

## FINAL REPORT

**Foundation Investigation and Design Report  
Proposed New Building at Cartier Patrol Yard  
Hwy 144, Sudbury Area  
WO 2009-11032  
MTO GEOCRES No. 41I-247**

Prepared for:  
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**Trow Associates Inc.**

March 25, 2010

SD000360624e

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# 1. Part I: FOUNDATION INVESTIGATION

## 1.1 Introduction

This report presents the results of a geotechnical investigation completed by Trow Associates Inc. (Trow) for the proposed new building located at Cartier Patrol Yard, Cartier Township, Sudbury Area. The proposed structure will consist of a dome or conventional building to replace the existing maple dome on site. It is Trow's understanding that the proposed building will have a footprint of approximately 24 m x 36 m and it is expected to accommodate about 5300 tones of winter sand including the area needed to allow for inside loading.

The work was undertaken under Agreement # 5006-E-0094, Assignment No. 4. The terms of reference were as presented in MTO letter dated August 24, 2009.

The purpose of the investigation is to examine the existing soil conditions within the proposed construction limits. The site specific geotechnical investigation consisted of test borings, borehole logging, and field and laboratory testing. 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 site is located on the northwest corner of the intersection of King's Highway 144 and Old Cartier Road (i.e., formerly Hwy 544) in Township of Cartier, approximately 58 km north of Sudbury. Currently, there is a maple dome and a salt dome on site. The existing maple dome of about 30 m diameter has been in place for at least 25 years, and it will be replaced by the new building. The salt dome is approximately 13.6 m northwest of the existing maple dome. About 53 m northwest of the maple dome is an about 7 m deep ravine having side slopes of approximately 2 horizontal to 1 vertical.

The site plan is as shown on the drawings in Appendix B.

### 1.2.2 Geological Setting

According to Bedrock Geology of Ontario Map 2543 (Ministry of Northern Development and Mines, Ontario), the bedrock underlying the site is from the Neo-to Mesozoic geologic era (approximately 2.5 to 3.4 billion years old) and falls under Intrusive Igneous Rocks which consists of massive to foliated granodiorite to granite.

## 1.3 Investigation Procedures

### 1.3.1 General

The field work for this investigation was performed between November 17 and November 20, 2009. This consisted of drilling five (5) sampled boreholes (BH-1, BH-2, BH-3, BH-4, and BH-5). The five (5) boreholes were strategically located adjacent to the existing maple dome to permit geotechnical investigation for the foundation of the proposed new building. Drawing No. 1 in Appendix B shows the locations of the five boreholes.

Boreholes BH-1, BH-2, BH-3, BH-4 and BH-5 were advanced using a bombardier mounted CME 55 drill rig, equipped with continuous flight hollow stem augers. All borehole drilling/sampling were operated by a specialist drilling contractor, LandCore Drilling Co. Ltd.

During the drilling, soil samples were obtained using a 51 outside diameter (O.D.) split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures (ASTM D 1586), at intervals shown on the attached borehole logs (Appendix C). The 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, BH-2 and BH-3, sand heaving was encountered at a depth ranging from 9.14 to 12.2 m. In these cases, wash boring was utilized to facilitate taking representative sample at designated elevation with reasonable accuracy. In addition, dynamic cone testing was utilized at BH-4 below 8.2 m depth to verify the soil consistency condition established by the SPT tests in BH-1, BH-2, BH-3 and BH-5.

After completion, boreholes were sealed in accordance with accepted practice for decommissioning of boreholes.

The fieldwork was supervised by a member of Trow’s engineering staff who 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 moisture-proof bags and returned to Trow’s Sudbury and Brampton laboratories for additional visual, textual and olfactory examination.

Details of the soil strata encountered in the boreholes are included in attached borehole log sheets in Appendix C, and plotted on the profiles 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 south-east corner of the building (PBM 748076), as shown in the site survey map provided by MTO (PLAN H-698-1444-1) (Elevation 417.367 m ).

### 1.3.2 Laboratory Testing

All samples returned to the laboratory were subjected to visual examination and classification. The laboratory testing program included natural water content (LS-701) and grain size distribution tests (LS703/704) on approximately 25% of the collected soil samples.

The laboratory test results are provided on the attached borehole log sheets in Appendix C. The results of the grain size analyses are presented geographically 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. 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 cross section soil profiles are provided in Appendix B. It should be noted 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 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 site typically consists of sand and gravel followed by sand overlying boulder/broken rock.

A summary of the soil and groundwater conditions encountered in the boreholes is provided below.

### 1.4.1 Asphalt

At BH-4 and BH-5, asphaltic concrete was encountered at ground surface. The thickness of the asphaltic concrete layer ranges from 38 to 40 mm, and the top elevation of this layer is between about 417.4 m and 417.3 m.

### 1.4.2 Sand and Gravel

Sand and gravel was encountered at all boreholes. At BH-1, BH-2 and BH-3 the sand and gravel was encountered at ground surface, while at BH-4 and BH-5 it was found below surface asphalt. The thickness of the sand and gravel ranges from 0.8 m to 9.1 m. This layer extends from elevation of about 417.3 m to 408.0 m.

The composition of this layer is sand and gravel, trace to some silt, with occasional cobbles. The sand and gravel is brown in color, and dry to wet. Uncorrected STP “N” value ranges from 10 to 100 blows per 300 mm, classifying the material as compact to very dense in compactness condition.

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

Moisture Content:

- 5% to 15%

Grain Size Distribution:

- 17% to 54% gravel;
- 39% to 72% sand; and
- 3% to 21% silt and clay

The results of the moisture content and grain size distribution tests are provided on the record of borehole sheet in Appendix C. The results of the grain size distribution tests are also provided on Figures 1 and 2 in Appendix D.

### 1.4.3 Sand

Sand was encountered in BH-1, BH-2, BH-3, and BH-5. This sand layer has a thickness ranging from about 5.2 m to 11.0 m. It extends to depths between 9.1 m and 15.3 m, corresponding to approximate Elevations of 408.0 and 402.0 m, respectively.

The deposit consists of sand, trace to some gravel, and trace to some silt. At BH-2, the sand layer contains trace to some dark brown organic silt (possible fill) and extends down to about 3.1 m depth from the existing ground surface. The sand is brown to grey in color, and moist to wet. Uncorrected SPT “N” values range from 4 to 100 blows per 300 mm, classifying the sand as very loose to very dense in compactness condition.

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

Moisture Content:

- 18% to 22%

Grain Size Distribution:

- 0% to 7% gravel;
- 74% to 92% sand; and
- 8% to 26% silt and clay

The results of the moisture content and grain size distribution tests are provided on the record of borehole sheet in Appendix C. The results of the grain size distribution tests are also provided on Figures 3 and 4 in Appendix D.

#### 1.4.4 Boulder/Broken Rock

Beneath the sand layer, boulder was encountered at BH-1, BH-2 and BH-3. The fractured rock or boulders extend from about 11.0 m depth (approximately Elevation of 406.1 m) to 18.6 m depth at the borehole termination. Appendix E includes the photos of broken rock recovered.

### 1.5 Groundwater Conditions

The groundwater levels at the site were estimated from the sign of wet-spoon during field borehole drilling and the change of the sample moist contents in depth. The ground water levels encountered in the boreholes are also 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	November/18/2009	6.1	411.2
BH-2	November/19/2009	6.1	411.0
BH-3	November/20/2009	6.1	411.1
BH-4	November/20/2009	7.6	409.7
BH-5	November/17/2009	6.1	411.3



## 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 Cartier Patrol Yard, Cartier Township, Sudbury Area. The proposed building will consist of a dome or conventional building for storage of road sand. It is anticipated that the proposed building will have a footprint of about 24 x 36 m and will be expected to accommodate about 5300 tones of sand.

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 August 24, 2009.

### 2.2 Geotechnical Design Considerations for Foundations

#### 2.2.1 General

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 deposit of sand and gravel with thickness ranging from 0.8 m to 9.1 m, followed by sand overlying boulder.

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.

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 settlement may be supported on shallow foundations bearing on native soil,

sand and gravel below any surficial fill. Shallow foundation should consist of spread and/or strip footings.

### 2.2.2 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 is about 600 kPa assuming that the foundation width is over than 1m.
- Factored Geotechnical Resistance is 300 kPa using a Geotechnical Resistance factor of 0.5 assuming that the foundation width is over than 1m.

### 2.2.3 Geotechnical Reaction 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 that 25 mm of settlement is acceptable, then the geotechnical reaction at the Serviceability Limit States can be determined from the method recommend by *Canadian Foundation Engineering Manual* (p.g. 173, 2006).

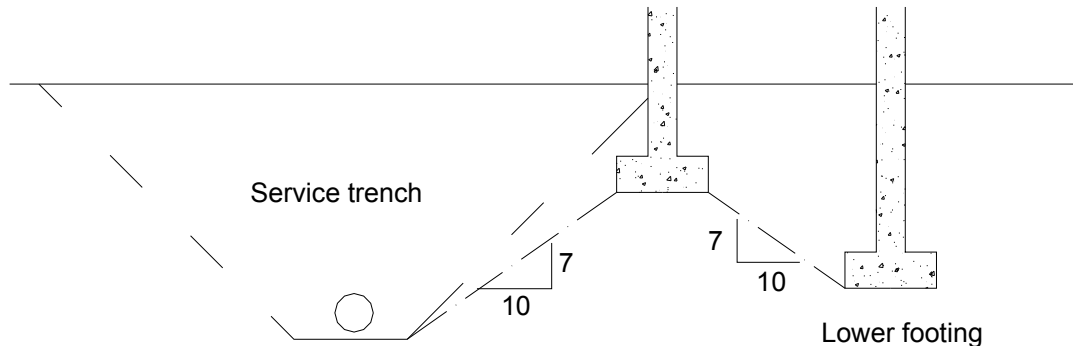
- Serviceability Limit State Reaction is 250 kPa assuming that 25 mm of settlement is acceptable and the foundation width is over than 1m.

### 2.2.4 Frost Protection

According to Ontario Provincial Standard Drawing (OPSD – 3090.101), the frost depth in Cartier 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 Floor Slab Construction and Permanent Drainage

The floor slabs for the proposed structures may be constructed as slab-on-grade on native soils. Slab-on-grade construction may be carried out in accordance with the following recommendations.

Prior to slab-on-grade construction, all obviously unsuitable material (e.g., the organic silt encountered in BH-2) 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 95 percent of the Standard Proctor Maximum Dry Density (SPMDD).

A 200 mm layer of 19 mm clear stone should be placed between the prepared subgrade and the floor slab to serve as a moisture barrier. Alternatively, free drainage material such as OPS Granular A can be used.

The design of the floor slab should consider the live load of heavy trucks. Adequate joints should be provided in the floor slab to control cracking. The concrete used for foundation should be designed to resist the anticipated harsh conditions due to the presence of salt.

Floor slabs can be designed based on a modulus of subgrade reaction of 54,000 kN/m<sup>3</sup> (~200 pci) on the sand and gravel or fill materials placed and compacted as previously discussed in this report.

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 floor slab is set at least 300 mm above the exterior grade and the grade is sloped away from the structure.

### 2.2.7 Liquefaction Considerations

The subsoil at the site mainly consists of granular materials (i.e., sand, gravel and boulder) with an average N-value over than 20. The water level is at about 7 to 9 m depth. According to the observations from the Niigata Earthquake (1964), the sand with  $N > 20$  are not susceptible to liquefaction (Section 6.6.3.1, CFEM, 2006). Thus, the subsoil at this site is not likely to liquefy.

### 2.2.8 Earthquake Considerations

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

#### *(a) 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 consisted of sand and gravel, and sand followed by boulder/broken rock. The foundations will be founded in the sand and gravel. The reported N-values for the soil below the founding level ranged from 3 to >100.

#### *(b) 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 30m, corrected to a rod energy efficiency of 60% of the theoretical maximum”. It should be noted that the drillers in the Toronto 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.

### *(c) 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 14.3 to 18.6 m deep. The overburden soils mainly consist of sand, gravel, and boulders encountered within a depth of 18.6 m below the ground surface. Therefore, the site classification recommendation would be based on the available information as well as our interpretation of conditions below the boreholes.

### *(d) Site Classification*

Our recommendation is based on the assumption that the soil below the recommended founding elevations is similar to that encountered in the boreholes and has an average N-value between 15 and 50.

Based on the above assumptions and interpretations, and the soil conditions, the Site Class for this site is “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.

## **2.3 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.

## **2.4 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 2 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.

## 2.5 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 G. Qu, 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.**

G. Qu, Ph.D.  
Geotechnical Specialist

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



Encl.

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



## **APPENDIX A: PHOTOGRAPHS**





Photograph 1 SITE VIEW (BH-2 facing northeast)

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Photograph 2     SITE VIEW (BH-4, facing east)

## **APPENDIX B : DRAWING**

DIMENSIONS ARE IN METERS  
AND/OR MILLIMETERS  
UNLESS OTHERWISE SHOWN

WO No. 2009-11032  
Geocres No. 411-247



SITE PLAN AND  
BOREHOLE LOCATIONS

SHEET  
1



KEY MAP  
Not to Scale

LEGEND



Borehole	North	East	Elev.
BH-1	5173528.8	262121.5	417.3
BH-2	5173502.6	262137.0	417.1
BH-3	5173514.0	262162.8	417.2
BH-4	5173539.3	262148.6	417.3
BH-5	5173558.1	262146.8	417.4

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  
Vertical datum : Elevation are GEODETIC based on (CGVD28)



SCALE:  
5m 10m



**Trow Associates Inc.**

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(905) 796-3200

PROJECT TITLE AND LOCATION:

**Proposed New Building at  
Cartier Patrol Yard, Sudbury**

DRAWING TITLE:

**SITE PLAN AND  
BOREHOLE LOCATIONS**

PROJECT NO.

**2009-11032**

DWN.:

**GQ**

SCALE:

**AS NOTED**

CHKD.:

**SM**

DATE:

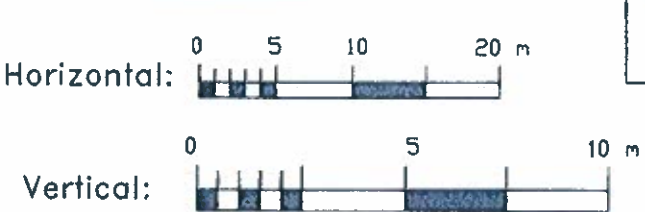
**Dec. 2009**

DWG. No.:

**1**



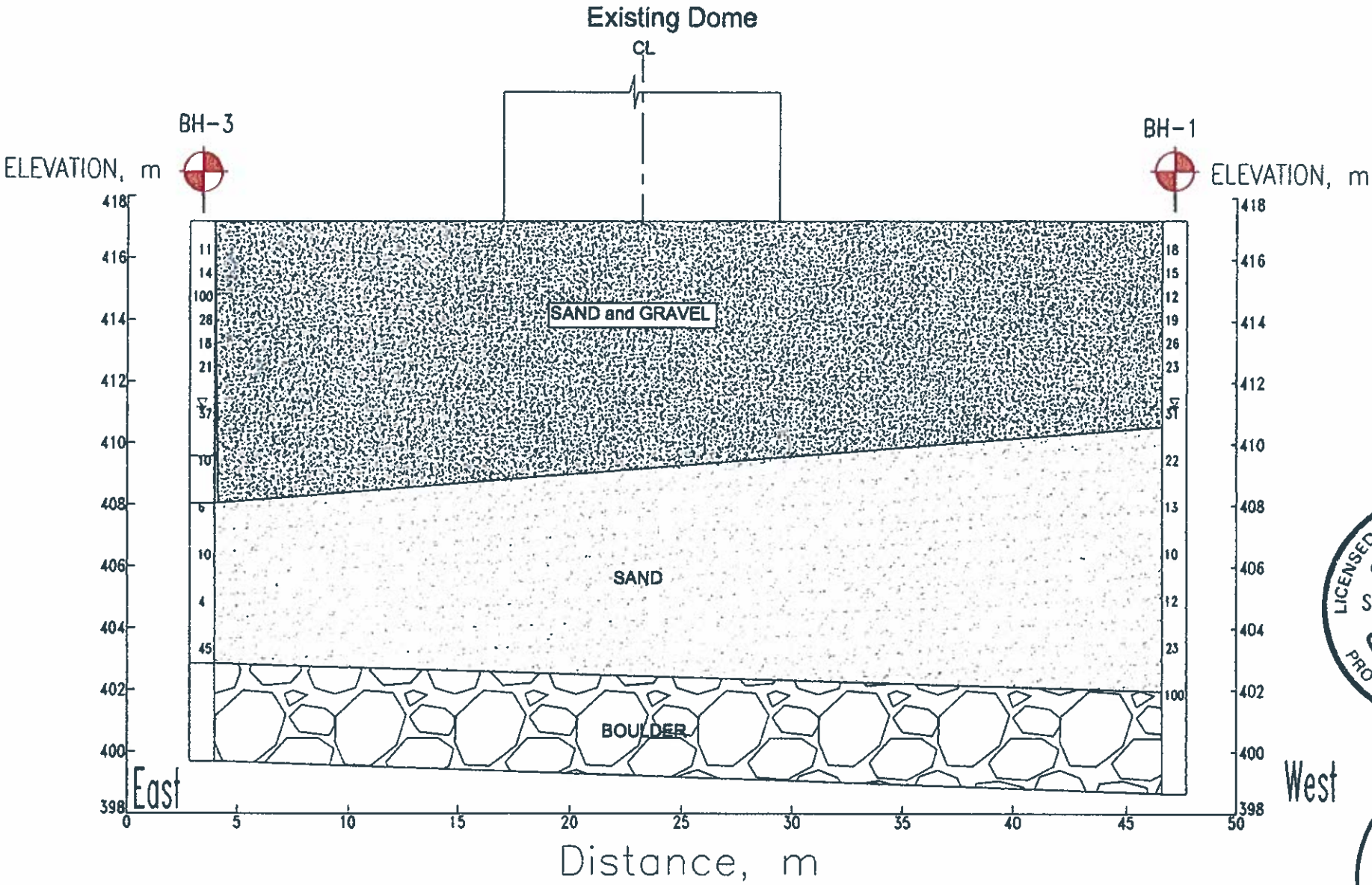
# A-A Cross Section



DIMENSIONS ARE IN METERS  
AND/OR MILLIMETERS  
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WO No. 2009-11032  
Geocres No. 411-247

N  
SHEET  
2



## LEGEND

- BOREHOLE
- Water Level

## NOTES

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing to be read with subject report.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration only.
- Borehole locations are approximate.
- Water level was assumed at where the wet-spoon was first encountered during borehole drilling in November 2009.



REVISION	DATE	BY	DESCRIPTION

## SOIL STRATA SYMBOLS

- SAND
- BOULDER
- SAND AND GRAVEL

**Trow Associates Inc.**

56 QUEEN STREET EAST, SUITE 301  
BRAMPTON, ONTARIO, L6V 4M8  
(905) 796-3200

PROJECT TITLE AND LOCATION:

**Proposed New Building at  
Cartier Patrol Yard,  
Sudbury**

DRAWING TITLE:

**A-A CROSS-SECTION**

PROJECT NO.	2009-11032	DWN.	GQ
SCALE	AS NOTED	CHKD.	SM
DATE	Dec. 2009	DWG. No.	2

# B-B Cross Section

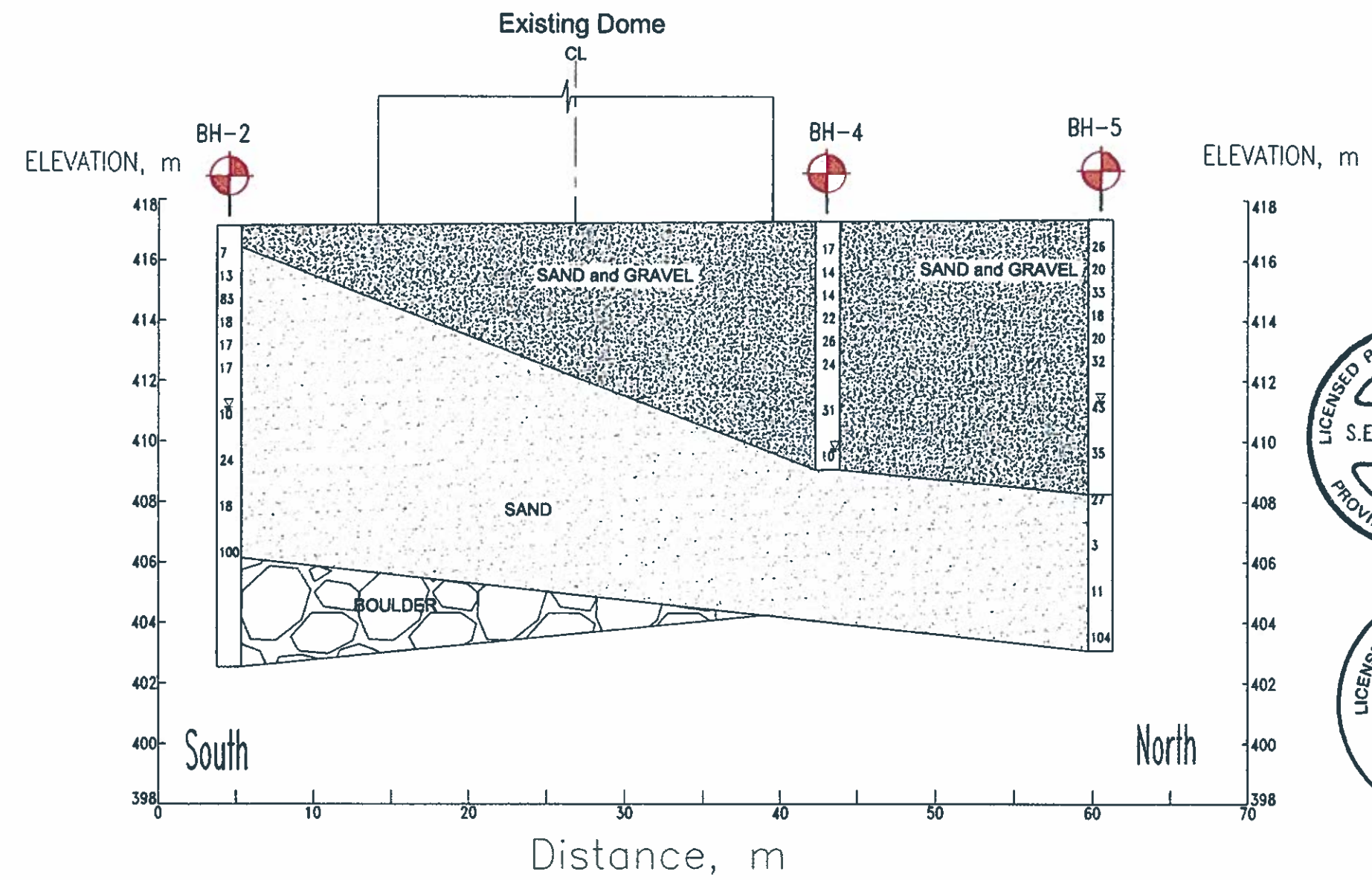
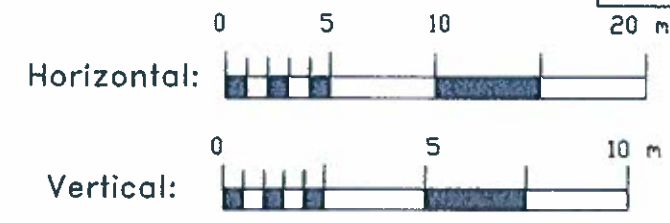
DIMENSIONS ARE IN METERS  
AND/OR MILLIMETERS  
UNLESS OTHERWISE SHOWN

WO No. 2009-11032  
Geocres No. 411-247



SHEET

3



## LEGEND

- BOREHOLE
- Water Level

## -NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing to be read with subject report.
- This drawing is for subsurface information only.
- Surface details and features are for conceptual illustration only.
- Borehole locations are approximate.
- Water level was assumed at where the wet-spoon was first encountered during borehole drilling in November 2009.



REVISIONS	DATE	BY	DESCRIPTION

SOIL STRATA SYMBOLS:	SAND	SAND AND GRAVEL
	BOULDER	

**TROW Associates Inc.**  
56 QUEEN STREET EAST, SUITE 301  
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PROJECT TITLE AND LOCATION:  
**Proposed New Building at  
Cartier Patrol Yard,  
Sudbury**

DRAWING TITLE:  
**B-B CROSS-SECTION**

PROJECT NO. <b>2009-11032</b>	DWN.: GQ
SCALE: AS NOTED	CHKD.: SM
DATE: Dec. 2009	DWG. No. 3

## **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  $\bar{N}$ .

**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 COMPOSITION AND STRUCTURAL 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
$\sigma$	kPa	TOTAL NORMAL STRESS
$\sigma'$	kPa	EFFECTIVE NORMAL STRESS
$\tau$	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
$\epsilon$	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	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
$c_a$	1	RATE OF SECONDARY CONSOLIDATION
$c_v$	$\text{m}^2/\text{s}$	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
$T_v$	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
$\sigma'_{vo}$	kPa	EFFECTIVE OVERBURDEN PRESSURE
$\sigma'_p$	kPa	PRECONSOLIDATION PRESSURE
$\tau_f$	kPa	SHEAR STRENGTH
$c'$	kPa	EFFECTIVE COHESION INTERCEPT
$\phi'$	°	EFFECTIVE ANGLE OF INTERNAL FRICTION
$c_u$	kPa	APPARENT COHESION INTERCEPT
$\phi_u$	°	APPARENT ANGLE OF INTERNAL FRICTION
$\tau_R$	kPa	RESIDUAL SHEAR STRENGTH
$\tau_r$	kPa	REMOULDED SHEAR STRENGTH
$S_i$	1	SENSITIVITY = $c_u / \tau_r$

## PHYSICAL PROPERTIES OF SOIL

$P_s$	$\text{kg}/\text{m}^3$	DENSITY OF SOLID PARTICLES	$e$	1, %	VOID RATIO	$e_{\text{min}}$	1, %	VOID RATIO IN DENSEST STATE
$\gamma_s$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF SOLID PARTICLES	$n$	1, %	POROSITY	$I_D$	1	DENSITY INDEX = $\frac{e_{\text{max}} - e}{e_{\text{max}} - e_{\text{min}}}$
$P_w$	$\text{kg}/\text{m}^3$	DENSITY OF WATER	$w$	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
$\gamma_w$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF WATER	$s_r$	%	DEGREE OF SATURATION	$D_n$	mm	N PERCENT – DIAMETER
$P$	$\text{kg}/\text{m}^3$	DENSITY OF SOIL	$w_L$	%	LIQUID LIMIT	$C_u$	1	UNIFORMITY COEFFICIENT
$\gamma'$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF SOIL	$w_p$	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
$P_d$	$\text{kg}/\text{m}^3$	DENSITY OF DRY SOIL	$w_s$	%	SHRINKAGE LIMIT	q	$\text{m}^3/\text{s}$	RATE OF DISCHARGE
$\gamma_d$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF DRY SOIL	$I_p$	%	PLASTICITY INDEX = $(w_L - w_p)$	v	$\text{m}/\text{s}$	DISCHARGE VELOCITY
$P_{\text{sat}}$	$\text{kg}/\text{m}^3$	DENSITY OF SATURATED SOIL	$I_L$	1	LIQUIDITY INDEX = $(w - w_p) / I_p$	i	1	HYDRAULIC GRADIENT
$\gamma_{\text{sat}}$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF SATURATED SOIL	$I_C$	1	CONSISTENCY INDEX = $(w_L - w) / I_p$	k	$\text{m}/\text{s}$	HYDRAULIC CONDUCTIVITY
$P'$	$\text{kg}/\text{m}^3$	DENSITY OF SUBMERGED SOIL	$e_{\text{max}}$	1, %	VOID RATIO IN LOOSEST STATE	j	$\text{kN}/\text{m}^2$	SEEPAGE FORCE
$\gamma'$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF SUBMERGED SOIL						



# RECORD OF BOREHOLE No BH-1

1 OF 1

METRIC

W.P. WO: 2009-11032 GEOCRETS No. 411-241 LOCATION N 5173528.8 E 262121.5 ORIGINATED BY PR  
 DIST HWY 144 BOREHOLE TYPE CME Hollow Stem Auger/Diamond COMPILED BY GQ  
 DATUM Geodetic DATE 11.17.09 - 11.18.09 CHECKED BY SM

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									
								20	40	60	80	100					
417.3																	
0.0	SAND and GRAVEL (GW), trace to some silt, brown, moist to wet, compact to dense		1	AS													38 55 (7)
			2	SS	18												
			3	SS	15												
	- fine sand occurred from 2.3 to 3.0 m depth.		4	SS	12												29 63 (8)
			5	SS	19												
			6	SS	26												
			7	SS	23												
			8	SS	31												54 39 (7)
409.7																	
7.6	SAND (SM), trace to some gravel, trace to some silt, brown, wet, compact to dense		9	SS	22												
			10	SS	13												
			11	SS	10												
	- Wash boring blow 11.3 m ( due to heaving sand )		12	SS	12												0 74 (26)
	- grey sand, very wet		13	SS	23												
	- coarse sand and gravel, grey, very wet		14	SS	100												
402.0																	
15.3	BOULDER / BROKEN ROCK																
	DIAMOND DRILLING STARTED AT ~ 15.3 m DEPTH																
	1st Run (from 15.3 to 15.7 m depth): - no water return;																
	2nd Run (from 15.7 to 16.8 m depth): - 40% water return;																
398.7																	
18.6	3rd Run (from 16.8 to 18.6 m depth): - no water return; BOREHOLE TERMINATED AT ~ 18.6 m DEPTH																
	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. A local benchmark was employed ( PBM748076, Elev=417.367m, Location: Tablet SE Corner 73.4 LT 21+942.7).																

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ON\_MOT\_CARTIER.03.GPJ ON\_MOT\_GDT 3/25/10

# RECORD OF BOREHOLE No BH-2

1 OF 1

METRIC

W.P. WO: 2009-11032 GEOCRETS No. 411-241 LOCATION N 5173502.6 E 262137.0 ORIGINATED BY PR  
DIST                      HWY 144 BOREHOLE TYPE CME Hollow Stem Auger/Diamond COMPILED BY GQ  
DATUM Geodetic DATE 11.19.09 - 11.19.09 CHECKED BY SM

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 (%)  GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    x LAB VANE								WATER CONTENT (%)
417.1							20	40	60	80	100					
0.0	SAND and GRAVEL (GW), brown, moist		1	AS		▽										12 72 (16)
416.3			2	SS	7											
0.8	SAND (SM), trace to some gravel, trace to some dark brown organic silt (possible fill), with suspected cobbles. brown, moist, loose to very dense. - Suspected cobble at split spoon's tip		3	SS	13											
			4	SS	83											
414.1			5	SS	18											
3.1	SAND (SW), trace to some gravel, trace silt. brown, moist, compact.		6	SS	17											
			7	SS	17											
411.0			8	SS	10											
6.1	SAND (SP), trace gravel, trace silt. brown, wet, compact to very dense.		9	SS	24											
	- Wash boring blow 9.14 m ( due to heaving sand )		10	SS	18											
406.1	- Coarse gravel, grey, wet, and suspected boulder and cobble below 10.5 m		11	SS	100											
11.0	BOULDER / BROKEN ROCK															
	DIAMOND DRILLING STARTED AT ~ 11 m DEPTH 1st Run (from 11.0 to 12.2 m depth): - 30% water return; 2nd Run (from 12.2 to 13.1 m depth): - 30% water return; 3rd Run (from 13.1 to 14.6 m depth): - 40% water return; BOREHOLE TERMINATED AT ~ 14.6 m DEPTH															
402.5																
14.6																
<div>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. A local benchmark was employed ( PBM748076, Elev=417.367m, Location: Tablet SE Corner 73.4 LT 21+942.7).</div>																

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. A local benchmark was employed ( PBM748076, Elev=417.367m, Location: Tablet SE Corner 73.4 LT 21+942.7).

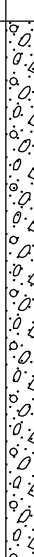


+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

# RECORD OF BOREHOLE No BH-3

1 OF 1

**METRIC**

W.P. WO: 2009-11032 GEOCRETS No. 411-241 LOCATION N 5173514.0 E 262162.8 ORIGINATED BY PR  
 DIST                      HWY 144 BOREHOLE TYPE CME Hollow Stem Auger/Diamond COMPILED BY GQ  
 DATUM Geodetic DATE 11.19.09 - 11.20.09 CHECKED BY SM

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 (%)  GR SA SI CL					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)				
								○ UNCONFINED								+ FIELD VANE			
								● QUICK TRIAXIAL								× LAB VANE			
417.2							20	40	60	80	100								
0.0	SAND and GRAVEL(SW-SM), trace silt, occasional cobble, brown, moist to wet, compact to very dense.		1	AS		▽													
			2	SS	11														
			3	SS	14														
	- suspected cobbles at spoon tip		4	SS	100														
			5	SS	28														
			6	SS	18														
			7	SS	21														
	- wet spoon		8	SS	37														
			9	SS	10														
408.0																			
9.1	SAND (SM), coarse sand, trace to some gravel, trace to some silt, brown to grey, wet, very loose to dense.		10	SS	6														
			11	SS	10														
	- Wash boring blow 12.2 m ( due to heaving sand )		12	SS	4														
402.8			13	SS	45														
14.3	BOULDER / BROKEN ROCK																		
	DIAMOND DRILLING STARTED AT ~ 14.3 m DEPTH																		
	1st Run (from 14.34 to 14.9 m depth): - 10% water return;																		
	2nd Run (from 14.9 to 15.2 m depth): - 10% water return;																		
	3rd Run (from 15.2 to 16.0 m depth): - 10% water return;																		
399.7																			
17.5	4th Run (from 16.0 to 16.6 m depth): - 5% water return; 5th Run (from 16.6 to 17.5 m depth): - 10% water return; BOREHOLE TERMINATED AT ~ 17.5 m																		
	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. A local benchmark was employed ( PBM748076, Elev=417.367m, Location: Tablet SE Corner 73.4 LT 21+942.7).																		

ON\_MOT\_CARTIER 03.GPJ ON\_MOT\_GDT 3/25/10

# RECORD OF BOREHOLE No BH-4

1 OF 1

METRIC

W.P. WO: 2009-11032 GEOCRETS No. 411-241 LOCATION N 5173539.3 E 262148.6 ORIGINATED BY PR  
 DIST HWY 144 BOREHOLE TYPE CME Hollow Stem Auger COMPILED BY GQ  
 DATUM Geodetic DATE 11.20.09 - 11.20.09 CHECKED BY SM

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 (%)		
								20	40	60						80	100	20
417.3																		
410.0	ASPHALT, (~ 38 mm) SAND and Gravel (SP-SM), trace to some silt, dry to wet, compact to dense.		1	AS			416									17 72 (21)		
			2	SS	17													
			3	SS	14													
			4	SS	14													
			5	SS	22		414											
			6	SS	26													
			7	SS	24											27 68 (5)		
			8	SS	31		412											
			9	SS	10		410									30 67 (3)		
409.1	- wet spoon																	
8.2	BOREHOLE TERMINATED AT ~ 8.2 m DEPTH						408											
							406											
							404											
							402											
400.8																		
16.5	DYNAMIC CONE PENETRATION TERMINATED AT ~ 16.5 m DEPTH DUE TO SPOON BOUNCING																	
	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. A local benchmark was employed ( PBM748076, Elev=417.367m, Location: Tablet SE Corner 73.4 LT 21+942.7).																	

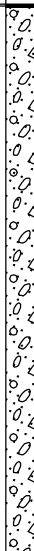
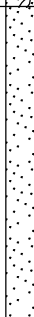
ON\_MOT\_CARTIER.03.GPJ ON\_MOT\_GDT\_3/25/10

# RECORD OF BOREHOLE No BH-5

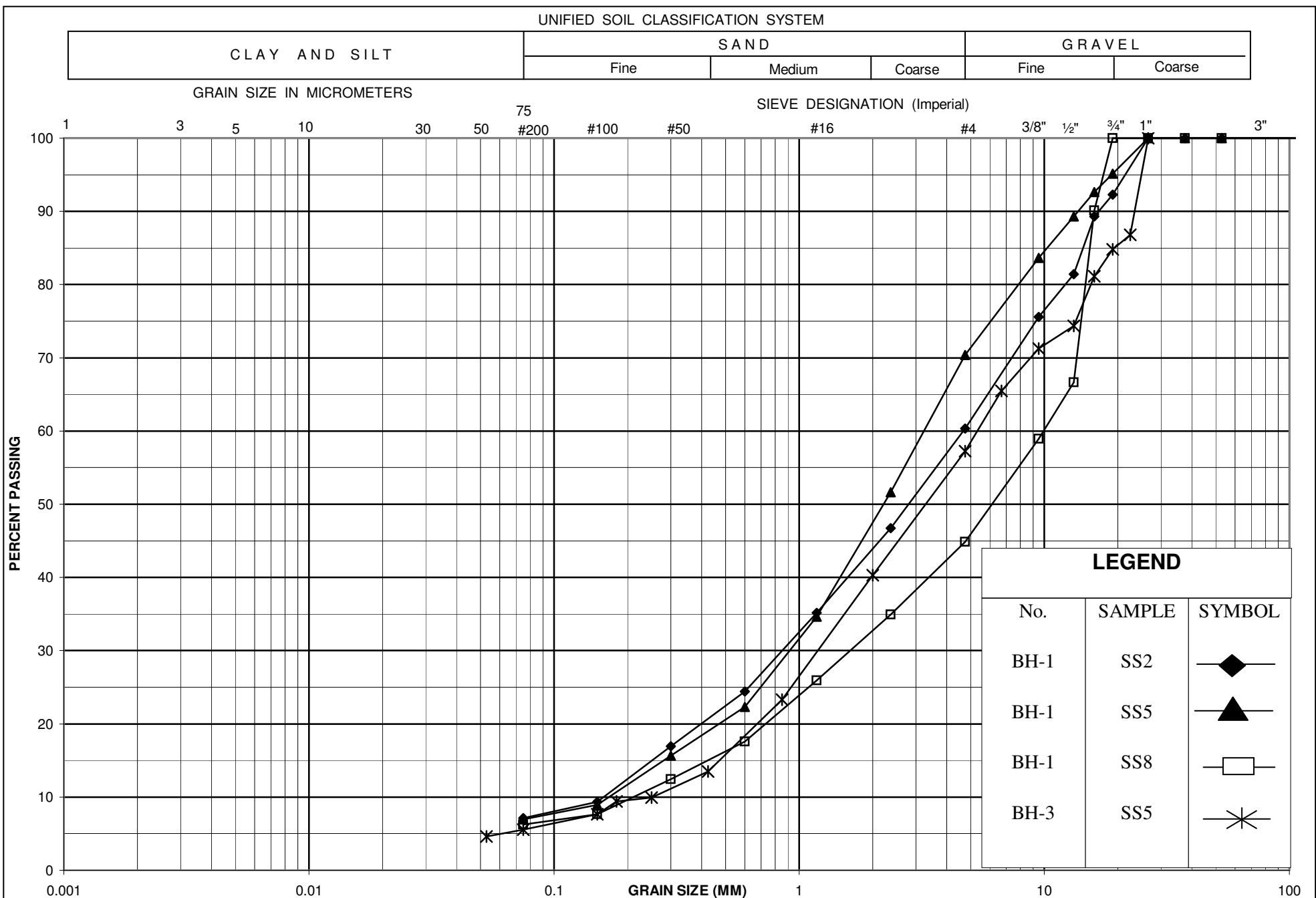
1 OF 1

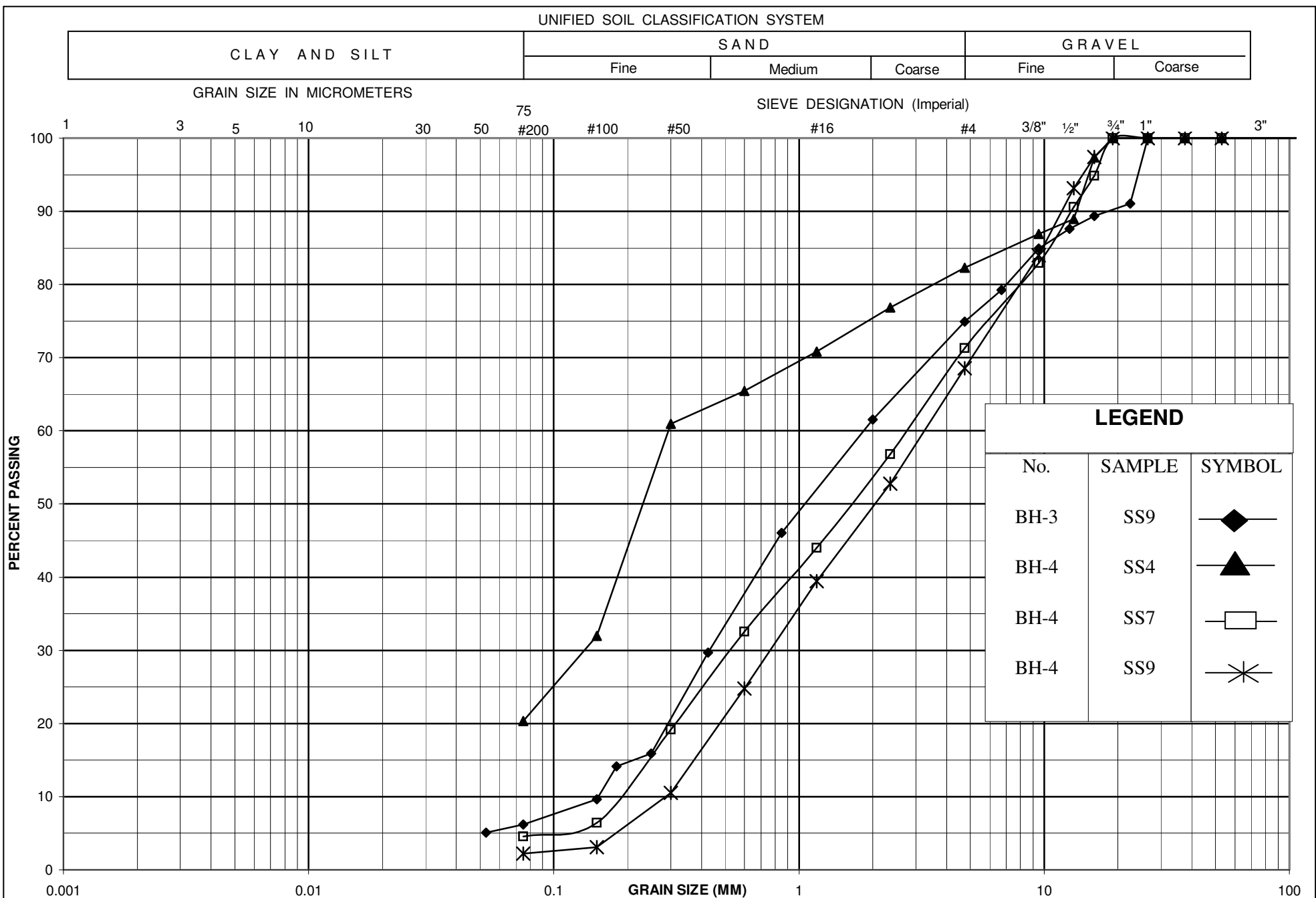
METRIC

W.P. WO: 2009-11032 GEOCRETS No. 411-241 LOCATION N 5173558.1 E 262146.8 ORIGINATED BY PR  
 DIST HWY 144 BOREHOLE TYPE CME Hollow Stem Auger COMPILED BY GQ  
 DATUM Geodetic DATE 11.17.09 - 11.17.09 CHECKED BY SM

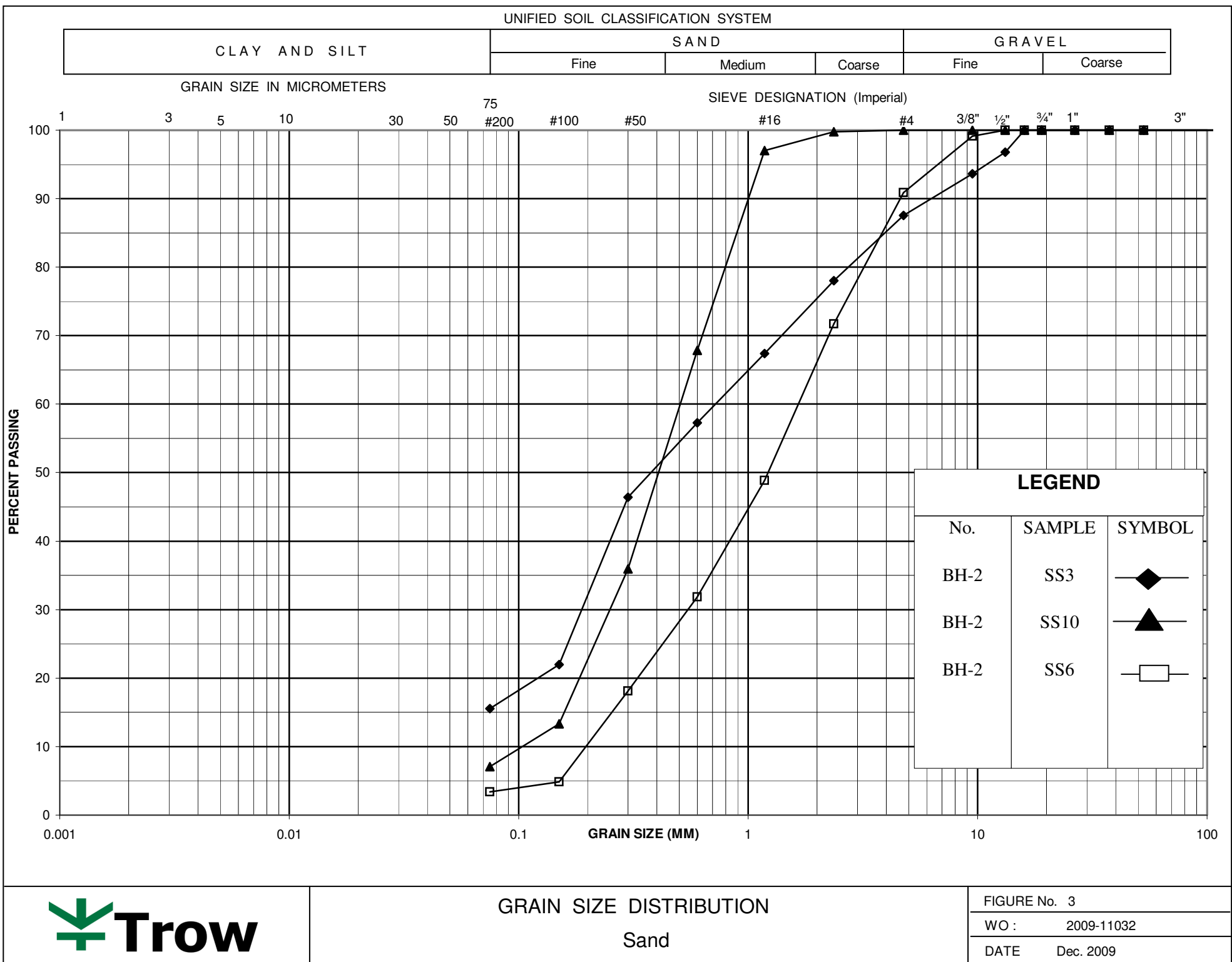
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
417.4								20	40	60	80	100								
410.0	ASPHALT, (~ 40 mm) SAND and GRAVEL (SW-SM), trace to some silt, brown, moist to wet, compact to dense.		1	AS		▽	416													
			2	SS	26															
			3	SS	20															
			4	SS	33															
			5	SS	18			414												
			6	SS	20															
			7	SS	32															
								412												
			9	SS	43															
								410												
			10	SS	35															
408.2								408												
9.1	SAND, coarse sand, trace to some gravel, trace to some silt, brown, wet, very loose to very dense. - Heaving sand occurred below a depth of 9.14 m.		11	SS	27															
			12	SS	3		406													
			13	SS	11															
							404													
			14	SS	104															
403.0																				
14.3	BOREHOLE TERMINATED AT ~ 14.33 m DEPTH  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. A local benchmark was employed ( PBM748076, Elev=417.367m, Location: Tablet SE Corner 73.4 LT 21+942.7).																			

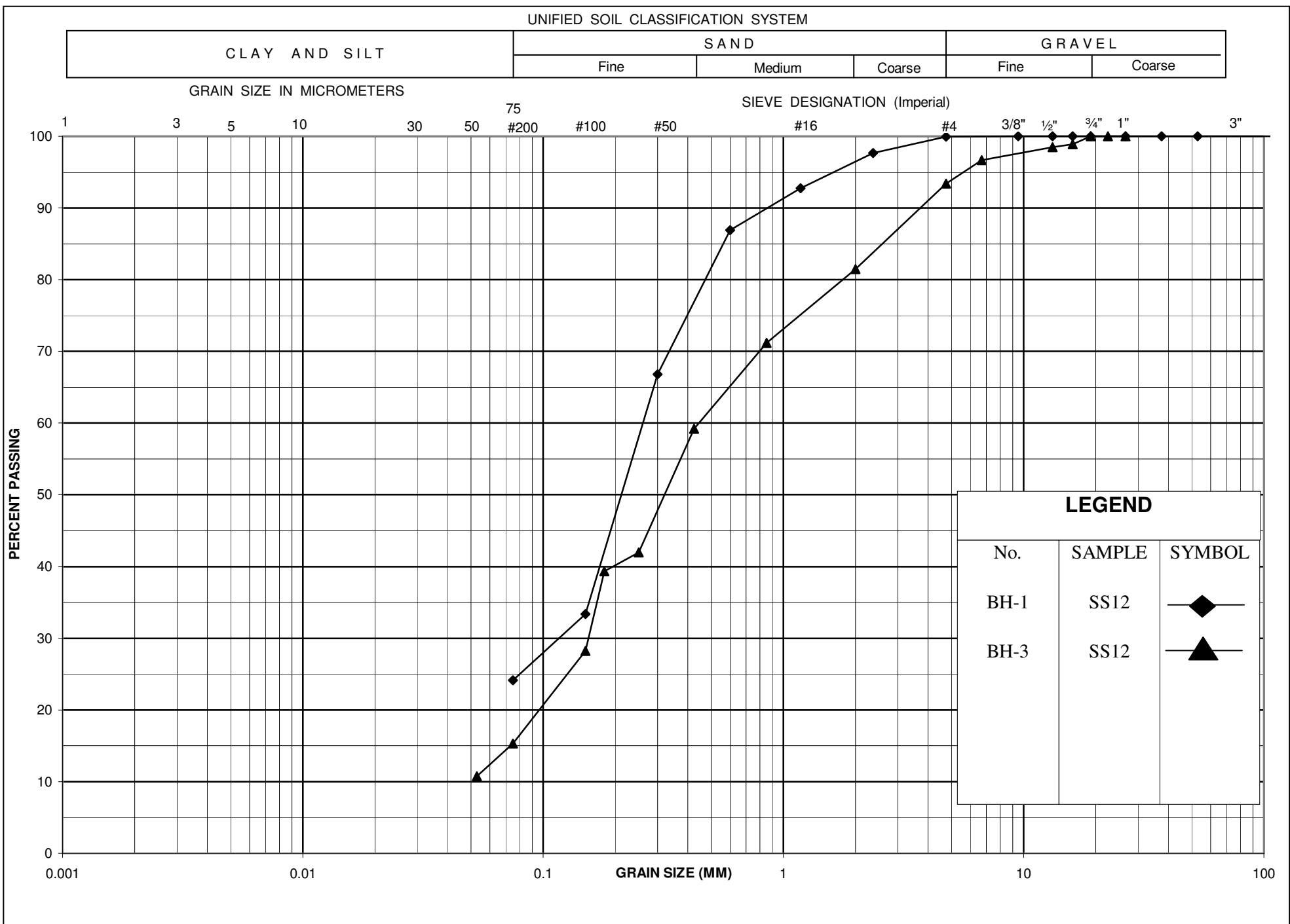
## **Appendix D: LABORATORY DATA**











## **APPENDIX E: BOULDER CORE PHOTOGRAPHS**

(a) Overall



Photograph 1    **BH-1**

( c ) Middle portion



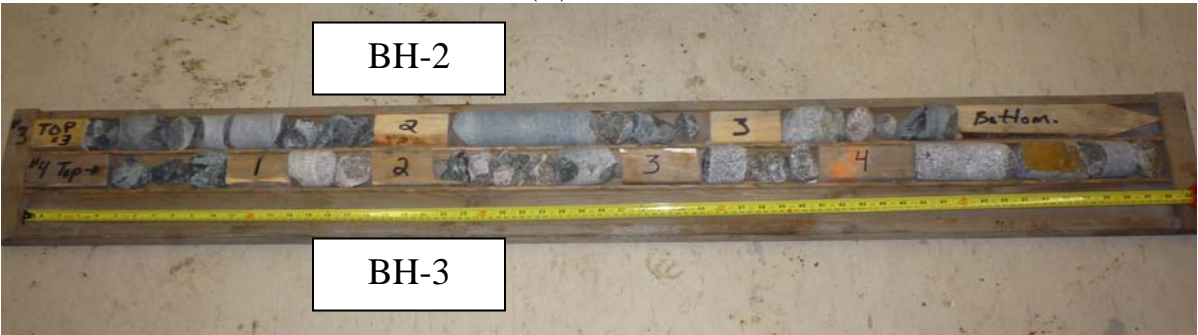
(d) Bottom





Photograph 2    **BH-2 and BH-3**

( a ) Overall

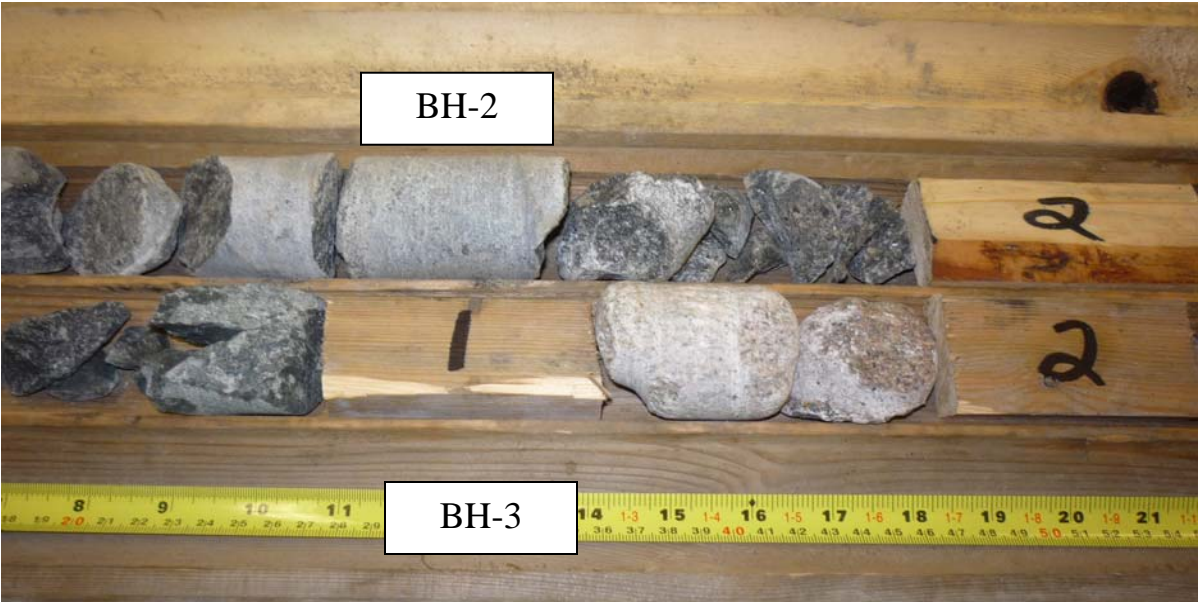


(b) Top



Photograph 2    **BH-2 and BH-3**

(c) Mid -1



( d ) Mid -2





Photograph 2    **BH-2 and BH-3**

( e ) Mid -3



( f ) Bottom

