FINAL REPORT

Foundation Investigation and Design Report
Proposed New Storage Structure at Verner Patrol Yard
- HWY 17, Township of Caldwell, Sudbury Area
WO 2011-11001, District 54
MTO GEOCRES No. 41I-270

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1. Part I: FOUNDATION INVESTIGATION

1.1 Introduction

This report presents the results of a geotechnical investigation carried out by Trow Associates Inc. (Trow) for the proposed new storage structure located at Verner Patrol Yard, Cardwell Township on Highway 17, District 54, Sudbury Area. The proposed 24.4 m x 40.3 m storage structure will allow for inside loading and dumping. It will be similar to the building structures constructed at the Cartier Patrol Yard located on Hwy 144 for which Trow Associates Inc. carried out Foundation Investigation and Design.

The work was undertaken under Agreement # 5009-E-0060, Assignment No. 1. The terms of reference were as presented in The Ministry of Transportation (MTO) letter dated December 03, 2010.

The purpose of the investigation is to establish the existing subsurface conditions at the proposed location of the Patrol Yard structure within the construction limits. The site specific geotechnical investigation was carried out by means of borehole drilling, in situ testing, and subsequent geotechnical laboratory testing on selected samples. This foundation investigation report has been prepared specifically and solely for the project described herein. It contains the factual results of the investigation and the laboratory testing.

1.2 Site Description and Geological Setting

1.2.1 Site Description

The proposed Verner Patrol Yard is located on Highway 17 in the Township of Caldwell approximately 0.2 km east of Highway 575 junction (see Key Map on Drawing 1, Appendix B). The terrain at the structure site is relatively flat as shown on photographs included in Appendix A. In the proposed structure area, there are gravel stock pile, sand stock pile, and silt and sand domes. The existing sand dome of about 35 m diameter is located approximately 70 m east of the existing benchmark GBM 001993U602 (Elev. 213.543 m) as marked on the site map, PLAN H-627-17-1, provided by MTO and shown on Drawing 1 in Appendix B. The salt dome is about 25 m in diameter and is located approximately 100 m northeast of the benchmark.

The site plan is as shown on the drawing in Appendix B (from the site map PLAN H-627-17-1, provided by MTO).

1.2.2 Geological Setting

According to Bedrock Geology of Ontario Map 2544 (Ministry of Northern Development and Mines, Ontario), the bedrock underlying the site is from the Mesoproterozoic geologic era (approximately 0.57 to 1.6 billion years old) and falls under Central Gneiss Belt which consists of igmatitic rocks and gneisses of uncertain protolith commonly layered biotite gneisses and migmatites and locally includes quartzofeldspatic gneisses, orthogneisses, and paragneisses.

According to Surfacial Geology Map by the Province of Ontario's Ministry of Northern Development, Mines and Forestry (MNDMF), the surficial deposit in this area is a discontinuous layer of drift Precambrian deposit.

1.3 Investigation Procedures

1.3.1 General

The current field investigation was carried out between January 18 and 28, 2011, during which time five (5) boreholes (BH-1, BH-2, BH-3, BH-4, and BH-5) were drilled. The boreholes were initially proposed to be drilled at the each corner of the proposed building and in the middle of the building. However, the borehole locations were dictated by accessibility to these locations at the site at the time of drilling. Two sand stockpiles were present at the site and they obstructed the proposed layout of the boreholes. The boreholes were drilled at the best accessible locations within the proposed structure area. Drawing No. 1 in Appendix B shows the locations of five boreholes. The depths of the boreholes were: 34 m (BH-1), 15.7 m (BH-2), 15.7 m (BH-3), 30.6 m (BH-4) and 20.3 m (BH-5).

The boreholes were advanced using track-mounted CME 55 drill rig, equipped with continuous fight hollow stem augers. All borehole drilling/sampling were operated by a specialist drilling contractor, LandCore Drilling Co. Ltd. During the drilling operation, soil samples were obtained using a 51 mm outside diameter split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586), at intervals shown on the attached borehole logs (Appendix C). The SPT “N” values were recorded and used to provide an assessment of in-situ consistency or relative density of non-cohesive soils. At BH-1 sand heaving was encountered at a depth ranging from 14.9 to 16.8 m. In this case, wash boring was utilized to facilitate taking representative samples at designated elevation with reasonable accuracy. A standpipe piezometer was installed in BH-1. After completion, boreholes were sealed in accordance with accepted practice for decommissioning of boreholes.

Field vane testing was performed in the boreholes throughout the cohesive soils to measure the in-situ undrained shear strength of the soils. The field vane used had dimensions of 150 mm long and 80 mm diameter. The field vane testing was conducted in accordance with ASTM D2573-08. Two 50 mm diameter “Shelby” tube samples were also obtained in cohesive deposits to provide undisturbed samples for laboratory testing.

The fieldwork was co-ordinated and supervised by a member of Trow engineering staff. They located the boreholes, directed the drilling and sampling operation, logged borehole data in accordance with MTO Soils Classification System for foundation report, and retrieved soil samples for subsequent laboratory testing and identification. All of the recovered soil samples were placed in appropriate labeled moisture-proof containers and transported to Trow’s Sudbury and Brampton laboratories for further detailed visual examination and laboratory testing.

Details of the soil strata encountered in the boreholes are included in attached borehole log sheets in Appendix C, and plotted on the cross sections in Appendix B. The borehole locations and the ground surface elevations along the cross sections were surveyed by Trow personnel, with reference to the benchmark at the southwest of the sand dome (GBM 001993U602) (Elevation 213.543), as shown in the site map provided by MTO (PLAN H-627-17-1).

1.3.2 Laboratory Testing

On all of the samples returned to the laboratory, further visual examination and classification were carried out. The laboratory testing program included natural water content (LS-701), grain size distribution tests (LS703/704) and Atterberg limits (LS-703/704) on approximately 25% of the collected soil samples. Consolidation and strength testing (unconfined compression test) were attempted to perform, but the recovered thin wall samples of grey silty clay were too varved (silt and clay layer laminated) that they were not able to be cut without significant disturbance.

The laboratory test results are provided on the borehole logs in Appendix C. The results of the grain size analyses and Atterberg limits tests are also included in Appendix D.

1.4 Subsurface Conditions

The detailed subsurface conditions encountered in the boreholes advanced during this investigation are presented on the borehole log sheets in Appendix C. The “Explanation of Terms Used in Report” is shown in the first page of the borehole logs sheets in Appendix C and should be read in conjunction with this report.

Appendix B shows the borehole location plan and three cross section soil profiles. It has to be underlined that the stratigraphic boundaries indicated on the borehole log and cross section soil profiles are inferred from non-continuous sampling, observations of drilling progress, and field vane and Standard Penetration Tests results. 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 sand fill or top soil, underlain successively by silt, silty clay, clayey silt, and sand and gravel deposits. Bedrock was not encountered at the investigated locations within 34 m depth (BH-1 was 34 m deep). A brief summary of the soil and groundwater conditions encountered in the boreholes is provided below.

1.4.1 Top Soil

At BH-3, BH-4 and BH-5, top soil was encountered at ground surface. It has a thickness of about 200 mm and its top elevation is approximately between 214.8 and 215.1 m.

1.4.2 Sand and Gravel Fill

At BH-1 and BH-2, a layer of sand and gravel fill was encountered with a thickness of about 0.8 m. This layer extends approximately from elevations of 215.4 to 214.4 m.

This sand and gravel fill layer is composed of fine to coarse grained sand and gravel and trace to some silt. The fill has loose relative density. It is brown in colour and damp to wet.

The natural water content performed on selected samples of the sand and gravel fill was between 7% and 10%. The results of moisture content tests are presented on the record of the borehole sheets in Appendix C.

1.4.3 Silt

Below the fill or top soil, a layer of silt was encountered in all boreholes with a thickness ranging from about 5.3 m to 6.4 m. It extends to depths between 5.5 m and 7.2 m, corresponding to approximate elevations of 209.6 and 207.8 m, respectively. At all boreholes the silt layer was underlain by a silty clay layer.

The silt layer is composed of thin, generally horizontal, layers of silt, silty fine to medium sand and silty clay. The varves of clay are approximately 5 to 10 mm thick. The layer of silt also consists of trace of gravel and organic material. The colour of this layer changes with depth from brown to grey. Its natural moisture content also changes from damp to wet with increasing in depth. The uncorrected SPT "N" values range between 4 and 18 blows per 300 mm of penetration indicating a loose to compact relative density, but more typically compact density.

The results of the laboratory testing performed on selected samples of the silt layer are as follows:

- Moisture content:
    - 21% to 39%
- Grain size distribution:
    - 5% gravel;
    - 1% to 8% sand;
    - 53% to 86% silt; and
    - 13% to 34% clay

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

1.4.4 Silty Clay

Underlying the silt in all boreholes, a stratum of silty clay, ranging in thickness between 3.2 to 7.6 m, was encountered. The stratum extends to depths between 8.9 m (BH-3) and 14.6 m (BH-4), corresponding to approximate elevations of 206.0 and 200.2 m, respectively.

The silty clay layer was varved. The individual layers of laminations varied in thickness from a few millimeters to a few centimeters, but in general were about 20 mm and 15 mm thick layers of clay and silt, respectively. The stratum also consists of trace of sand and trace to some of gravel. It is grey in colour and wet.

As mentioned in Section 1.3.1, field vane testing was carried out to measure in situ undrained shear strengths of the silty clay. However, for the majority of the field vane tests it was recorded that they maxed out the scale (> 50 lb) without turning the vane, suggesting that the undrained shear strength exceeds 75 kPa. Only two field vane tests yielded the results below that value. Due to a highly stratified nature of varved clays and presence of silty layers, it is common that field vane yields somewhat higher undrained strengths than those obtained from carefully taken thin wall tube samples. The field vane undrained shear strength values measured at the site ranged from 58 kPa to 66 kPa indicating a stiff consistency. Sensitivity ranged from 6 to 11, indicating the silty clay is medium to highly sensitive. The undrained shear strengths of thin wall tube silty clay samples were attempted to be measured by unconfined compression tests as well, but the samples were significantly disturbed and produced results were found invalid. In addition, due to a varved nature of silty clay samples the attempts to determine consolidation properties of the silty clay by consolidation tests were unsuccessful. The consolidation properties were determined based on results of Atterberg Limits tests.

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

- Moisture content:
  - 21% to 54%
- Grain size distribution:
  - 0% to 12% gravel;
  - 1% to 3% sand;
  - 48% to 56% silt; and
  - 29% to 53% clay
- Atterberg Limits:
  - Plastic limit, PL = 15%-18%;
  - Liquid limit, LL = 30%-45%; and
  - Plasticity index, PI = 15%-27%

The details of the moisture content, grain size distribution and Atterberg Limits tests results are presented on the record of the borehole sheets in Appendix C. The results of the grain size distribution tests are also presented on Figure 2 in Appendix D. The plasticity chart showing the Atterberg limits test results is included on Figure 5, Appendix D.

1.4.5 Clayey Silt

A layer of clayey silt was encountered in BH-1, BH-2, BH-3 and BH-5 below the silty clay layer. This clayey silt layer has a thickness ranging from about 3.0 m to 4.5 m. It extends to depths between 13.1 m and 14.9 m, corresponding to approximate elevations of 201.9 and 200.4 m, respectively. At all locations where it was encountered, the clayey silt layer was underlain by a stratum of sand.

The clayey silt layer was markedly varved with clay. The individual layers of clay varied in thickness from a few millimeters to a few centimeters, but in general were about one 1.0centimeter thick. It is grey in color and wet. Based on "N" values (1 to 8) obtained from the SPT, the consistency of the clayey silt appears to be very soft to firm. The vane shear strength of 48 kPa was measured at an approximately 14 m depth confirming that the clayey silt is firm at that depth.

The results of the laboratory testing performed on selected samples of the lower silt layer are as follows:

- Moisture content:
    - 13% to 51%
- Grain size distribution:
    - 8% sand;
    - 63% to 67% silt; and
    - 25% and 29% clay
- Atterberg Limits:
    - Plastic limit, PL = 13-16%;
    - Liquid limit, LL = 26-28%; and
    - Plasticity index, PI = 10%-27%

The details of the moisture content, grain size distribution and Atterberg Limits tests results are presented on the record of the borehole sheet in Appendix C. The results of the grain size distribution tests are also presented on Figure 3 in Appendix D. The plasticity chart showing the Atterberg limits test results is included on Figure 5, Appendix D.

1.4.6 Sand

Beneath the clayey silt layer, a stratum of sand was encountered in all boreholes. This layer of sand is between 3.2 and 7 m thick and extends from Elev. 200.5 to 1.93.4 m. BH-2 and BH-3 are terminated in this stratum.

The deposit consists of trace to some of gravel, and trace of silt and clay. It is grey in color and wet. Small boulders and cobbles were encountered at a depth of 21.8 m. The uncorrected SPT "N" values range between 1 and 26 blows per 300 mm, classifying the sand as very loose to compact in compactness conditions.

The results of the laboratory testing performed on selected samples of this sand layer are as follows:

- Moisture content:
  - 18% to 24%
- Grain size distribution:
  - 1% to 8% gravel;
  - 86% to 96% sand; and
  - 3% to 6% silt and clay

The details of the moisture content and grain size distribution test results are presented on the record of the borehole sheet in Appendix C. The results of the grain size distribution tests are also presented on Figure 4 in Appendix D.

1.4.7 Sand and Gravel

A deposit of sand and gravel was encountered in BH-1, BH-4 and BH-5below the sand layer. This layer extends from Elev. 197.2 to 181.4 m. BH-1, BH-4 and BH-5 were terminated in this layer at depths of approximately 34 m (Elev. 181.4 m), 30.6 m (Elev. 184.2 m) and 20.3 m (Elev. 194.8 m).

The stratum consists of trace of silt. It is grey in colour and wet. In BH-4 the top 8 m of this layer is brown in colour. Boulders were encountered in BH-1 at a 25.6 m depth. The uncorrected SPT “N” values range between 14 and >50 blows per 300 mm, classifying the sand as compact to very dense in compactness condition.

The natural water content performed on selected samples of the sand and gravel layer was between 3% and 25%. The results of moisture content results are presented on the record of the borehole sheet in Appendix C.

1.5 Groundwater Conditions

The groundwater levels at the site were estimated during field borehole drilling and the change of the sample moist contents in depth. In addition, the groundwater level is measured in a piezometer installed in BH-1. The ground water levels encountered in the boreholes are shown in Table 1.1. It should be noted that the groundwater level is subject to seasonal fluctuations.

Table 1.1 Groundwater levels at the site

Borehole No.	Date of drilling	Water level	
		Depth, (m)	Elevation, (m)
BH-1	January/ 18/2011	4.8	210.6
BH-2	January/ 25/2011	3.5	211.6
BH-3	January/ 26/2011	3.4	211.6
BH-4	January/ 27/2011	2.4	212.4
BH-5	January/ 27/2011	4.6	210.5

1.6 Closure

Field staff from Trow's Sudbury office supervised the field work. This report has been prepared by S. Micic, Ph.D., P.Eng and A. Geremew, Ph.D., and reviewed by S. Gonsalves, M.Eng., P.Eng., Designated MTO Foundation Contact.

2. Part II: ENGINEERING DISCUSSIONS AND RECOMMENDATIONS

2.1 Introduction

The purpose of the following subsections is to provide recommendations for the design and construction of the foundation to support the proposed new building located at Verner Patrol Yard, Cardwell Township on Highway 17, Sudbury Area. The recommendations are based on interpretation of the factual boreholes data obtained during the field investigation. The proposed building will consist of a conventional building for storage of road sand/salt, and will allow for inside loading and dumping. It is anticipated that the proposed building will be similar to that at the Cartier Patrol Yard, Cartier Township, in the Sudbury area. The building will have a footprint of about 24.4 m x 40.3 m. Based on the borehole information obtained from the site, a shallow foundation is considered as the best feasible foundation alternative for the proposed building. Due to the depth of firm ground of approximately 34 m, deep foundations are considered as not practical for this kind of structure.

This report will address the geotechnical design of the foundation for the proposed building 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)* (November 2006), the *Canadian Foundation Engineering Manual (CFEM)* (2006), and good practice.

Pertinent construction issues from a geotechnical standpoint are examined in general accordance with the Terms of Reference from MTO letter dated December 03, 2010. It is assumed that the sand would be set on grade protected by an asphaltic concrete surface. Based on MTO experience, it is anticipated that stockpiling scenarios may include, but are not limited to, the following:

- Salt stockpiled to the rear of the facility to the maximum allowable height of the “push wall” with the stock periodically replenished through out the winter (assume 1000 tonnes max at a given time), and
- Winter sand stacked to the maximum allowable height of the “push wall” at the rear of the facility occupying ¾ of building’s footprint with a ~500 tonne salt stock pile within the front ¼ of the building.
- In the future, there is a possibility that the storage facility will be loaded to its full allowable capacity. This scenario would consist of winter sand stacked to the

maximum allowable height of the "push 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** which contains details of the field and laboratory aspects of the investigation. In general, the stratigraphic sequence at the site typically consists of a 0.2 to 0.8 m thick layer of top soil or sand fill at the ground surface followed by a deposit of typically compact, stratified silt with thickness ranging from 5.3 m to 6.4 m. The silt layer is underlain with a 3.2 to 7.6 m thick layer of varved, soft to firm silty clay followed by a layer of varved clayey silt with thickness ranging from 3.0 to 4.5 m. Beneath the clayey silt a 3.2 to 7 m thick stratum of grey sand is present underlain by a layer of sand and gravel. The bedrock was not encountered during this investigation.

The foundation recommendations for the proposed construction in this project were developed based on soil conditions encountered in the geotechnical soil borings performed for this study. Lightly to moderately loaded structures and those structures where some total and differential settlements are permitted may be supported on shallow foundations bearing on the native silt material. Shallow foundation should consist of strip footings which typically for this kind of structure have a width of 3 m (exp. the Cartier Patrol Yard project). The feasibility of shallow foundations depends on whether the structure can be accommodated in ground conditions with the axial resistance and settlement conditions described below.

In the context of the *Canadian Highway Bridge Design Code* (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.

2.2.1 Geotechnical Resistance at Ultimate Limit States

Based on the results of the geotechnical investigation, the following recommendations for Ultimate Limit State design is presented:

- Ultimate Geotechnical Resistance at Ultimate Limit State of the foundation soil (silt layer) is about 800 kPa assuming that the foundation width is 3 m.

- Factored Geotechnical Resistance is 400 kPa using a Geotechnical Resistance factor of 0.5 assuming that the foundation width is 3 m.

2.2.2 Geotechnical Resistance at Serviceability Limit State

Serviceability Limit States generally consider the unfactored loads being used to determine total and differential settlements of the structure with the magnitude of unfactored loads and tolerable total and differential settlement limits being established by the Structural or Design Engineer.

In determining the settlement characteristics of the proposed building, the unfactored loads are required to be provided by the Structural or Design Engineer. However, assuming a variety of stockpiling scenarios inside the building as suggested in Section 2.1, settlement is calculated using the Settle 3D software and the results are presented in Table 2.1. The consolidation parameters used on settlement analyses are estimated based on the Atterberg Limits test data documented in Appendix D. According to the analyses, if 50 mm of total settlement and 25 mm differential are acceptable, then the geotechnical resistance at the Serviceability Limit States (SLS) is 120 kPa in the foundation area assuming that the fill heights would not exceed the height of the “push wall”. Conditions would be expected to be better than calculated noting that gravel stockpiles occupy significant areas of the proposed building area. If the acceptable settlement is reduced to 25 mm total, then the SLS value should be reduced to 100 kPa, again assuming that the fill heights would not exceed the height of the “push wall”. The footprint of stockpiling should be restricted to conditions that limit the loading on the foundations to the SLS values indicated. This should be reviewed with the structural designer.

2.2.3 Resistance to Lateral Loads

Section 6.7.5 of the CHBDC should be issued to compute resistance to lateral forces/sliding resistance between the subgrade and concrete. An unfactored value of 0.35 can be measured for the coefficient of friction tan ϕ between the base of concrete footing and the in situ granular soils below frost level. When calculating lateral resistance of factor a 0.8 should be applied in accordance with the CHBDC.

Table 2.1 Estimated settlements for different stockpiling scenarios

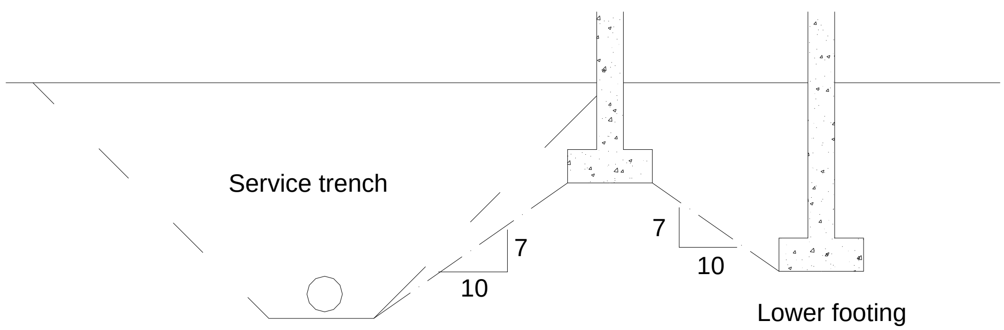
Pressure at Foundation Level* (@ 2m bgs) (kPa)	Pressure in Middle Area (kPa)	Max. Settlement in Foundation Area (mm)	Max. Settlement in Middle Area (mm)
60	40	33	35
	50	37	43
	60	41	50
	70	46	58
	80	50	66
	90	54	74
	100	58	83
70	40	35	36
	50	39	43
	60	44	51
	70	48	58
	80	52	66
	90	56	74
	100	61	84
80	40	37	36
	50	42	44
	60	46	51
	70	50	59
	80	54	67
	90	59	75
	100	63	85
90	40	40	37
	50	44	44
	60	48	52
	70	52	59
	80	57	68
	90	61	75
	100	66	86
100	40	42	37
	50	46	45
	60	50	52
	70	55	60
	80	59	68
	90	64	76
	100	68	87
120	40	46	38
	50	51	46
	60	55	53
	70	59	61
	80	64	69
	90	68	78
	100	73	89

2.2.4 Frost Protection

According to Ontario Provincial Standard Drawing (OPSD – 3090.101), the frost depth in Waters Township is about 2.1 m. Consequently, all footings exposed to seasonal freezing conditions should be protected from frost action by at least 2.1 m of soil cover or equivalent insulation.

2.2.5 Foundation Elevation

The footings which are to be placed at different elevations should be located such that the higher footings are set below a line drawn up at 10 horizontal to 7 vertical from the near edge of the lower footing or existing service trench, as indicated on the following sketch:.



FOOTINGS NEAR SERVICE TRENCHES OR AT DIFFERENT ELEVATIONS

This concept should also be applied to excavations for new foundations in relation to existing footings or underground services. Lower footings should be placed prior to upper foundations to prevent undermining conditions

Where footings are stepped down, a maximum level difference of 600 mm should be maintained.

2.2.6 Strip Footing Construction and Permanent Drainage

The 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.

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 footing and asphalt floor construction, all obviously unsuitable material should be fully removed from the entire underfooting and underfloor area. Following rough grading, the exposed subgrade should be proofrolled with a roller under the full-time supervision of qualified geotechnical personnel. Any soft spots detected during proofrolling should be sub-excavated and replaced with approved materials compacted to 98 percent of the Standard Proctor Maximum Dry Density (SPMDD). The prepared subgrade should be covered with at least 200 mm compacted OPS Granular A, 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. 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.

2.3 Evaluation of Foundation Alternatives

As mentioned before, considering the depth of firm ground, the high cost of pile foundations and the structure’s operating life it is unlikely that deep foundations can be considered feasible for this patrol yard structure. It appears that shallow foundations are more practical. However, an evaluation of these two foundation alternatives is included in this report. Advantages and disadvantages of spread footings and driven steel H-piles are presented in Table 2.2.

Given the subsurface conditions at the site the impact on settlements 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 both road sand and salt at strategic locations within the structure. Based on the information mentioned in Section 2.1, the maximum loading condition is likely to be sand stockpiled to at least the level of the “push wall” over the full footprint. Mounding in the centre at the angle of repose is also a possibility.

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 can include stockpiling constrains and/or structure support using bracing or the like in order to enhance serviceability.

Table 2.2 Evaluation of foundation alternatives

Options	Rank	Advantages	Disadvantages	Relative Costs	Risks/Consequences
Spread Footings on Insitu Silt Material	1*	▪ Straightforward construction	▪ Fairly low geotechnical resistance available ▪ Depending on conditions, some stockpiling constraints may be necessary	▪ Significantly lower relative cost compare to piles	▪ Risk of differential settlements due to loading patterns in the past and during operations ▪ Possible constraints on a storage volume
Driven Steel H-Piles	2	▪ Straightforward construction	▪ Not typical for this type of structure ▪ Very long piles, not warranted for this type of structure	▪ Higher relative costs compared with shallow foundations ▪ Unlikely to be economically feasible at the site	▪ Deep firm ground ▪ Not viable due to cost

* If geotechnical resistance is adequate, otherwise stockpiling constraints may be necessary.

2.4 Liquefaction Considerations

The first 5.5 to 7.2 m below the ground surface the site mainly consists of silt with SPT N-values ranging from 4 to 18. The water level in BH-3 after completion of drilling is at about 3.4 m depth. According to the observations of SPT's values, the subsoil could potentially be susceptible to liquefaction. Accordingly, liquefaction analyses have been performed using the Seed's approach, which is recommended by Canadian Foundation Engineering Manual (4th Edition 2006; Chapter 6, pg.101). This approach defines a factor of safety against liquefaction as the ratio of the induced cyclic stress ratio over the cyclic resistance ratio. The calculated factor of safety for the subsoil is generally more than 3.5. As a result, liquefaction is not likely to occur in the upper soils at the project site for the earthquake having 10% probability of exceedance in a 50-year period.

In addition, silty clay and clayey silt can be classified as fine-grained soils. As shown in the grain size distribution analysis, they have a significant portion (over 92%) of fines passing through #200 sieve.

To delineate liquefaction susceptibility, this report adopted the empirical criteria recommended in Canadian Foundation Engineering Manual (Chapter 6, pg. 111):

(1) $w/w_L \geq 0.85$ and $I_P \leq 12$: Susceptible to liquefaction or cyclic mobility

(2) $w/w_L \geq 0.80$ and $10 \leq I_P \leq 12$: Moderately susceptible to liquefaction

(3) $w/w_L < 0.85$ and $I_P \geq 12$: No liquefaction or cyclic mobility

Based on the above criteria, the liquefaction potential for the silty clay and clayey silt is assessed to be "not susceptible" and "moderately susceptible", respectively.

2.5 Earthquake Considerations

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

2.5.1 Subsoil Conditions

The subsoil and groundwater information at this site have been examined in relation to Section 4.1.8.4 of the Ontario Building Code (OBC, 2006). The subsoil generally consists of silt, silty clay, clayey silt, sand and sand and gravel layers. It is expected that the foundations will be founded in the silt layer underlain by silty clay, clayey silt and sand layers. The reported N-values for the soil below the founding level ranged from 1 to 50, with an average value greater than 15. The vane shear strength of the silty clay and clayey silt layer is between 48 and 66 kPa.

2.5.2 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 2006 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 Sudbury 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 2006 for the purpose of establishing the site classification.

2.5.3 Depth of Boreholes

Table 4.1.8.4.A. Site Classification for Seismic Site Response in OBC 2006 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 approximately 15.7 to 34 m deep. The overburden soils mainly consist of silt, silty clay, clayey silt, sand and gravel. It is estimated that the cohesive soils have the average undrained shear strength of 50 kPa.

2.5.4 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 2006.

These parameters should be reviewed by the structural engineer.

2.6 Backfill

It should be possible to reuse most of the excavated native materials for backfilling. With some adjustments to their natural moisture contents, it should be feasible to re-compact them to a high density.

Backfills under areas to be paved, side walks, under buildings, and all areas where long term settlement is to be avoided, should be placed in 200 mm loose lifts and compacted to minimum 95% SPMDD. Under pavement, the upper 600mm of the subgrades should be compacted to 98% SPMDD.

2.7 Excavation and Groundwater Control

For the construction of the proposed building, excavations at least about 2 m depth will be required. The excavations are expected to encounter mostly sand and gravel.

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.

No unusual construction conditions are expected for the excavations in the sand and gravel. The sand and gravel is hard and contains cobbles and boulders. Heavy duty equipment will be required to excavate the sand and gravel and progress could be slow. A Non-Standard Special Provision should be included in the contract documents to alert the Contractor of the possible presence of cobbles that may interfere with or slow the progress of excavation at some areas. Excavations are expected to be fairly shallow and well above groundwater levels measured during the investigation. Accordingly, no special groundwater control measures would be required.

A representative of Trow should be on-site during the foundation installation and for any fill material placement, to verify the design assumptions, and to verify the design recommendations.

2.8 Closure

The comments given in this report are intended only for the guidance of design engineers. The number of boreholes required to determine the localized underground conditions between boreholes affecting construction costs, techniques, sequencing, equipment, scheduling, etc. could be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the works, should, in this light, decide on their own investigations as well as their own interpretations of the factual borehole results so that 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 S. Micic, Ph.D., P.Eng and A. Geremew, Ph.D., and reviewed by S. Gonsalves, M.Eng., P.Eng., Designated MTO Foundation Contact.

We trust that these comments provide you with sufficient information to proceed with design. Should you have any questions, please do not hesitate to contact this office.

Yours truly,

Trow Associates Inc.

A. Geremew, Ph.D
Geotechnical Specialist

LICENSED PROFESSIONAL ENGINEER
05/12/11
S.E.M. GONSALVES
PROVINCE OF ONTARIO

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

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

LICENSED PROFESSIONAL ENGINEER
05/12/11
S. MICIC
100050187
PROVINCE OF ONTARIO

APPENDIX A: PHOTHOGRAPHS

Photograph 1. Site View (facing to north)

Photograph 2. Site View (facing to southeast)

Photograph 3. Site View (facing to northwest)

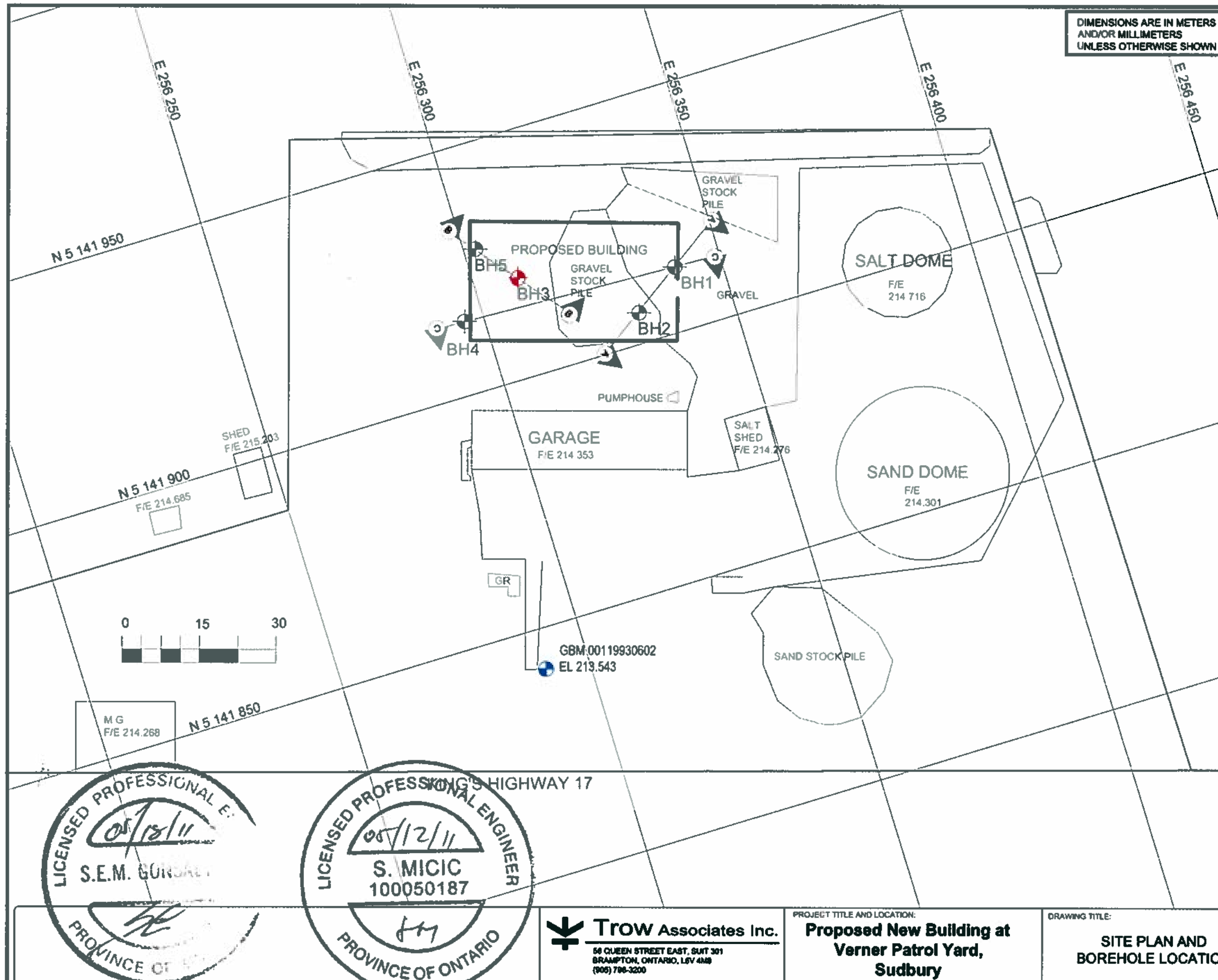
APPENDIX B: DRAWINGS

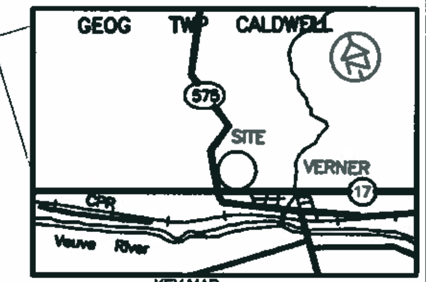
DIMENSIONS ARE IN METERS AND/OR MILLIMETERS UNLESS OTHERWISE SHOWN

WO No. 2011-11001
Geocres No. 411-270

Cardwell Township, District 54, Sudbury

SHEET 1





KEY MAP
Not to Scale

LEGEND

BOREHOLE

Borehole	North	East	Elev.
BH-1	5141913.5	256340.5	215.4
BH-2	5141906.0	256330.5	215.1
BH-3	5141920.2	256309.0	215.0
BH-4	5141914.9	256296.1	214.8
BH-5	5141928.6	256302.1	215.1

- NOTES -

1. This drawing to be read with subject report.
2. This drawing is for subsurface information only. Surface details and features are for conceptual illustration only.
3. Borehole locations are approximate.
4. Horizontal datum: NAD 83, MTM GRID Co-ordinate system
5. Vertical datum: Elevations are GEODETIC based on (CGVD28)

REVISION	DATE	BY	DESCRIPTION

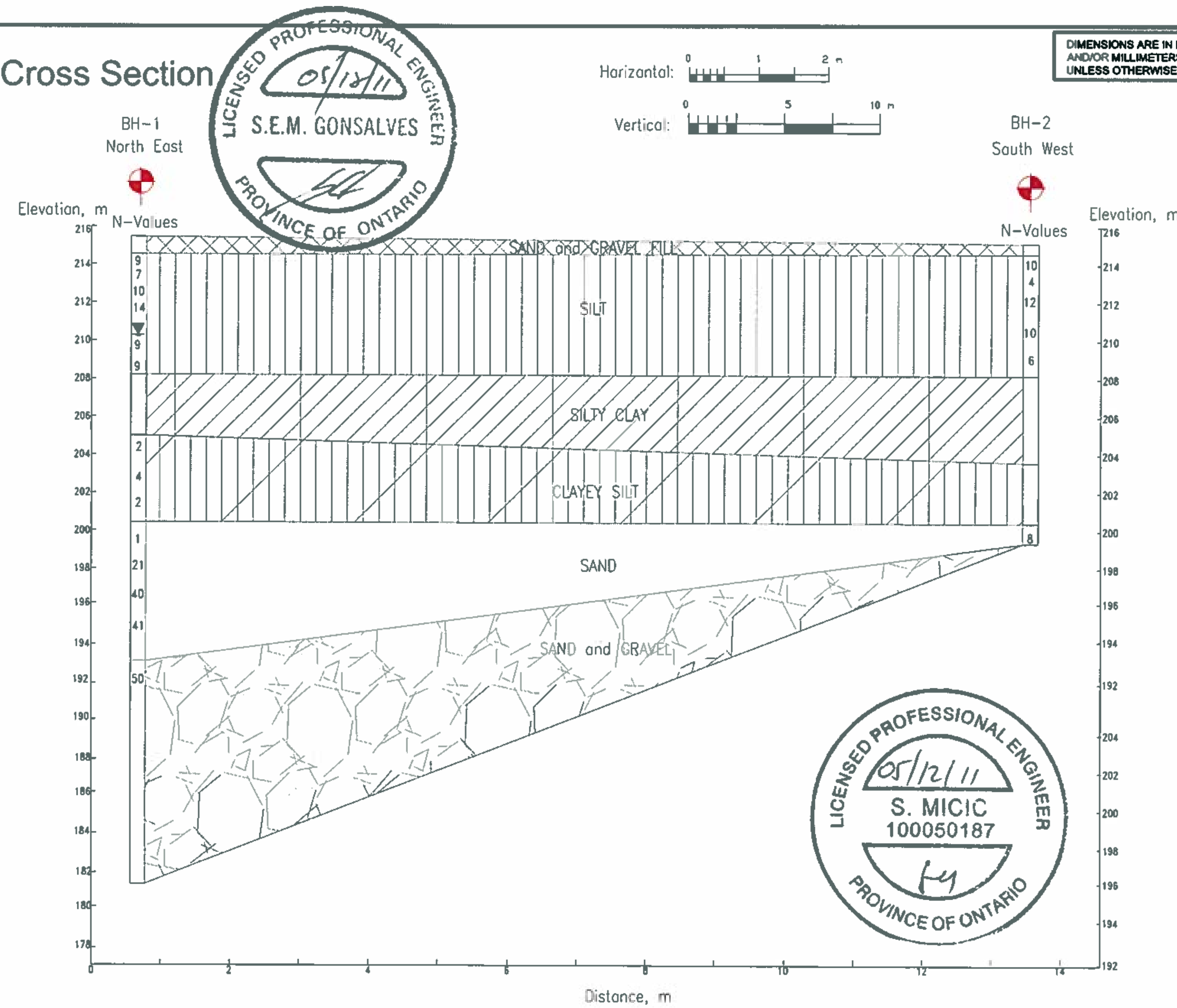
Trow Associates Inc.
56 QUEEN STREET EAST, SUIT 301
BRAMPTON, ONTARIO, L6V 4M8
(905) 796-3200

PROJECT TITLE AND LOCATION:
Proposed New Building at Verner Patrol Yard, Sudbury

DRAWING TITLE:
SITE PLAN AND BOREHOLE LOCATION

PROJECT NO.	ADM-00011530-A0-100SD	DWN	AG
SCALE:	AS NOTED	CHKD	SM
DATE:	MARCH 30, 2011	DEG No.	1

A-A Cross Section

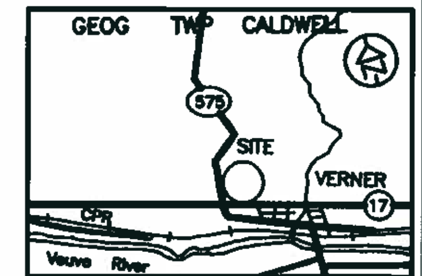


DIMENSIONS ARE IN METERS AND/OR MILLIMETERS UNLESS OTHERWISE SHOWN

WO No. 2011-11001
Geocres No. 41I-270

Cardwell Township, District 54, Sudbury

SHEET 2



KEY MAP
Not to Scale

LEGEND

- BOREHOLE
- Water Level

- NOTES -

1. This drawing to be read with subject report.
2. This drawing is for subsurface information only. Surface details and features are for conceptual illustration only.
3. Borehole locations are approximate.

REVISION	DATE	BY	DESCRIPTION

SOIL STRATA SYMBOLS: SAND and GRAVEL FILL, SILT, SILTY CLAY, CLAYEY SILT, SAND, SAND and GRAVEL

Trow Associates Inc.
56 QUEEN STREET EAST, SUIT 301
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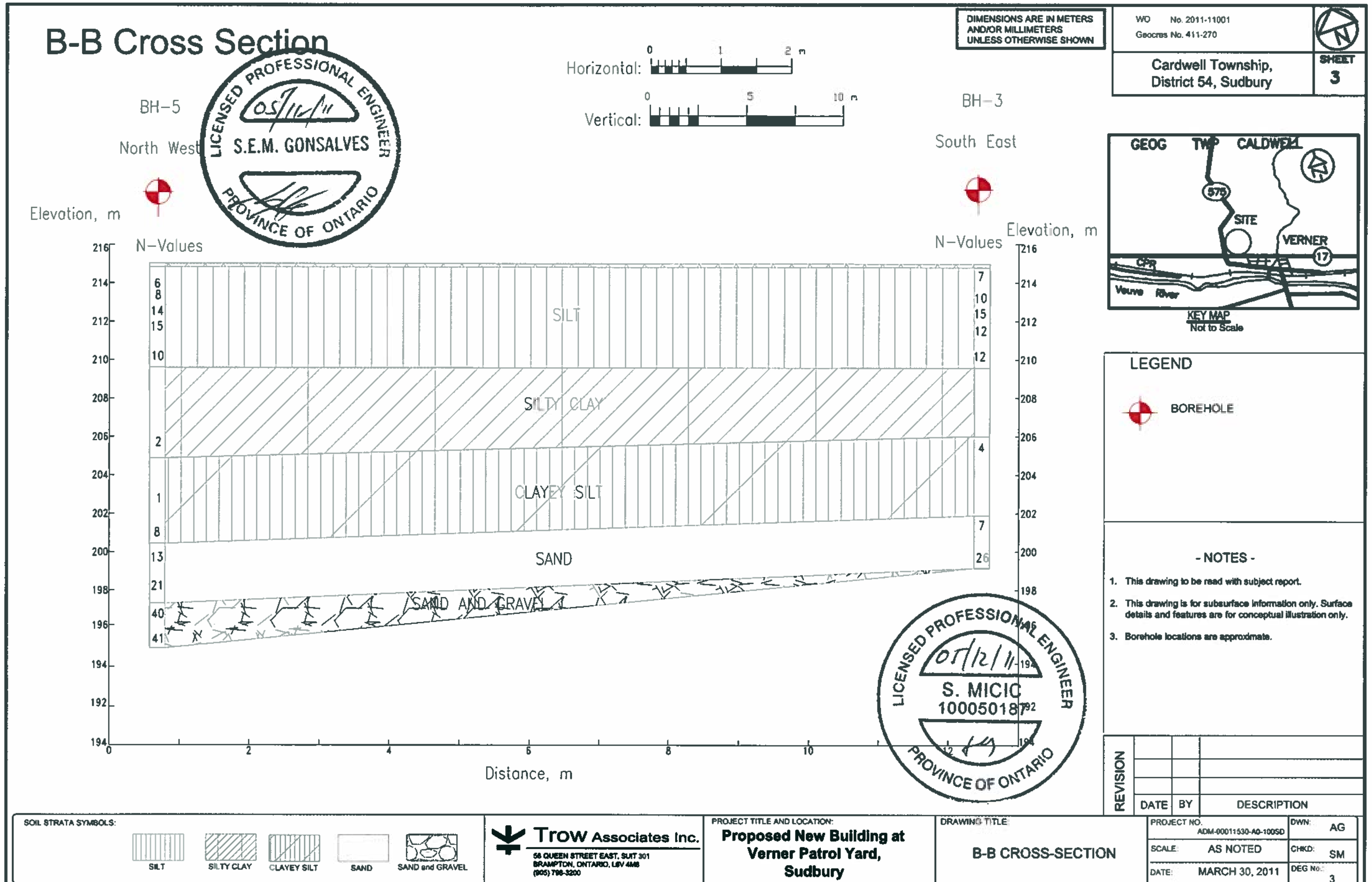
(905) 796-3200

PROJECT TITLE AND LOCATION:
Proposed New Building at Verner Patrol Yard, Sudbury

DRAWING TITLE:
A-A CROSS-SECTION

PROJECT NO	ADM-00011530-A0-10050	DWN:	AG
SCALE:	AS NOTED	CHKD:	SM
DATE:	MARCH 30, 2011	DEG No.:	2


B-B Cross Section
Horizontal:
Vertical:
BH-5
North West
BH-3
South East
Elevation, m
N-Values
SILT
SILTY CLAY
CLAYEY SILT
SAND
SAND AND GRAVEL
Distance, m
LICENSED PROFESSIONAL ENGINEER
S.E.M. GONSALVES
PROVINCE OF ONTARIO
S. MICIC
100050187
DIMENSIONS ARE IN METERS AND/OR MILLIMETERS UNLESS OTHERWISE SHOWN
WO No. 2011-11001
Geocres No. 411-270
Cardwell Township, District 54, Sudbury
SHEET
3
GEOG TWP CALDWELL
SITE
VERNER
CPR
Veuve River
KEY MAP
Not to Scale
LEGEND
BOREHOLE
- NOTES -
1. This drawing to be read with subject report.
2. This drawing is for subsurface information only. Surface details and features are for conceptual illustration only.
3. Borehole locations are approximate.
REVISION
DATE
BY
DESCRIPTION
SOIL STRATA SYMBOLS:
SILT
SILTY CLAY
CLAYEY SILT
SAND
SAND and GRAVEL
Trow Associates Inc.
PROJECT TITLE AND LOCATION:
Proposed New Building at Verner Patrol Yard, Sudbury
DRAWING TITLE:
B-B CROSS-SECTION
PROJECT NO.
SCALE: AS NOTED
DATE: MARCH 30, 2011
DWN: AG
CHKD: SM
DWG No.: 3

C-C Cross Section

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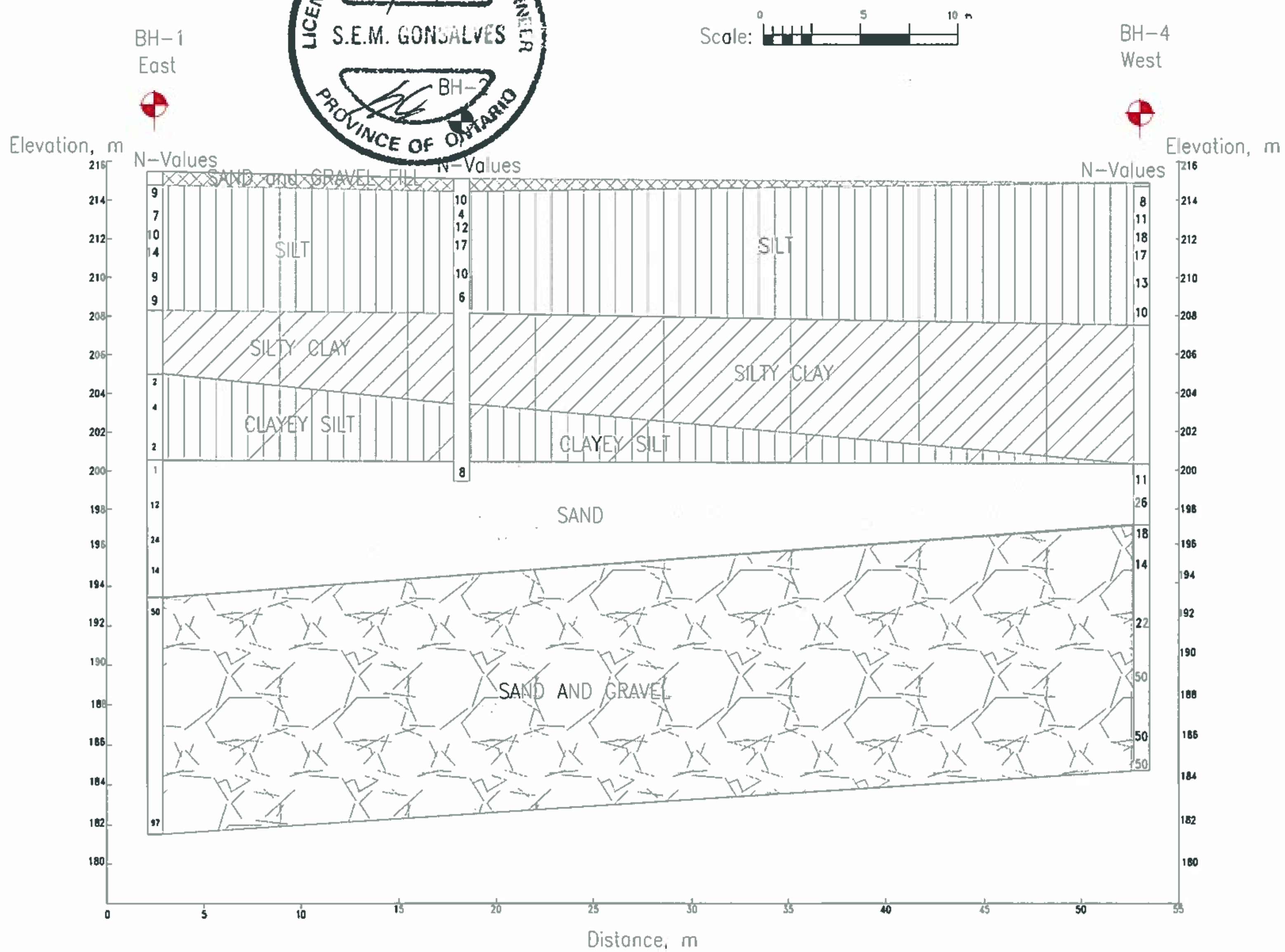
PROVINCE OF ONTARIO

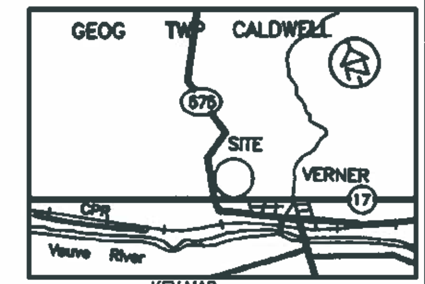
DIMENSIONS ARE IN METERS AND/OR MILLIMETERS UNLESS OTHERWISE SHOWN

WO No. 2011-11001
Geocres No. 411-270

Cardwell Township, District 54, Sudbury

SHEET 4





KEY MAP
Not to Scale

LEGEND

BOREHOLE

LICENSED PROFESSIONAL ENGINEER
05/12/11
S. MICIC
100050187
PROVINCE OF ONTARIO

- NOTES -

1. This drawing to be read with subject report.
2. This drawing is for subsurface information only. Surface details and features are for conceptual illustration only.
3. Borehole locations are approximate.

REVISION	DATE	BY	DESCRIPTION

SOIL STRATA SYMBOLS:

SAND and GRAVEL FILL, SILT, SILTY CLAY, CLAYEY SILT, SAND, SAND and GRAVEL

Trow Associates Inc.
55 QUEEN STREET EAST, SUIT 301
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(905) 796-3200

PROJECT TITLE AND LOCATION:
Proposed New Building at Verner Patrol Yard, Sudbury

DRAWING TITLE:
C-C CROSS-SECTION

PROJECT NO.	ADM-00011530-A0-300SD	DWN	AG
SCALE:	AS NOTED	CHKD.	SM
DATE:	MARCH 30, 2011	DEG No.	4

APPENDIX C: BOREHOLE LOGS

EXPLANATION OF TERMS USED IN REPORT

N-VALUE: THE STANDARD PENETRATION TEST (SPT) N-VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N-VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N-VALUE IS DENOTED THUS $\overline{N}$.

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

C_u (kPa)	0 – 12	12 – 25	25 – 50	50 – 100	100 – 200	>200
	VERY SOFT	*SOFT*	*FIRM*	*STIFF*	*VERY STIFF*	*HARD*

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 – 5	5 – 10	10 – 30	30 – 50	>50
	VERY LOOSE	*LOOSE*	*COMPACT*	*DENSE*	*VERY DENSE*

ROCKS ARE DESCRIBED BY THEIR COMPOSION AND STRUCUTRAL FEATURES AND/OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (RQD), FOR MODIFIED RECOVERY IS:

RQD (%)	0 – 25	25 – 50	50 – 75	75 – 90	90 – 100
	VERY POOR	*POOR*	*FAIR*	*GOOD*	*EXCELLENT*

JOINT AND BEDDING:

SPACING	50mm	50 – 300mm	0.3m – 1m	1m – 3m	>3m
JOINTING	*VERY CLOSE*	*CLOSE*	*MOD. CLOSE*	*WIDE*	*VERY WIDE*
BEDDING	*VERY THIN*	*THIN*	*MEDIUM*	*THICK*	*VERY THICK*

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

SS	SPLIT SPOON	TP	THINWALL PISTON
WS	WASH SAMPLE	OS	OSTERBERG SAMPLE
ST	SLOTTED TUBE SAMPLE	RC	ROCK CORE
BS	BLOCK SAMPLE	PH	TW ADVANCED HYDRAULICALLY
CS	CHUNK SAMPLE	PM	TW ADVANCED MANUALLY
TW	THINWALL OPEN	FS	FOIL SAMPLE

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

MECHANICALL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
c_c	1	COMPRESSION INDEX
c_s	1	SWELLING INDEX
c_s	1	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	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	e	1,%	VOID RATIO	e_{min}	1,%	VOID RATIO IN DENSEST STATE
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES	n	1,%	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
P_w	kg/m^3	DENSITY OF WATER	w	1,%	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	kN/m^3	UNIT WEIGHT OF WATER	s_r	%	DEGREE OF SATURATION	D_n	mm	N PERCENT – DIAMETER
P	kg/m^3	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
γ	kN/m^3	UNIT WEIGHT OF SOIL	w_P	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
P_d	kg/m^3	DENSITY OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	q	m^3/s	RATE OF DISCHARGE
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL	I_P	%	PLASTICITY INDEX = $(W_L - W_L)$	v	m/s	DISCHARGE VELOCITY
P_{sat}	kg/m^3	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $(W - W_P)/ I_P$	i	1	HYDAULIC GRADIENT
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $(W_L - W) / 1_P$	k	m/s	HYDRAULIC CONDUCTIVITY
P'	kg/m^3	DENSITY OF SUBMERED SOIL	e_{max}	1,%	VOID RATIO IN LOOSEST STATE	j	kN/m^3	SEEPAGE FORCE
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL						

RECORD OF BOREHOLE No BH-1

METRIC

W.P. **WO 2011-11001** LOCATION **Verner Patrol Yard** ORIGINATED BY CS

DIST **54, Sudbury** HWY 17 BOREHOLE TYPE CME Hollow Steam Auger/Diamond COMPILED BY AG

DATUM **Geodetic** DATE 2011 01 18 - 2011 01 20 CHECKED BY SM

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
215.4	**Ground Surface**				
0.0	SAND and GRAVEL FILL (SW), trace to some silt, brown, wet, loose	1	AS		
214.6 / 0.8	SILT (ML), some clay, trace sand, grey, damp, loose	2	SS	9	
	- varved, trace gravel, brown, wet	3	SS	7	5 8 53 34
	- dark brown seams, moist, compact	4	SS	10	
		5	SS	14	
	- dark grey seams (approximately 2 - 5 mm wide), wet, loose	6	SS	9	
	- trace to some clay, 50-60 mm sand and gravel, fine gravel seam	7	SS	9	
208.2 / 7.2	SILTY CLAY (CL), trace sand, trace gravel, grey, wet, firm, varved	8	SS	WH	
		9	SS	WH	1 2 54 43
205.0 / 10.4	CLAYEY SILT (CL), some sand, grey, wet, soft	10	SS	2	
		11	SS	4	
	- trace gravel, trace sand, grey, soft to firm, varved	12	SS	2	0 8 67 25
200.5 / 14.9	SAND (SW), trace gravel, trace silt, grey, wet, very loose - heaving - wash bored to 16.8 m due to flowing sand - compact	13	SS	1	
		14	SS	17	
		15	SS	24	
	- becomes fine to coarse grained - small boulder or cobble at 21.8 m	16	SS	14	
193.4 / 21.9	SAND and GRAVEL, grey, wet				

Continued Next Page

Columns: STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (215 to 193); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L — WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³

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

RECORD OF BOREHOLE No BH-1

METRIC

W.P. **WO 2011-11001**	LOCATION **Verner Patrol Yard**		ORIGINATED BY CS
DIST **54, Sudbury** HWY 17	BOREHOLE TYPE CME Hollow Steam Auger/Diamond		COMPILED BY AG
DATUM **Geodetic**	DATE 2011 01 18 - 2011 01 20		CHECKED BY SM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	SAMPLE TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND and GRAVEL, grey, wet *(continued)*		17	SS	50		192		o		
							191				
	- boulders at approximately 25.6 mm						190				
							189				
							188				
							187				
	- becomes more sand, very dense						186				
							185				
							184				
							183				
181.4			18	SS	97		182		o		
34.0	END OF BOREHOLE										

NOTES:
1. This drawing is to be read with the subject report and project number as presented above.
2. Interpretation assistance by Trow is required before use by others.
3. "WH" means "Weight of Hammer"

Legend: O UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × LAB VANE. PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L.

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

RECORD OF BOREHOLE No BH-2

METRIC

W.P.	**WO 2011-11001**	LOCATION	**Verner Patrol Yard**
DIST	**54, Sudbury** HWY 17	BOREHOLE TYPE	CME Hollow Steam Auger/Diamond
DATUM	**Geodetic**	DATE	2011 01 25 - 2011 01 25
ORIGINATED BY	CS	COMPILED BY	AG
CHECKED BY	SM		

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
215.1	**Ground Surface**				
0.0	SAND and GRAVEL FILL (SW), trace silt, brown, damp, loose	1	AS		
214.4 / 0.8	SILT (ML), some clay, brown, damp, compact	2	SS	10	
	- loose, varved (15 mm silt and 10 mm clay)	3	SS	4	
	- trace clay, compact	4	SS	12	
	- becomes grey, wet	5	SS	17	
		6	SS	10	
	- some clay, loose	7	SS	6	
208.1 / 7.0	SILTY CLAY (CL), trace gravel, trace sand, grey, wet, very soft, varved (15 mm clay and 20 mm silt)	8	SS	WH	
		9	SS	WH	3 2 53 42
		10	TW		
203.5 / 11.6	CLAYEY SILT (CL), some sand, wet, very soft, varved (5 to 10 mm clay seam)	11	SS	WH	
		12	SS	WH	
200.5 / 14.6	SAND (SW), trace to some fine gravel, grey, wet, loose	13	SS	8	8 86 (6)
199.4 / 15.7	END OF BOREHOLE				

NOTES:
1. This drawing is to be read with the subject report and project number as presented above.
2. Interpretation assistance by Trow is required before use by others.
3. "WH" means "Weight of Hammer"

Column headings: GROUND WATER CONDITIONS; ELEVATION SCALE (215 to 200); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³.

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

Trow Associates Inc.
Brampton, Ontario

Foundation Design

RECORD OF BOREHOLE No BH-3

METRIC

W.P. **WO 2011-11001** LOCATION **Verner Patrol Yard** ORIGINATED BY CS

DIST **54, Sudbury** HWY 17 BOREHOLE TYPE CME Hollow Steam Auger/Diamond COMPILED BY AG

DATUM **Geodetic** DATE 2011 01 26 - 2011 01 26 CHECKED BY SM

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	NATURAL MOISTURE CONTENT / REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
215.0	**Ground Surface**					
215.0 / 0.2	TOP SOIL	1	AS			
	SILT (ML), trace to some and fine to coarse sand, trace organics, brown, damp, loose					
	- some clay	2	SS	7	214	
	- some clay, trace sand, trace gravel, compact	3	SS	10	213	
	- varved with clay seam, 5 - 10 mm clay, approximately 20 - 30 mm silt	4	SS	15	212	0 1 86 13
	- grey, wet	5	SS	12	211	
		6	SS	12	210	
209.5 / 5.5	SILTY CLAY (CL), some gravel, trace sand, grey, wet, varved	7	SS	WH	209	
	- varved 20 mm clay, 5 mm silt - stiff	8	SS	WH	208 / 207	
206.0 / 8.9	CLAYEY SILT (CL), some sand, grey, wet, soft	9	SS	4	206 / 205	
	- very soft	10	SS	WH	204	
		11	SS	WH	203	51
201.9 / 13.1	SAND (SW), trace silt, brown, wet, loose	12	SS	7	202 / 201	1 96 (3)
199.3 / 15.7	- becomes compact	13	SS	26	200	
	END OF BOREHOLE					

NOTES:
1. This drawing is to be read with the subject report and project number as presented above.
2. Interpretation assistance by Trow is required before use by others.
3. "WH" means "Weight of Hammer"

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100
PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30
UNIT WEIGHT γ kN/m³

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

RECORD OF BOREHOLE No BH-4

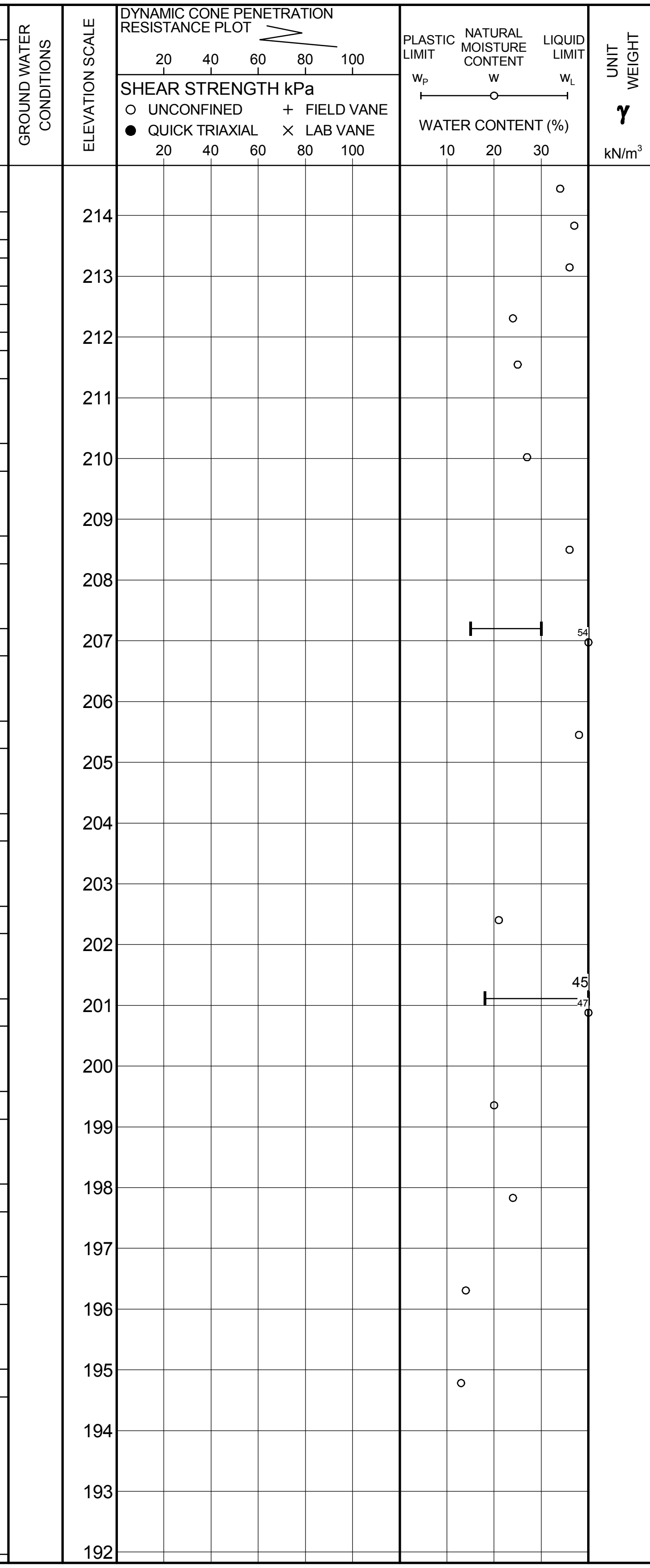
METRIC

W.P. **WO 2011-11001** LOCATION **Verner Patrol Yard** ORIGINATED BY CS

DIST **54, Sudbury** HWY 17 BOREHOLE TYPE CME Hollow Steam Auger/Diamond COMPILED BY AG

DATUM **Geodetic** DATE 2011 01 26 - 2011 01 28 CHECKED BY SM

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
214.8	**Ground Surface**							
214.6 0.2	TOPSOIL	1	AS					
	SILT (ML), some sand, trace gravel, trace organics, brown, damp, loose							
	- some clay, moist	2	SS	8				
	- compact	3	SS	11				
	- trace clay, wet	4	SS	18				
		5	SS	17				
	- grey	6	SS	13	0	7	78	15
	- varved with 20-30 mm silt and 5-10 mm clay	7	SS	10				
207.8 7.0	SILTY CLAY (CL), some gravel, trace sand, grey, varved, soft							
	- some fine sand, wet, very soft	8	SS	WH	12	3	56	29
		9	SS	WH				
	- no recovery, wet sand	10	SS	WH				
		11	SS	WH				
	- varved, trace sand, trace gravel, grey, wet	12	SS	WH	0	3	44	53
200.2 14.6	SAND (SW), trace silt, grey, wet, compact	13	SS	11				
		14	SS	26				
197.0 17.8	SAND and GRAVEL, trace silt, brown, wet, compact	15	SS	18				
		16	SS	14				



Continued Next Page

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

RECORD OF BOREHOLE No BH-4

METRIC

W.P. **WO 2011-11001**	LOCATION **Verner Patrol Yard**		ORIGINATED BY CS
DIST **54, Sudbury** HWY 17	BOREHOLE TYPE CME Hollow Steam Auger/Diamond		COMPILED BY AG
DATUM **Geodetic**	DATE 2011 01 26 - 2011 01 28		CHECKED BY SM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND and GRAVEL, trace silt, brown, wet, compact *(continued)*		17	SS	22				○		
							191				
							190				
	- very dense										
	- grey		18	SS	50		189		○		
							188				
	- some silt and sand						187				
							186				
			19	SS	50				○		
			20	SS	50		185				
184.2 / 30.6	END OF BOREHOLE								○		

NOTES:
1. This drawing is to be read with the subject report and project number as presented above.
2. Interpretation assistance by Trow is required before use by others.
3. "WH" means "Weight of Hammer"

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

RECORD OF BOREHOLE No BH-5

METRIC

W.P. **WO 2011-11001**	LOCATION **Verner Patrol Yard**		ORIGINATED BY CS
DIST **54, Sudbury** HWY 17	BOREHOLE TYPE CME Hollow Steam Auger/Diamond		COMPILED BY AG
DATUM **Geodetic**	DATE 2011 01 26 - 2011 01 27		CHECKED BY SM

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
215.1	**Ground Surface**				
214.9 / 0.2	TOPSOIL	1			
	SILT (ML), some clay, trace organics, brown, damp, loose	2	SS	6	
		3	SS	8	
	- trace clay, compact	4	SS	14	
	- brown to grey	5	SS	15	
	- grey	6	SS	10	
209.6 / 5.5	SILTY CLAY (CL), trace sand, trace gravel, grey, wet, very soft, varved	7	SS	WH	1 1 48 50
		8	TW		
		9	SS	2	
204.9 / 10.2	CLAYEY SILT (CL), trace sand, grey, wet, very soft, varved	10	SS	WH	
		11	SS	WH	0 8 63 29
	- firm	12	SS	8	
200.4 / 14.6	SAND (SW), trace silt, grey, wet, compact	13	SS	13	
		14	SS	21	
197.2 / 17.8	SAND and GRAVEL, grey, dense	15	SS	40	
194.8		16	SS	41	
20.3	END OF BOREHOLE				

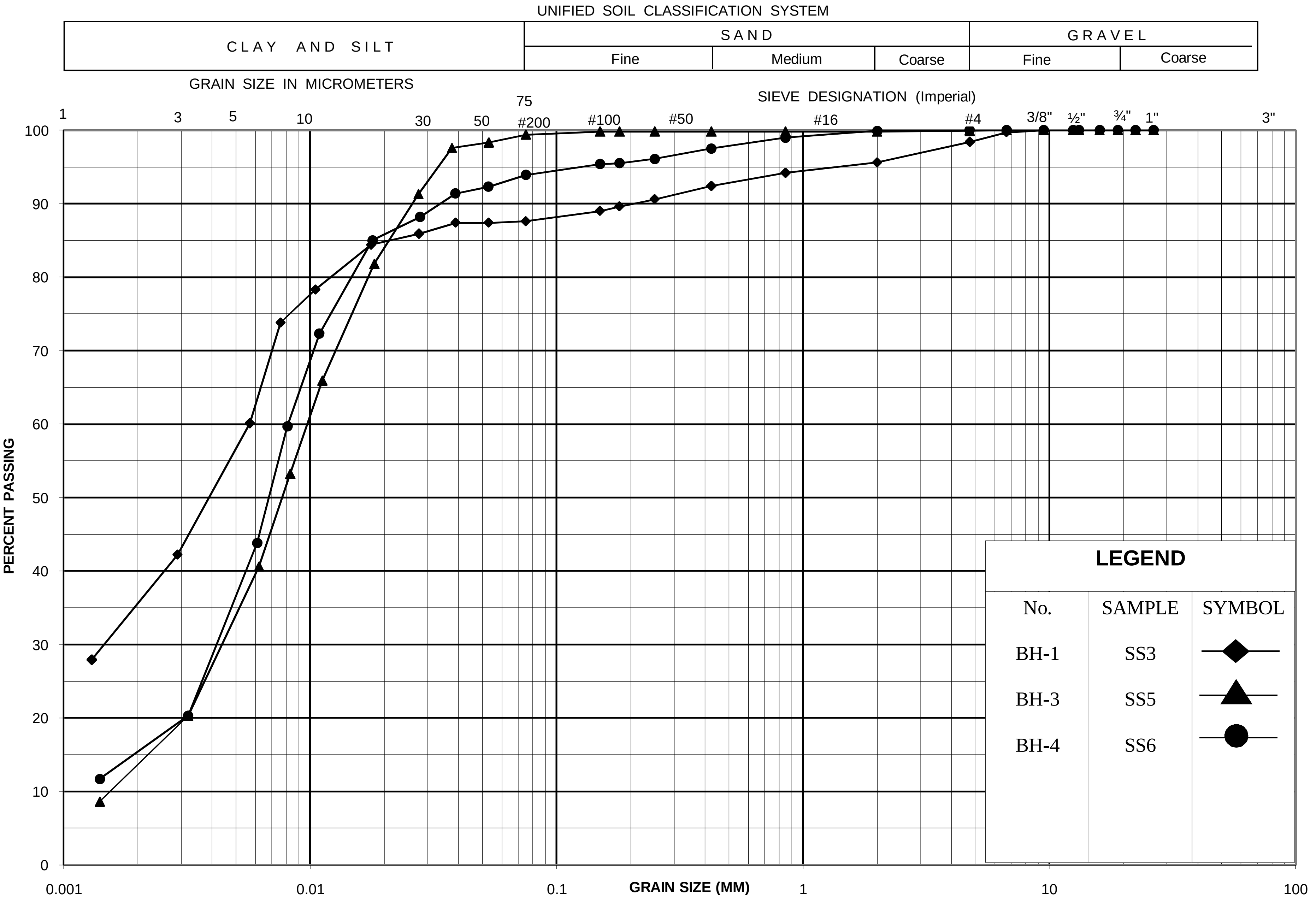
Column headings: STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (214 to 195); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L, WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³.

NOTES:
1. This drawing is to be read with the subject report and project number as presented above.
2. Interpretation assistance by Trow is required before use by others.
3. "WH" means "Weight of Hammer"

+ 3, × 3: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

APPENDIX D: LABORATORY DATA



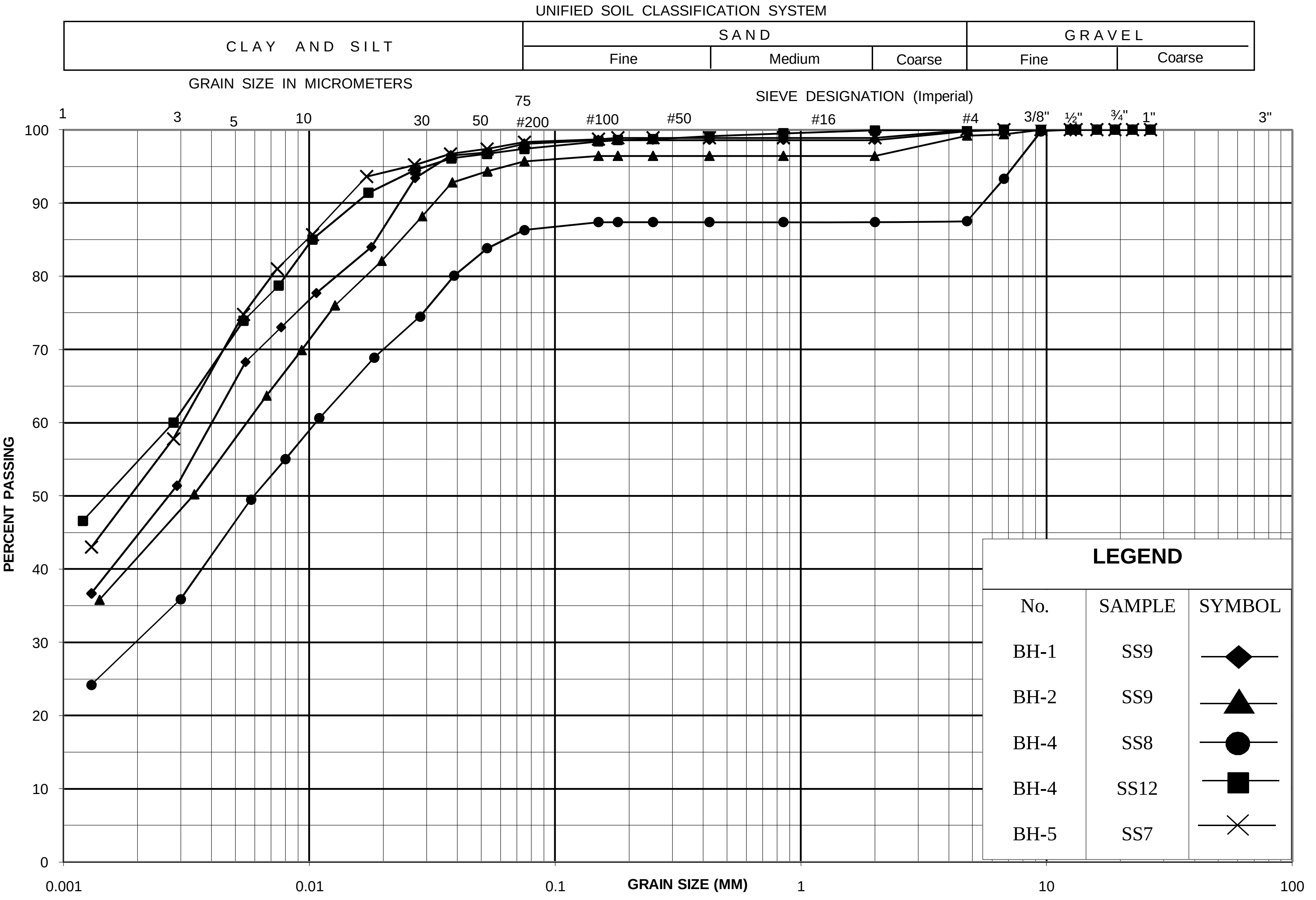
GRAIN SIZE DISTRIBUTION

SILT (ML)

FIGURE No. 1

WO :

DATE March/ 30/2011



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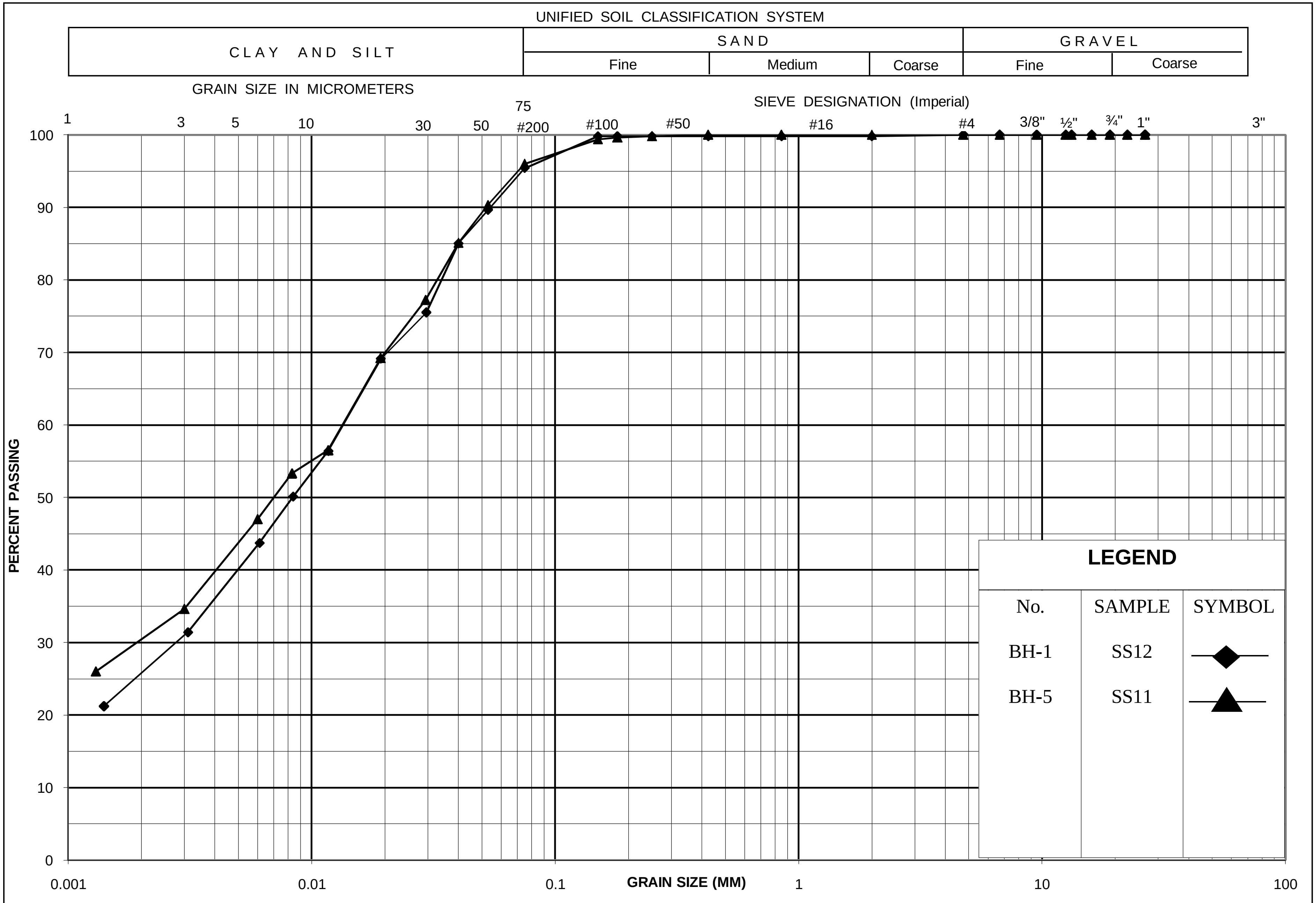
GRAIN SIZE DISTRIBUTION

SILTY CLAY (CL)

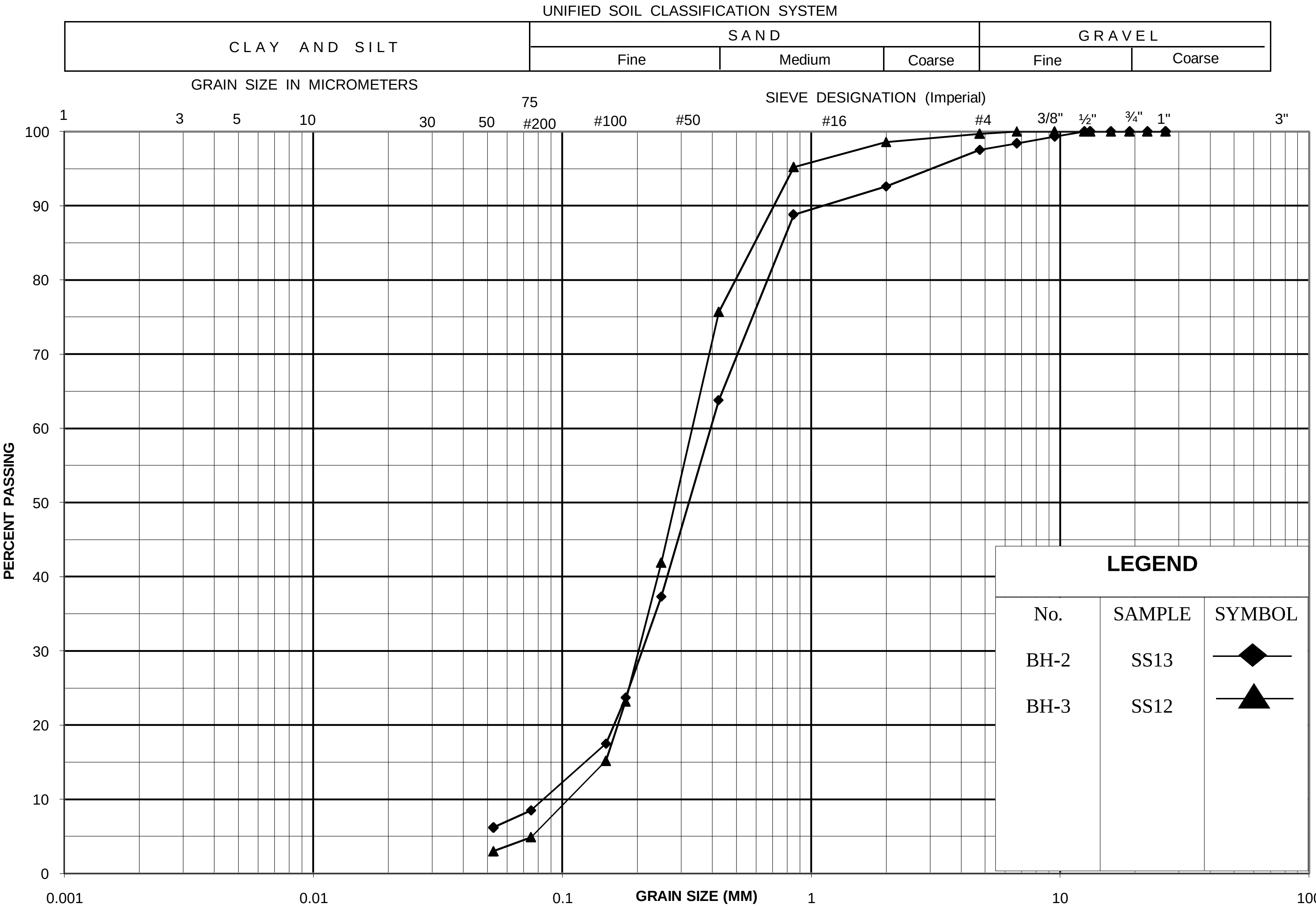
FIGURE No. 2

WO :

DATE March/ 30 /2011



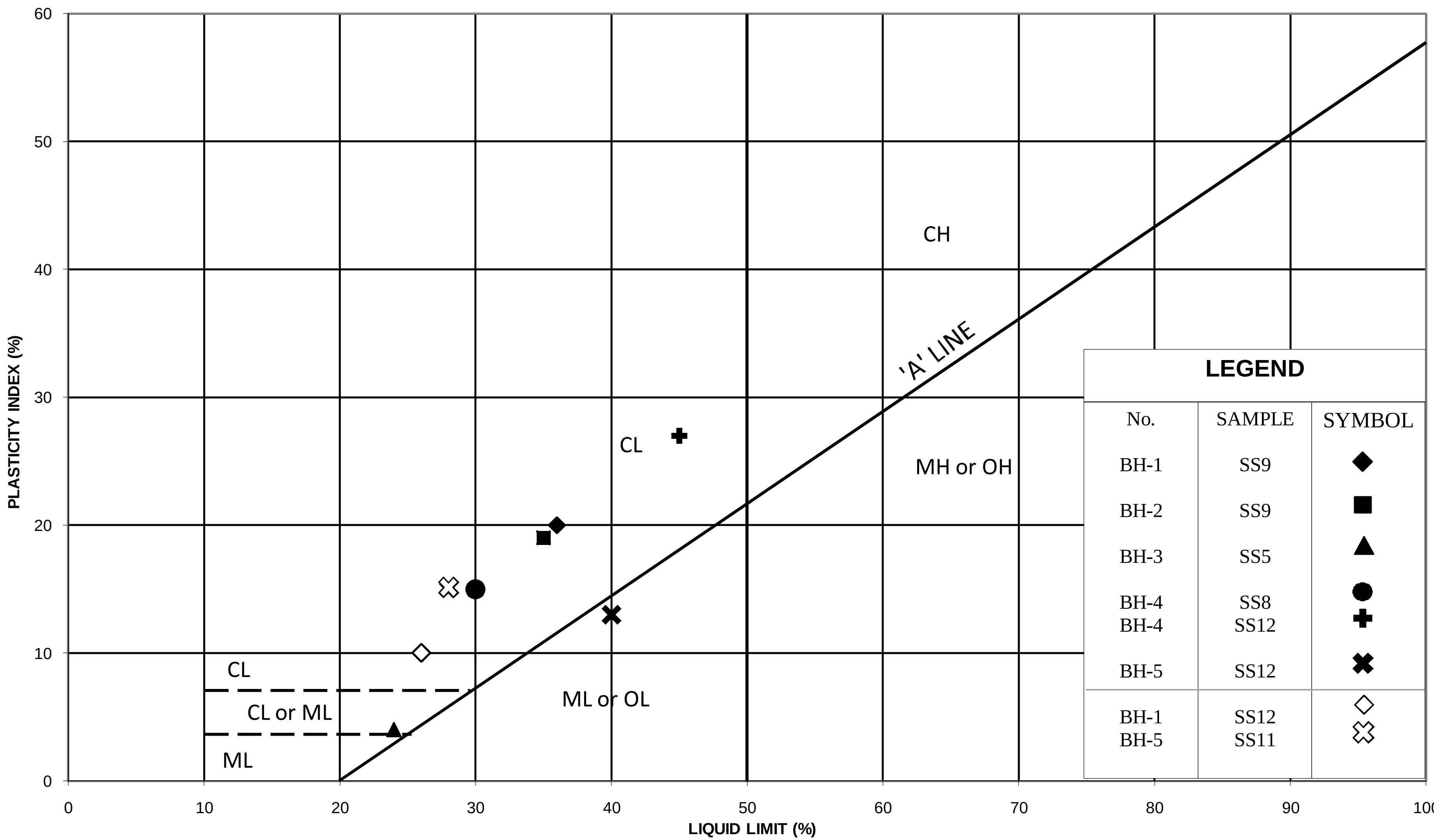
Trow	GRAIN SIZE DISTRIBUTION CLAYEY SILT (CL)	FIGURE No. 3 WO : DATE March/ 30/ 2011



Trow

GRAIN SIZE DISTRIBUTION SAND (SW)	FIGURE No. 4 WO : DATE March/ 30/ 2011

VERNER PATROL YARD



Trow

PLASTICITY CHART: UNIFIED SYSTEM

SILTY CLAY and CLAYEY SILT

FIGURE No. 5

WO :

DATE March/ 30/2011