



# Terraprobe

*Consulting Geotechnical & Environmental Engineering  
Construction Materials Inspection & Testing*

**FOUNDATION INVESTIGATION & DESIGN REPORT  
OVERHEAD SIGN SUPPORT STRUCTURES  
HIGHWAY 406 TWINNING  
PORT ROBINSION ROAD TO EAST MAIN STREET  
AGREEMENT No. 2008-E-0016, W.P. 280-99-00  
GEOCRES NO: 30M3-268**

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File No. 1-09-4135  
January 25, 2011

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**FOUNDATION INVESTIGATION REPORT  
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**PART 1: FACTUAL INFORMATION**

**1 INTRODUCTION**

This report presents the factual findings obtained from foundation investigations conducted on East Main Street and along the alignment of the proposed Highway 406 SBL for overhead sign support structures. This project extends from East Main Street, City of Welland to about 1.0 km north of Port Robinson Road, City of Thorold, Ontario.

The purpose of this investigation was to explore the subsurface conditions at the overhead sign locations and based on the data obtained, to provide borehole location plans, records of boreholes, laboratory test results and a description of the subsurface conditions.

Terraprobe conducted the investigation as a sub-consultant to Giffels Associates Ltd./IBI Group, under the Ministry of Transportation Ontario (MTO) Agreement Number 2008-E-0016.

**2 SITE DESCRIPTION & PHYSIOGRAPHY**

The south limit of the project is Sta. 10+000 located at the existing Highway 406 terminus at East Main Street in the City of Welland. East Main Street gradually slopes downwards from west to east towards the west entrance of the East Main Street Tunnel. The original ground approaching the tunnel was cut about 10 m (from about elevation 183 m to 173 m) to construct the tunnel access.

The north limit of this project is about Sta. 6+400 approximately 1.0 km north of Port Robinson Road in the City of Thorold. This approximately 6.5 km long route traverses across generally flat terrain and crosses Woodlawn Road, Merritt Road and Port Robinson Road. There is an at grade railway intersection (Trillium Railway) about 265 m south of Woodlawn Road. The alignment also crosses the Welland River and Old Welland Canal.

The site is located between the Niagara Escarpment and Lake Erie in the physiographic region of Southern Ontario referred to as the Haldimand Clay Plain. The Haldimand Clay Plain is best described as falling into a series of parallel belts with the highest ground adjacent to the Escarpment. Generally this region is flat and poorly drained although it includes several distinctive



landforms such as dunes, cobble, clay and sand beaches, limestone pavements and back-shore wetland basins<sup>1</sup>.

The Niagara Region is underlain by a sequence of very gently south-dipping dolostones, limestones, shales and sandstones overlying Precambrian basement rock. The key elements in the bedrock geology of the region are the multiple layers of softer sedimentary limestones, shale, sandstone and dolostone.

The bedrock units within the project limits consist of the Salina Formation and Guelph Formation of Upper Silurian Age<sup>2</sup>. The Salina Formation consists essentially of easily weathered, grey, very finely crystalline, laminated argillaceous dolostone with grey, calcareous shale partings and gypsum veins and lenses of varying thicknesses. The Guelph Formation consists essentially of unweathered, grey, laminated argillaceous dolostone.

### **3 SITE INVESTIGATION AND FIELD TESTING**

The site investigation and field testing for this project were carried from October 19, 2010 to October 20, 2010 and consisted of drilling and sampling four boreholes to depths ranging from 8.1 m to 8.5 m. The boreholes were numbered OS1, OS2, OS3 and OS5 and their approximate locations are shown on the attached Borehole Locations Drawings in Appendix C.

An overhead sign was originally proposed at the bullnose of Ramp East Main E-406 N and Borehole OS4 was staked out at this location. However, this ramp was removed from this project and consequently Borehole OS4 was not drilled.

The borehole locations were marked in the field by surveyors from Callon Dietz Inc. who also provided Terraprobe with their coordinates and geodetic elevations. Utility clearances and permits were obtained by Terraprobe prior to drilling.

Samples of the overburden soils were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT), as specified in ASTM Method D1586. In the cohesive (clayey) deposits the undrained shear strength of the soil was measured in-situ by means of field vane tests using an MTO type field vane. Ground water conditions in the open boreholes were observed throughout the drilling operations and upon completion of the boreholes.

The drilling, sampling and in-situ testing operations were observed on a full time basis by members of Terraprobe's technical staff who logged the boreholes and processed the recovered soil samples for transport to Terraprobe's Brampton laboratory for further examination and testing.

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<sup>1</sup> Chapman and Putnam, "The Physiography of South Ontario", 3<sup>rd</sup> Edition, 1984.

<sup>2</sup> Ontario Division of Mines, "Quaternary Geology Of The Welland Area", Preliminary Map P.796, 1972.



#### **4 LABORATORY TESTING**

The recovered soil samples were subjected to Visual Identification (VI) and natural moisture content determination. Select samples were also subjected to a laboratory testing programme consisting of gradation analysis, Atterberg Limits tests and unit weight. The results of this testing program are shown on the Record of Borehole sheets in Appendix A and the Figures in Appendix B.

#### **5 DESCRIPTION OF SUBSURFACE CONDITIONS**

Reference is made to the Record of Borehole sheets in Appendix A for details of the encountered soil stratigraphy. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets governs any interpretation of the site conditions.

In general, the site is underlain by a asphalt concrete, fill material (sand and gravel to gravel and sand, and silty clay), and native overburden deposits of silty clay, clayey silt and silty clay to clayey silt till.

##### **5.1 Asphalt Concrete**

Boreholes OS1 and OS3 were drilled through the existing pavement of East Main Street. These boreholes encountered a flexible pavement consisting of 310 mm to 330 mm of asphaltic concrete.

##### **5.2 Fill – Sand and Gravel**

Fill material ranging in composition from sand and gravel to gravel and sand was encountered in all of the boreholes. On East Main Street the granular fill was encountered below asphalt concrete in Boreholes OS1 and OS3 and ranged from 1070 mm to 1090 mm in thickness.

Boreholes OS2 and OS5 were drilled through the gravel shoulders of the existing Highway 406. These two boreholes encountered granular fill ranging from 610 to 680 mm in thickness.

The grain size distribution curves of tested samples of this granular fill are presented in Figure B1. These results show a grain size distribution consisting of 35-44% gravel, 43-54% sand, 10-13% silt and 0-4% clay size particles.

Standard Penetration tests in the granular fill gave 'N' values that ranged from 19 to more than 100 blows for 0.3 m penetration. Based on these results the granular fill is considered to have a compact to very dense relative density. The moisture content of samples of this fill ranged from 3% to 8% by weight.



### 5.3 Fill – Silty Clay

Silty clay fill material was encountered only in Boreholes OS2 and OS3 where it extends to depths ranging from 1.7 m (Elev. 180.4 m) to 2.1 m (Elev. 175.0 m) below ground surface.

The grain size distribution curve of a sample of this fill is shown in Figure B2. The results show a grain size distribution consisting of 5% gravel, 10% sand, 39% silt and 46% clay size particles.

A sample was also subjected to an Atterberg Limits test and the results are plotted on the plasticity chart in Figure B3. The summarized index values from this test are presented below.

Liquid Limit:	44%
Plastic Limit:	23%
Plasticity Index:	21%
Natural Moisture Content:	22%

These values are characteristic of clayey soils of intermediate plasticity.

Standard Penetration tests in the silty clay fill gave 'N' values that ranged from 6 to 19 blows for 0.3 m penetration. Based on these results the fill is considered to have a firm to very stiff consistency. The moisture content of samples of the silty clay fill ranged from 12% to 30% by weight.

### 5.4 Silty Clay

A native silty clay deposit was encountered in Boreholes OS1, OS2 and OS5. The boreholes were terminated in this deposit at depths of 8.5 m below ground surface or at elevations ranging from 174.3 m to 173.6 m.

The results of grain size distribution tests conducted on samples obtained from this deposit are illustrated in Figures B4 and B5. These results show a grain size distribution consisting of 0% gravel, 1-4% sand, 51-68% silt and 28-47% clay size particles.

Samples were also subjected to Atterberg Limits tests and the results are presented on the plasticity charts, Figures B6 and B7. The index values from these tests are summarized below:

Liquid Limit:	24-39%
Plastic Limit:	15-23%
Plasticity Index:	9-18%
Natural Moisture Content:	20-23%

These values indicate that the silty clay has a generally low to intermediate plasticity.

Standard Penetration tests in this deposit gave 'N' values that ranged from 9 to 28 blows for 0.3 m penetration and field vane tests gave in-situ undrained shear strengths in excess of 120 kPa. Based on these results the consistency of the silty clay is stiff to very stiff. The moisture content of samples of the silty clay ranged from 20% to 26% by weight and the unit weight of selected samples ranged from 20.1 to 20.8 kN/m<sup>3</sup>.



## 5.5 Clayey Silt

A 0.8 m thick layer of clayey silt containing some sand and trace gravel was encountered in Borehole OS3 where it extends to a depth of 2.9 m (Elev. 174.2 m) below ground surface.

The grain size distribution curve of a tested sample of the clayey silt is illustrated in Figure B8. The results show a grain size distribution consisting of 3% gravel, 18% sand, 58% silt and 21% clay size particles.

A sample of this soil was also subjected to an Atterberg Limits test and the results are shown on the plasticity chart, Figure B9. The index values from this test are summarized below:

Liquid Limit:	21%
Plastic Limit:	14%
Plasticity Index:	7%
Natural Moisture Content:	14%

These results are typical for low plasticity clayey silt soils.

An SPT 'N' value of 10 blows for 0.3 m penetration was obtained from a Standard Penetration test conducted in this deposit. Based on this result, the deposit is considered to have a stiff consistency. The moisture content of a sample from this deposit is 14% by weight and its unit weight is 21.8 kN/m<sup>3</sup>.

## 5.6 Silty Clay to Clayey Silt Till

A deposit of silty clay to clayey silt till was encountered in Borehole OS3 extending at least to a borehole termination depth of 8.1 m (Elev. 169.0 m) below ground surface.

The grain size distribution curve of a tested sample from this stratum is depicted in Figure B10. These results show a grain size distribution consisting of 12% gravel, 19% sand, 49% silt and 20% clay size particles. Till soils will also contain random cobble and boulder inclusions.

A sample was also subjected to an Atterberg Limits test and the results are plotted on the plasticity chart, Figure B11. The index values from these tests are summarized below:

Liquid Limit:	22%
Plastic Limit:	14%
Plasticity Index:	8%
Natural Moisture Content:	12%

These values are typical of clayey soils of low plasticity.

Standard Penetration tests in this stratum yielded 'N' values ranging from 11 to 42 blows per 0.3 m penetration and a field vane test gave an in-situ undrained shear strength in excess of 120 kPa. Based on these results, the silty clay to clayey silt till is considered to have a stiff to hard consistency. The moisture content of samples from this deposit varies from 12% to 15% by weight.



## 5.7 Water Levels

The ground water table was estimated based on our review of moisture contents of the retrieved samples. This interpretation indicates a phreatic surface that generally follows the ground surface topography. The ground water table on East Main Street exists at about Elev.  $\pm 181$  m at Borehole OS1 and it falls to the west where it is estimated to be Elev.  $\pm 174.5$  m at Borehole OS3 just west of the tunnel. Along the current Highway 406 alignment the water table is at about Elev.  $\pm 180$  m at Borehole OS2 rising gradually to about Elev.  $\pm 181$  m at Borehole OS5.

Perched water can also be expected to occur where permeable layers of sand and gravel are underlain by relatively impermeable layers of silty clay and clayey silt soils.

All ground water observations at this site are short term and the levels are expected to fluctuate seasonally and after severe weather events.

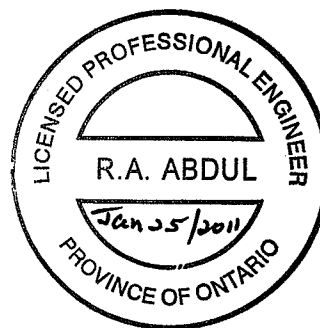
## 5.8 Miscellaneous

The drilling, sampling and in-situ testing operations were conducted with a truck mounted drill rig owned and operated by DBW Drilling Limited of Ajax, Ontario. The boreholes were advanced using solid stem auger drilling techniques.

Mr. Phil Khuu, B.A.T., observed and recorded the field work and the laboratory testing was performed at Terraprobe's Brampton laboratory. The report was written by Rehman Abdul, P.Eng. and reviewed by Michael Tanos, P.Eng.

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OVERHEAD SIGN SUPPORT STRUCTURES  
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**PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**6 GENERAL**

This report provides geotechnical recommendations for the design of overhead sign support structures. Overhead signs are required on East Main Street at Sta. 9+755 and Sta. 9+930 and on the proposed Highway 406 SBL at approximately Sta. 10+095 and Sta. 10+700. The site is located in the City of Welland, Ontario.

The discussion and recommendations presented in this report are based on our understanding of the project and on the factual data obtained in the course of the investigations.

**7 SUMMARIZED SUBSURFACE CONDITIONS**

In general, the site is underlain by a asphalt concrete, fill material (sand and gravel to gravel and sand and silty clay), and native overburden deposits of silty clay, clayey silt and silty clay to clayey silt till.

The ground water table was estimated based on our review of moisture contents of the retrieved samples. This interpretation indicates a phreatic surface that generally follows the ground surface topography. The ground water table on East Main Street exists at about Elev.  $\pm 181$  m at Borehole OS1 and it falls to the west towards the tunnel where it is estimated to be Elev.  $\pm 174.5$  m at Borehole OS3. Along the current Highway 406 alignment the water table is at about Elev.  $\pm 180$  m at Borehole OS2 rising gradually to about Elev.  $\pm 181$  m at Borehole OS5.

Perched water can also be expected to occur where permeable layers of sand and gravel are underlain by relatively impermeable layers of silty clay and clayey silt soils. The groundwater will also fluctuate seasonally and after severe weather events.

**8 DESIGN CONSIDERATIONS**

Generally, overhead sign support structures can be supported on caissons (i.e. drilled and cast-in-place concrete pile) foundations. The depth of the caisson would vary depending on the design of the overhead sign, and the subsurface conditions encountered. The design can be carried out in accordance with the following documents and papers.



- Canadian Highway Bridge Design Code and Commentary (2000). CAN/CSA-S6-00 and S6.1-00.
- Ministry of Transportation, Ontario (2007) “Sign Support Manual”, Bridge Office, Engineering Standards Branch.
- BROMS, B.B.: Lateral Resistance of Piles in Cohesive Soils, Journal of the Soil Mechanics and Foundation Division, ASCE, Vol. 90 No. SM2, Paper No. 3825, March 1964.
- BROMS, B.B.: Lateral Resistance of Piles in Cohesive Soils, Journal of the Soil Mechanics and Foundation Division, ASCE, Vol. 90 No. SM3, Paper No. 3909, March 1964.
- BROMS, B.B.: Design of Laterally Loaded Piles, Journal of the Soil Mechanics and Foundation Division, ASCE, Vol. 91. Paper No. SM3, May 1965.

The recommended soil parameters for the design of augered caisson foundation units are given in Table 8.0.

**Table 8.0 – Recommended Soil Parameters**

BH No.	Elevation (m)		Type of Soil	Consistency or Compactness Condition	$q_u$ (kPa)	$\phi$ (degrees)	$\gamma$ (kN/m <sup>3</sup> )	Water Level Depth (Elevation) (m)
	From	To						
OS-1	182.3	181.2	Fill Cohesive	Compact to V/Dense Stiff to Very Stiff	-	33	19.0	1.6 <sup>♦</sup>
	181.2	174.1			200	-	20.5	(181.0) <sup>♦</sup>
OS-2	182.1	181.5	Fill	Dense	-	33	19.0	2.1 <sup>♦</sup>
	181.5	180.4	Fill	Stiff to Very Stiff	100	-	19.0	(180.0) <sup>♦</sup>
	180.4	173.6	Cohesive	Stiff to Very Stiff	200	-	20.5	
OS-3	176.8	175.7	Fill	Dense to Very Dense	-	33	19.0	2.6 <sup>♦</sup> (174.5) <sup>♦</sup>
	175.7	175.0	Fill	Firm	50	-	18.5	
	175.0	174.2	Cohesive	Stiff	100	-	21.0	
	174.2	169.0	Cohesive	Stiff to Hard	200	-	21.0	
OS-5	182.8	182.1	Fill	Compact	-	33	19.0	1.8 <sup>♦</sup>
	182.1	179.0	Cohesive	Stiff to Very Stiff	300	-	20.0	(181.0) <sup>♦</sup>
	179.0	174.3	Cohesive	Stiff	200	-	20.0	

♦ = estimated

The notations used in Table 8.0 are defined below:

- $\phi$  = apparent angle of friction for cohesionless soils in degrees.  
 $q_u$  = unconfined compressive strength in kPa ( $q_u = 2 \times C_u$ ) for cohesive soils (estimated based on field and laboratory vane tests and correlations with SPT “N” values).  
 $C_u$  = undrained shear strength in kPa.  
 $\gamma$  = bulk unit weight of soil in kN/m<sup>3</sup>.

The subsurface conditions indicate competent soils of uniform composition and we recommend that the footings be proportioned in accordance with Standard Drawings SS118-3, SS118-4 and/or SS118-5 of MTO’s sign support manual dated April 2007. In order to take into account frost action and surficial disturbance, the ultimate lateral passive resistance in front of a caisson and caisson sidewall adhesion within the upper 1.2 m below final grade, should be neglected in the



foundation design. It is also recommended that all surficial weak or variable soils be neglected in determining lateral resistance.

When designing for the portion of a caisson below the groundwater level, the submerged unit weight should be used.

The required depth of the drilled shaft will be governed by lateral loads, including wind loads. Appropriate load and resistance factors should be applied for caisson design.

## **9 CONSTRUCTION CONSIDERATIONS**

The boreholes indicate the presence of sand and gravel and gravel and sand fill material, silty clay fill, and native deposits of silty clay, clayey silt and silty clay to clayey silt till. The glacial till deposit can be expected to contain random cobbles and boulders. Cobbles and boulders if encountered during excavation can increase the level of construction effort required for caisson installation, such as increasing the time required for drilling etc. Bidders should be advised of these conditions and be required to provide adequate equipment to handle the obstructions.

The cohesive silty clay fill material, silty clay, clayey silt and silty clay to clayey silt till are expected to be self-supporting. Due to the relatively low permeability of these strata minor water seepage is expected in caisson holes, even below the groundwater table.

Where relatively more pervious and granular soils (e.g. sand and gravel and gravel and sand) are encountered dry cave-ins may occur in unsupported holes made in these cohesionless soils above the groundwater table. It is therefore recommended that temporary liner(s) be available on site to support the caisson sidewalls and to provide seepage cut-off as and where required.

The concrete should be poured expeditiously on completion of the caisson hole. It is recommended that the concrete be placed by the tremie method in accordance with OPSS PROV 904 as soon as the hole reaches its desired depth. The liner should be withdrawn as concrete is placed. During liner withdrawal, the level of concrete in the caisson hole must always be at least 0.6 m above the bottom of the temporary liner.

We recommend that the following notes be included in the contract documents:

- At the foundation locations the strata may consist of fill material (sand and gravel and gravel and sand, silty clay), and native deposits of silty clay, clayey silt and silty clay to clayey silt till. Groundwater is likely to be encountered above the base of the excavations.
- The contractor shall maintain the stability of the soil along the sides and in the bases of the holes for the concrete footings at all times from the commencement of their construction to the placing of the concrete.
- Dewatering and/or temporary liners may be required to maintain a sufficiently dry condition for proper construction of the caisson hole and the placement of concrete.



Caisson construction should be monitored by qualified geotechnical personnel to verify the soil conditions and to confirm that those conditions are consistent with the design assumptions in this report. Sign support structures should be constructed in accordance with OPSS 915 and excavations should be undertaken in accordance with OPSS 902. Caissons should be constructed in accordance with OPSS 903.

**Terraprobe Inc.**



*Rahman Abdul*

Engineering Analysis and Report Preparation by:  
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Senior Geotechnical Engineer

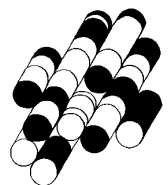
*Michael Tanos*

Report Reviewed by:  
Michael Tanos, P.Eng.,  
Review Principal



# TABLES

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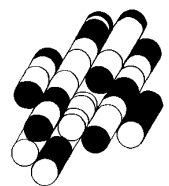
**TABLE 1**

<b>DOCUMENT</b>	<b>TITLE</b>
OPSS 902	Construction Specification for Excavation & Backfilling of Structures
OPSS 903	Construction Specification for Deep Foundations
OPSS PROV 904	Construction Specification for Concrete Structures
OPSS 915	Construction Specification for Sign Support Structures



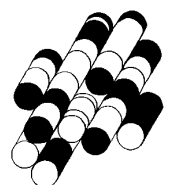
# APPENDICES

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# APPENDIX A

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## **LIMITATIONS AND RISK**

### **Procedures**

The soil conditions were confirmed at the borehole and test pit locations only and conditions may vary between and beyond the boreholes. The boundaries between the various strata as shown on the logs are based on non-continuous sampling. These boundaries represent an inferred transition between the various strata, rather than a precise plane of stratigraphic change.

This investigation has been carried out using investigation techniques and engineering analysis methods consistent with those ordinarily exercised by Terraprobe and other engineering practitioners, working under similar conditions and subject to the time, financial and physical constraints applicable to this project. The discussions and recommendations that have been presented are based on the factual data obtained.

It must be recognized that there are special risks whenever engineering or related disciplines are applied to identify subsurface conditions. Even a comprehensive sampling and testing programme implemented in accordance with the most stringent level of care may fail to detect certain conditions. Terraprobe has assumed for the purposes of providing design parameters and advice, that the conditions that exist between sampling points are similar to those found at the sample locations. The conditions that Terraprobe has interpreted to exist between sampling points can differ from those that actually exist.

It may not be possible to drill a sufficient number of boreholes or sample and report them in a way that would provide all the subsurface information that could affect construction costs, techniques, equipment and scheduling. Contractors bidding on or undertaking work on the project should be directed to draw their own conclusions as to how the subsurface conditions may affect them, based on their own investigations and their own interpretations of the factual investigation results, cognizant of the risks implicit in the subsurface investigation activities.

### **Changes In Site And Scope**

It must be recognized that the passage of time, natural occurrences, and direct or indirect human intervention at or near the site have the potential to alter subsurface conditions. Groundwater levels are particularly susceptible to seasonal fluctuations.

The design advice is based on the factual data obtained from this investigation made at the site by Terraprobe and are intended for use by the owner and its retained designers in the design phase of the project. If there are changes to the project scope and development features, or there is any additional information relevant to the interpretations made of the subsurface information, the geotechnical design parameters and comments relating to constructibility issues and quality control may not be relevant or complete for the revised project. Terraprobe should be retained to review the implications of such changes with respect to the contents of this report

This report was prepared for the express use of the Ministry of Transportation, its retained design consultants and Giffels Associates Ltd./IBI Group. It is not for use by others. This report is copyright of Terraprobe Inc. and no part of this report may be reproduced by any means, in any form, without the prior written permission of Terraprobe Inc. The Ministry of Transportation, its retained design consultants and Giffels Associates Ltd./IBI Group, are authorized users.

## 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

**JOINTING 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

$m_v$	kPa <sup>-1</sup>	COEFFICIENT OF VOLUME CHANGE
$C_c$	1	COMPRESSION INDEX
$C_s$	1	SWELLING INDEX
$C_\alpha$	1	RATE OF SECONDARY CONSOLIDATION
$C_v$	m <sup>2</sup> /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
$S_r$	1	SENSITIVITY = $c_u / \tau_r$

## PHYSICAL PROPERTIES OF SOIL


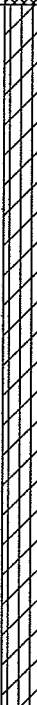
$\rho_s$	kg/m <sup>3</sup>	DENSITY OF SOLID PARTICLES	e	1%	VOID RATIO	$e_{mh}$	1%	VOID RATIO IN DENSEST STATE
$\gamma_s$	kN/m <sup>3</sup>	UNIT WEIGHT OF SOLID PARTICLES	n	1%	POROSITY	$I_D$	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{mh}}$
$\rho_w$	kg/m <sup>3</sup>	DENSITY OF WATER	w	1%	WATER CONTENT	D	mm	GRAIN DIAMETER
$\gamma_w$	kN/m <sup>3</sup>	UNIT WEIGHT OF WATER	$S_r$	%	DEGREE OF SATURATION	$D_n$	mm	n PERCENT - DIAMETER
$\rho$	kg/m <sup>3</sup>	DENSITY OF SOIL	$w_L$	%	LIQUID LIMIT	$C_u$	1	UNIFORMITY COEFFICIENT
$\gamma$	kN/m <sup>3</sup>	UNIT WEIGHT OF SOIL	$w_p$	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
$\rho_d$	kg/m <sup>3</sup>	DENSITY OF DRY SOIL	$w_s$	%	SHRINKAGE LIMIT	q	m <sup>2</sup> /s	RATE OF DISCHARGE
$\gamma_d$	kN/m <sup>3</sup>	UNIT WEIGHT OF DRY SOIL	$I_p$	%	PLASTICITY INDEX = $(w_L - w_p)$	v	m/s	DISCHARGE VELOCITY
$\rho_{sat}$	kg/m <sup>3</sup>	DENSITY OF SATURATED SOIL	$I_L$	1	LIQUIDITY INDEX = $(w - w_p) / I_p$	i	1	HYDRAULIC GRADIENT
$\gamma_{sat}$	kN/m <sup>3</sup>	UNIT WEIGHT OF SATURATED SOIL	$I_c$	1	CONSISTENCY INDEX = $(w_L - w) / I_p$	k	m/s	HYDRAULIC CONDUCTIVITY
$\rho'$	kg/m <sup>3</sup>	DENSITY OF SUBMERGED SOIL	$e_{max}$	1%	VOID RATIO IN LOOSEST STATE	j	kN/m <sup>2</sup>	SEEPAGE FORCE
$\gamma'$	kN/m <sup>3</sup>	UNIT WEIGHT OF SUBMERGED SOIL						

# RECORD OF BOREHOLE No OS1

1 OF 1

METRIC

W.P. 280-99-00 LOCATION Coords: N:4761550.0 E:327317.0 ORIGINATED BY PK  
DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB  
DATUM Geodetic DATE 10.20.10 CHECKED BY MP

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									
								○ UNCONFINED    + FIELD VANE									
182.6	Ground Surface						20	40	60	80	100						
0.0 182.3	330mm ASPHALT						20	40	60	80	100						
0.3	1070mm FILL - Sand and Gravel, some silt, trace clay, compact to very dense, brown, damp to moist		1	SS	100/ 15cm		182						○				
			2	SS	29									○			38 47 12 3
181.2	SILTY CLAY trace sand, stiff to very stiff, brown, damp to moist		3	SS	12		181							○			
1.4			4	SS	28		180							○		20.8	0 2 52 46
			5	SS	20									○			
							179										
			6	SS	15		178								○		0 1 59 40
							177										
			7	SS	14		176								○		
			8	SS	11		175							○			
174.1	End of Borehole																
8.5	Sampler wet at 1.5m.  Borehole was dry (not stabilized) and hole open to full depth on completion.																

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

# RECORD OF BOREHOLE No OS2

1 OF 1

METRIC

W.P. 280-99-00 LOCATION Coords: N:4761674.3 E:327396.4 ORIGINATED BY PK  
 DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB  
 DATUM Geodetic DATE 10.19.10 CHECKED BY MP

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			20	40	60	80	100					
182.1 0.0	Ground Surface						182										
181.5 0.6	610mm FILL - Sand and Gravel, some silt, dense, grey, damp to moist		1	SS	35		181										35 54 (11)
	FILL - Silty Clay, some sand, trace gravel, trace organics, stiff to very stiff, brown, damp to moist		2	SS	11		180										5 10 39 46
180.4 1.7	SILTY CLAY trace sand, stiff to very stiff, brown, damp to moist		3	SS	19		179										
			4	SS	16		178										
			5	SS	18		177										0 2 51 47
			6	SS	15		176										0 3 56 41
			7	SS	11		175										
173.6 8.5	End of Borehole						174										
	Borehole was dry (not stabilized) and hole open to full depth on completion.																

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

# RECORD OF BOREHOLE No OS3

1 OF 1

METRIC

W.P. 280-99-00 LOCATION Coords: N:4761567.8 E:327486.0 ORIGINATED BY PK  
DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB  
DATUM Geodetic DATE 10.20.10 CHECKED BY MP

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									

177.1	Ground Surface						177									
0.0 176.8	310mm ASPHALT															
0.3	1090mm FILL - Sand and Gravel, some silt, trace clay, dense to very dense, brown, damp to moist		1	SS	65											
			2	SS	49											
175.7	FILL - Silty Clay, some sand, trace to some gravel, firm, brown, damp to moist						176									43 43 10 4
1.4			3	SS	6											
175.0	CLAYEY SILT some sand, trace gravel, stiff, brown, damp to moist						175									
2.1			4	SS	10											
174.2	SILTY CLAY TO CLAYEY SILT some sand, some gravel, occasional cobbles, stiff to hard, brown, damp to moist  (GLACIAL TILL)		5	SS	11		174									
2.9							173									
			6	SS	15											
							172									
			7	SS	42		171									
							170									
169.0			8	SS	18											
8.1	End of Borehole						169									
	No sample recovery at SS5. Sampler redriven and disturbed sample collected.  Resistance to augering at 6.4m.  Borehole was dry (not stabilized) and hole open to full depth on completion.															

# RECORD OF BOREHOLE No OS5

1 OF 1

METRIC

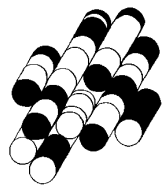
W.P. 280-99-00 LOCATION Coords: N:4762252.7 E:327556.8 ORIGINATED BY PK  
 DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB  
 DATUM Geodetic DATE 10.19.10 CHECKED BY MP

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
								○ UNCONFINED	+	FIELD VANE							
						● QUICK TRIAXIAL	x	LAB VANE				WATER CONTENT (%)					
						20	40	60	80	100	10	20	30				
182.8	Ground Surface																
0.0	680mm FILL - Gravel and Sand, some silt, compact, grey, damp to moist		1	SS	19										44 43 (13)		
182.1																	
0.7	SILTY CLAY trace sand, stiff to very stiff, brown, damp to moist		2	SS	14		182										
			3	SS	22		181								0 2 51 47		
			4	SS	19		180										
			5	SS	21		179										
			6	SS	11		178							20.1	0 2 59 39		
			7	SS	9		177										
			8	SS	10		176										
174.3							175								0 4 68 28		
8.5	End of Borehole																
	Borehole was dry (not stabilized) and hole open to full depth on completion.																

ONTARIO MOT 1-09-4135 OVERHEAD SIGNS.GPJ ONTARIO MOT.GDT 11/17/10

# APPENDIX B

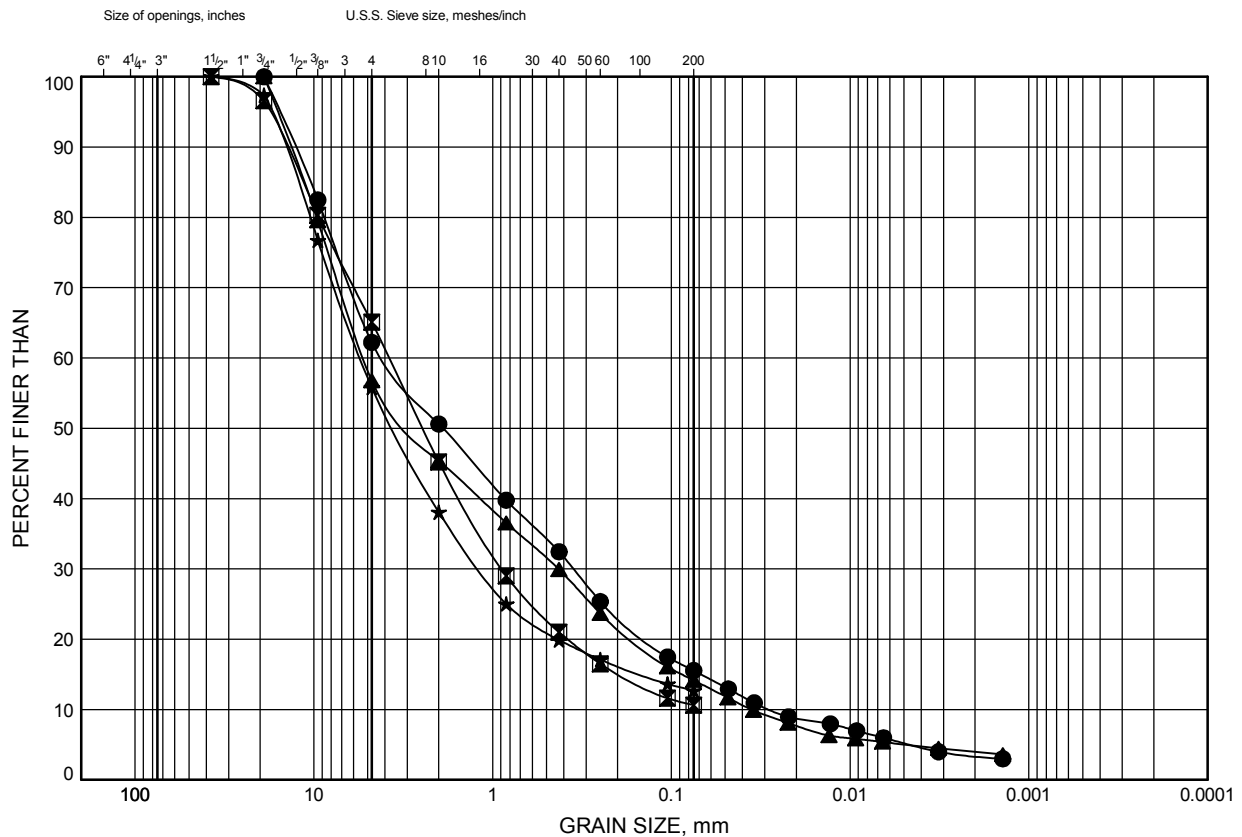
**TERRAPROBE INC.**



# GRAIN SIZE DISTRIBUTION

FIGURE B1

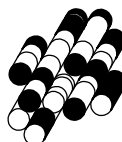
## FILL - Sand and Gravel



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	OS1	1.0	181.6
⊠	OS2	0.3	181.8
▲	OS3	1.0	176.1
★	OS5	0.3	182.5

Date November 2010

Project 1-09-4135



Prep'd DB

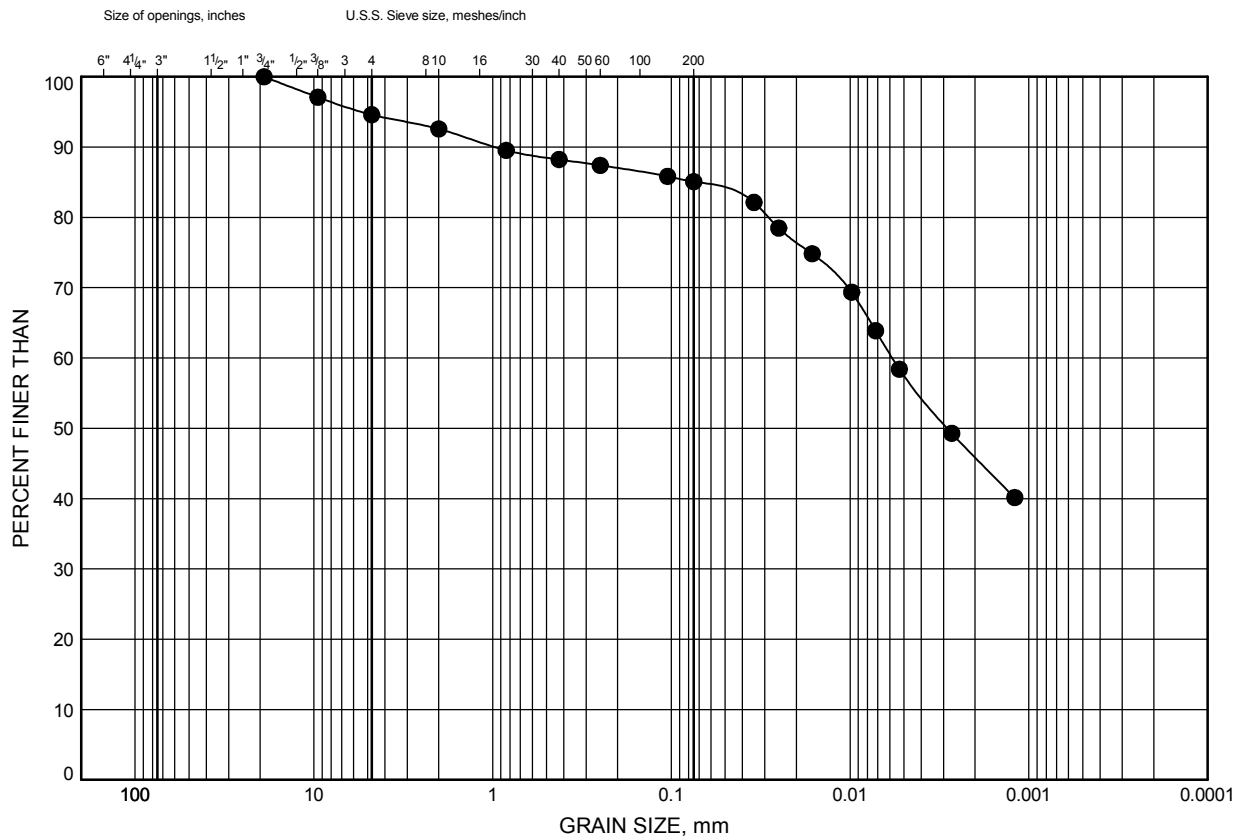
Chkd. HA



# GRAIN SIZE DISTRIBUTION

FIGURE B2

## FILL - Silty Clay

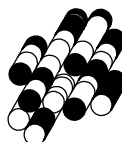


COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	OS2	1.0	181.1

Date November 2010

Project 1-09-4135



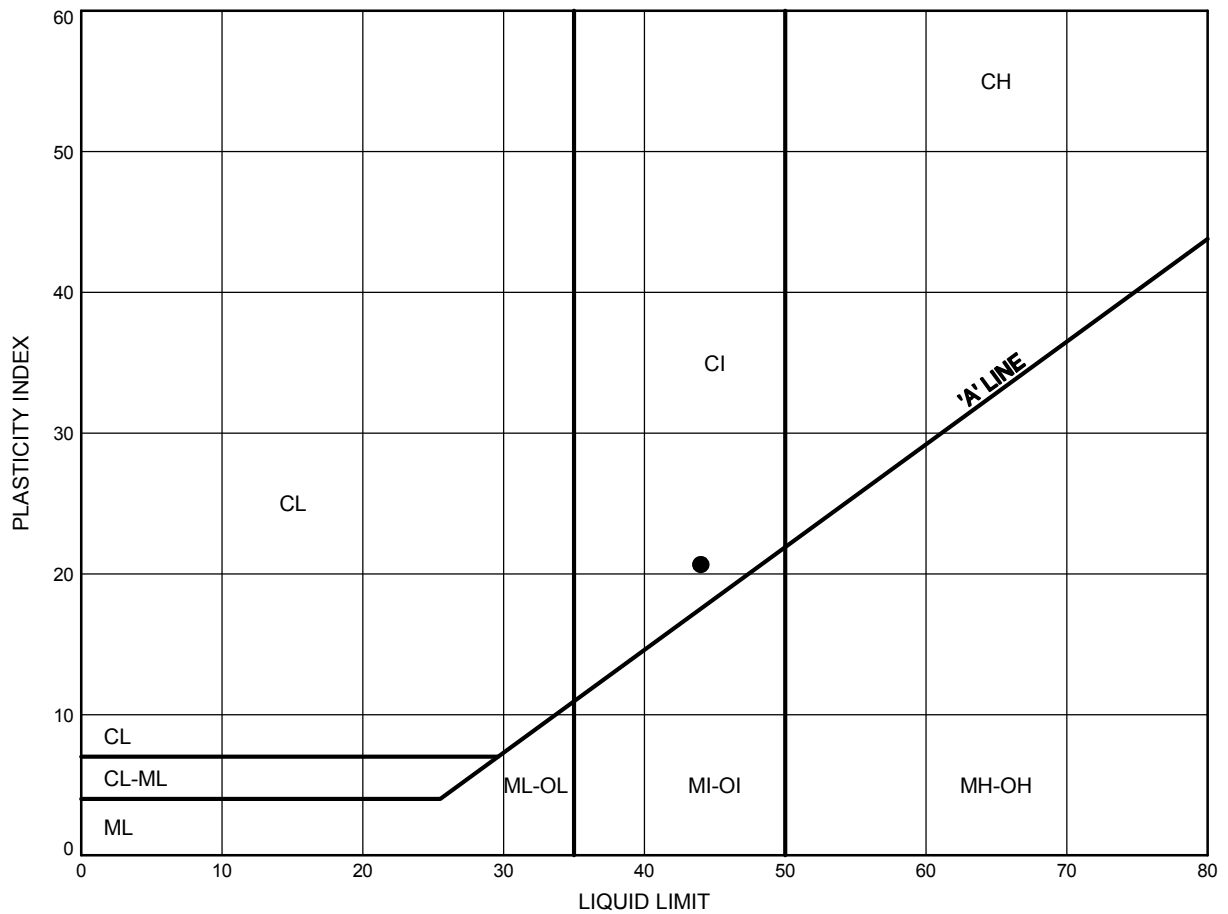
Prep'd DB

Chkd. HA

# ATTERBERG LIMITS TEST RESULTS

FIGURE B3

## FILL - Silty Clay



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	OS2	1.0	181.1

Date November 2010

Project 1-09-4135



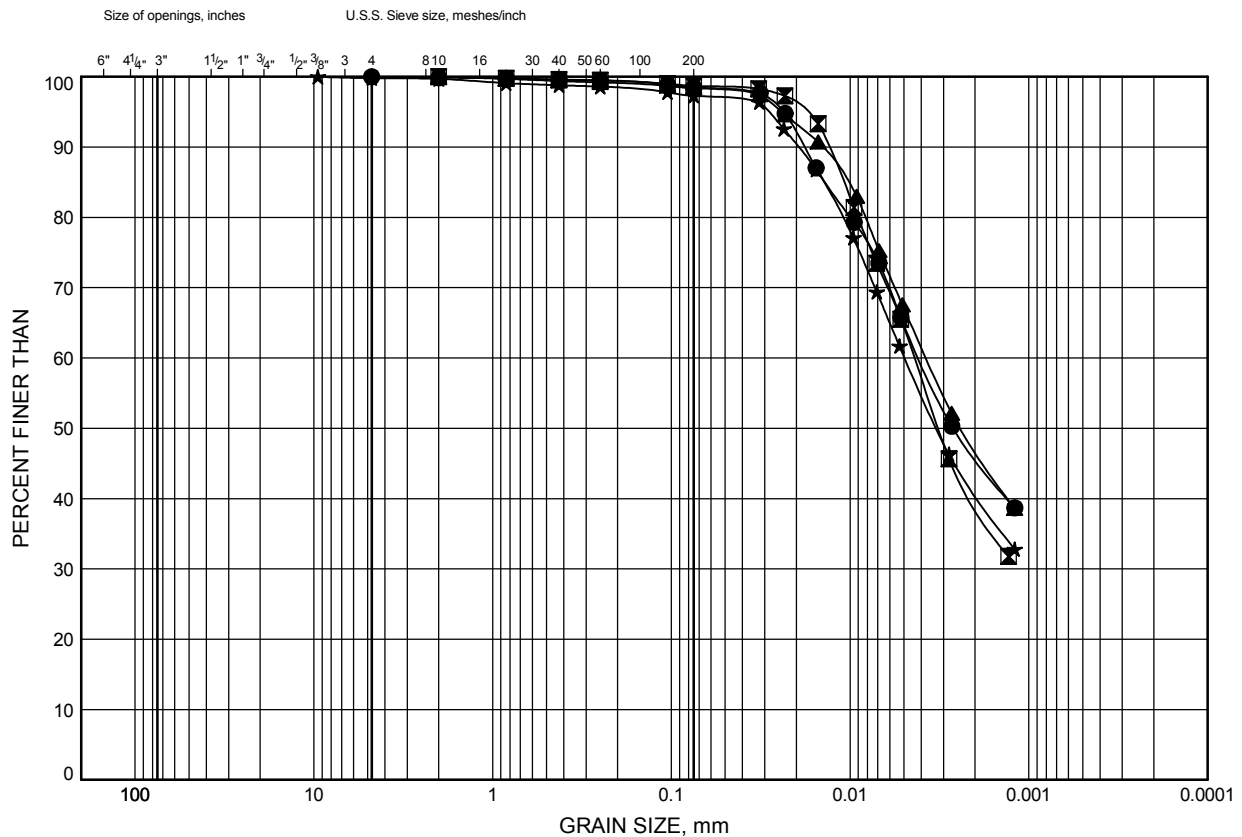
Prep'd DB

Chkd. HA

# GRAIN SIZE DISTRIBUTION

FIGURE B4

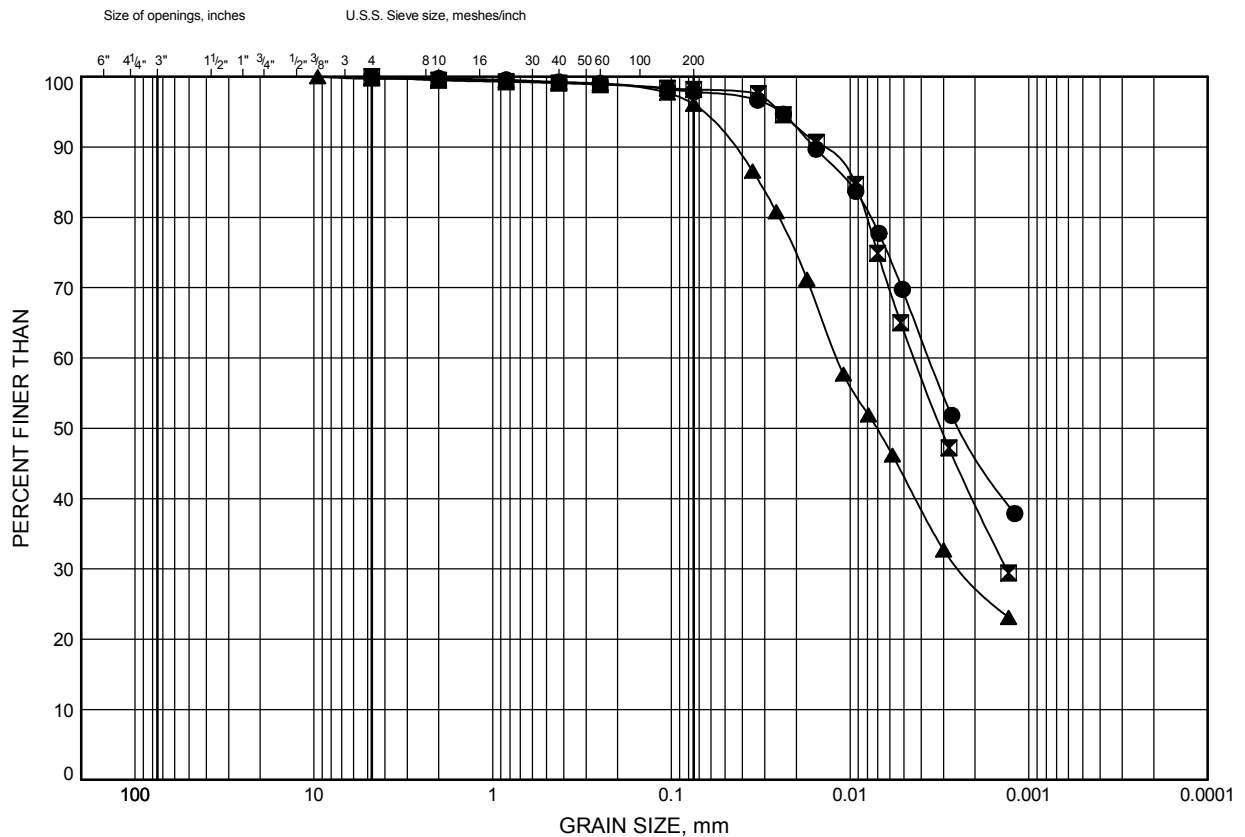
## SILTY CLAY



# GRAIN SIZE DISTRIBUTION

FIGURE B5

## SILTY CLAY



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	OS5	1.7	181.1
⊠	OS5	4.7	178.1
▲	OS5	7.8	175.0

Date November 2010

Project 1-09-4135



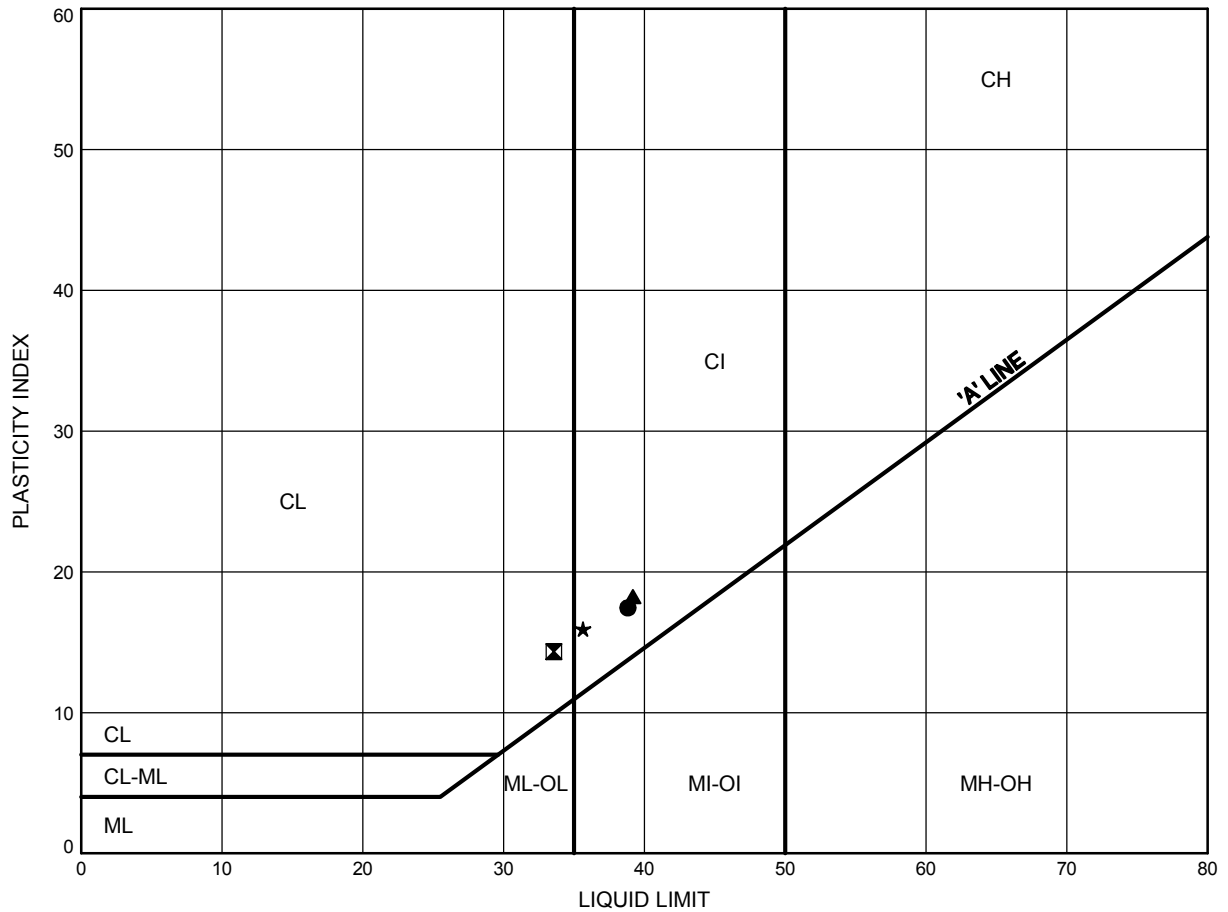
Prep'd DB

Chkd. HA

# 

FIGURE B6

### SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	OS1	2.5	180.1
⊠	OS1	4.7	177.9
▲	OS2	4.7	177.4
★	OS2	6.3	175.8

Date November 2010

Project 1-09-4135



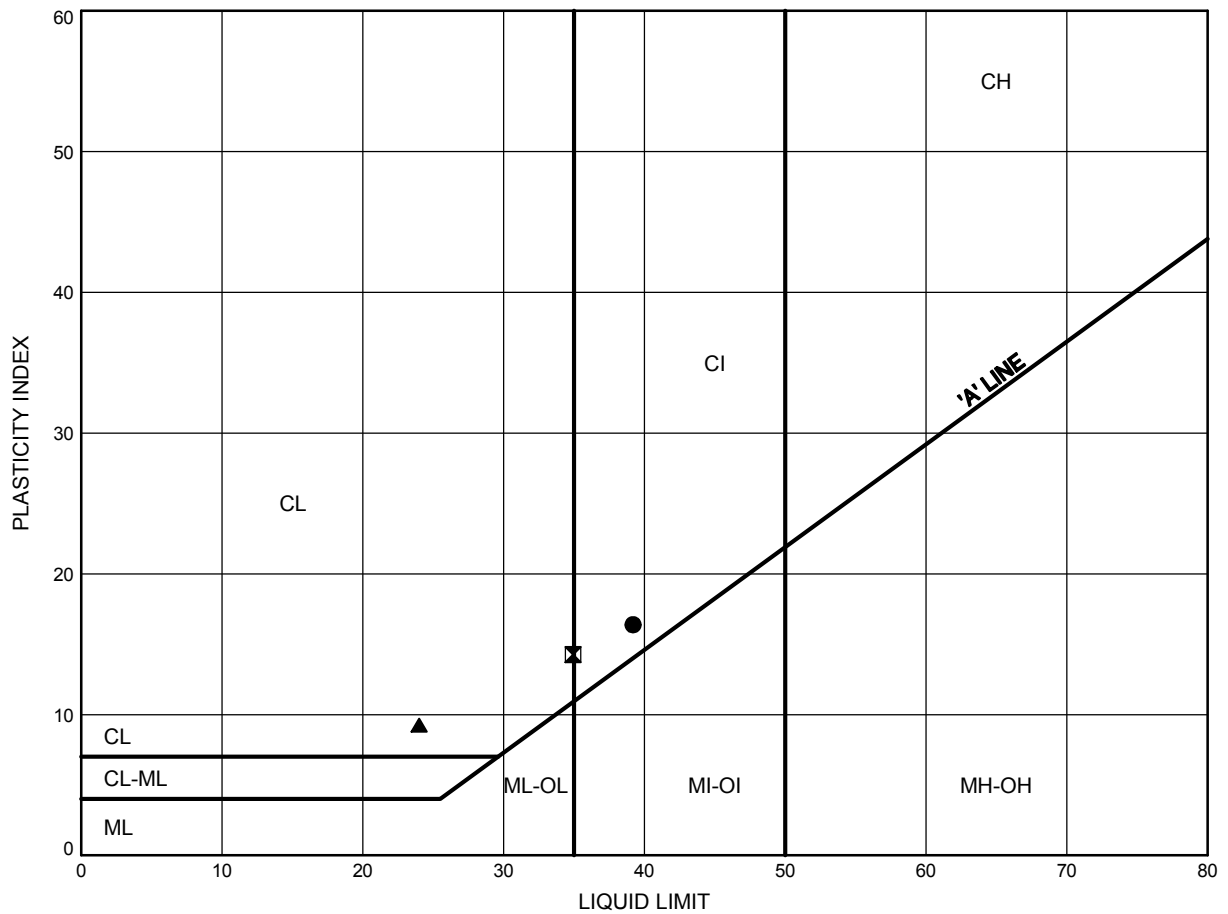
Prep'd DB

Chkd. HA

# 

FIGURE B7

### SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	OS5	1.7	181.1
⊠	OS5	4.7	178.1
▲	OS5	7.8	175.0

Date November 2010

Project 1-09-4135



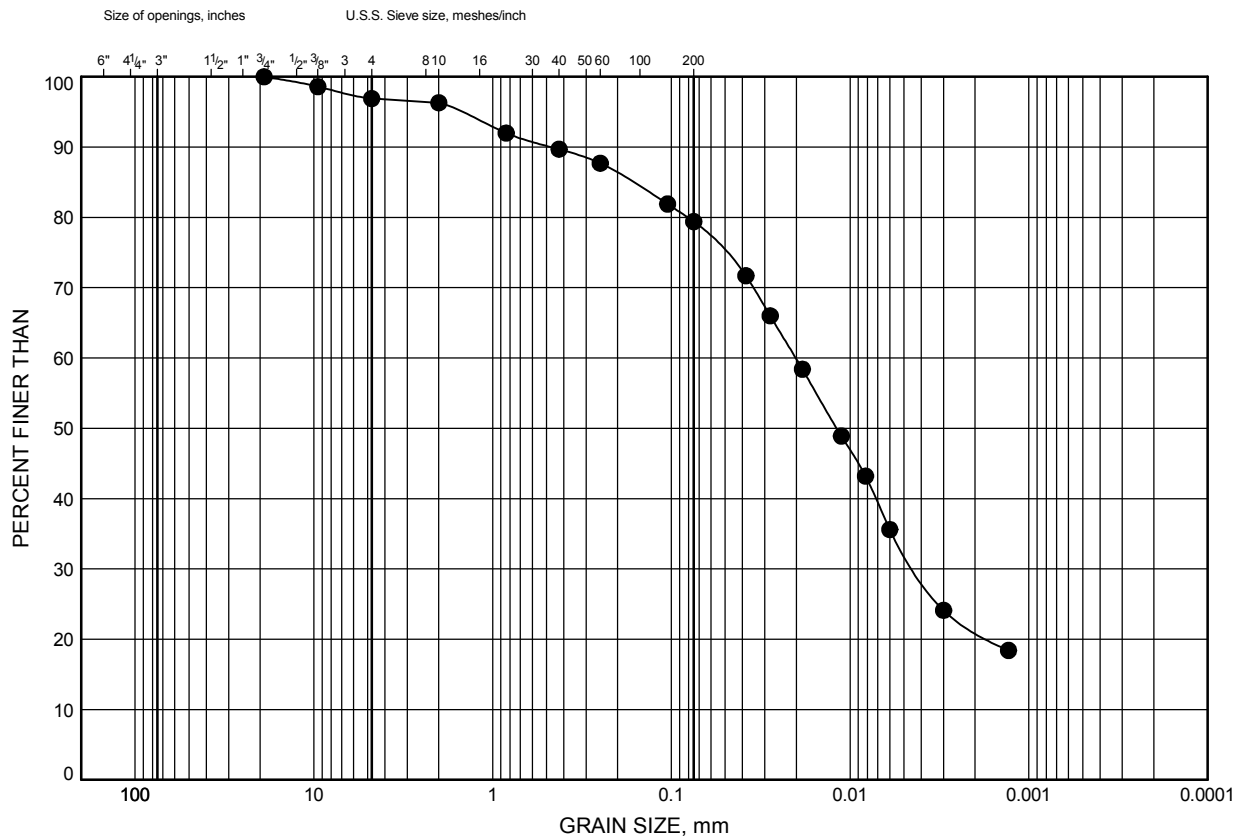
Prep'd DB

Chkd. HA

# GRAIN SIZE DISTRIBUTION

FIGURE B8

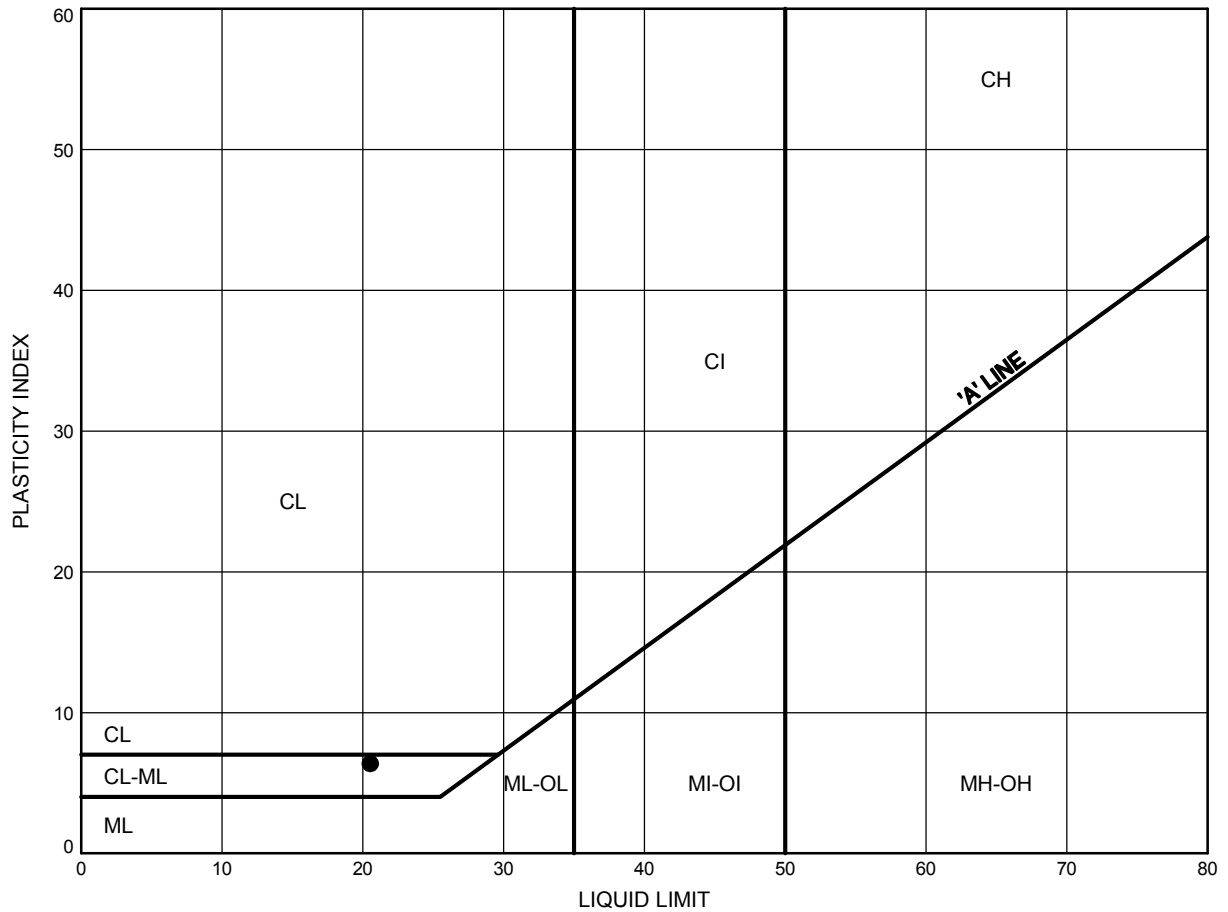
## CLAYEY SILT



# ATTERBERG LIMITS TEST RESULTS

FIGURE B9

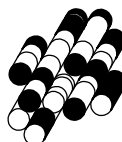
## CLAYEY SILT



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	OS3	2.5	174.6

Date November 2010

Project 1-09-4135



Prep'd DB

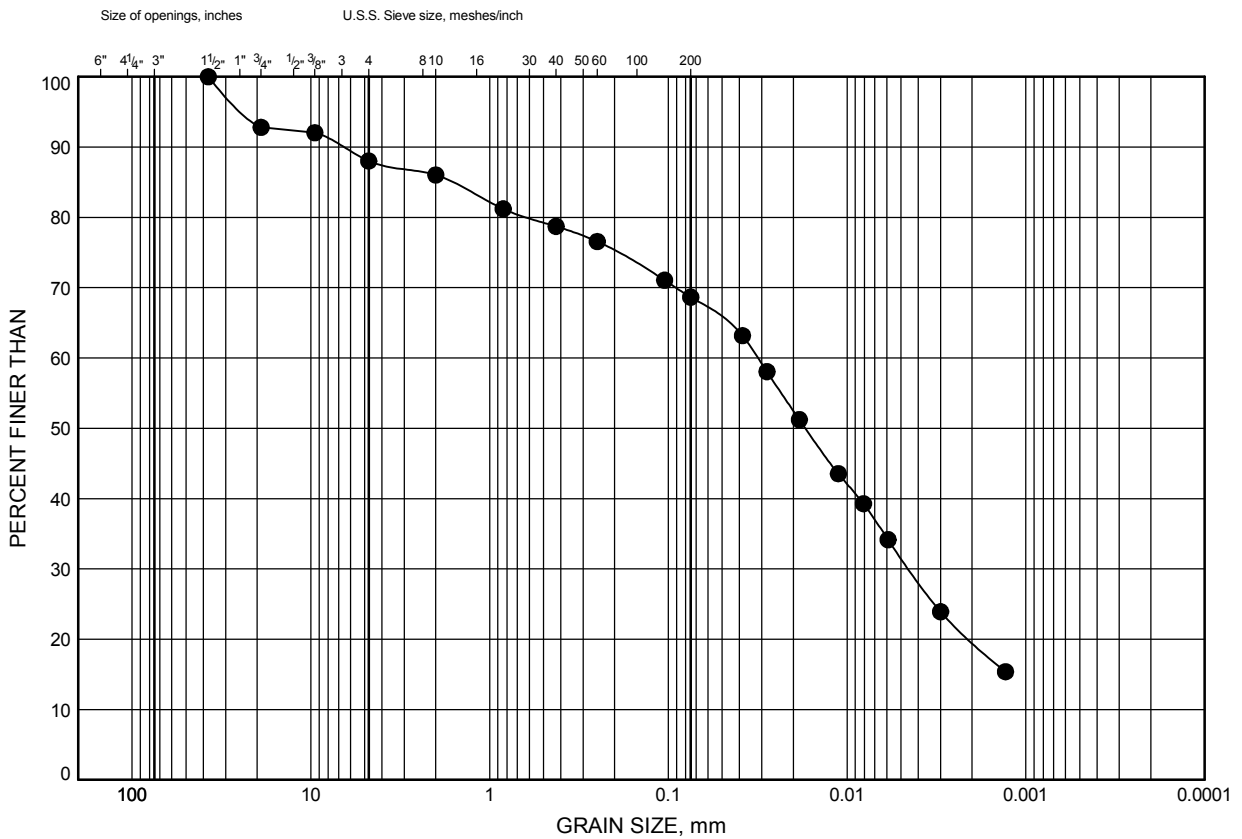
Chkd. HA



# GRAIN SIZE DISTRIBUTION

FIGURE B10

## SILTY CLAY TO CLAYEY SILT TILL

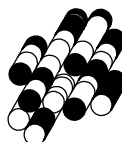


COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	OS3	6.3	170.8

Date November 2010

Project 1-09-4135



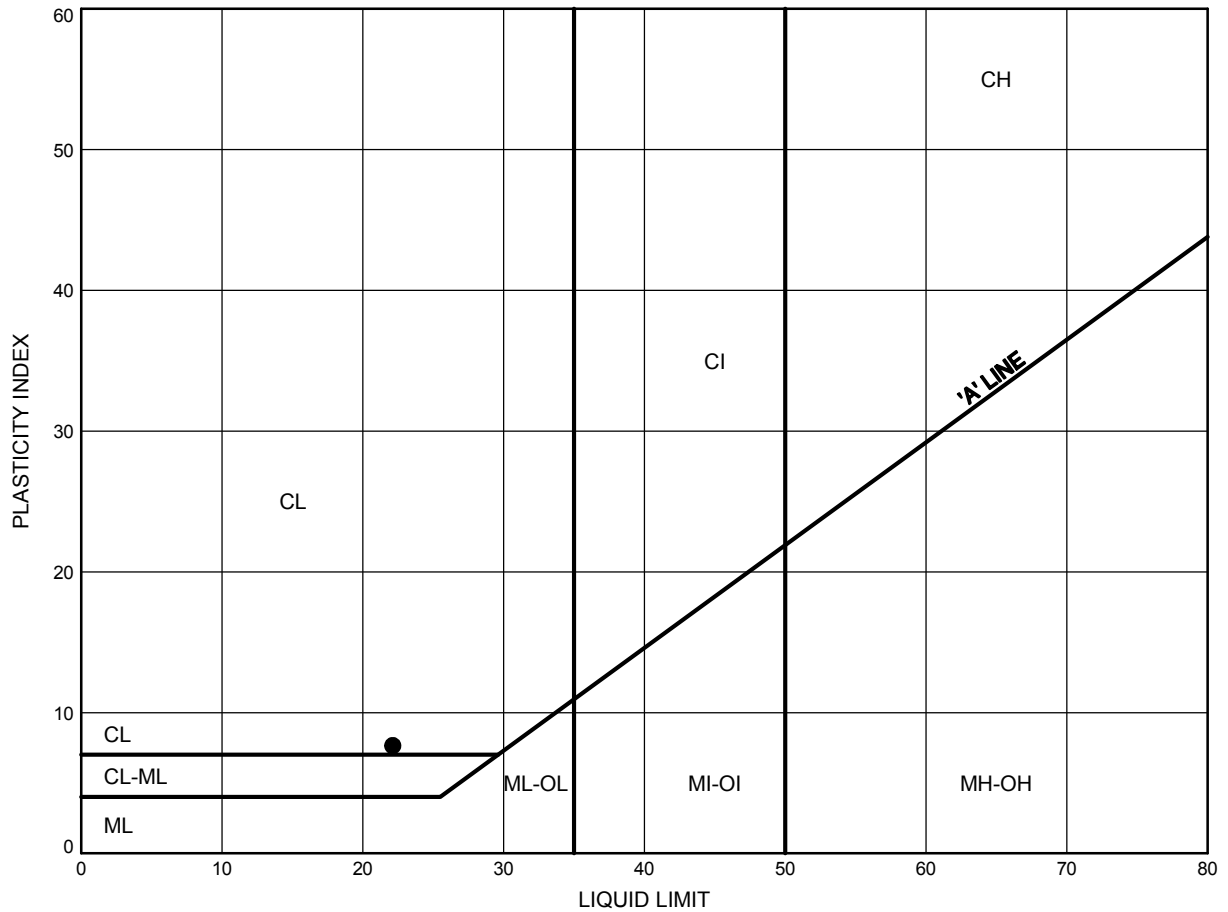
Prep'd DB

Chkd. HA

# ATTERBERG LIMITS TEST RESULTS

FIGURE B11

## SILTY CLAY TO CLAYEY SILT TILL



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	OS3	6.3	170.8

Date November 2010

Project 1-09-4135

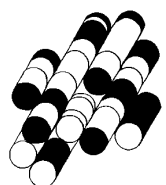


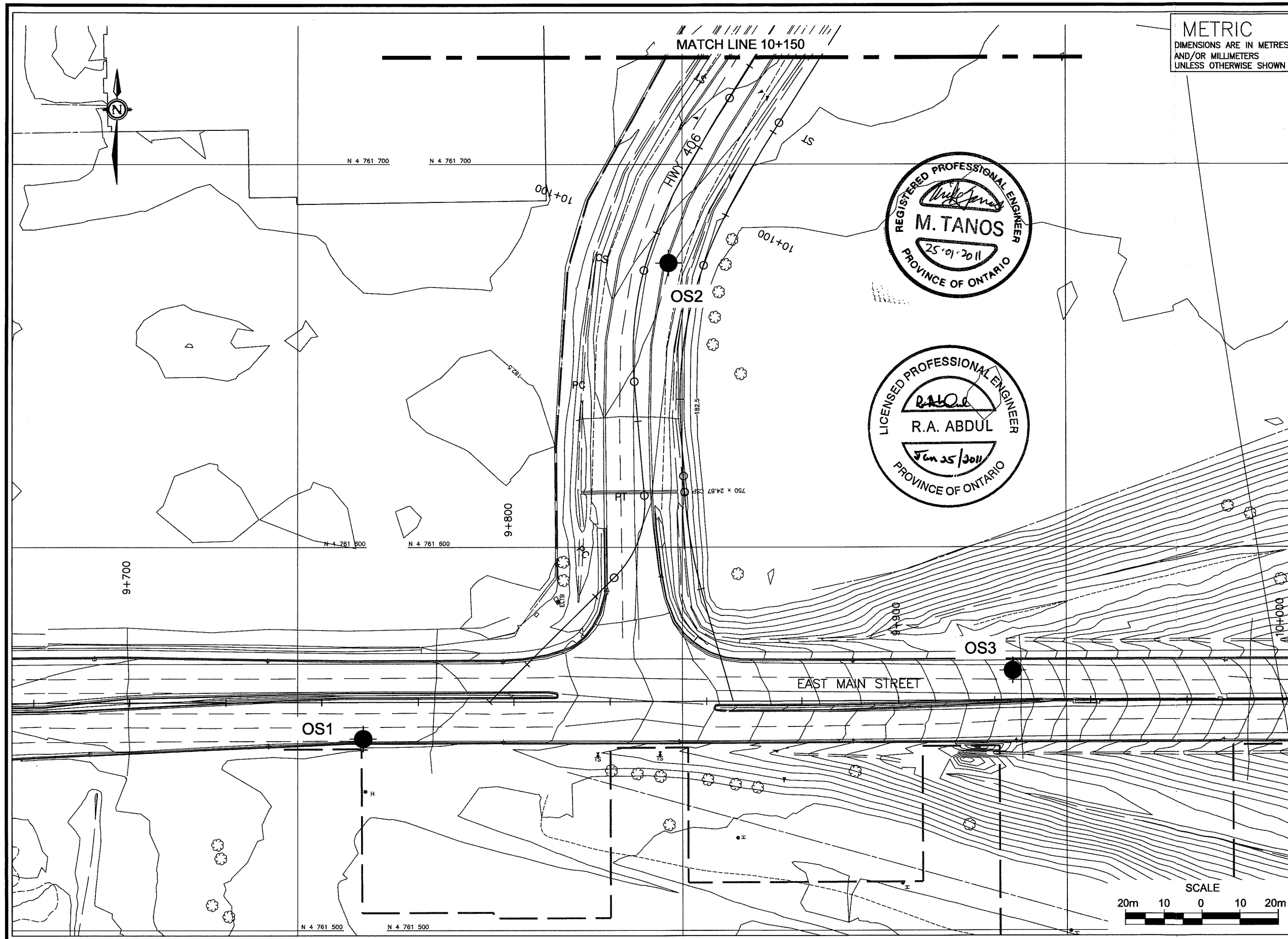
Prep'd DB

Chkd. HA


# APPENDIX C

**TERRAPROBE INC.**

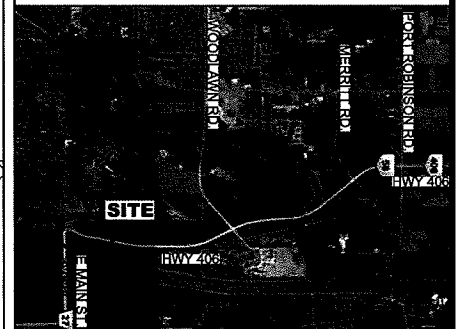










METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETERS  
UNLESS OTHERWISE SHOWN

CONT No WP No 280-99-00	
HIGHWAY 406 OVERHEAD SIGNS BOREHOLE LOCATIONS	SHEET 1 OF
<b>Giffels Associates Limited</b> Consulting Engineers and Architects An IBI Group Company	

 **Terraprobe Inc.**  
Consulting Geotechnical & Environmental Engineering  
Construction Materials Engineering, Inspection & Testing  
10 Bram Court - Brampton Ontario L6W 3R6 (905) 796-2650



KEY PLAN	
LEGEND	
	Bore Hole
	Dynamic Cone Penetration Test
	Bore Hole And Cone
'N'	Blows/0.3m (Std Pen Test, 475 J/blow)
CONE	Blows/0.3m (60° Cone, 475 J/blow)
	WL at Time of Investigation
	WL in Piezometer
	Piezometer
90%	Rock Quality Designation
A/R	Auger Refusal

[illegible]

**NOTE**

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

REVISIONS					
	DATE	BY	DESCRIPTION		
DESIGN	R.A.	CODE	CHBDC2006	LOAD	DATE NOV.2010
DRAWN	K.C.	CHK	R.A.	STRUCT	GEOCRETS 30M3-268

