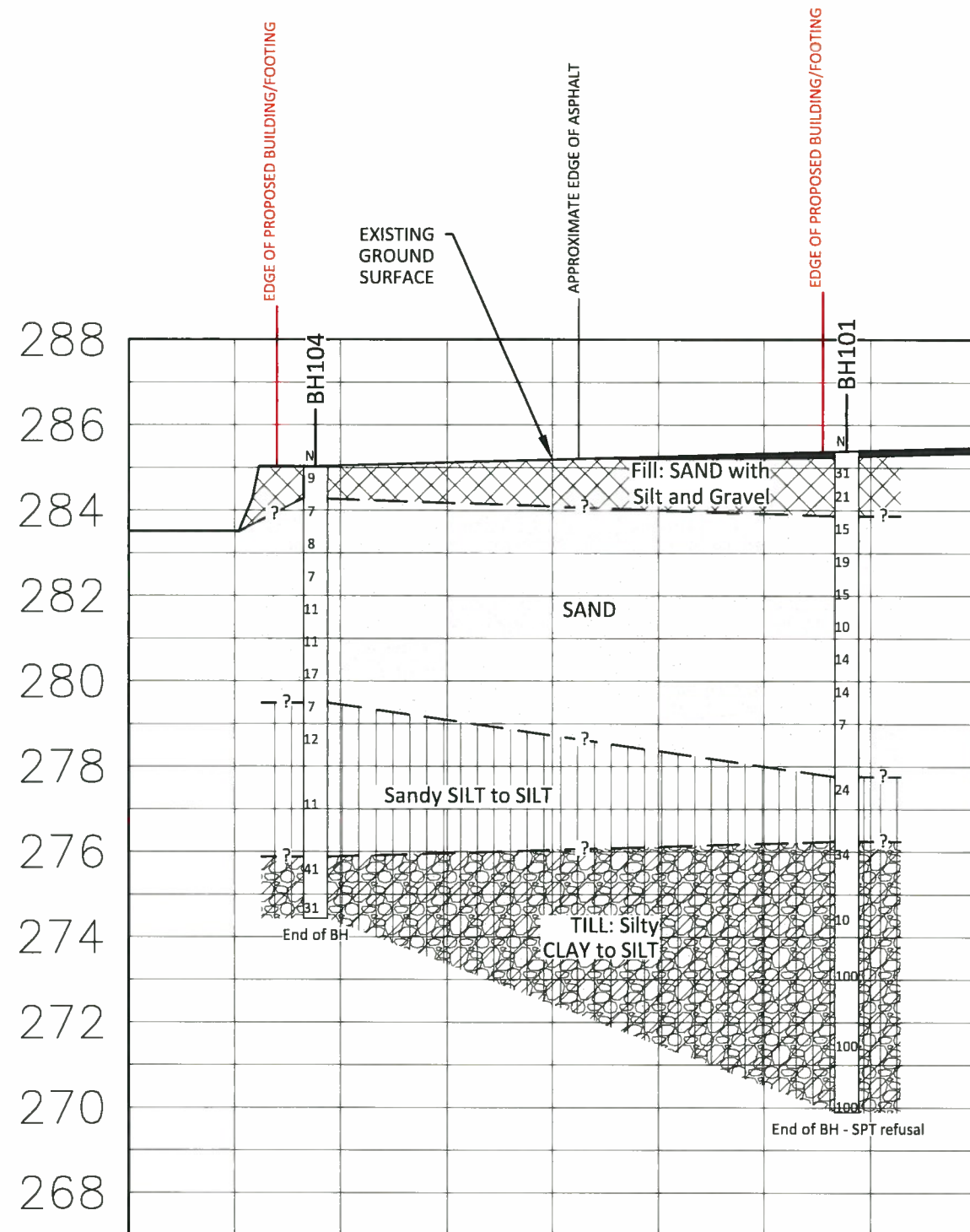
BH No.	APPROX. ELEV. (m)	MTM COORDINATES	
		NORTH	EAST
BH101	285.39	5,362,008	334,118
BH102	285.47	5,361,993	334,108
BH103	284.97	5,362,001	334,080
BH104	285.04	5,362,026	334,104

NOTES

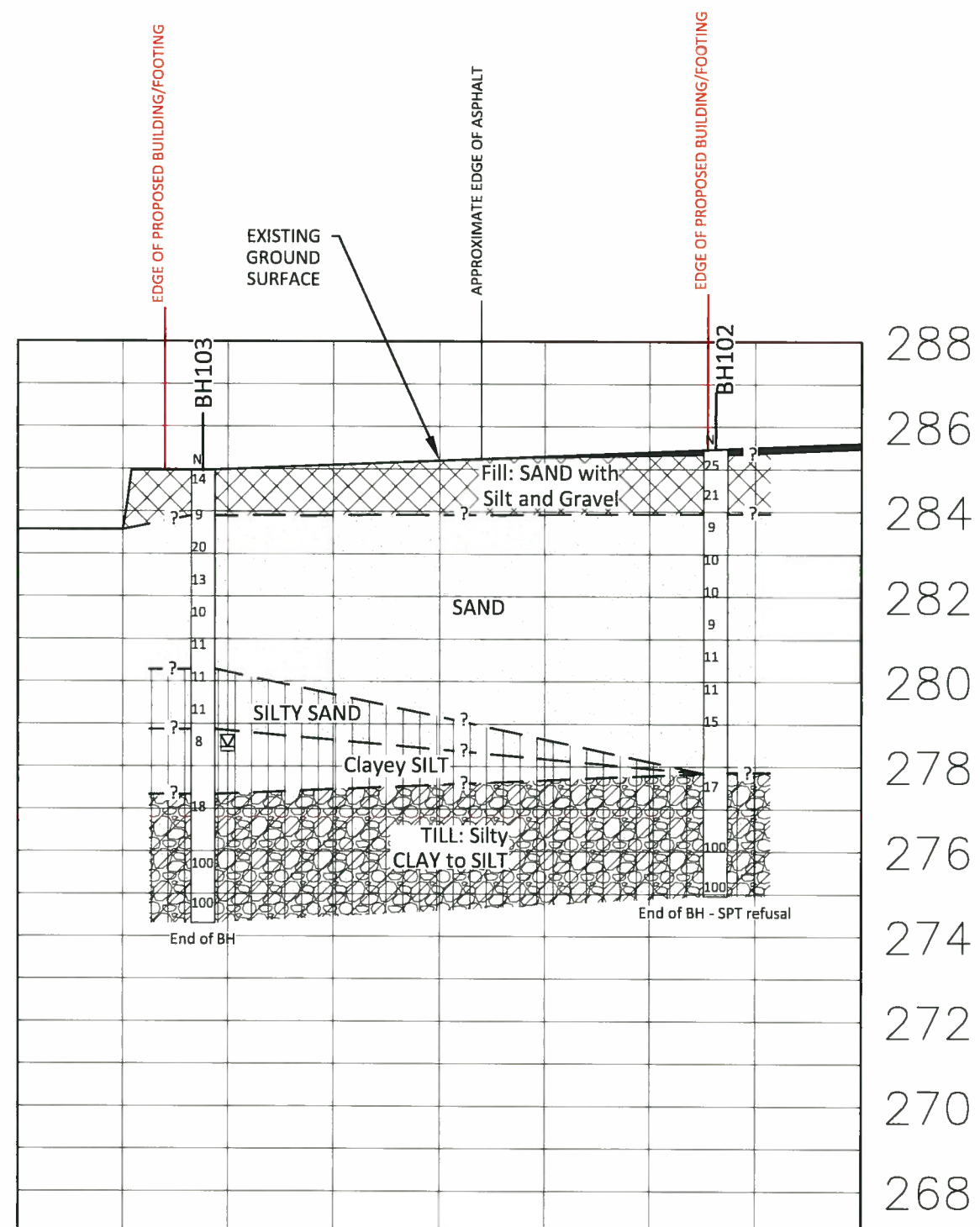
- ALL DIMENSIONS ARE IN METRES.
- BASE MAP PROVIDED BY CLIENT.
- MTM COORDINATES BASE ON MTM ZONE ON-15 PROJECTION.
- THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. THE PROPOSED AND EXISTING STRUCTURE DETAILS/WORKS ARE SHOWN FOR ILLUSTRATION PURPOSES ONLY.
- BENCHMARK LOCATED ON CONCRETE APRON AT SOUTHERN MOST POINT OF OUTSIDE OF BAY 5 DOOR, AT ONSITE GARAGE/ADMINISTRATIVE BUILDING.

REVISIONS

DATE	BY	DESCRIPTION
GEOCRE No. 52A-221		Project No. ADM-00223648-L0
Date: June 28, 2016		Horizontal Scale : 1:300
Drawn By: RM		Vertical Scale : 1:150
Checked By: DG		



A - A'  
NORTHEAST SECTION



B-B'  
SOUTHWEST SECTION



## **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		
0.002	0.006	0.02	0.06	0.2	0.6	2.0	6.0	20	60	200	
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:

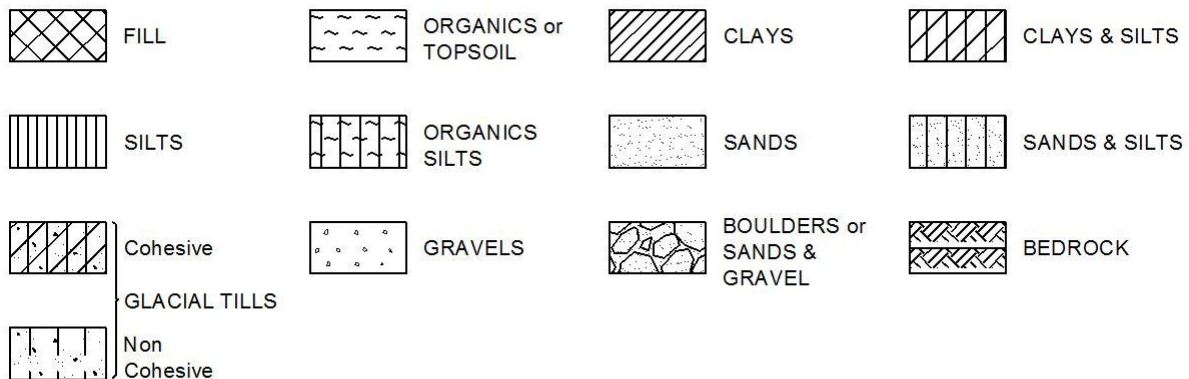
Table c: Consistency of Cohesive Soil

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
$\sigma$	kPa	Total normal stress
$\sigma'$	kPa	Effective normal stress
$\tau$	kPa	Shear stress
$\sigma_1, \sigma_2, \sigma_3$	kPa	Principal stresses
$\varepsilon$	%	Linear strain
$\varepsilon_1, \varepsilon_2, \varepsilon_3$	%	Principal strains
E	kPa	Modulus of linear deformation
G	kPa	Modulus of shear deformation
$\mu$	1	Coefficient of friction

### MECHANICAL PROPERTIES OF SOIL

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

### PHYSICAL PROPERTIES OF SOIL

$P_s$	$\text{kg}/\text{m}^3$	Density of solid particles
$\gamma_s$	$\text{kN}/\text{m}^3$	Unit weight of solid particles
$\rho_w$	$\text{kg}/\text{m}^3$	Density of water
$\gamma_w$	$\text{kN}/\text{m}^3$	Unit weight of water
$\rho$	$\text{kg}/\text{m}^3$	Density of soil
$\gamma$	$\text{kN}/\text{m}^3$	Unit weight of soil
$\rho_d$	$\text{kg}/\text{m}^3$	Density of dry soil
$\gamma_d$	$\text{kN}/\text{m}^3$	Unit weight of dry soil
$\rho_{sat}$	$\text{kg}/\text{m}^3$	Density of saturated soil
$\gamma_{sat}$	$\text{kN}/\text{m}^3$	Unit weight of saturated soil
$\rho'$	$\text{kg}/\text{m}^3$	Density of submerged soil
$\gamma'$	$\text{kN}/\text{m}^3$	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	$\text{m}^3/\text{s}$	Rate of discharge
v	m/s	Discharge velocity
i	1	Hydraulic gradient
k	m/s	Hydraulic conductivity
j	$\text{kN}/\text{m}^3$	Seepage force

# RECORD OF BOREHOLE No BH101

1 OF 1

METRIC

W.P. \_\_\_\_\_ LOCATION **Kakabeka Patrol Yard - MTM ON-15 5,362,008N 334,118E** ORIGINATED BY **RM**  
 DIST **61** HWY **Hwy 11/17** BOREHOLE TYPE **CME 55 Truck Mount / HSA** COMPILED BY **AM**  
 DATUM **Geodetic** DATE **6.13.16 - 6.13.16** CHECKED BY **DG**

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							WATER CONTENT (%)		
285.4	Asphalt							20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>		GR SA SI CL
286.0	<b>ASPHALT</b> - about 150 mm																
0.2	<b>Poorly Graded Sand with Silt and Gravel (FILL)</b> - dense to compact, brown, damp to moist		S1	SS	31		285						○				23 66 (11)
			S2	SS	21								○				
283.9	<b>Well Graded SAND with Silt</b> - compact, brown, moist						284						○				
1.5			S3	SS	15								○				6 86 (8)
			S4	SS	19		283						○				
			S5	SS	15		282						○				
			S6	SS	10								○				
			S7	SS	14		281						○				
																	No Recovery
280.1	<b>Poorly Graded SAND</b> - compact, brown, moist, medium grained		S8	SS	14		280						○				8 87 (5)
5.3	- becoming loose, wet at about 6.1 m depth		S9	SS	7		279						○				
							278										
277.8	<b>SILT</b> - compact, brown, wet - becoming grey at about 7.8 m depth		S10	SS	24		277						○				0 5 79 16
7.6																	
276.2	<b>Silty CLAY to SILT (TILL)</b> - loose to very dense, grey, moist		S11	SS	34		276						○				
9.2							275										
			S12	SS	10		274						○				0 5 46 49
			S13	SS	100		273						○				
							272										
			S14	SS	100		271						○				
269.9	<b>End of Borehole</b> - refusal to SPT		S15	SS	100		270						○				
15.5																	

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

# RECORD OF BOREHOLE No BH102

1 OF 1

METRIC

W.P. \_\_\_\_\_ LOCATION **Kakabeka Patrol Yard - MTM ON-15 5,361,993N 334,108E** ORIGINATED BY **RM**  
 DIST **61** HWY **Hwy 11/17** BOREHOLE TYPE **CME 55 Truck Mount / HSA** COMPILED BY **AM**  
 DATUM **Geodetic** DATE **6.13.16 - 6.13.16** CHECKED BY **DG**

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				WATER CONTENT (%)				
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE								
285.5	Asphalt						20	40	60	80	100	20	40	60		
286.0	ASPHALT - about 150 mm															
0.2	Poorly Graded Sand with Silt and Gravel (FILL) - compact, brown, moist		S1	SS	25											
			S2	SS	21											
284.0																
1.5	Poorly Graded SAND - loose to compact, brown, moist, fine grained		S3	SS	9											
			S4	SS	10											
			S5	SS	10							○				0 95 (5)
			S6	SS	9							○				0 97 (3)
			S7	SS	11											
	- becoming medium grained at about 4.8 m depth															
			S8	SS	11											
			S9	SS	15											
277.8																
7.6	Silty CLAY to SILT (TILL) - compact to very dense, grey, moist		S10	SS	17								○			1 9 50 40
			S11	SS	100											
	- occasional cobbles and boulders noted during augering at about 9.5 m depth															
			S12	SS	100											
275.0																
10.5	End of Borehole - refusal to SPT															

ONL MOT F-16126-AG - ADM-00223648-L0 - MTO 13 - SALT STORAGE BLDG - KAKABEKA PATROL YARD GPJ ON MOT.GDT 6/28/16

# RECORD OF BOREHOLE No BH103

1 OF 1

METRIC

W.P. \_\_\_\_\_ LOCATION **Kakabeka Patrol Yard - MTM ON-15 5,362,001N 334,080E** ORIGINATED BY **RM**  
 DIST **61** HWY **Hwy 11/17** BOREHOLE TYPE **CME 55 Truck Mount / HSA** COMPILED BY **AM**  
 DATUM **Geodetic** DATE **6.14.16 - 6.14.16** CHECKED BY **DG**

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)
285.0	Sand and Gravel							20	40	60	80	100					
0.0	<b>Poorly Graded Sand with Silt and Gravel (FILL)</b> - compact to loose, brown, moist, trace organics		S1	SS	14												
283.9			S2	SS	9		284										
1.1	<b>Poorly Graded SAND</b> - loose to compact, brown, moist		S3	SS	20		283										
			S4	SS	13		282										
			S5	SS	10		281										
			S6	SS	11		280										
280.4			S7	SS	11		280										0 71 (29)
4.6	<b>SILTY SAND</b> - compact, brown, moist  - becoming wet, medium grained at about 5.3 m depth		S8	SS	11		279										
278.9			S9	SS	8		278										0 29 59 12
6.1	<b>Clayey SILT with Sand</b> - firm to stiff, brown, wet						277										
277.3			S10	SS	18		276										6 20 57 17
7.6	<b>Clayey SILT to SILT with Sand (TILL)</b> - compact to very dense, grey, moist		S11	SS	100		275										
			S12	SS	100												
274.3	<b>End of Borehole</b>																
10.7	  <																

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

# RECORD OF BOREHOLE No BH104

1 OF 1

METRIC

W.P. \_\_\_\_\_ LOCATION **Kakabeka Patrol Yard - MTM ON-15 5,362,026N 334,104E** ORIGINATED BY **RM**  
 DIST **61** HWY **Hwy 11/17** BOREHOLE TYPE **CME 55 Truck Mount / HSA** COMPILED BY **AM**  
 DATUM **Geodetic** DATE **6.14.16 - 6.14.16** CHECKED BY **DG**

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)	
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE										
285.0	Sand and Gravel						20	40	60	80	100							
0.0	<b>Poorly Graded Sand with Silt and Gravel (FILL)</b> - loose, brown, moist		S1	SS	9													
284.3																		
0.8	<b>Poorly Graded SAND</b> - loose to compact, brown, moist, fine grained		S2	SS	7													
			S3	SS	8													
			S4	SS	7													
			S5	SS	11													
			S6	SS	11													
			S7	SS	17													
279.5	- becoming wet at about 5.3 m depth		S8	SS	7													
5.5	<b>Sandy SILT</b> - loose, brown, wet		S9	SS	12													
			S10	SS	11													
275.9																		
9.2	<b>Clayey SILT to SILT with Sand (TILL)</b> - dense, grey, moist		S11	SS	41													
			S12	SS	31													
274.4																		
10.6	<b>End of Borehole</b>																	

ONL MOT F-16126-AG - ADM-00223648-L0 - MTO 13 - SALT STORAGE BLDG - KAKABEKA PATROL YARD GPJ ON MOT.GDT 6/28/16



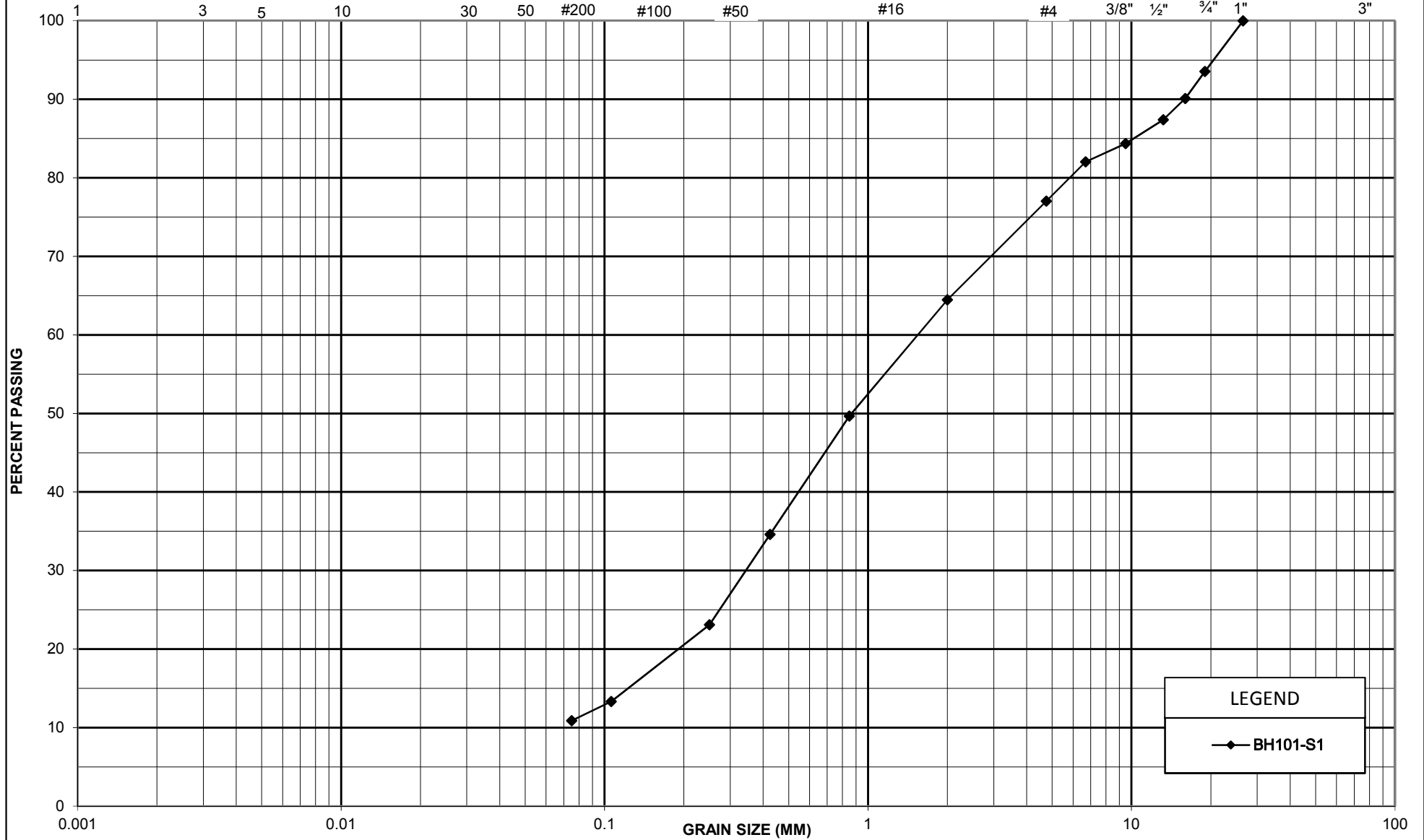
## **Appendix D – Laboratory Data**

# UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse

GRAIN SIZE IN MICROMETERS

SIEVE DESIGNATION (Imperial)



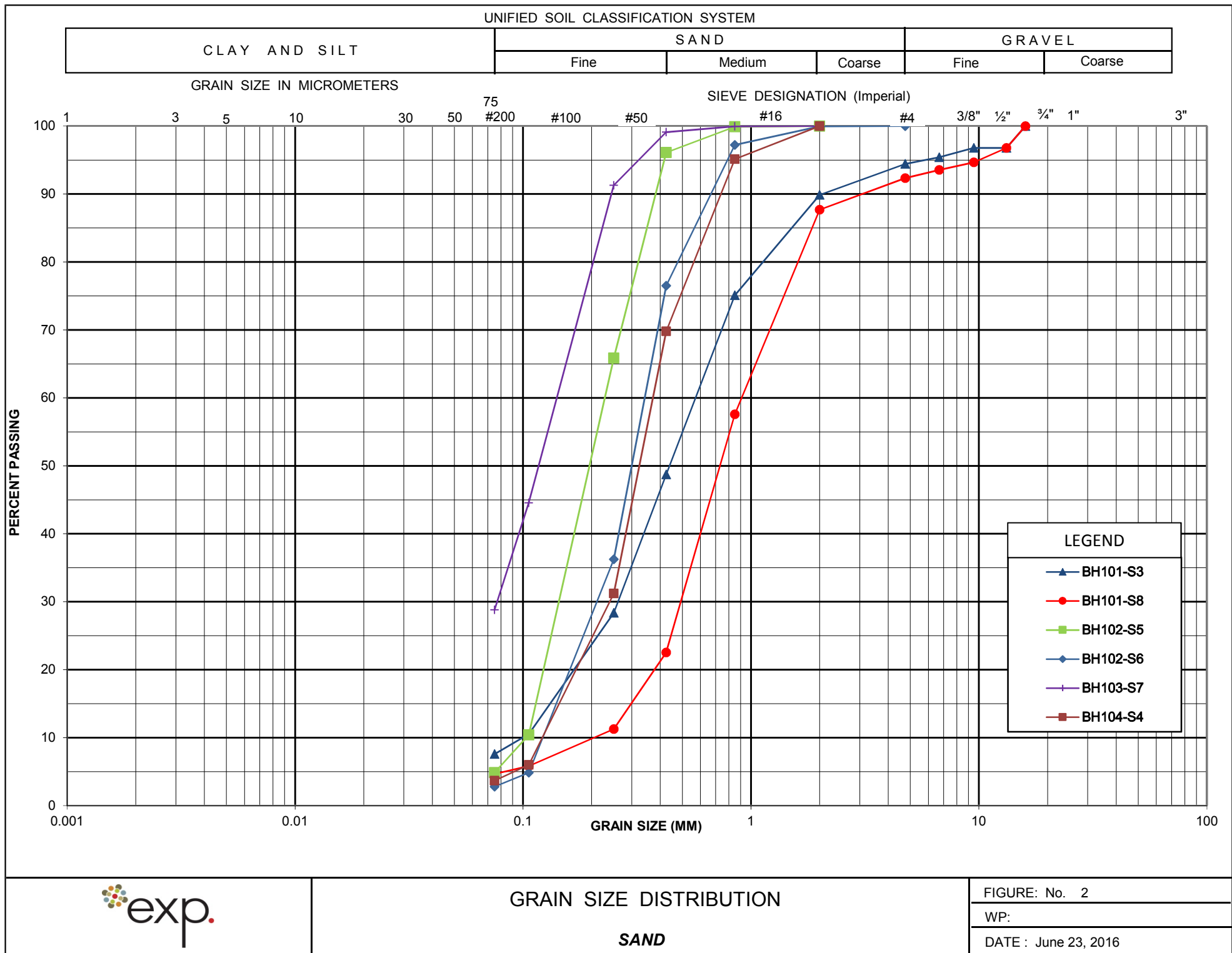
## GRAIN SIZE DISTRIBUTION

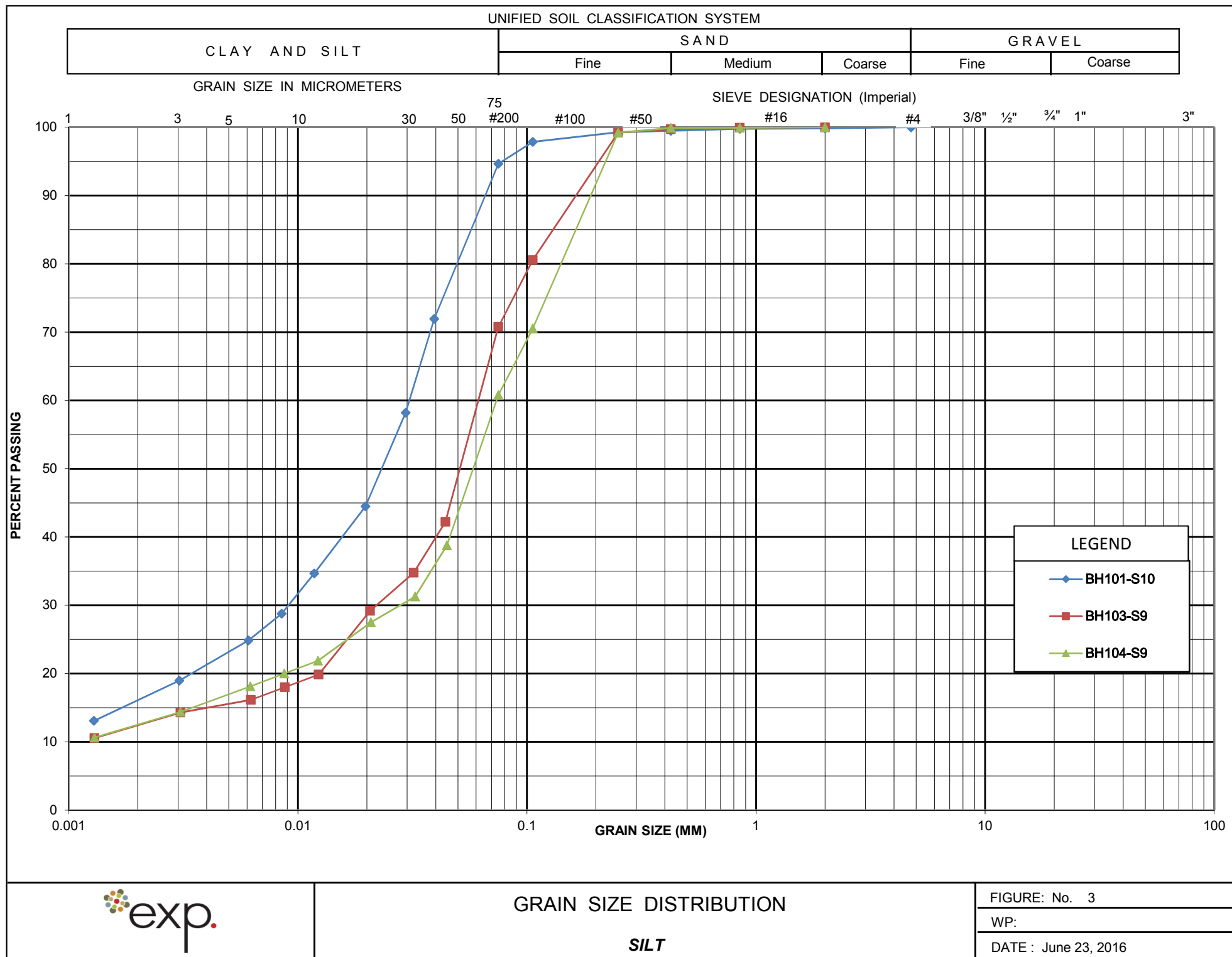
*Poorly Graded Sand with Silt and Gravel (FILL)*

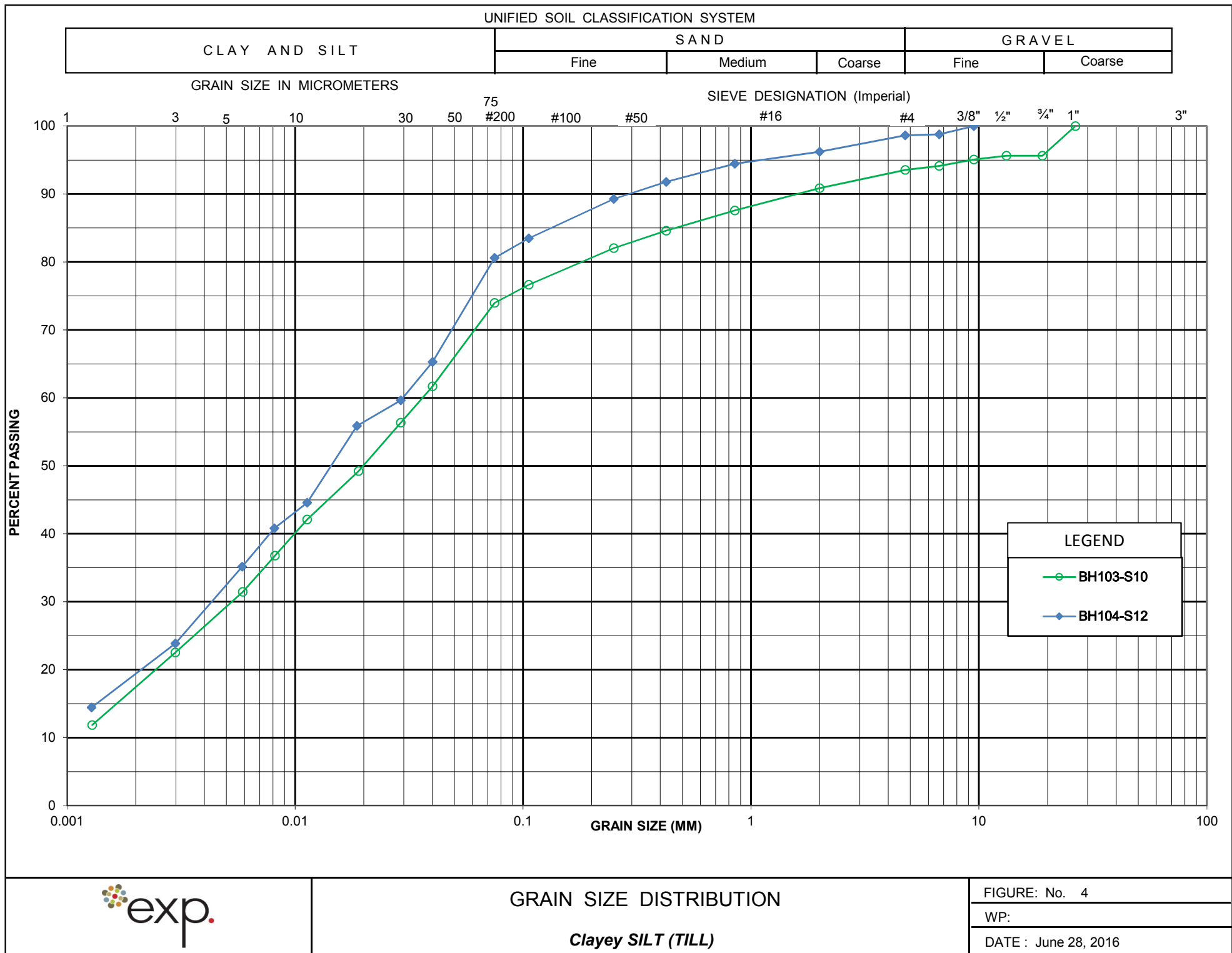
FIGURE: No. 1

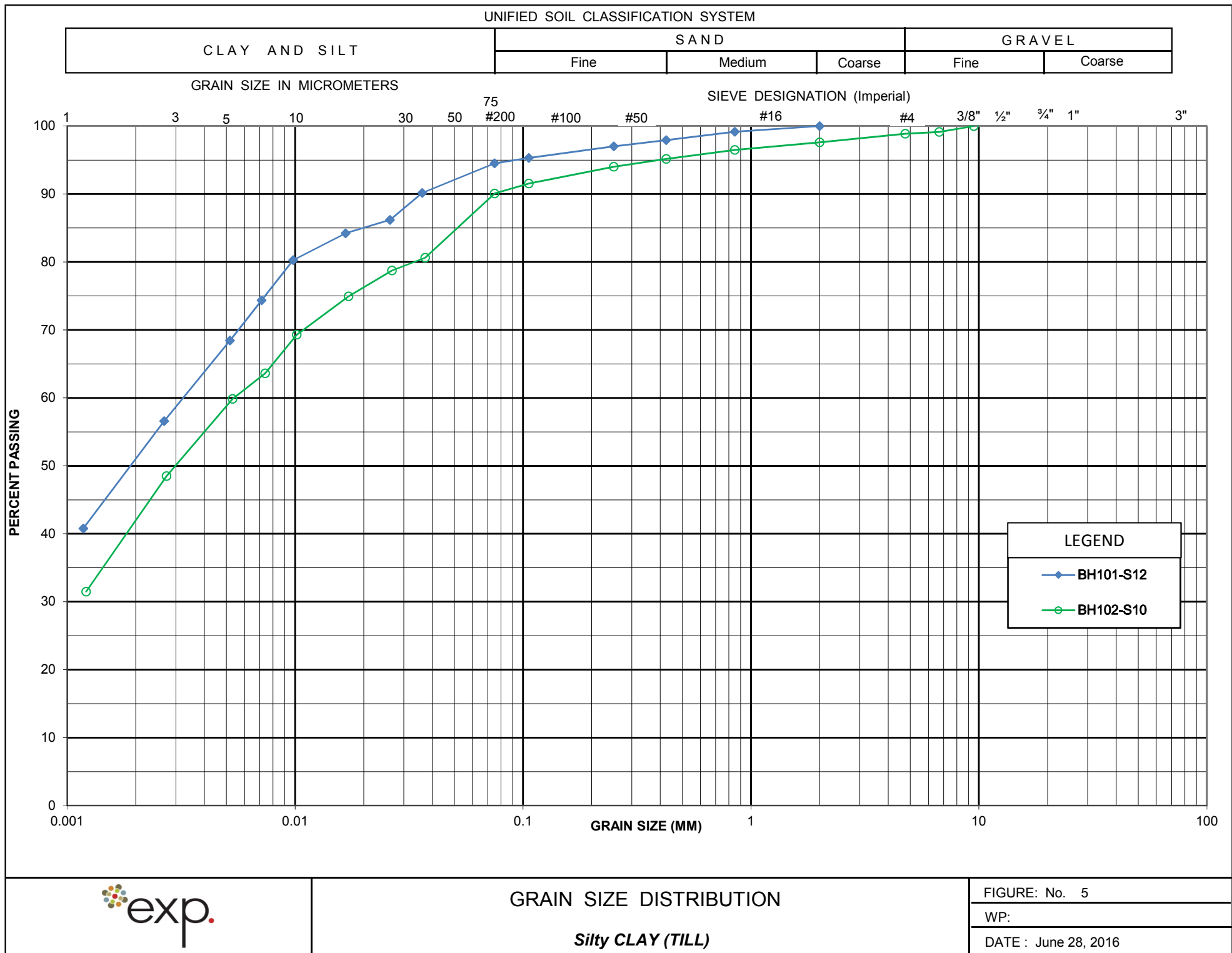
WP:

DATE : June 23, 2016

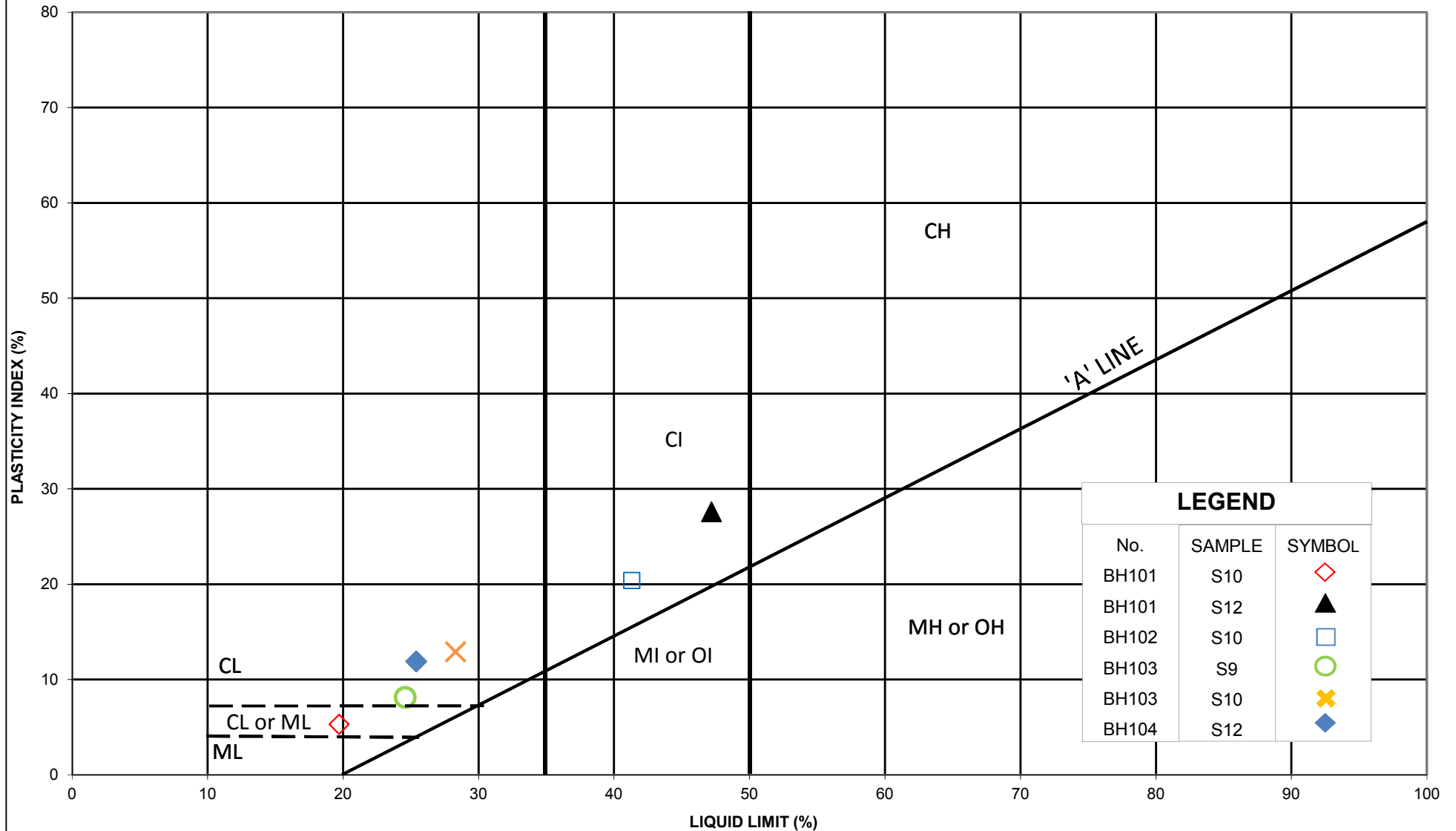








**New Salt Storage Building, Kakabeka Patrol Yard  
WP No. ??, Highway 11/17, Oliver Paipoonge, Ontario**



## **Appendix E – Results of Stability Analyses**



July 6, 2016

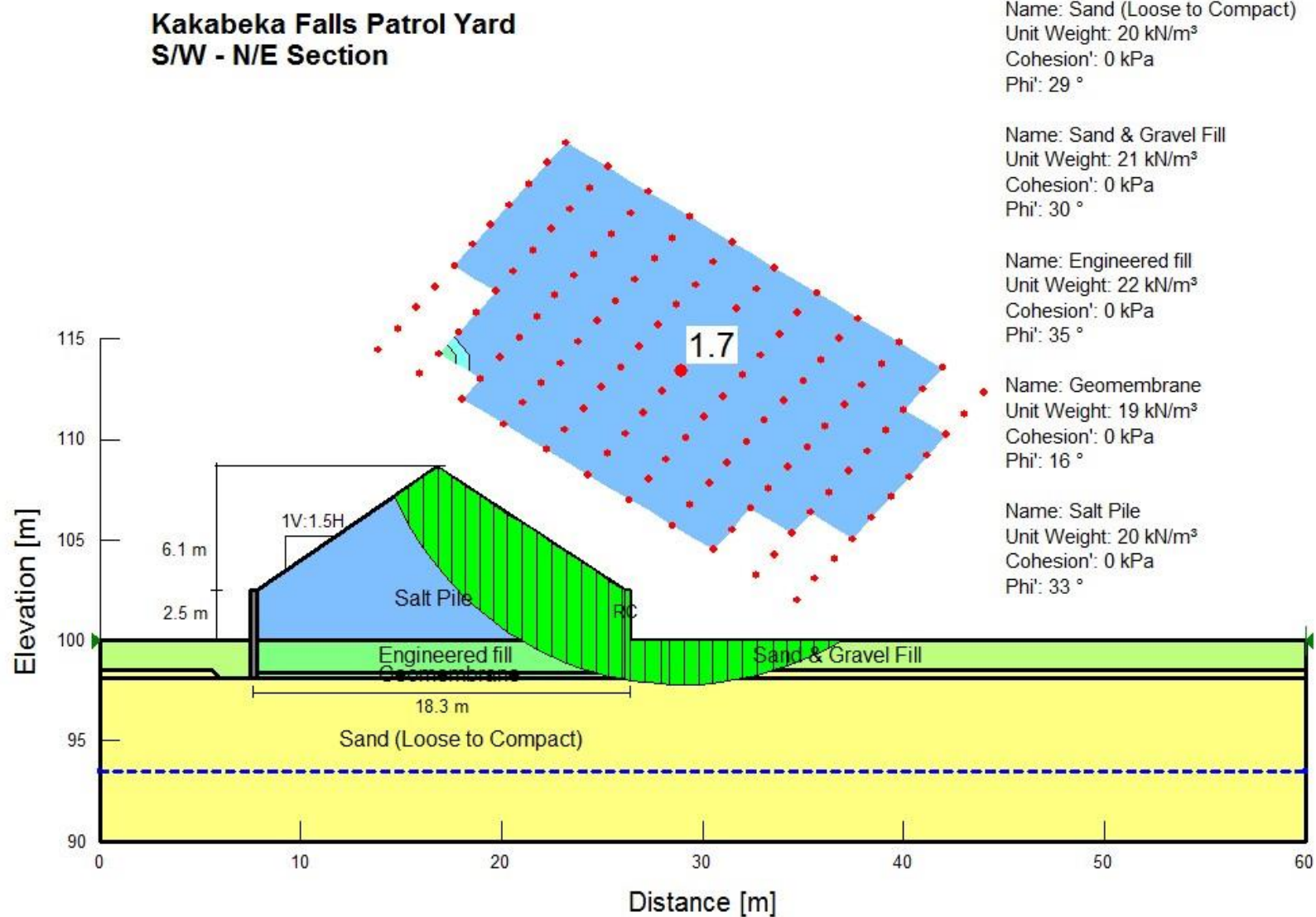


Figure E1. Results of global stability analyses with full allowable capacity – S/W – N/E section

July 6, 2016

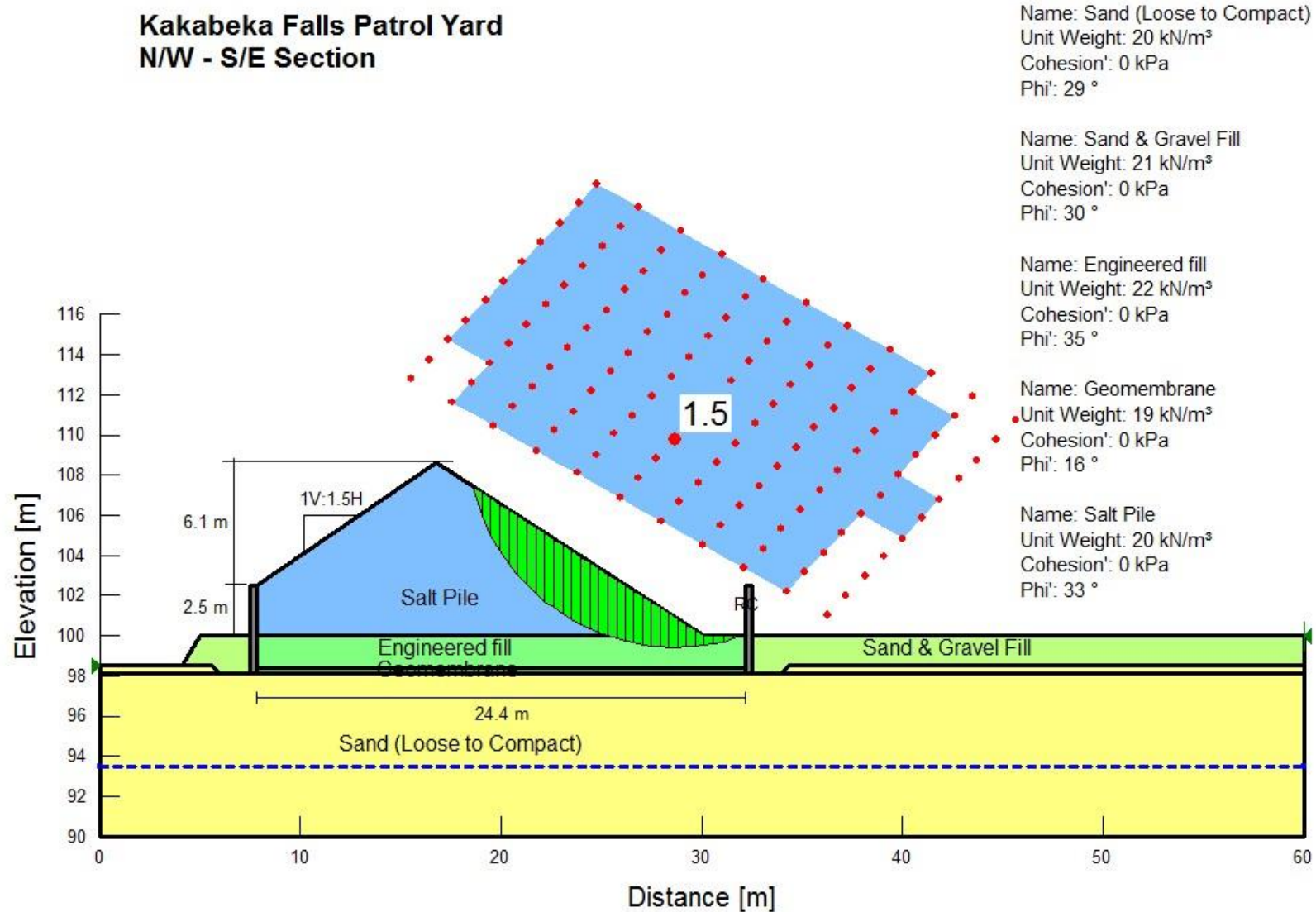
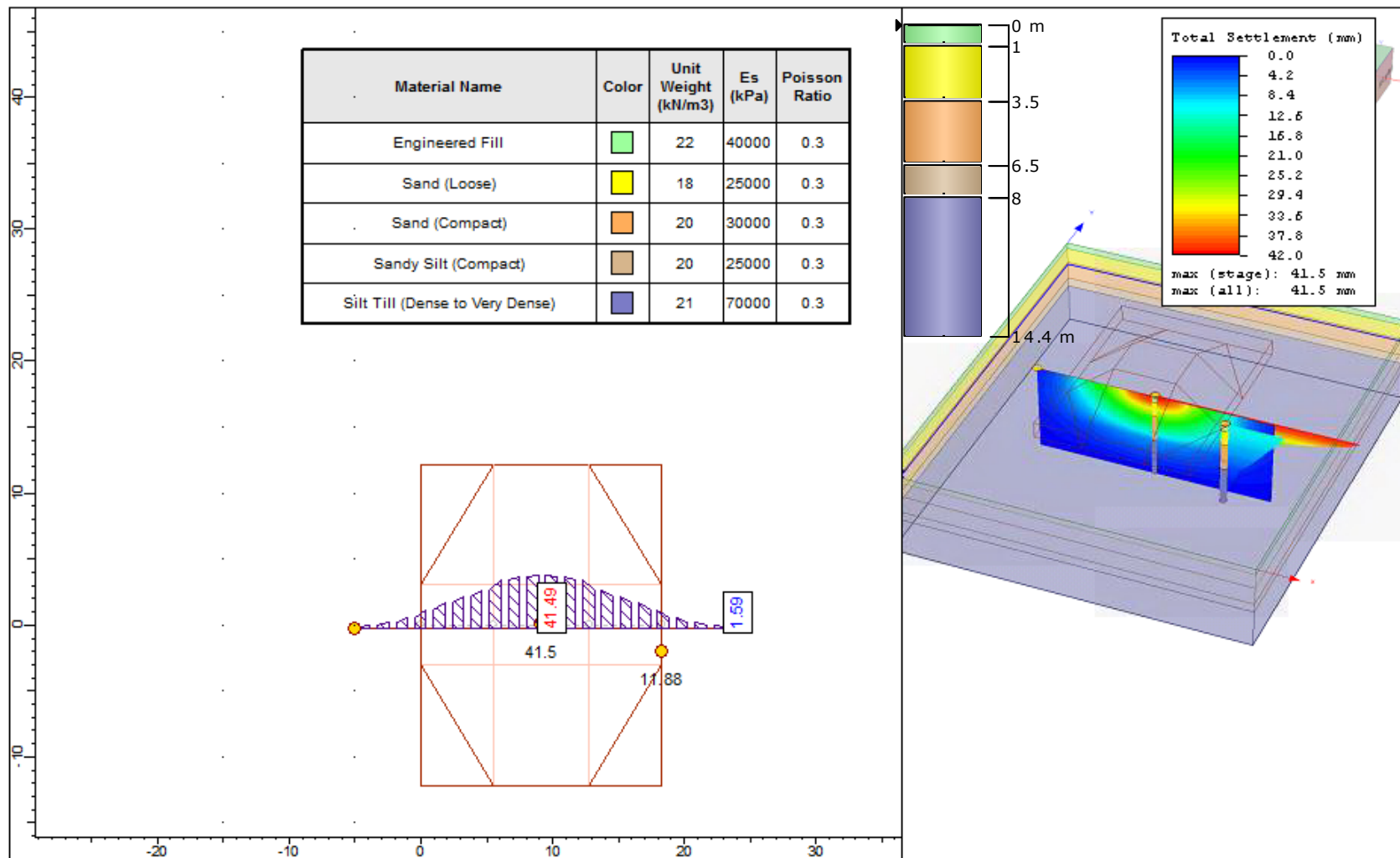


Figure E2. Results of global stability analyses with full allowable capacity – N/W – S/E section

## **Appendix F – Results of Settlement Analyses**



*Project:* New Salt Storage at Kakabeka Patrol Yard, Kakabeka Falls

*Analysis Description:* Stockpile full height – **Total Settlement**

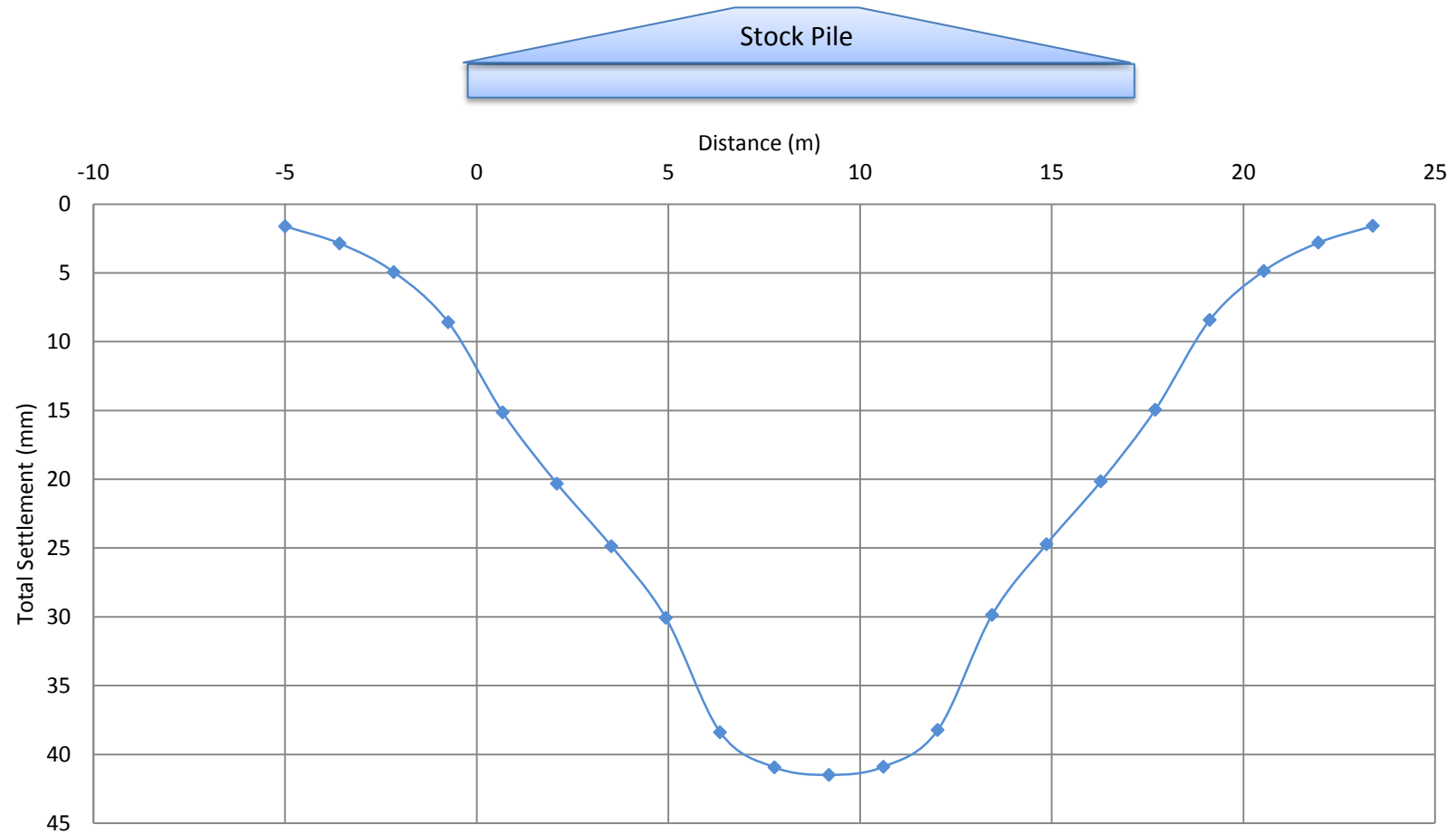
*Figure No:* F-1

*Company:* **exp** Services Inc.

*Date:* June, 2016

*File Name:* Settlement Analysis – Kakabeka Patrol Yard

## Distance vs. Total Settlement



*Project:* New Salt Storage at Kakabeka Patrol Yard, Kakabeka Falls

*Analysis Description:* Stockpile full height – **Total Settlement**

*Figure No:* F-2

*Company:* **exp** Services Inc.

*Date:* June, 2016

*File Name:* Settlement Analysis – Kakabeka Patrol Yard