# Terraprobe

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

**FOUNDATION INVESTIGATION REPORT**

**TRILLLIUM OVERHEAD, HIGHWAY 406 NBL**

**HIGHWAY 406 TWINNING**

**PORT ROBINSION ROAD TO EAST MAIN STREET**

**AGREEMENT No. 2008-E-0016, W.P. 280-99-00, SITE: 34-464/1**

**GEOCRES. No. 30M3-255**

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File No. 1-09-4135
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## PART 1: FACTUAL INFORMATION

## 1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted at the Trillium overhead bridge site on the proposed Highway 406 NBL in the City of Welland, Ontario.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic profile and cross-sections, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained.

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 site is located where the Trillium Railway crosses the existing Highway 406 at a signalized at grade intersection with Highway 406 about 250 m south of Woodlawn Road in the City of Welland, Regional Municipality of Niagara, Ontario.

At this site Highway 406 is a two-lane highway with gravel shoulders carrying both north and south bound traffic. The Trillium Railway consists of a pair of tracks that crosses Highway 406 at an approximately east-west orientation then heads north where it intersects Daimler Parkway.

The topography is generally flat and vegetation at this site consists primarily of deciduous trees and wild bush. There is a small east to west flowing watercourse located approximately 40 m south of the Trillium Railway tracks. This watercourse flows under Highway 406 via a 3.0 m x 1.5 m concrete box culvert which will be replaced.

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[1].

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 unit at this site is the Salina Formation of Upper Silurian Age[2]. This unit 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.

## 3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project were carried out between November 4 and February 17, 2010 and consisted of drilling and sampling six boreholes to depths ranging from 12.0 m to 35.0 m. The boreholes were labelled NBL 12+375Lt, NBL 12+440Rt, TN1, TN2, TN3, and TN4 and their approximate locations are shown on the attached Borehole Locations and Soil Strata Drawing in Appendix C.

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. Relatively undisturbed soil samples were also collected with thin-walled Shelby Tube samplers. The boreholes at the abutments were also advanced into bedrock by NQ size diamond coring techniques.

Ground water conditions in the open boreholes were observed throughout the drilling operations and standpipe piezometers consisting of 19 mm diameter PVC pipe with a slotted screen enclosed in sand were installed in selected boreholes to permit longer term ground water level monitoring. The remaining boreholes were abandoned in accordance with MOE Regulation 903 by sealing/grouting with a bentonite slurry mixture after drilling was complete.

The locations and completion details of the piezometers are shown in Table 3.1.

[1] Chapman and Putnam, "The Physiography of South Ontario", 3rd Edition, 1984.
[2] Ontario Division of Mines, "Quaternary Geology Of The Welland Area", Preliminary Map P.796, 1972.

**Table 3.1 – Piezometer Installation Details**

| Piezometer Location | Piezometer Details | |
|---|---|---|
| | Tip Depth/ Elevation (m) | Completion Details |
| NBL 12+375Lt | 11.0/172.2 | Piezometer with 3.0 m slotted screen installed with filter sand to 7.2 m, bentonite seal from 7.2 m to 6.6 m, drill cuttings from 6.6 m to 0.6 m and bentonite seal from 0.6 m to ground surface. |
| NBL 12+440Rt | 12.2/170.8 | Piezometer with 3.0 m slotted screen installed with filter sand to 8.5 m, bentonite seal from 8.5 m to 7.9 m, drill cuttings from 7.9 m to 0.3 m and bentonite seal from 0.3 m to ground surface. |
| TN2 | 25.9/158.3 | Hole sealed to 25.9 m with bentonite piezometer with 1.5 m slotted screen installed with filter sand to 23.5 m, bentonite seal from 23.5 m to 1.5 m, sand from 1.5 m to 0.3 m and a flush mounted casing installation from 0.15 m to ground surface. |
| TN3 | 19.8/164.3 | Hole sealed to 19.8 m with bentonite, piezometer with 1.5 m slotted screen installed with filter sand to 17.7 m, bentonite seal from 17.7 m to 0.3 m, and a flush mounted casing installation from 0.15 m to ground surface. |

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

## 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, consolidation tests, unit weight, unconfined compression test and undrained shear strength testing with a laboratory vane. 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. Details of the encountered soil and rock stratigraphy are presented in these appendices and on the "Borehole Locations and Soil Strata" drawings in Appendix C. 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 topsoil and about 29.6 m to 30.6 m of overburden soils consisting of fill material (sandy gravel, silty sand and silty clay) and native deposits of silty clay, silty clay to clayey silt till, sandy silt to silty sand till, and sand and gravel till. These soils are underlain by bedrock of the Salina Formation.

### 5.1 Topsoil

Topsoil was encountered at this site beyond the gravel shoulders of the existing Highway 406. Topsoil ranged from 50 mm to 130 mm in thickness. Topsoil thickness may vary between and beyond the boreholes.

### 5.2 Fill – Silty Sand

Cohesionless fill material consisting of silty sand with some gravel was encountered at this site extending to a depth of 1.4 m (Elev. 182.1 m) below ground surface.

The results of a grain size distribution test conducted on a sample of this fill is illustrated in Figure B1. These results show a grain size distribution consisting of 13% gravel, 65% sand and 22% silt and clay size particles.

Standard Penetration tests in this silty sand fill gave 'N' values that ranged from 14 to 16 blows for 0.3 m penetration. Based on these results the fill is considered to have a compact relative density. The moisture content of samples of this fill ranged from 14% to 19% by weight.

### 5.3 Fill – Sandy Gravel

Boreholes drilled through the shoulders of the existing Highway 406 encountered fill material consisted of sandy gravel and gravel with some sand containing trace to some silt. This granular fill extends to depths ranging from 0.7 m to 0.8 m or to elevations ranging from 183.4 m to 183.3 m.

The grain size distribution plots of tested samples of this granular fill are presented in Figure B2. These results show a grain size distribution consisting of 66-72% gravel, 17-27% sand and 7-11% silt and clay size particles.

Standard Penetration tests in the granular fill gave 'N' values that ranged from 19 to 53 blows for 0.3 m penetration. Based on these results the granular fill is considered to have a generally compact to very dense consistency. The moisture content of samples of the granular fill ranged from 2% to 6% by weight.

### 5.4 Fill – Silty Clay

Silty clay fill material was encountered at this site extending to depths ranging from 1.4 m to 2.9 m below ground surface and elevations of 182.1 m to 180.1 m.

The grain size distribution plots of tested samples of this fill are presented in Figure B3. These results show a grain size distribution consisting of 13-15% gravel, 12-18% sand, 41-53% silt and 22-26% clay size particles.

A sample was also subjected to an Atterberg Limits test and the results are presented in Figure B4. The index values from these tests are summarized below:

| | |
|---|---|
| Liquid Limit: | 24% |
| Plastic Limit: | 14% |
| Plasticity Index: | 10% |
| Natural Moisture Content: | 15% |

These values are characteristic of clayey soils of low plasticity.

Standard Penetration tests in the silty clay fill gave 'N' values that ranged from 6 to 35 blows for 0.3 m penetration. Based on these results the fill is considered to have a firm to hard consistency. The moisture content of samples of the silty clay fill ranged from 6% to 23% by weight and a moisture content of 44% (by weight) was recorded from a sample retrieved from an organic rich zone in the fill.

### 5.5 Silty Clay

A native silty clay deposit was encountered across the site. This deposit was fully penetrated in some of the boreholes where it was found to extend to depths ranging from 14.7 m to 15.2 m below ground surface or to elevations ranging from 169.5 m to 168.8 m. The approach boreholes were terminated in this deposit at depths of 12.0 m (Elev. 171.3 m) and 13.4 m (Elev. 169.6 m).

The grain size distribution plots of tested samples of the silty clay are presented in Figures B5 to B9 inclusive. These results show a grain size distribution consisting of 0-7% gravel, 1-7% sand, 36-87% silt and 12-58% clay size particles. One tested sample from borehole TN3 at approximately 5.5 m depth (Elev. 178.6 m) contained 41% sand and was described as sandy.

Samples were also subjected to Atterberg Limits tests and the results are illustrated on the plasticity charts, Figures B10 to B13 inclusive. The index values from these tests are summarized below:

| | |
|---|---|
| Liquid Limit: | 23-45% |
| Plastic Limit: | 16-23% |
| Plasticity Index: | 5-23% |
| Natural Moisture Content: | 12-30% |

These values indicate that the silty clay has a generally low to intermediate plasticity with occasional clayey silt zones.

Standard Penetration tests in this stratum gave 'N' values that ranged from 9 to 50 blows for 0.3 m penetration. Field vane tests gave in-situ undrained shear strengths ranging from 40 kPa to in excess of 100 kPa. An unconfined compression test gave an undrained shear strength of 93 kPa and laboratory vane tests on relatively undisturbed Shelby tube samples gave undrained shear strengths ranging from 52 kPa to 72 kPa. These values indicate that the consistency of the silty clay is generally stiff to hard with infrequent firm zones. The moisture content of samples from this stratum ranged from 12% to 30% by weight and the unit weight of tested samples ranged from 20.6 kN/m$^3$ and 20.7 kN/m$^3$.

The variation of undrained shear strength with elevation is depicted in Figure B18. The plot illustrates a wide scatter in the data with no obvious trend with depth. An interpreted dashed line is shown representing a lower bound trend with depth, for the data. The upper portion of this deposit up to about Elev. 176.0 m is estimated to have relatively high shear strength i.e. in excess of 100 kPa. Below Elev. 176.0 m the undrained shear strength decreases with depth and is about 60 kPa at Elev. 174.0 m. Below Elev. 174.0 m the trend indicates increasing undrained shear strength with depth.

The Atterberg Limits tests results are also plotted against elevation, Figure B19. These results illustrate that the natural moisture contents are generally below or slightly above the plastic limit up to Elev. 178.0 m. Below Elev. 178.0 the moisture content is slightly above the plastic limit with a trend of increasing moisture content with depth.

Consolidation tests of the silty clay deposit were also performed on Shelby tube samples retrieved from Boreholes NBL 12+375Lt and NBL 12+440Rt and the results are presented in Figures B20 to B25 inclusive. These results indicate an estimated preconsolidation pressure that ranges between 310 kPa and 480 kPa.

### 5.6 Silty Clay to Clayey Silt Till

Discontinuous layers of silty clay to clayey silt till were encountered at this site extending to depths ranging from 27.7 m (Elev. 156.4 m) to 28.4 m (Elev. 155.1 m) below ground surface.

The grain size distribution plots of samples of the silty clay to clayey silt till deposits are presented in Figure B14. These results show a grain size distribution consisting of 0-11% gravel, 4-22% sand, 38-63% silt and 12-42% clay size particles. Till soils can also be expected to contain random cobble and boulder inclusions.

Samples of the silty clay to clayey silt till were also subjected to Atterberg Limits tests and the results are presented in Figures B15. The index values from these tests are summarized below:

| | |
|---|---|
| Liquid Limit: | 17-32% |
| Plastic Limit: | 11-16% |
| Plasticity Index: | 6-16% |
| Natural Moisture Content: | 9-29% |

These values indicate that the silty clay to clayey silt till has a low plasticity.

Standard Penetration tests in the silty clay to clayey silt till yielded ‘N’ values ranging from 14 to more than 100 blows for 0.3 m penetration. Field vane tests gave in-situ undrained shear strengths ranging from 88 kPa to in excess of 100 kPa. These values indicate that the consistency of the silty clay to clayey silt till is generally very stiff to hard with occasional stiff zones. Moisture contents of samples of the silty clay to clayey silt till range from 7% to 25% by weight.

### 5.7 Silty Sand to Sandy Silt Till

The site is underlain by discontinuous granular till deposits ranging from silty sand to sandy silt. These deposits extend to depths ranging from 23.9 m to 30.6 m below ground surface or to elevations ranging from 160.3 m to 153.0 m.

The results of grain size distribution tests conducted on samples obtained from these till deposits are illustrated in Figure B16. These results show grain size distributions of 4-27% gravel, 28-72% sand, 15-34% silt and 6-17% clay size particles. Till soils will also contain random cobble and boulder inclusions.

Standard Penetration tests in these deposits gave 'N' values that ranged from 43 to more than 100 blows per 0.3 m penetration indicating a dense to very dense relative density. The moisture content of samples from these strata ranged from 6% to 28% by weight.

### 5.8 Sand and Gravel Till

Layers of sand and gravel and gravel and sand till were found overlying bedrock in Boreholes TN2 and TN3. These deposits are approximately 1.9 m to 2.1 m thick and extend to depths of 29.6 m and 30.5 m below the ground surface, or elevations of 154.5 m and 153.7 m.

Grain size distribution tests were performed on representative samples from these deposits and the results are illustrated in Figure B17. These results show grain size distributions of 31-39% gravel, 33-36% sand, 18-29% silt and 7% clay size particles. Till soils will also contain random cobble and boulder inclusions.

The blow counts from Standard Penetration tests conducted in these deposits ranged from 23 to more than 100 blows for 0.3 m penetration indicating a compact to very dense relative density. The moisture content of samples from these strata ranged from 6% to 8% by weight.

### 5.9 Bedrock (Salina Formation)

The overburden soils described above are underlain by the Salina Formation. Bedrock was proved by coring at the abutment locations. Table 5.1 summarizes the bedrock depth and the elevations to the top of bedrock.

**Table 5.1 – Depth to Bedrock**

| Location | BH Number | Depth to Bedrock (m) | Top of Bedrock Elevation (m) |
|---|---|---|---|
| South Abutment | TN1 | 30.5 | 153.0 |
| | TN2 | 30.5 | 153.7 |
| North Abutment | TN3 | 29.6 | 154.5 |
| | TN4 | 30.6 | 153.4 |

The bedrock is described as unweathered and its colour is generally grey. It is thinly laminated with white unweathered gypsum and calcite veins and coarse grained calcitic vugs. Total core recovery in the bedrock generally ranged from 36% to 100% and a recorded TCR of 0% was obtained in the first run of Borehole TN2.

The RQD values ranged widely from 0% to 67% but generally most of the RQD values were below 50%. Rubble and highly fractured zones were observed in the rock cores, which contributed to the relatively low RQD values. The core data also reveals that there is no trend of improving rock quality with depth. Based on these results the rock quality is considered to be very poor to poor with occasional zones of fair quality rock.

## 5.10 Water Levels

A standpipe piezometer was installed in selected boreholes. The water level readings measured on separate visits made after the completion of drilling are presented in Table 5.2.

**Table 5.2 – Water Level Measurements**

| Borehole | Date | Water Levels | |
|---|---|---|---|
| | | Depth (m) | Elevation (m) |
| NBL 12+375Lt | November 19, 2009 | 5.8 | 177.5 |
| | November 30, 2009 | 3.2 | 180.1 |
| | December 07, 2009 | 1.3 | 182.0 |
| | December 15, 2009 | 1.8 | 181.5 |
| | January 19, 2010 | 1.7 | 181.6 |
| NBL 12+440Rt | November 09, 2009 | 8.2 | 174.8 |
| | November 19, 2009 | 2.1 | 180.9 |
| | November 30, 2009 | 1.9 | 181.1 |
| | December 08, 2009 | 1.9 | 181.1 |
| TN2 | April 16, 2010 | 2.6 | 181.6 |
| | April 29, 2010 | 1.6 | 182.6 |
| | May 04, 2010 | 6.2 | 178.0 |
| | May 06, 2010 | 6.2 | 178.0 |
| TN3 | April 16, 2010 | 3.9 | 180.2 |
| | April 29, 2010 | 4.7 | 179.4 |
| | May 04, 2010 | 8.7 | 175.4 |
| | May 06, 2010 | 9.4 | 174.7 |
| | May 18, 2010 | 3.8 | 180.3 |

The ground water table was estimated based on the recorded water levels in the standpipe piezometers and our review of moisture contents of the retrieved samples. Based on these observations, the local ground water level is estimated at approximately Elev. ±181.5 m.

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

## 5.11 Miscellaneous

The drilling, sampling and in-situ testing operations were conducted with track and truck mounted drill rigs owned and operated by Groundworks Drilling Limited of Toronto, Ontario, DBW Drilling Limited of Ajax, Ontario and Determination Drilling & Soil Investigations of Hamilton, Ontario. A combination of hollow-stem auger and solid stem auger drilling techniques and casing and washboring methods were used to advance the boreholes.

Messrs. Alexander Winkelmann, E.I.T., Marc Paoliello, E.I.T., and Phil Khuu, B.A.T, carried out 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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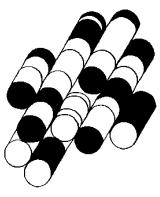
# APPENDIX A

TERRAPROBE INC.



# 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

| | | |
|---|---|---|
| $m_v$ | $kPa^{-1}$ | COEFFICIENT OF VOLUME CHANGE |
| $C_c$ | 1 | COMPRESSION INDEX |
| $C_s$ | 1 | SWELLING INDEX |
| $C_\alpha$ | 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 |
| $\sigma'_{vo}$ | 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 |
| $S_t$ | 1 | SENSITIVITY = $c_u / \tau_r$ |

# PHYSICAL PROPERTIES OF SOIL

| | | |
|---|---|---|
| $\rho_s$ | $kg/m^3$ | DENSITY OF SOLID PARTICLES |
| $\gamma_s$ | $kN/m^3$ | UNIT WEIGHT OF SOLID PARTICLES |
| $\rho_w$ | $kg/m^3$ | DENSITY OF WATER |
| $\gamma_w$ | $kN/m^3$ | UNIT WEIGHT OF WATER |
| $\rho$ | $kg/m^3$ | DENSITY OF SOIL |
| $\gamma$ | $kN/m^3$ | UNIT WEIGHT OF SOIL |
| $\rho_d$ | $kg/m^3$ | DENSITY OF DRY SOIL |
| $\gamma_d$ | $kN/m^3$ | UNIT WEIGHT OF DRY SOIL |
| $\rho_{sat}$ | $kg/m^3$ | DENSITY OF SATURATED SOIL |
| $\gamma_{sat}$ | $kN/m^3$ | UNIT WEIGHT OF SATURATED SOIL |
| $\rho'$ | $kg/m^3$ | DENSITY OF SUBMERGED SOIL |
| $\gamma'$ | $kN/m^3$ | UNIT WEIGHT OF SUBMERGED SOIL |

| | | |
|---|---|---|
| e | 1,% | VOID RATIO |
| n | 1,% | POROSITY |
| w | 1,% | WATER CONTENT |
| $S_r$ | % | DEGREE OF SATURATION |
| $w_L$ | % | LIQUID LIMIT |
| $w_P$ | % | PLASTIC LIMIT |
| $w_S$ | % | SHRINKAGE LIMIT |
| $I_P$ | % | PLASTICITY INDEX = $(w_L - w_P)$ |
| $I_L$ | 1 | LIQUIDITY INDEX = $(w - w_P)/I_P$ |
| $I_C$ | 1 | CONSISTENCY INDEX = $(w_L - w)/I_P$ |
| $e_{max}$ | 1,% | VOID RATIO IN LOOSEST STATE |

| | | |
|---|---|---|
| $e_{min}$ | 1,% | VOID RATIO IN DENSEST STATE |
| $I_D$ | 1 | DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$ |
| D | mm | GRAIN DIAMETER |
| $D_n$ | mm | n PERCENT - DIAMETER |
| $C_u$ | 1 | UNIFORMITY COEFFICIENT |
| h | m | HYDRAULIC HEAD OR POTENTIAL |
| q | $m^3/s$ | RATE OF DISCHARGE |
| v | m/s | DISCHARGE VELOCITY |
| i | 1 | HYDRAULIC GRADIENT |
| k | m/s | HYDRAULIC CONDUCTIVITY |
| j | $kN/m^3$ | SEEPAGE FORCE |

# EXPLANATORY SHEET FOR CORE LOG

**Column Number**

1. Elevation of borehole collar.
2. Depth of geotechnical boundary in borehole
3. Geologic symbol for rock or soil material
4. General description of geotechnical unit - qualitative description, including rock type(s), percentage rock types, frequency and sizes of interbeds, colour, texture.

**Joint (discontinuity) Characteristics**

5. Number of joint sets: a rock mass can be intersected by a number of joint sets of varying orientations.
6. Joint type: B = Bedding joint C = Cross joint
7. Orientation: only variations in dip can be identified in core; dip direction is from field mapping or oriented core:
   F = Flat = 0 - 20° D = Dipping = 20 - 50° V = Vertical = 50 - 90°
8. Joint spacing: this is an approximate measure of spacing between joints in specific joint sets.

| SPACING | > 3 m | 1 m – 3 m | 0.3 m – 1 m | 50 mm – 300 mm | < 50 mm |
|---|---|---|---|---|---|
| | VERY WIDE | WIDE | MODERATE | CLOSE | VERY CLOSE |

9. Roughness:

RU = Rough Undulating
SU = Smooth Undulating
LU = Slickensided Undulating
RP = Rough Planar
SP = Smooth Planar
LP = Slickensided Planar

10. Filling:

| | Approximate φ |
|---|---|
| T = Tight, hard, non-softened | 25 - 35 |
| O = Oxidation surface staining only | 25 - 30 |
| SA = Slightly altered; clay-free | 25 - 30 |
| S = Sandy particles; clay-free | 20 - 25 |
| Si = Sandy and silty, minor clay | 16 - 24 |
| NC = Non-softening Clays; 5mm | 6 - 12 |
| SC = Swelling Clay fillings; 5mm | |

11. Aperture: estimated size of joint opening.
12. Degree of weathered rock material:

| DEGREE | DESCRIPTION |
|---|---|
| UNWEATHERED | NO SIGNS OF DISCOLOURATION OR OXIDIZATION |
| SLIGHTLY WEATHERED | PARTIAL DISCOLOURATION; FRACTURES (JOINTS), TYPICALLY OXIDIZED |
| MODERATELY WEATHERED | TOTAL DISCOLOURATION |
| HIGHLY WEATHERED | TOTAL DISCOLOURATION; TYPICALLY FRIABLE AND PITTED |
| COMPLETELY WEATHERED | RESEMBLE A SOIL; ROCK STRUCTURE - USUALLY PRESERVED |

13. Strength of rock material:

| | | MPa |
|---|---|---|
| VERY HIGH STRENGTH | SPECIMEN CAN ONLY BE CHIPPED BY GEOLOGICAL HAMMER | > 200 |
| HIGH STRENGTH | SPECIMEN REQUIRES A NUMBER OF BLOWS OF A GEOLOGICAL HAMMER TO FRACTURE IT; CANNOT BE SCRAPED WITH POCKET KNIFE | 50 - 200 |
| MEDIUM STRENGTH | SPECIMEN CANNOT BE FRACTURED BY A SINGLE, FIRM BLOW OF GEOLOGICAL HAMMER; CAN BE SCRAPED WITH POCKET KNIFE, NOT PEELED | 15 - 50 |
| LOW STRENGTH | SHALLOW INDENTATIONS MADE BY FIRM BLOW WITH POINT OF GEOLOGICAL HAMMER; CAN BE PEELED WITH POCKET KNIFE WITH DIFFICULTY | 4 -15 |
| VERY LOW STRENGTH | CRUMBLES UNDER FIRM BLOW WITH POINT OF GEOLOGICAL HAMMER; CAN BE PEELED | 1 - 4 |

14. Fracture frequency: number of natural joints occurring over a meter length of core. All natural joints are counted irrespective of the number of joint sets.

| FRACTURE FREQUENCY | JOINT SPACING | LENGTH |
|---|---|---|
| 0.3 m | VERY WIDE | > 3 m |
| 0.3 – 1 m | WIDE | 1 m – 3 m |
| 1 – 3 m | MODERATE | 0.03 m – 1 m |
| 3 – 20 m | CLOSE | 0.005 m - 0.03 m |
| 20 m | VERY CLOSE | < 0.005 m |

15. Run number and Core Recovery
(i) Drill run number
(ii) Total Core Recovery is the total length of core pieces, irrespective of their individual lengths obtained in a core run, and expressed as a percentage of the length of that core run.
16. Rock Quantity Designation (RQD): The total length of those pieces of sound core which are 0.01 metres or greater in length in a core run, expressed as a percentage of the total length of that core run. Sound pieces of rock are those pieces separated by natural breaks and not machine breaks or subsequent artificial breaks.

Rock Mass Classification (after Deare)

| RQD (%) | 0 - 25 | 25 - 50 | 50 - 75 | 75 - 90 | 90 - 100 |
|---|---|---|---|---|---|
| DESCRIPTION | VERY POOR | POOR | FAIR | GOOD | EXCELLENT |

17. Core and Casing sizes: changes of core and casing sizes are indicated.
18. Water recovery, level and tests:
(i) percentage drill water recovery
(ii) water level depth
(iii) positions and results of tests, e.g., permeability and packer tests

## 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

# RECORD OF BOREHOLE No NBL 12+375Lt 1 OF 2 METRIC

W.P. 280-99-00 LOCATION Coords: N:4763888.1 E:327476.6 ORIGINATED BY AW

DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY DB

DATUM Geodetic DATE 11.18.09 CHECKED BY RA

| ELEV / DEPTH | DESCRIPTION | STRAT PLOT | SAMPLES NUMBER | SAMPLES TYPE | SAMPLES "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) | PLASTIC LIMIT $w_P$ / NATURAL MOISTURE CONTENT $w$ / LIQUID LIMIT $w_L$ — WATER CONTENT (%) (10 20 30) | UNIT WEIGHT $\gamma$ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 183.3 | Ground Surface | | | | | | | | | | |
| 183.2 / 0.1 | 130mm TOPSOIL | | | | | | | | | | |
| | FILL - Silty Clay, trace to some sand, trace to some gravel, trace organics, occasional cobbles, very stiff, dark brown / brown, moist | | 1 | SS | 19 | | 183 | | | | |
| | | | 2 | SS | 26 | | 182 | | | | 15 18 41 26 |
| 181.2 | | | 3 | SS | 28 | ▼ | | | | | |
| 2.1 | SILTY CLAY trace sand, stiff to very stiff, brown, moist | | 4 | SS | 26 | | 181 | | | | |
| | | | 5 | SS | 20 | | 180 | | | | |
| | | | 6 | SS | 26 | | 179 | | | | 0 4 69 27 |
| | | | 7 | SS | 16 | | 178 | | | | |
| | | | 8 | SS | 12 | | 177 | | | | 0 3 68 29 |
| | | | 9 | TW | PH | | 176 | + 1.6, >> 1.1 | | 20.6 | 3 3 66 28 |
| | | | 10 | SS | 12 | | 175 | + 1.6, + 1.4 | | | 0 3 71 26 |
| 171.3 / 12.0 | End of Borehole | | | | | | 174 | + 1.6, >> 1.5 | | | |
| | Borehole was dry (not stabilized) and hole open to full depth on completion. | | | | | | 173 | | | | |
| | Consolidation test performed on TW 9. | | | | | | 172 | | | | |

Continued Next Page

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

# RECORD OF BOREHOLE No NBL 12+375Lt 2 OF 2 METRIC

W.P. 280-99-00 LOCATION Coords: N:4763888.1 E:327476.6 ORIGINATED BY AW

DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY DB

DATUM Geodetic DATE 11.18.09 CHECKED BY RA

| SOIL PROFILE | | | SAMPLES | | | 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 20 40 60 80 100 | PLASTIC LIMIT $w_P$ / NATURAL MOISTURE CONTENT $w$ / LIQUID LIMIT $w_L$ — WATER CONTENT (%) 10 20 30 | UNIT WEIGHT $\gamma$ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEV / DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | | | | GR SA SI CL |

Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 3.0m slotted screen.

Water Level Readings:

| Date | Depth(m) | Elevation(m) |
|---|---|---|
| Nov.19.09 | 5.8 | 177.5 |
| Nov.30.09 | 3.2 | 180.1 |
| Dec.07.09 | 1.3 | 182.0 |
| Dec.15.09 | 1.8 | 181.5 |
| Jan.19.10 | 1.7 | 181.6 |

$+^3$, $\times^3$ Numbers refer to Sensitivity $\circ^{3\%}$ STRAIN AT FAILURE

# RECORD OF BOREHOLE No TN1 1 OF 3 METRIC

W.P. 280-99-00 LOCATION Coords: N:4763901.9 E:327473.4 ORIGINATED BY MP

DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers / Casing and Washboring / NQ Rock Coring COMPILED BY DB

DATUM Geodetic DATE 12.10.09 - 12.14.09 CHECKED BY RA

| SOIL PROFILE ELEV / DEPTH | DESCRIPTION | STRAT PLOT | SAMPLES NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × 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 $\gamma$ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 183.5 Ground Surface | | | | | | | | | | | |
| 183.5 / 0.1 | 50mm TOPSOIL | | | | | | | | | | |
| | FILL - Silty Sand, some gravel, trace organics, compact, black / brown, moist | | 1 | SS | 16 | | 183 | | | | |
| | | | 2 | SS | 14 | | | | | | 13 65 (22) |
| 182.1 / 1.4 | | | | | | | 182 | | | | |
| | SILTY CLAY trace sand, occasional gravel inclusions, stiff to hard, brown, damp to moist | | 3 | SS | 24 | | | | | | |
| | | | 4 | SS | 33 | | 181 | | 45 | | 0 1 41 58 |
| | | | 5 | SS | 36 | | | | | | |
| | | | 6 | SS | 36 | | 180 | | | | |
| | | | 7 | SS | 21 | | 179 | | | | 1 4 54 41 |
| | | | 8 | SS | 32 | | 178 | | | | |
| | | | 9 | SS | 22 | | | | | | |
| | | | | | | | 177 | | | | |
| | | | 10 | SS | 19 | | 176 | | | | 0 2 68 30 |
| | | | | | | | | | | | commence casing and washboring |
| | | | 11 | SS | 15 | | 175 | >> | | | |
| | | | | | | | | >> | | | |
| | | | | | | | 174 | + 1.6 | | | |
| | | | 12 | SS | 20 | | 173 | + 1.2 | | | 1 7 69 23 |
| | | | | | | | 172 | + 1.5 | | | |
| | | | 13 | TW | PH | | | | 1.5 | | |
| | | | | | | | 171 | + 1.5 | | | |
| | | | 14 | SS | 23 | | 170 | >> | | | |
| 168.8 / 14.7 | | | | | | | 169 | >> | | | |

Continued Next Page

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

# RECORD OF BOREHOLE No TN1 2 OF 3 METRIC

W.P. 280-99-00 LOCATION Coords. N:4763901.9 E:327473.4 ORIGINATED BY MP

DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers / Casing and Washboring / NQ Rock Coring COMPILED BY DB

DATUM Geodetic DATE 12.10.09 - 12.14.09 CHECKED BY RA

| ELEV / DEPTH | DESCRIPTION | STRAT PLOT | SAMPLES NUMBER | SAMPLES TYPE | SAMPLES "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) | PLASTIC LIMIT $w_P$ / NATURAL MOISTURE CONTENT $w$ / LIQUID LIMIT $w_L$ — WATER CONTENT (%) | UNIT WEIGHT $\gamma$ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | SILTY CLAY<br>trace to some sand, trace gravel,<br>very stiff to hard,<br>brown, damp to moist<br><br>(GLACIAL TILL) | | 15 | SS | 22 | | 168 | >> | | | 4 12 57 27 |
| | | | | | | | | + 1.1 | | | |
| | | | 16 | SS | 133/<br>28cm | | 167 | | | | |
| | | | | | | | 166 | | | | |
| | | | 17 | SS | 117 | | 165 | | | | |
| 163.8 | | | | | | | | | | | Dec.10<br>Dec.11 |
| 19.7 | SAND<br>some silt, trace clay, trace gravel,<br>very dense, grey, wet<br><br>(GLACIAL TILL) | | 18 | SS | 60 | | 164 | | | | 7 72 15 6 |
| 162.0 | | | | | | | 163 | | | | |
| 21.5 | CLAYEY SILT<br>trace to some gravel, trace sand,<br>hard, brown, moist<br><br>(GLACIAL TILL) | | 19 | SS | 77 | | 162 | | | | |
| | | | 20 | SS | 95 | | 161 | | | | |
| 159.6 | | | | | | | 160 | | | | |
| 23.9 | SILTY SAND<br>trace to some clay,<br>trace gravel,<br>very dense, brown, wet<br><br>(GLACIAL TILL) | | 21 | SS | 73 | | 159 | | | | 4 51 28 17 |
| | | | 22 | SS | 78 | | 158 | | | | |
| 156.6 | | | | | | | 157 | | | | Dec.11<br>Dec.14 |
| 26.9 | CLAYEY SILT TO SILTY CLAY<br>some gravel, trace to some sand,<br>very stiff, brown, wet<br><br>(GLACIAL TILL) | | 23 | SS | 19 | | 156 | | | | |
| 155.1 | | | | | | | | >> | | | |
| 28.4 | SILTY SAND<br>some gravel, trace clay,<br>very dense, brown, moist to wet<br><br>(GLACIAL TILL) | | 24 | SS | 90 | | 155 | | | | |
| | | | | | | | 154 | | | | |

Continued Next Page

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

# RECORD OF BOREHOLE No TN1 3 OF 3 METRIC

W.P. 280-99-00 LOCATION Coords: N:4763901.9 E:327473.4 ORIGINATED BY MP

DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers / Casing and Washboring / NQ Rock Coring COMPILED BY DB

DATUM Geodetic DATE 12.10.09 - 12.14.09 CHECKED BY RA

| SOIL PROFILE ELEV / DEPTH | DESCRIPTION | STRAT PLOT | SAMPLES 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 20 40 60 80 100 | PLASTIC LIMIT $w_P$ / NATURAL MOISTURE CONTENT $w$ / LIQUID LIMIT $w_L$ WATER CONTENT (%) 10 20 30 | UNIT WEIGHT $\gamma$ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 153.0 | | | | | | | 153 | | | | |
| 30.5 | BEDROCK - INTERBEDDED DOLOSTONE AND SHALE Unweathered, thinly laminated, grey, medium strength, argillaceous with unweathered, laminated, white, very low strength gypsum and calcite layers / veins and frequent unweathered, white, low strength, coarse grained calcitic vugs. | | 1 | RUN | NQ | | 152 | | | | RUN#1 TCR=95% SCR=87% RQD=59% |
| | | | 2 | RUN | NQ | | 151 | | | | RUN#2 TCR=93% SCR=83% RQD=67% |
| 150.0 | | | | | | | 150 | | | | |
| 33.6 | End of Borehole<br>Borehole open to full depth and filled with drill water upon completion of drilling.<br>Unable to push vane to 16.4m and 28.6m.<br>Borehole sealed with bentonite slurry to ground surface. | | | | | | | | | | |

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

# CORE LOG

Terraprobe

| | | | | | |
|---|---|---|---|---|---|
| Project: Highway 406 Twinning | Orientation: Vertical | Ground Elevation: 183.5m | Datum: Geodetic | Borehole No.: TN1 | |
| Location: Welland, Ontario | Date Started: December 14, 2009 | Completed: December 14, 2009 | Logged By: AW | Sheet 1 of 1 | |
| W.P.: 280-99-00 | Drilling Agency: DBW | Drill Type: Track-Mount | Core Barrel & Bit Design: NQ | Project No.: 1-09-4135 | |

| ELEVATION (m) | DEPTH (m) | SYMBOL | GENERAL DESCRIPTION | Joint Characteristics: No. OF SETS | JOINT TYPE | ORIENTATION | SPACING | ROUGHNESS | FILLING | APERTURE | WEATHERING | STRENGTH | FRACTURE FREQUENCY | RUN NO. CORE RECOVERY % | R Q D % | CORE SIZE/CASING | UNCONFINED COMPRESSIVE STRENGTH MPa | UNIT WEIGHT (KN/m³) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 153.5 | 30.0 | | Overburden, see Borehole Log TN1 | | | | | | | | | | | | | | | |
| 153.0 | 30.5 | | SALINA FORMATION BEDROCK<br><br>INTERBEDDED DOLOSTONE AND SHALE Unweathered, thinly laminated, grey, medium strength, argillaceous with unweathered, laminated, white, very low strength gypsum and calcite layers / veins and frequent unweathered, white, low strength, coarse grained calcitic vugs. | 1 | B | F | VC | RP | T | 0 to 1 | | | | #1 TCR 95 SCR 87 | 59 | NQ | | |
| 152.5 | 31.0 | | | 1 | B | F | C | RP | T | 0 to 1 | | | | | | | | |
| 152.0 | 31.5 | | | 1 | B | F | VC | RP | T | 0 to 1 | | | | | | | | |
| 151.5 | 32.0 | | | 1 | B | F | C | RP | T | 0 to 1 | | | | | | | | |
| 151.0 | 32.5 | | | 1 | B | F | VC | RP | T | 0 to 2 | | | | | | | | |
| 150.5 | 33.0 | | | 1 | B | F | C | SP | T | 0 to 2 | | | | | | | | |
| 150.0 | 33.5 | | | 1 | B | F | VC | SP | T | | | | | #2 TCR 93 SCR 83 | 67 | NQ | | |
| | | | | 1 | B | F | C | SP | T | | | | | | | | | |
| | | | | 2 | BC | FV | VC | SP | T | 0 to 1 | | | | | | | | |
| | | | | 1 | B | F | C | RP | T | | | | | | | | | |
| 149.5 | 34.0 | | End of Core Log<br><br>Rubbilized zones at:<br><br>30.50-30.53m; 31.10-31.15m; 31.63-31.66m; 32.10-32.13m; 32.85-32.95m.<br>Rubble indicated by '«'. | | | | | | | | | | | | | | | |
| 149.0 | 34.5 | | | | | | | | | | | | | | | | | |
| 148.5 | 35.0 | | | | | | | | | | | | | | | | | |
| 148.0 | 35.5 | | | | | | | | | | | | | | | | | |

Remarks:

LEGEND:

- Interbedded Dolostone and Shale
- Rubble

# RECORD OF BOREHOLE No TN2 1 OF 3 METRIC

W.P. 280-99-00 LOCATION Coords: N:4763920.1 E:327481.1 ORIGINATED BY AW

DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers / NQ Rock Coring COMPILED BY DB

DATUM Geodetic DATE 02.05.10 - 02.17.10 CHECKED BY RA

| ELEV / DEPTH | DESCRIPTION | STRAT PLOT | SAMPLES NUMBER | SAMPLES TYPE | SAMPLES "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × 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 $\gamma$ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 184.2 Ground Surface | | | | | | | | | | | |
| 0.0 | 800mm FILL - Sandy Gravel, trace silt, very dense, grey, dry | | 1 | SS | 19 | | 184 | | | | |
| 183.4 | | | | | | | | | | | |
| 0.8 | FILL - Silty Clay, trace to some sand, trace to some gravel, trace organics, very stiff to hard, brown / dark brown, damp to moist | | 2 | SS | 35 | | 183 | | | | 13 12 53 22 |
| 182.1 | | | 3 | SS | 18 | | | | | | |
| 2.1 | SILTY CLAY trace sand, occasional gravel inclusions, stiff to hard, brown, damp to moist | | 4 | SS | 37 | | 182 | | | | |
| | | | 5 | SS | 42 | | 181 | | 43 | | 0 2 44 54 |
| | | | 6 | SS | 32 | | 180 | | | | Jan.26 / Feb.05 |
| | | | 7 | SS | 19 | | | | | | |
| | | | 8 | SS | 21 | | 179 | | | | 0 2 60 38 |
| | | | 9 | SS | 17 | | 178 | | | | |
| | | | 10 | SS | 19 | | 177 | | | | |
| | | | 11 | SS | 10 | | 176 | | | | |
| | | | 12 | SS | 11 | | 175 | | | | 0 5 65 30 |
| | | | 13 | TW | PH | | 174 | | 1.2 >> | | |
| | --- firm --- | | | | | | 173 | | 1.1 >> 2.0 >> | | |
| | | | 14 | SS | 16 | | 172 | | | | |
| 169.5 | | | | | | | 171 | | 1.3 | | |
| 14.7 | | | | | | | 170 | | | | 1 3 72 24 |

Continued Next Page

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

# RECORD OF BOREHOLE No TN2 2 OF 3 METRIC

W.P. 280-99-00 LOCATION Coords: N:4763920.1 E:327481.1 ORIGINATED BY AW

DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers / NQ Rock Coring COMPILED BY DB

DATUM Geodetic DATE 02.05.10 - 02.17.10 CHECKED BY RA

| ELEV / DEPTH | DESCRIPTION | STRAT PLOT | SAMPLES NUMBER | SAMPLES TYPE | SAMPLES "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × 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 $\gamma$ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | SILTY CLAY<br>trace sand, trace gravel,<br>stiff to very stiff, brown, damp<br><br>(GLACIAL TILL) | | 15 | SS | 14 | | 169 | | ○ ⊢⊣ | | 2 9 63 26 |
| | | | | | | | 168 | | | | |
| | | | 16 | SS | 16 | | 167 | | ○ | | |
| | | | | | | | 166 | | | | |
| | | | 17 | SS | 26 | | | | ○ | | |
| | | | | | | | 165 | | | | Feb.05<br>---<br>Feb.12 |
| 163.5 | | | | | | | 164 | | | | |
| 20.7 | SAND<br>some silt, trace to some gravel,<br>trace clay,<br>very dense, brown, moist to wet<br><br>(GLACIAL TILL) | | | | | | 163 | | | | |
| | | | 18 | SS | 70 | | 162 | | | | |
| | | | | | | | | | | | |
| | | | 19 | SS | 61 | | 161 | | ○ | | |
| 160.3 | | | | | | | | | | | |
| 23.9 | CLAYEY SILT<br>and sand, some gravel,<br>very stiff to hard, brown, damp to<br>moist<br><br>(GLACIAL TILL) | | 20 | SS | 30 | | 160 | | ○ | | |
| | | | | | | | 159 | | | | |
| | | | 21 | SS | 29 | | 158 | | ○ ⊢⊣ | | 11 39 38 12 |
| | | | | | | | 157 | | | | |
| | | | 22 | SS | 38 | | | | ○ | | |
| 155.8 | | | | | | | 156 | | | | |
| 28.4 | GRAVEL AND SAND<br>some silt, trace clay,<br>compact, brown, moist<br><br>(GLACIAL TILL) | | 23 | SS | 23 | | 155 | | ○ | | 39 36 18 7 |

Continued Next Page

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

# RECORD OF BOREHOLE No TN2 3 OF 3 METRIC

W.P. 260-99-00 LOCATION Coords: N:4763920.1 E:327481.1 ORIGINATED BY AW

DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers / NQ Rock Coring COMPILED BY DB

DATUM Geodetic DATE 02.05.10 - 02.17.10 CHECKED BY RA

| ELEV / DEPTH | DESCRIPTION | STRAT PLOT | SAMPLES NUMBER | SAMPLES TYPE | SAMPLES "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × 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 $\gamma$ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 153.7 | | | 24 | SS | 100/ 15cm | | 154 | | | | Feb.12 |
| 30.5 | BEDROCK - INTERBEDDED DOLOSTONE AND SHALE Unweathered, thinly laminated, grey, medium strength, argillaceous with unweathered, laminated, white, very low strength gypsum and calcite layers / veins and frequent unweathered, white, low strength, coarse grained calcitic vugs. | | 1 | RUN | NQ | | | | | | Feb.17<br>RUN#1 TCR=0% SCR=0% RQD=0% |
| | | | 2 | RUN | NQ | | 153 | | | | RUN#2 TCR=71% SCR=66% RQD=16% |
| | | | 3 | RUN | NQ | | 152 | | | | RUN#3 TCR=100% SCR=78% RQD=44% |
| | | | 4 | RUN | NQ | | 151 | | | | RUN#4 TCR=93% SCR=92% RQD=54% |
| 150.1 | | | | | | | | | | | |
| 34.1 | End of Borehole<br><br>Borehole filled with drill water upon completion of drilling.<br><br>No sample recovery at SS9. Sampler redriven and disturbed sample collected.<br><br>Unable to push vane to 16.1m.<br><br>Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 1.52m slotted screen.<br><br>Water Level Readings:<br>Date / Depth(m) / Elevation(m)<br>Apr.16.10 2.6 181.6<br>Apr.29.10 1.6 182.6<br>May.04.10 6.2 178.0<br>May.06.10 6.2 178.0 | | | | | | | | | | |

$+^3, \times^3$ Numbers refer to Sensitivity $\circ^{3\%}$ STRAIN AT FAILURE

# CORE LOG

Terraprobe

| | | | | | |
|---|---|---|---|---|---|
| Project: Highway 406 Twinning | Orientation: Vertical | Ground Elevation: 184.2m | Datum: Geodetic | Borehole No.: TN2 | |
| Location: Welland, Ontario | Date Started: February 17, 2010 | Completed: February 17, 2010 | Logged By: AW | Sheet 1 of 1 | |
| W.P.: 280-99-00 | Drilling Agency: DDSI | Drill Type: Truck Mount | Core Barrel & Bit Design: NQ | Project No.: 1-09-4135 | |

| ELEVATION (m) | DEPTH (m) | SYMBOL | GENERAL DESCRIPTION | Joint Characteristics: No. OF SETS | JOINT TYPE | ORIENTATION | SPACING | ROUGHNESS | FILLING | APERTURE | WEATHERING | STRENGTH | FRACTURE FREQUENCY | RUN NO. CORE RECOVERY % | R Q D % | CORE SIZE/CASING | UNCONFINED COMPRESSIVE STRENGTH MPa | UNIT WEIGHT (KN/m³) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 154.2 | 30.0 | | Overburden, see Borehole Log TN2 | | | | | | | | | | | | | | | |
| 153.7 | 30.5 | | SALINA FORMATION BEDROCK | | | NO RECOVERY | | | | | NO RECOVERY | | | #1 TCR 0 SCR 0 | 0 | NQ | | |
| 153.2 | 31.0 | | INTERBEDDED DOLOSTONE AND SHALE Unweathered, thinly laminated, grey, medium strength, argillaceous with unweathered, laminated, white, very low strength gypsum and calcite layers / veins and frequent unweathered, white, low strength, coorse grained calcitic vugs. | 1 | B | F | VC | RP | T | 0 to 1 | | | | | | | | |
| 152.7 | 31.5 | | | 1 | B | F | C | RP | T | 0 to 3 | | | | #2 TCR 71 SCR 66 | 16 | NQ | | |
| 152.2 | 32.0 | | | 1 | B | F | VC | RP | T | 0 to 1 | | | | | | | | |
| | | | | 1 | B | F | C | RP | T | | | | | | | | | |
| | | | | 1 | B | F | VC | RU | T | | | | | | | | | |
| | | | | 1 | B | F | C | SP | T | 0 to 1 | | | | #3 TCR 100 SCR 78 | 44 | NQ | | |
| 151.7 | 32.5 | | | 2 | BC | FD | VC | SP | T | | | | | | | | | |
| | | | | 1 | B | F | C | SP | T | | | | | | | | | |
| | | | | 1 | B | F | C | SP | T | | | | | | | | | |
| 151.2 | 33.0 | | | 1 | B | F | VC | SP | T | | | | | | | | | |
| | | | | | | | | | | | | | | #4 TCR 93 SCR 92 | 54 | NQ | | |
| 150.7 | 33.5 | | | 1 | B | F | M | SP | T | 0 to 1 | | | | | | | | |
| 150.2 | 34.0 | | | | | | | | | | | | | | | | | |
| 149.7 | 34.5 | | End of Core Log<br>Rubbilized zones at:<br>31.10-31.30m; 32.00-32.10m; 32.35-32.40m;<br>Rubble indicated by '◁'. | | | | | | | | | | | | | | | |
| 149.2 | 35.0 | | Highly fractured zones at:<br>31.90-31.95m; 32.80-32.85. | | | | | | | | | | | | | | | |
| 148.7 | 35.5 | | | | | | | | | | | | | | | | | |

Remarks:

LEGEND:
- Interbedded Dolostone and Shale
- Rubble

# RECORD OF BOREHOLE No TN3 1 OF 3 METRIC

W.P. 280-99-00 LOCATION Coords: N:4763930.0 E:327463.7 ORIGINATED BY MP

DIST HWY 406 BOREHOLE TYPE Solid Stem Augers / Casing and Washboring / NQ Rock Coring COMPILED BY DB

DATUM Geodetic DATE 02.02.10 - 02.11.10 CHECKED BY RA

| 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 ● QUICK TRIAXIAL + FIELD VANE × 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 $\gamma$ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 184.1 | Ground Surface | | | | | | | | | | |
| 0.0 / 183.3 | 800mm FILL - Sandy Gravel, trace silt, very dense, grey, dry | | 1 | SS | 53 | | 184 | | | | 66 27 (7) |
| 0.8 / 181.2 | FILL - Silty Clay, trace to some sand, trace gravel, trace to some organics, very stiff to hard, black / brown, damp to moist | | 2 | SS | 27 | | 183 | | | | |
| | | | 3 | SS | 19 | | 182 | | | | |
| | | | 4 | SS | 32 | | | | | | |
| 2.9 | SILTY CLAY trace sand, trace gravel, stiff to hard, brown, damp to moist | | 5 | SS | 42 | | 181 | | | | |
| | | | 6 | SS | 44 | ▼ | 180 | | | | 0 2 49 49 |
| | ---- | | 7 | SS | 35 | | 179 | | | | |
| | sandy | | 8 | SS | 24 | | | | | | 1 41 36 22 |
| | ---- | | 9 | SS | 22 | | 178 | | | | |
| | | | 10 | TW | PH | | 177 | 1.5 | | | |
| | | | | | | | | >> 1.6 | | | |
| | | | | | | | 176 | 1.8 | | | |
| | | | 11 | SS | 12 | | 175 | >> 1.5 | | | 1 3 65 31 |
| | ---- | | | | | | | | | | |
| | firm | | | | | | 174 | | | | |
| | ---- | | 12 | SS | 17 | | 173 | 1.0 + 1.6 | | | |
| | | | | | | | | + 1.8 | | | |
| | | | 13 | TW | 21 | | 172 | >> | | | |
| | | | | | | | 171 | >> | | | Feb.02 / Feb.04 |
| | | | 14 | SS | 18 | | 170 | + 1.3 | | | 1 3 72 24 |

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

# RECORD OF BOREHOLE No TN3 2 OF 3 METRIC

W.P. 280-99-00 LOCATION Coords: N:4763930.0 E:327463.7 ORIGINATED BY MP

DIST HWY 406 BOREHOLE TYPE Solid Stem Augers / Casing and Washboring / NQ Rock Coring COMPILED BY DB

DATUM Geodetic DATE 02.02.10 - 02.11.10 CHECKED BY RA

| ELEV / DEPTH | DESCRIPTION | STRAT PLOT | SAMPLES NUMBER | SAMPLES TYPE | SAMPLES "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) | PLASTIC LIMIT $w_P$ / NATURAL MOISTURE CONTENT $w$ / LIQUID LIMIT $w_L$ — WATER CONTENT (%) (10 20 30) | UNIT WEIGHT $\gamma$ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 168.9 | | | | | | | 169 | | | | |
| 15.2 | SILTY CLAY<br>some sand, trace gravel,<br>very stiff to hard,<br>brown, damp to moist<br><br>(GLACIAL TILL) | | 15 | SS | 27 | | | 1.2 | | | |
| | | | | | | | 168 | 1.6 >> | | | |
| | | | | | | | | 1.4 | | | |
| | | | 16 | SS | 26 | | 167 | | | | 4 17 56 23 |
| | | | | | | | 166 | 1.8 >> | | | |
| | | | 17 | SS | 74 | | | | | | |
| | | | | | | | 165 | | | | |
| | | | 18 | SS | 100 | | 164 | | | | |
| 162.5 | | | | | | | | | | | |
| 21.6 | SANDY SILT TO SILTY SAND<br>some gravel, trace clay,<br>dense to very dense, brown, moist<br><br>(GLACIAL TILL) | | 19 | 120 | 100/13cm | | 163 | | | | commence casing and washboring |
| | | | | | | | 162 | | | | |
| | | | 20 | SS | 71 | | 161 | | | | Feb.04<br>Feb.08 |
| | | | | | | | 160 | | | | |
| | | | 21 | SS | 48 | | 159 | | | | |
| | | | 22 | SS | 43 | | 158 | | | | Feb.08<br>Feb.09 |
| 157.2 | | | | | | | | | | | |
| 26.9 | CLAYEY SILT TO SILTY CLAY<br>trace sand, trace gravel,<br>hard, brown, moist (GLACIAL TILL) | | | | | | 157 | | | | |
| 156.4 | | | 23 | SS | 112 | | | | | | |
| 27.7 | SAND AND GRAVEL<br>silty, trace clay,<br>very dense, brown, moist<br><br>(GLACIAL TILL) | | | | | | 156 | | | | |
| | | | 24 | SS | 108 | | 155 | | | | 31 33 29 7<br>Feb.09<br>Feb.11 |
| 154.5 | | | | | | | | | | | |
| 29.6 | BEDROCK | | | | | | | | | | |

Continued Next Page

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

# RECORD OF BOREHOLE No TN3 3 OF 3 METRIC

W.P. 280-99-00 LOCATION Coords: N:4763930.0 E:327463.7 ORIGINATED BY MP

DIST HWY 406 BOREHOLE TYPE Solid Stem Augers / Casing and Washboring / NQ Rock Coring COMPILED BY DB

DATUM Geodetic DATE 02.02.10 - 02.11.10 CHECKED BY RA

| SOIL PROFILE ELEV / DEPTH | DESCRIPTION | STRAT PLOT | SAMPLES 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 20 40 60 80 100 | PLASTIC LIMIT $w_P$ / NATURAL MOISTURE CONTENT $w$ / LIQUID LIMIT $w_L$ WATER CONTENT (%) 10 20 30 | UNIT WEIGHT $\gamma$ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | BEDROCK - INTERBEDDED DOLOSTONE AND SHALE Unweathered, thinly laminated, grey, medium strength, argillaceous with unweathered, laminated, white, very low strength gypsum and calcite layers / veins and frequent unweathered, white, low strength, coarse grained calcitic vugs. | | 1 | RUN | NQ | | 154 | | | | RUN#1 TCR=91% SCR=72% RQD=8% |
| | | | 2 | RUN | NQ | | 153 | | | | RUN#2 TCR=95% SCR=78% RQD=17% |
| 150.9 | | | 3 | RUN | NQ | | 152 | | | | RUN#3 TCR=98% SCR=84% RQD=16% |
| 33.2 | End of Borehole | | | | | | 151 | | | | |

Borehole was open to 21.3m and filled with drill water on completion of drilling.

Unable to push vane to 13.3m.

Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 1.52m slotted screen.

Water Level Readings:

| Date | Depth(m) | Elevation(m) |
|---|---|---|
| Apr.16.10 | 3.9 | 180.2 |
| Apr.29.10 | 4.7 | 179.4 |
| May.04.10 | 8.7 | 175.4 |
| May.06.10 | 9.4 | 174.7 |
| May.18.10 | 3.8 | 180.3 |

$+^{3}$, $\times^{3}$: Numbers refer to Sensitivity  $\circ^{3\%}$ STRAIN AT FAILURE

# CORE LOG

Terraprobe

| | | | |
|---|---|---|---|
| Project: Highway 406 Twinning | Orientation: Vertical | Ground Elevation: 184.1m | Datum: Geodetic | Borehole No.: TN3 |
| Location: Welland, Ontario | Date Started: February 11, 2010 | Completed: February 11, 2010 | Logged By: AW | Sheet 1 of 1 |
| W.P.: 280-99-00 | Drilling Agency: DBW | Drill Type: Track-Mount | Core Barrel & Bit Design: NQ | Project No.: 1-09-4135 |

| ELEVATION (m) | DEPTH (m) | SYMBOL | GENERAL DESCRIPTION | Joint Characteristics: No. OF SETS | JOINT TYPE | ORIENTATION | SPACING | ROUGHNESS | FILLING | APERTURE | WEATHERING | STRENGTH | FRACTURE FREQUENCY | RUN NO. CORE RECOVERY % | R Q D % | CORE SIZE/CASING | UNCONFINED COMPRESSIVE STRENGTH MPa | UNIT WEIGHT (KN/m³) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 154.6 | 29.5 | | Overburden, see Borehole Log TN3 | | | | | | | | | | | | | | | |
| | | | Sand and Gravel TILL, see Borehole Log TN3 | | | | | | | | | | | | | | | |
| 154.1 | 30.0 | | SALINA FORMATION BEDROCK | 1 | B | F | C | RP | T | | | | | | | | | |
| | | | | 1 | B | F | VC | SP | T | | | | | | | | | |
| | | | INTERBEDDED DOLOSTONE AND SHALE Unweathered, thinly laminated, grey, medium strength, argillaceous with unweathered, laminated, white, very low strength gypsum and calcite layers / veins and frequent unweathered, white, low strength, coarse grained calcitic vugs. | 1 | B | F | C | SP | T | | | | | | | | | |
| | | | | 1 | B | F | VC | SP | T | 0 to 1 | | | | #1 TCR 91 SCR 72 | 8 | NQ | | |
| 153.6 | 30.5 | | | 1 | B | F | C | SP | T | | | | | | | | | |
| | | | | 1 | B | F | VC | SP | T | | | | | | | | | |
| 153.1 | 31.0 | | | 1 | B | F | VC | RP | T | | | | | | | | | |
| | | | | 1 | B | F | VC | RP | T | | | | | | | | | |
| | | | | 1 | B | F | C | RP | T | | | | | | | | | |
| 152.6 | 31.5 | | | 2 | BC | FV | VC | RP | T | | | | | | | | | |
| | | | | 1 | B | F | C | RP | T | | | | | | | | | |
| | | | | 1 | B | F | VC | RP | T | 0 to 1 | | | | #2 TCR 95 SCR 78 | 17 | NQ | | |
| 152.1 | 32.0 | | | 1 | B | F | C | SP | T | | | | | | | | | |
| 151.6 | 32.5 | | | 1 | B | F | VC | SP | T | | | | | | | | | |
| | | | | 1 | B | F | VC | SP | T | | | | | #3 TCR 98 SCR 84 | 16 | NQ | | |
| 151.1 | 33.0 | | | 1 | B | F | C | SP | T | 0 to 1 | | | | | | | | |
| | | | End of Core Log | | | | | | | | | | | | | | | |
| 150.6 | 33.5 | | Rubbilized zones at: 30.15-31.18m; 30.25-30.33m; 30.90-31.05m; 31.50-31.60m; 31.70-31.73m; 32.45-32.5m. Rubble indicated by '4'. | | | | | | | | | | | | | | | |
| 150.1 | 34.0 | | Highly fractured zone at: 32.50-32.60m. | | | | | | | | | | | | | | | |
| 149.6 | 34.5 | | Weathered zone at: 30.90-30.97m. | | | | | | | | | | | | | | | |
| 149.1 | 35.0 | | | | | | | | | | | | | | | | | |

Remarks:

LEGEND:
- Interbedded Dolostone and Shale
- Rubble
- Sand and Gravel TILL

# RECORD OF BOREHOLE No TN4 1 OF 3 METRIC

W.P. 280-99-00 LOCATION Coords: N:4763941.4 E:327469.8 ORIGINATED BY MP

DIST HWY 406 BOREHOLE TYPE Solid Stem Augers / NQ Rock Coring COMPILED BY DB

DATUM Geodetic DATE 01.26.10 - 02.17.10 CHECKED BY RA

| ELEV / DEPTH | DESCRIPTION | STRAT PLOT | SAMPLES NUMBER | SAMPLES TYPE | SAMPLES "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa 20 40 60 80 100 (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE) | PLASTIC LIMIT $w_P$ / NATURAL MOISTURE CONTENT $w$ / LIQUID LIMIT $w_L$ WATER CONTENT (%) 10 20 30 | UNIT WEIGHT $\gamma$ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 184.0 Ground Surface | | | | | | | | | | | |
| 0.0 | 740mm FILL - Gravel, some sand, trace to some silt, dense, grey, damp | | 1 | SS | 41 | | | | | | 72 17 (11) |
| 183.3 | | | | | | | | | | | |
| 0.7 | FILL - Silty Clay, some gravel, trace sand, trace organics, stiff, dark brown / brown, damp to moist | | 2 | SS | 10 | | 183 | | | | |
| | | | 3 | SS | 15 | | | | | | |
| 181.9 | | | | | | | 182 | | | | |
| 2.1 | SILTY CLAY trace sand, stiff to hard, brown, damp to moist | | 4 | SS | 29 | | | | 44 | | 0 3 47 50 |
| | | | 5 | SS | 36 | | 181 | | | | |
| | | | 6 | SS | 50 | | 180 | | | | 0 3 74 23 |
| | | | 7 | SS | 43 | | | | | | |
| | | | | | | | 179 | | | | Jan.26 |
| | | | 8 | SS | 23 | | | | | | Feb.05 0 3 65 32 |
| | | | 9 | SS | 17 | | 178 | | | | |
| | | | | | | | 177 | 1.3 | | | |
| | | | 10 | SS | 23 | | | 1.4 | | | |
| | | | | | | | 176 | >> | | | |
| | | | 11 | SS | 9 | | 175 | 1.6 | | | 0 3 66 31 |
| | | | | | | | 174 | 1.9 | | | |
| | | | 12 | TW | PH | | | 1.7 | | | |
| | | | | | | | 173 | 2.0 | | | |
| | | | 13 | SS | 16 | | 172 | | 1.4 | | |
| | | | | | | | 171 | | 1.7 | | |
| | | | 14 | SS | 17 | | 170 | | 1.7 | | |
| 169.3 | | | | | | | | | >> | | |
| 14.7 | | | | | | | | | | | |

Continued Next Page

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

# RECORD OF BOREHOLE No TN4 2 OF 3 METRIC

W.P. 280-99-00 LOCATION Coords: N:4763941.4 E:327469.8 ORIGINATED BY MP

DIST HWY 406 BOREHOLE TYPE Solid Stem Augers / NQ Rock Coring COMPILED BY DB

DATUM Geodetic DATE 01.26.10 - 02.17.10 CHECKED BY RA

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (20 40 60 80 100): ○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE | PLASTIC LIMIT $w_P$ / NATURAL MOISTURE CONTENT $w$ / LIQUID LIMIT $w_L$ — WATER CONTENT (%) (10 20 30) | UNIT WEIGHT $\gamma$ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEV / DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | | | | GR SA SI CL |
| | SILTY CLAY<br>some sand to sandy, trace gravel,<br>very stiff to hard, brown, damp<br><br>(GLACIAL TILL) | | 15 | SS | 35 | | 168 | >> | ○ | | |
| | | | 16 | SS | 30 | | 167 | | | | 4 22 54 20 |
| | | | 17 | SS | 87 | | 166 | | ○ | | |
| | | | 18 | SS | 84 | | 165 | | ○ | | |
| 163.6<br>20.4 | SANDY SILT TO SILTY SAND<br>some gravel to gravelly,<br>trace to some clay,<br>very dense, brown, moist to wet<br><br>(GLACIAL TILL) | | 19 | SS | 96 | | 164 | | ○ | | Feb.05<br>Feb.12<br>27 28 34 11 |
| | | | 20 | SS | 129 | | 163 | | ○ | | |
| | | | 21 | SS | 109 | | 162 | | ○ | | |
| 157.5<br>26.5 | SILTY CLAY<br>trace sand,<br>hard, brown, moist<br><br>(GLACIAL TILL) | | 22 | SS | 65 | | 161 | | ○ | | |
| | | | 23 | SS | 40 | | 160 | | ○ | | 0 4 54 42 |
| 155.6<br>28.4 | SAND AND SILT<br>some gravel, trace to some clay,<br>very dense, brown, wet<br><br>(GLACIAL TILL) | | 24 | SS | 60 | | 159 | | ○ | | 19 39 32 10 |
| | | | | | | | 158 | | | | |
| | | | | | | | 157 | | | | |
| | | | | | | | 156 | | | | |
| | | | | | | | 155 | | | | |

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

# RECORD OF BOREHOLE No TN4 3 OF 3 METRIC

W.P. 280-99-00 LOCATION Coords: N:4763941.4 E:327469.8 ORIGINATED BY MP

DIST HWY 406 BOREHOLE TYPE Solid Stem Augers / NQ Rock Coring COMPILED BY DB

DATUM Geodetic DATE 01.26.10 - 02.17.10 CHECKED BY RA

| ELEV / DEPTH | DESCRIPTION | STRAT PLOT | SAMPLES: NUMBER | SAMPLES: TYPE | SAMPLES: "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (20 40 60 80 100): ○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE | PLASTIC LIMIT $w_P$ / NATURAL MOISTURE CONTENT $w$ / LIQUID LIMIT $w_L$ — WATER CONTENT (%) (10 20 30) | UNIT WEIGHT $\gamma$ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 153.4 | | | | | | | | | | | Feb.12 ---------- Feb.17 |
| 30.6 | BEDROCK - INTERBEDDED DOLOSTONE AND SHALE Unweathered, thinly laminated, grey, medium strength, argillaceous with unweathered, laminated, white, very low strength gypsum and calcite layers / veins and frequent unweathered, white, low strength, coarse grained calcitic vugs. | | 1 | RUN | NQ | | 153 | | | | RUN#1 TCR=36% SCR=7% RQD=0% |
| | | | 2 | RUN | NQ | | 152 151 | | | | RUN#2 TCR=59% SCR=45% RQD=7% |
| | | | 3 | RUN | NQ | | 150 | | | | RUN#3 TCR=97% SCR=71% RQD=27% |
| 149.0 | | | | | | | 149 | | | | |
| 35.0 | End of Borehole<br>Borehole filled with drill water upon completion of coring.<br>Borehole sealed with bentonite slurry to ground surface. | | | | | | | | | | |

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

# CORE LOG

Terraprobe

| | | | | | |
|---|---|---|---|---|---|
| Project: Highway 406 Twinning | Orientation: Vertical | Ground Elevation: 184.0m | Datum: Geodetic | Borehole No.: TN4 | |
| Location: Welland, Ontario | Date Started: February 17, 2010 | Completed: February 17, 2010 | Logged By: AW | Sheet 1 of 1 | |
| W.P.: 280-99-00 | Drilling Agency: DBW | Drill Type: Track-Mount | Core Barrel & Bit Design: NQ | Project No.: 1-09-4135 | |

| ELEVATION (m) | DEPTH (m) | SYMBOL | GENERAL DESCRIPTION | Joint Characteristics: No. OF SETS | JOINT TYPE | ORIENTATION | SPACING | ROUGHNESS | FILLING | APERTURE | WEATHERING | STRENGTH | FRACTURE FREQUENCY | RUN NO. CORE RECOVERY % | R Q D % | CORE SIZE/CASING | UNCONFINED COMPRESSIVE STRENGTH MPa | UNIT WEIGHT (KN/m³) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 154.0 | 30.0 | | Overburden, see Borehole Log TN4 | | | | | | | | | | | | | | | |
| 153.5 | 30.5 | | | | | | | | | | | | | | | | | |
| | | | SALINA FORMATION BEDROCK | | | | | | | | | | | | | | | |
| 153.0 | 31.0 | | INTERBEDDED DOLOSTONE AND SHALE Unweathered, thinly laminated, grey, medium strength, argillaceous with unweathered, laminated, white, very low strength gypsum and calcite layers / veins and frequent unweathered, white, low strength, coarse grained calcitic vugs. | | | | | | | | | | | | | | | |
| | | | | 2 | BC | FV | VC | RP | T | 0 to 1 | | | | #1 TCR 36 SCR 7 | 0 | NQ | | |
| 152.5 | 31.5 | | | 1 | B | F | C | SP | T | | | | | | | | | |
| 152.0 | 32.0 | | | 1 | B | F | VC | SP | T | 0 to 2 | | | | | | | | |
| 151.5 | 32.5 | | | 1 | B | F | C | SP | T | 0 to 1 | | | | | | | | |
| | | | | 1 | B | F | VC | RU | T | 0 to 1 | | | | #2 TCR 59 SCR 45 | 7 | NQ | | |
| 151.0 | 33.0 | | | 1 | B | F | C | SP | T | 0 to 1 | | | | | | | | |
| 150.5 | 33.5 | | | 1 | B | F | VC | RU | T | 0 to 1 | | | | | | | | |
| | | | | 1 | B | F | C | RU | S | 10 | | | | | | | | |
| | | | | 1 | B | F | C | SP | T | 0 to 1 | | | | | | | | |
| 150.0 | 34.0 | | | 1 | B | F | VC | SP | T | 0 to 1 | | | | | | | | |
| | | | | 1 | B | F | C | SP | T | 0 to 1 | | | | #3 TCR 97 SCR 71 | 27 | NQ | | |
| 149.5 | 34.5 | | | | | | | | | | | | | | | | | |
| 149.0 | 35.0 | | End of Core Log | | | | | | | | | | | | | | | |
| 148.5 | 35.5 | | Rubbilized zones at: 30.60-31.90m; 32.65-32.85m; 33.55-33.75m; 33.95-34.00m. Rubble indicated by '<'. Highly fractured zone at: 32.00-32.50m. Weathered zone at: 33.75-33.80m. | | | | | | | | | | | | | | | |

Remarks:

LEGEND:
- Interbedded Dolostone and Shale
- Rubble

# RECORD OF BOREHOLE No NBL 12+440Rt 1 OF 2 METRIC

W.P. 280-99-00 LOCATION Coords: N:4763962.9 E:327465.8 ORIGINATED BY MP

DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY DB

DATUM Geodetic DATE 11.04.09 CHECKED BY RA

| ELEV / DEPTH | DESCRIPTION | STRAT PLOT | SAMPLES NUMBER | SAMPLES TYPE | SAMPLES "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE) | PLASTIC LIMIT $w_P$ / NATURAL MOISTURE CONTENT $w$ / LIQUID LIMIT $w_L$ / WATER CONTENT (%) | UNIT WEIGHT $\gamma$ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 183.0 | Ground Surface | | | | | | | | | | |
| 182.9 / 0.1 | 130mm TOPSOIL | | | | | | | | | | |
| | FILL - Silty Clay, trace sand, trace gravel, trace organics, firm to stiff, brown, damp to moist | | 1 | SS | 6 | | 182 | | | | |
| | | | 2 | SS | 12 | | | | | | |
| | | | 3 | SS | 13 | ▼ | 181 | | | | |
| | | | 4 | SS | 14 | | | | | | |
| 180.1 / 2.9 | SILTY CLAY trace sand, occasional gravel inclusions, stiff to very stiff, brown, moist | | 5 | SS | 17 | | 180 | | | | 0 1 56 43 |
| | | | 6 | SS | 26 | | 179 | | | | |
| | | | 7 | SS | 15 | | 178 | | | | 1 3 67 29 |
| | | | 8 | SS | 25 | | 177 | | | | 0 1 87 12 |
| | | | 9 | SS | 10 | | 176 | | | | |
| | | | 10 | TW | PH | | 175 | 1.5 >> | | 20.7 | 1 3 72 24 |
| | | | | | | | 174 | >> | | | |
| | | | | | | | 173 | 1.8 | | | |
| | | | 11 | SS | 12 | | 172 | >> | | | 7 2 72 19 |
| 169.6 / 13.4 | End of Borehole | | | | | | 171 | >> | | | |
| | Borehole was dry (not stabilized) and hole open to full depth on completion. | | | | | | 170 | | | | |
| | Consolidation test performed on TW 10. | | | | | | | | | | |

Continued Next Page

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

# RECORD OF BOREHOLE No NBL 12+440Rt 2 OF 2 METRIC

W.P. 280-99-00 LOCATION Coords: N:4763962.9 E:327465.8 ORIGINATED BY MP

DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY DB

DATUM Geodetic DATE 11.04.09 CHECKED BY RA

| SOIL PROFILE | | | SAMPLES | | | 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 20 40 60 80 100 | PLASTIC LIMIT $w_P$ / NATURAL MOISTURE CONTENT $w$ / LIQUID LIMIT $w_L$ — WATER CONTENT (%) 10 20 30 | UNIT WEIGHT $\gamma$ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEV / DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | | | | |
| | Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 3.0m slotted screen.<br><br>Water Level Readings:<br>Date Depth(m) Elevation(m)<br><br>Nov.09.09 8.2 174.8<br>Nov.19.09 2.1 180.9<br>Nov.30.09 1.9 181.1<br>Dec.08.09 1.9 181.1 | | | | | | | | | | |

$+^3$, $\times^3$: Numbers refer to Sensitivity $\circ^{3\%}$ STRAIN AT FAILURE


**Bedrock Core Sample**
Borehole: TN1
Runs: 1 & 2
Depth: 30.5m – 33.6m

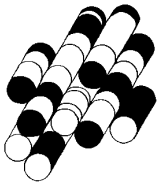

**Bedrock Core Sample**
Borehole: TN2
Runs: 1, 2, 3 & 4
Depth: 30.5m – 34.1m


**Bedrock Core Sample**
Borehole: TN3
Runs 1, 2 & 3
Depth: 29.6m – 33.2m


**Bedrock Core Sample**
Borehole: TN4
Runs: 1, 2 & 3
Depth: 30.6m – 35.0m

# APPENDIX B

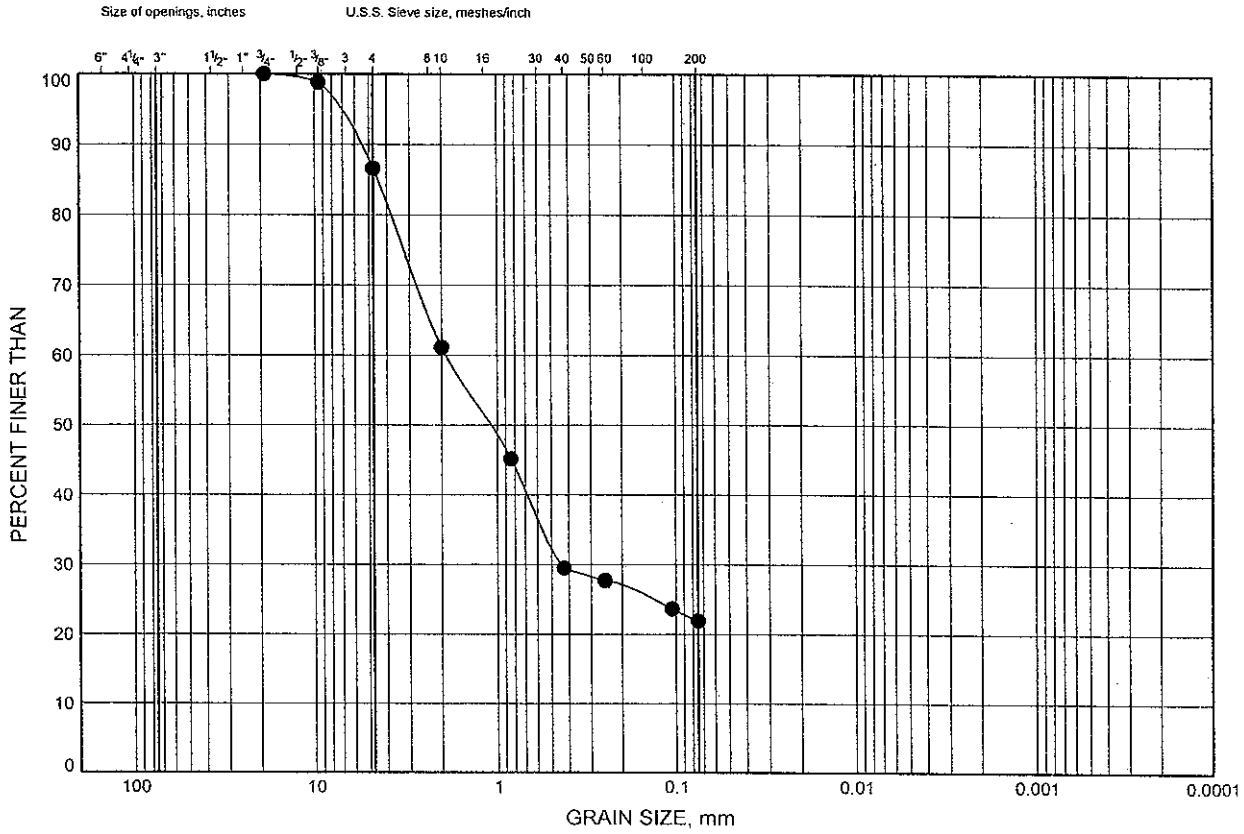
TERRAPROBE INC.



# GRAIN SIZE DISTRIBUTION

FIGURE B1

## FILL - Silty Sand




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

| SYMBOL | BOREHOLE | DEPTH (m) | ELEVATION (m) |
|---|---|---|---|
| ● | TN1 | 1.0 | 182.5 |

Date May 2010

Project 1-09-4135

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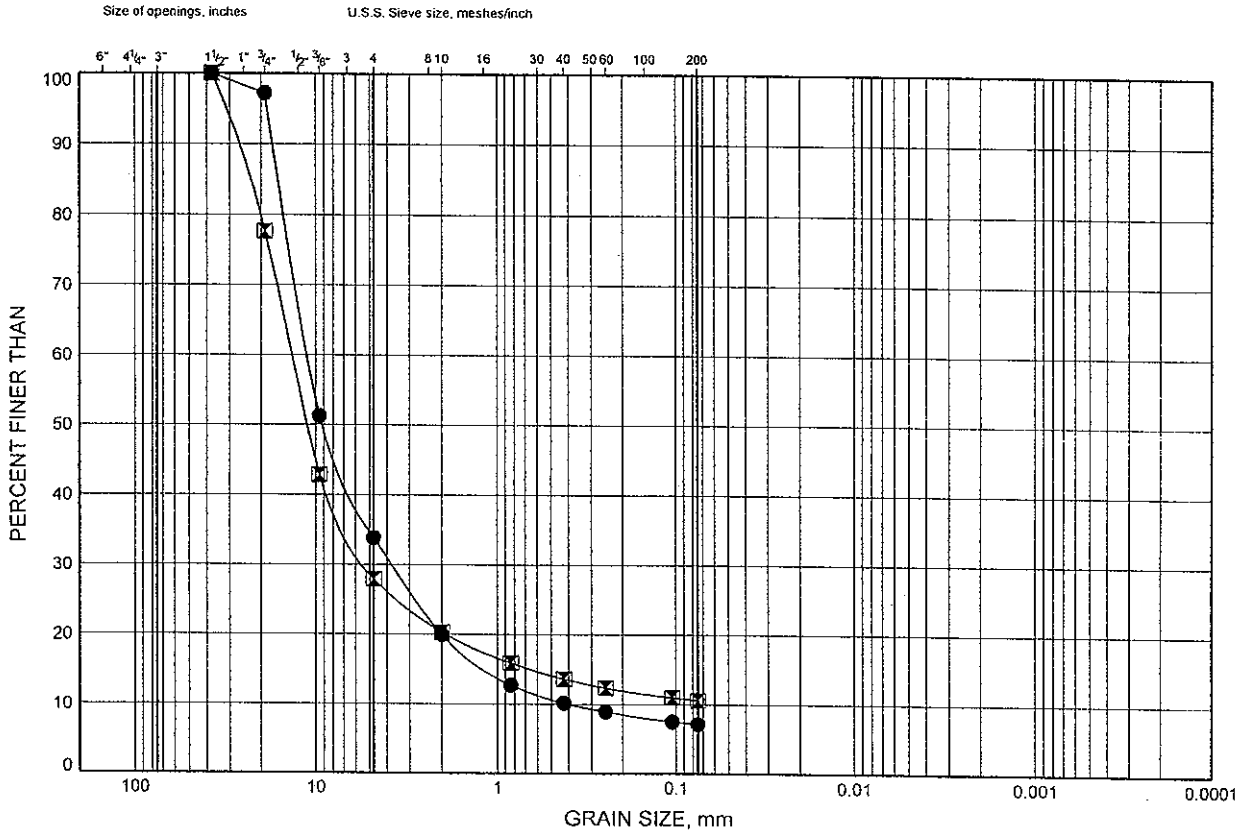
# GRAIN SIZE DISTRIBUTION

FIGURE B2

## FILL - Sandy Gravel




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

| SYMBOL | BOREHOLE | DEPTH (m) | ELEVATION (m) |
|---|---|---|---|
| ● | TN3 | 0.3 | 183.8 |
| ⊠ | TN4 | 0.3 | 183.7 |

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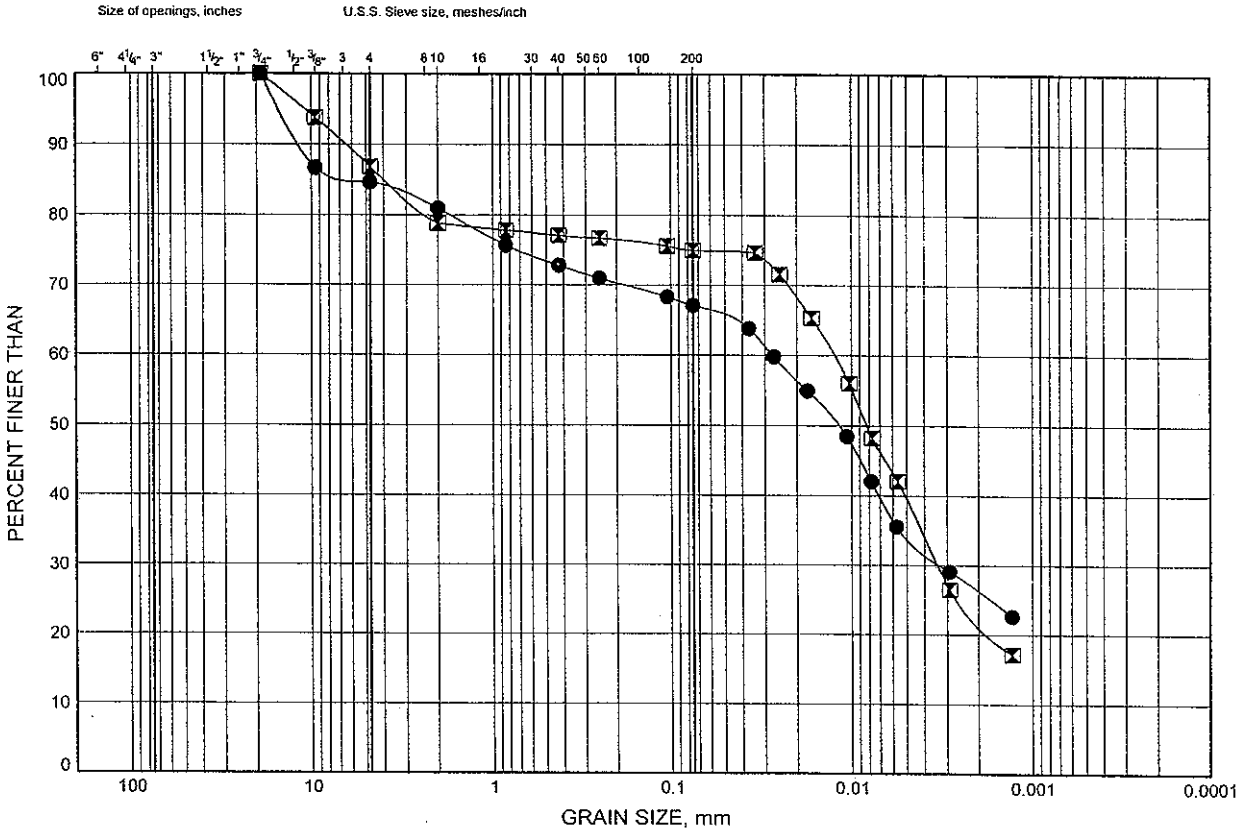
# GRAIN SIZE DISTRIBUTION

FIGURE B3

## FILL - Silty Clay




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

| SYMBOL | BOREHOLE | DEPTH (m) | ELEVATION (m) |
|---|---|---|---|
| ● | NBL 12+375Lt | 1.0 | 182.3 |
| ⊠ | TN2 | 1.0 | 183.2 |

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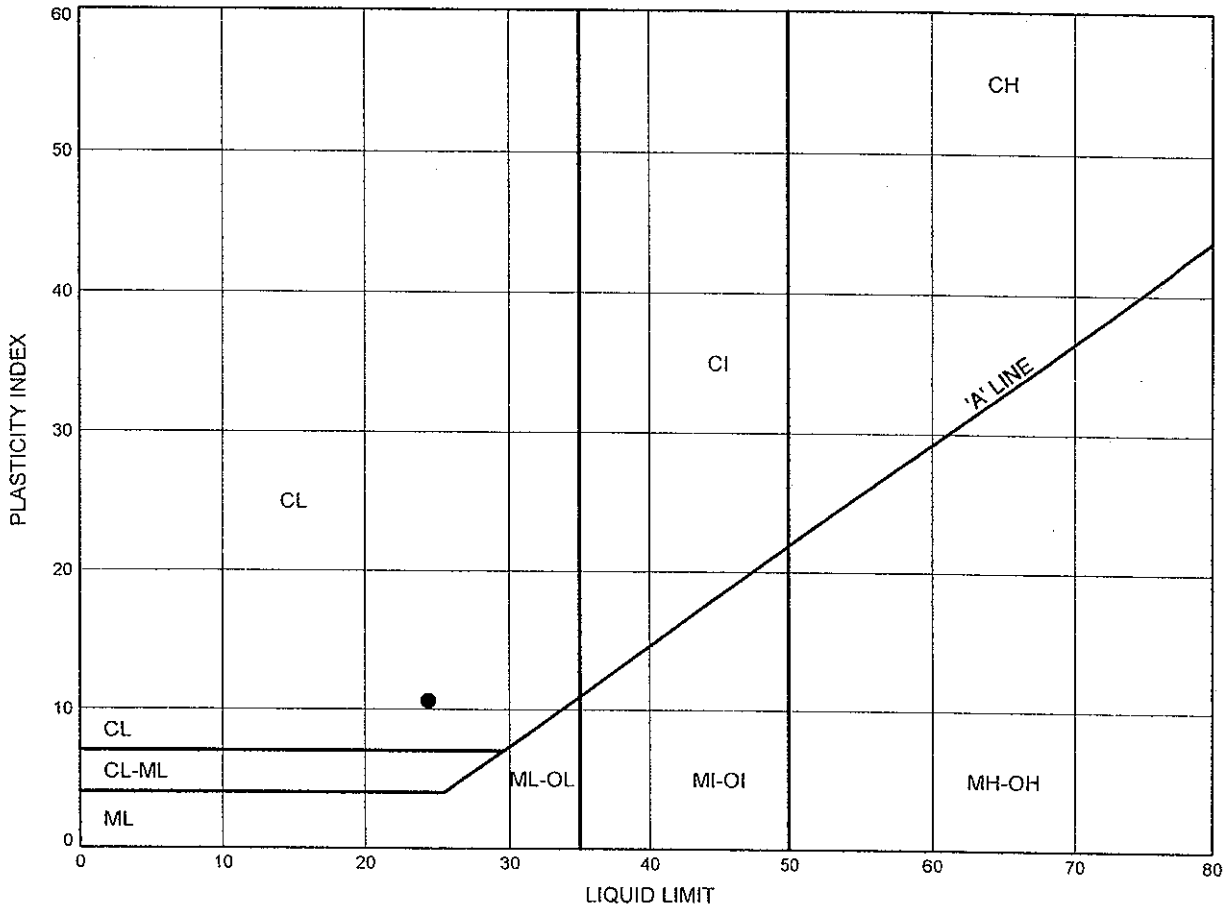
# ATTERBERG LIMITS TEST RESULTS

FIGURE B4

## FILL - Silty Clay




| SYMBOL | BOREHOLE | DEPTH (m) | ELEVATION (m) |
|---|---|---|---|
| ● | TN2 | 1.0 | 183.2 |

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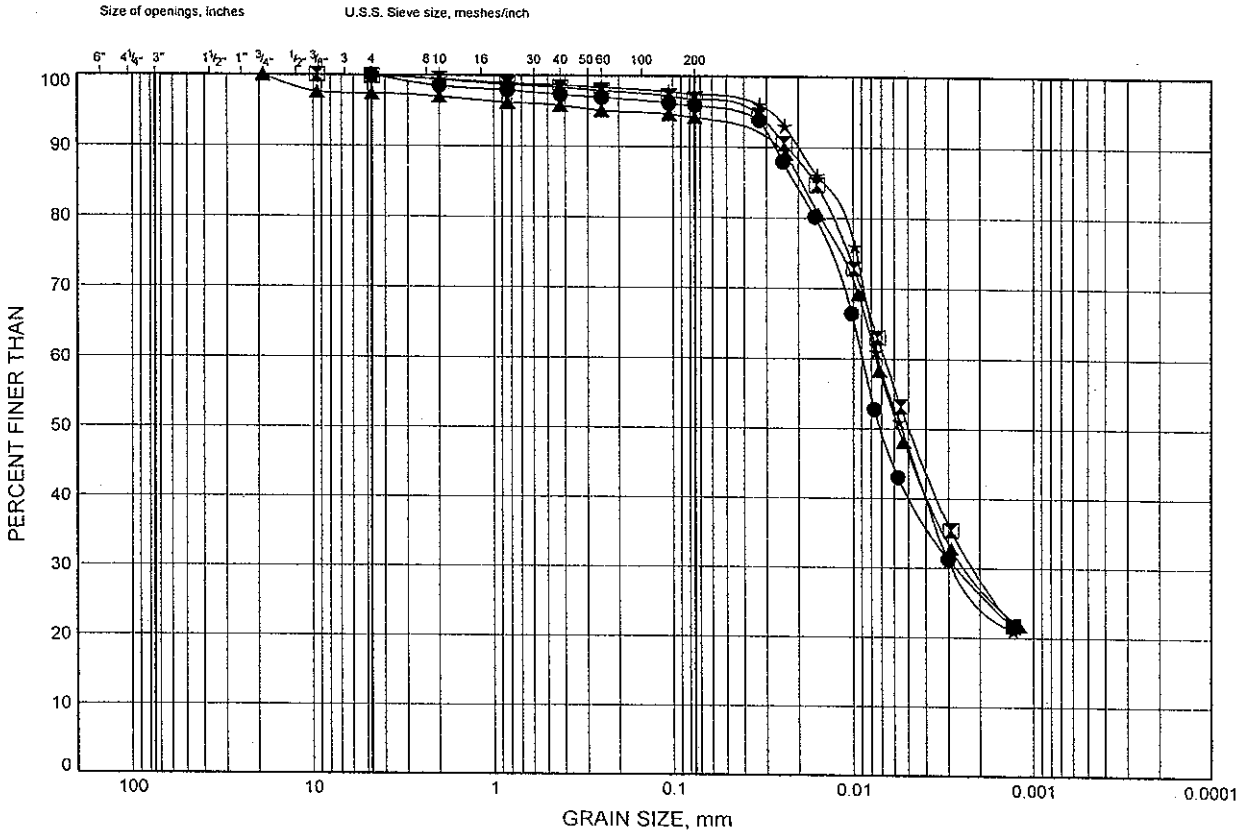
# GRAIN SIZE DISTRIBUTION

FIGURE B5

## SILTY CLAY




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

| SYMBOL | BOREHOLE | DEPTH (m) | ELEVATION (m) |
|---|---|---|---|
| ● | NBL 12+375Lt | 4.7 | 178.6 |
| ⊠ | NBL 12+375Lt | 7.8 | 175.5 |
| ▲ | NBL 12+375Lt | 9.3 | 174.0 |
| ★ | NBL 12+375Lt | 10.9 | 172.4 |

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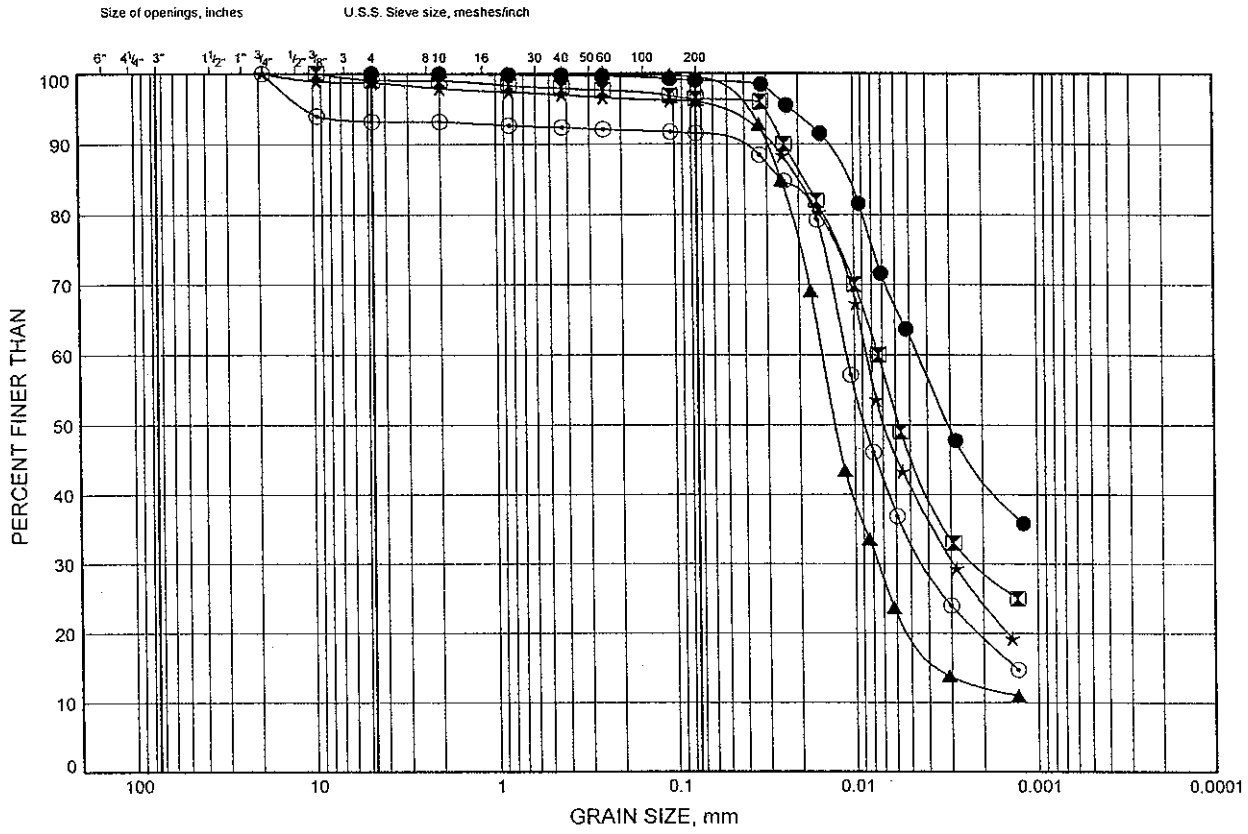
# GRAIN SIZE DISTRIBUTION

FIGURE B6

## SILTY CLAY




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

| SYMBOL | BOREHOLE | DEPTH (m) | ELEVATION (m) |
|---|---|---|---|
| ● | NBL 12+440Rt | 3.2 | 179.8 |
| ⊠ | NBL 12+440Rt | 6.3 | 176.7 |
| ▲ | NBL 12+440Rt | 7.8 | 175.2 |
| ★ | NBL 12+440Rt | 10.9 | 172.1 |
| ⊙ | NBL 12+440Rt | 12.4 | 170.6 |

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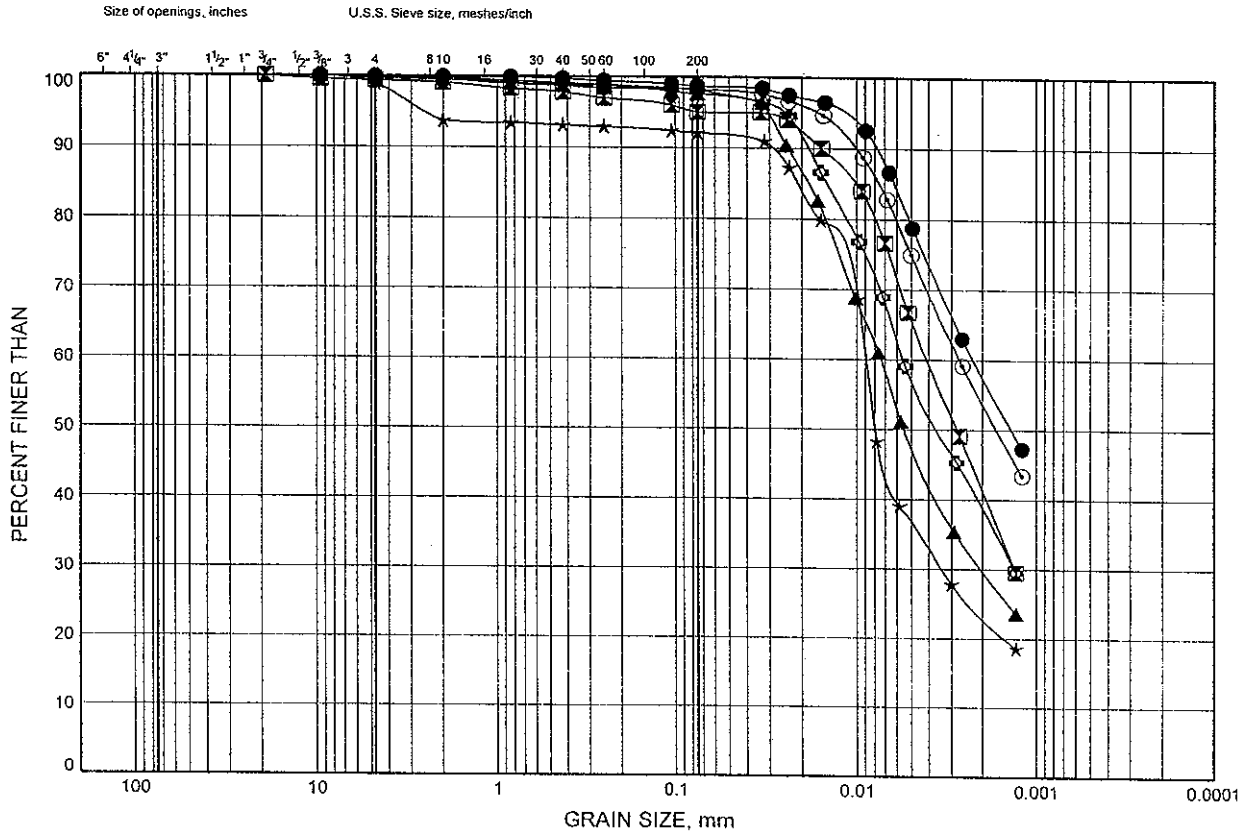
# GRAIN SIZE DISTRIBUTION

FIGURE B7

## SILTY CLAY




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

| SYMBOL | BOREHOLE | DEPTH (m) | ELEVATION (m) |
|---|---|---|---|
| ● | TN1 | 2.5 | 181.0 |
| ⊠ | TN1 | 4.7 | 178.8 |
| ▲ | TN1 | 7.8 | 175.7 |
| ★ | TN1 | 10.9 | 172.6 |
| ⊙ | TN2 | 3.2 | 181.0 |
| ✿ | TN2 | 5.5 | 178.7 |

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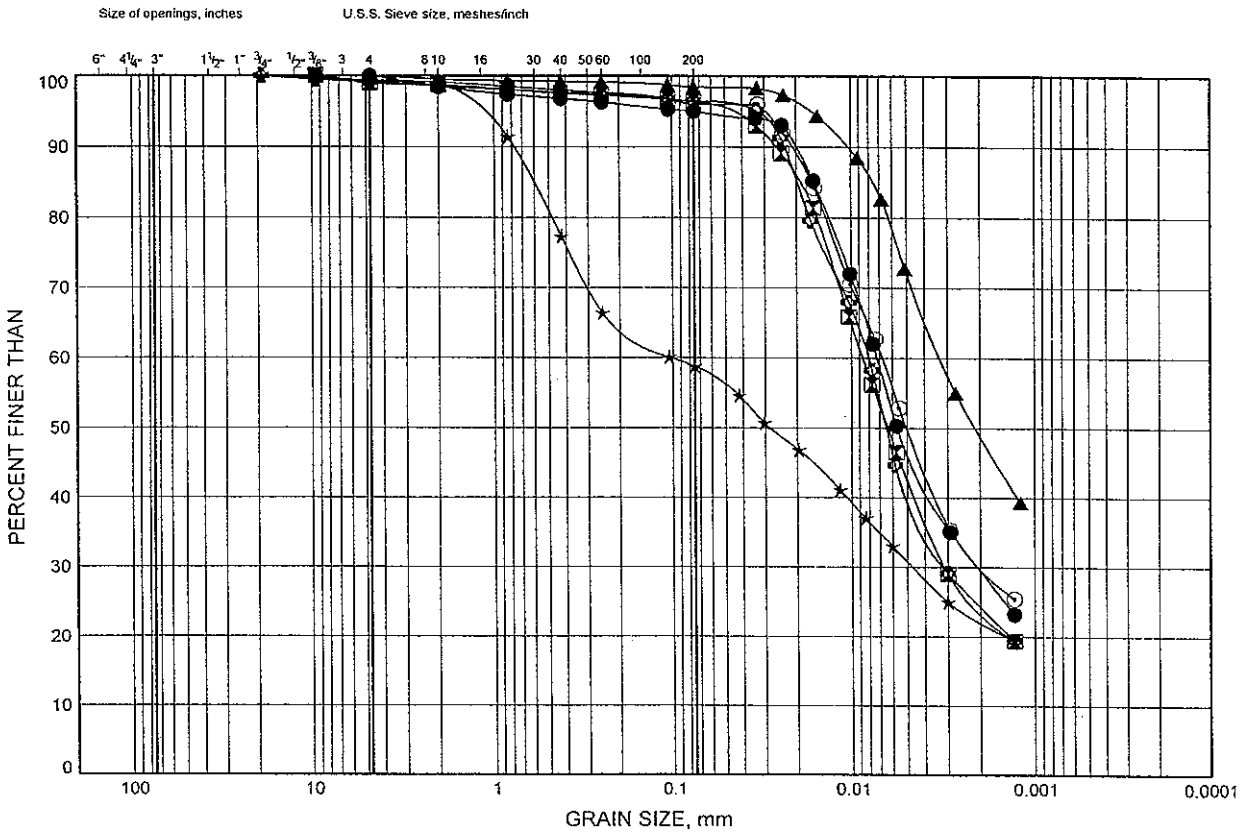
# GRAIN SIZE DISTRIBUTION

FIGURE B8

## SILTY CLAY




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

| SYMBOL | BOREHOLE | DEPTH (m) | ELEVATION (m) |
|---|---|---|---|
| ● | TN2 | 9.3 | 174.9 |
| ⊠ | TN2 | 13.9 | 170.3 |
| ▲ | TN3 | 4.0 | 180.1 |
| ★ | TN3 | 5.5 | 178.6 |
| ⊙ | TN3 | 9.3 | 174.8 |
| ✿ | TN3 | 13.9 | 170.2 |

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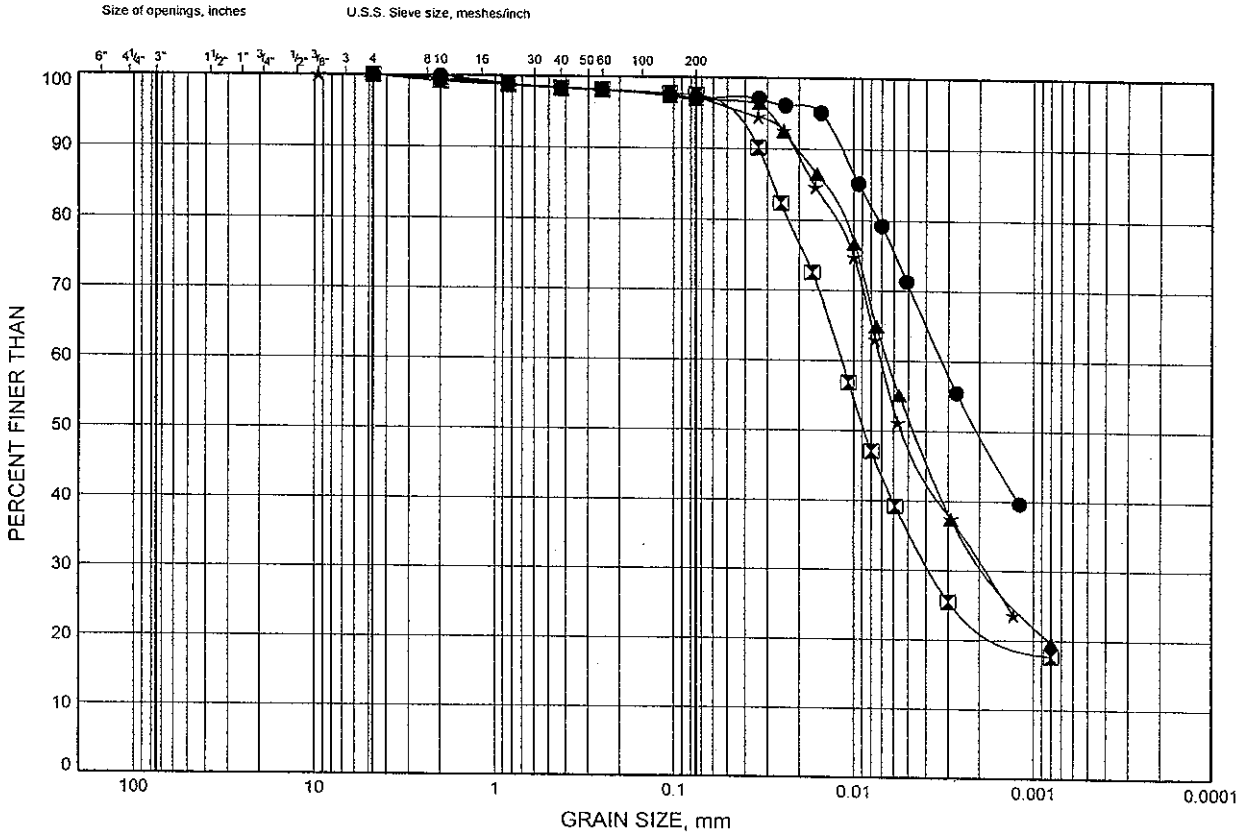
# GRAIN SIZE DISTRIBUTION

FIGURE B9

## SILTY CLAY




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

| SYMBOL | BOREHOLE | DEPTH (m) | ELEVATION (m) |
|---|---|---|---|
| ● | TN4 | 2.5 | 181.5 |
| ⊠ | TN4 | 4.0 | 180.0 |
| ▲ | TN4 | 5.5 | 178.5 |
| ★ | TN4 | 9.3 | 174.7 |

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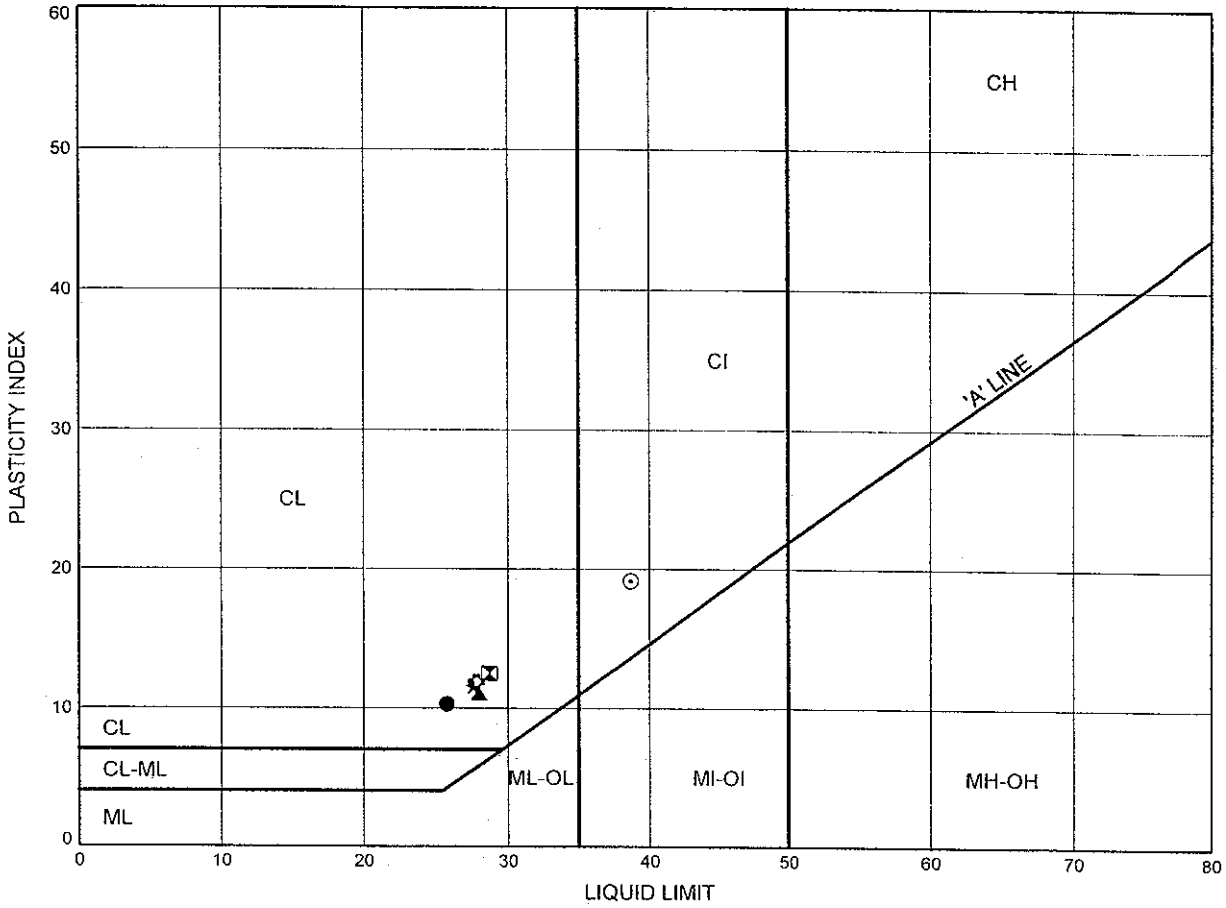
# ATTERBERG LIMITS TEST RESULTS

FIGURE B10

## SILTY CLAY




| SYMBOL | BOREHOLE | DEPTH (m) | ELEVATION (m) |
|---|---|---|---|
| ● | NBL 12+375Lt | 4.7 | 178.6 |
| ⊠ | NBL 12+375Lt | 7.8 | 175.5 |
| ▲ | NBL 12+375Lt | 9.3 | 174.0 |
| ★ | NBL 12+375Lt | 10.9 | 172.4 |
| ⊙ | NBL 12+440Rt | 3.2 | 179.8 |
| ✿ | NBL 12+440Rt | 6.3 | 176.7 |

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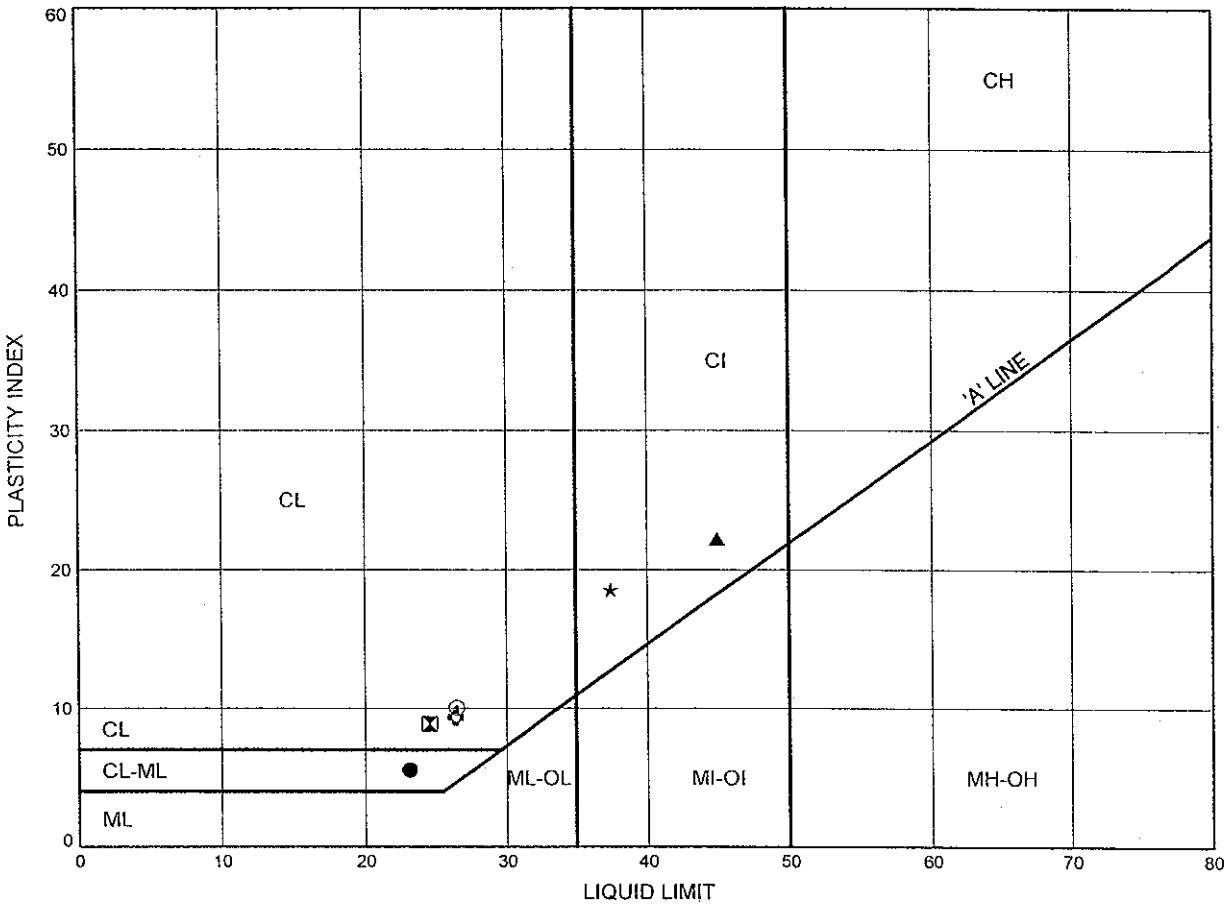
# ATTERBERG LIMITS TEST RESULTS

FIGURE B11

## SILTY CLAY




| SYMBOL | BOREHOLE | DEPTH (m) | ELEVATION (m) |
|---|---|---|---|
| ● | NBL 12+440Rt | 7.8 | 175.2 |
| ⊠ | NBL 12+440Rt | 12.4 | 170.6 |
| ▲ | TN1 | 2.5 | 181.0 |
| ★ | TN1 | 4.7 | 178.8 |
| ⊙ | TN1 | 7.8 | 175.7 |
| ✿ | TN1 | 10.9 | 172.6 |

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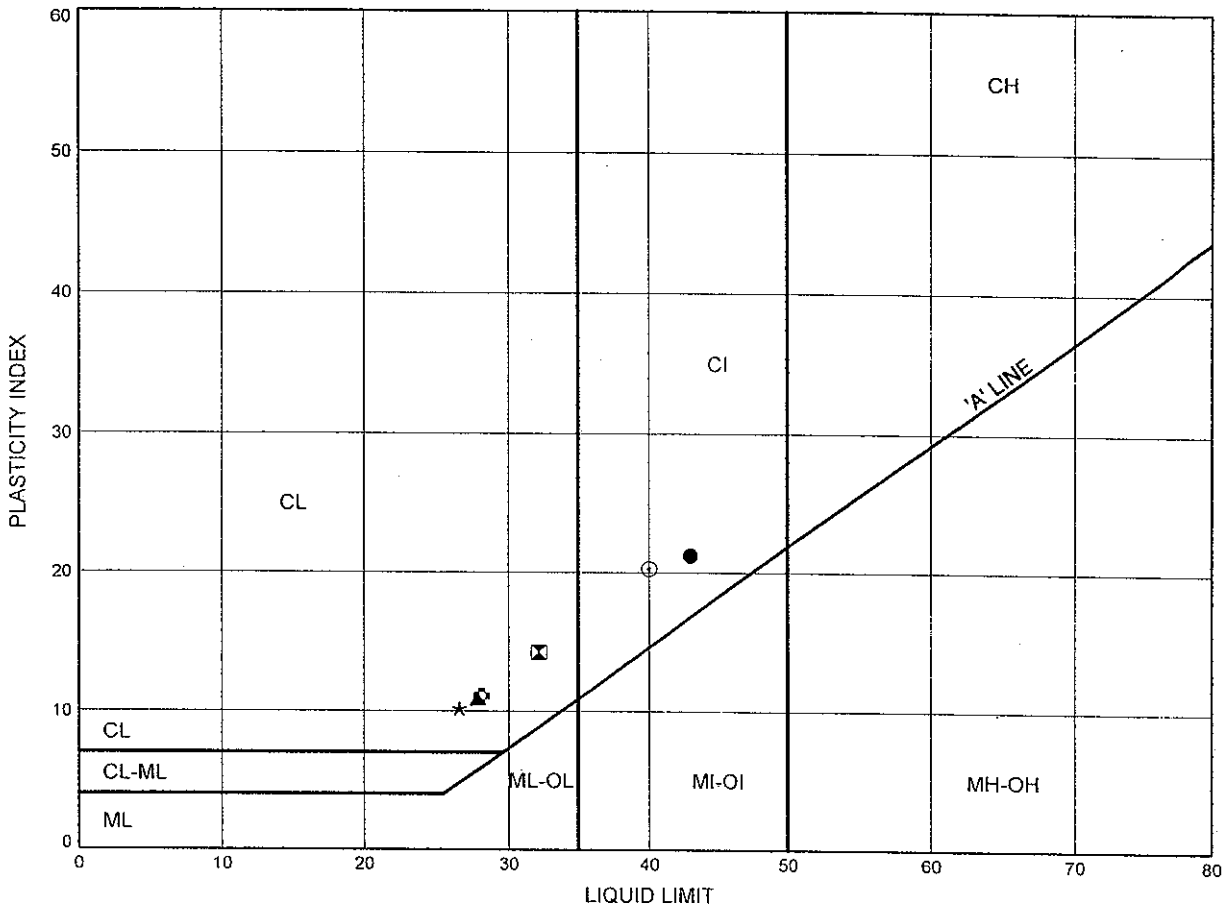
# ATTERBERG LIMITS TEST RESULTS

FIGURE B12

## SILTY CLAY




| SYMBOL | BOREHOLE | DEPTH (m) | ELEVATION (m) |
|---|---|---|---|
| ● | TN2 | 3.2 | 181.0 |
| ⊠ | TN2 | 5.5 | 178.7 |
| ▲ | TN2 | 9.3 | 174.9 |
| ★ | TN2 | 13.9 | 170.3 |
| ⊙ | TN3 | 4.0 | 180.1 |
| ✿ | TN3 | 5.5 | 178.6 |

Date May 2010

Project 1-09-4135

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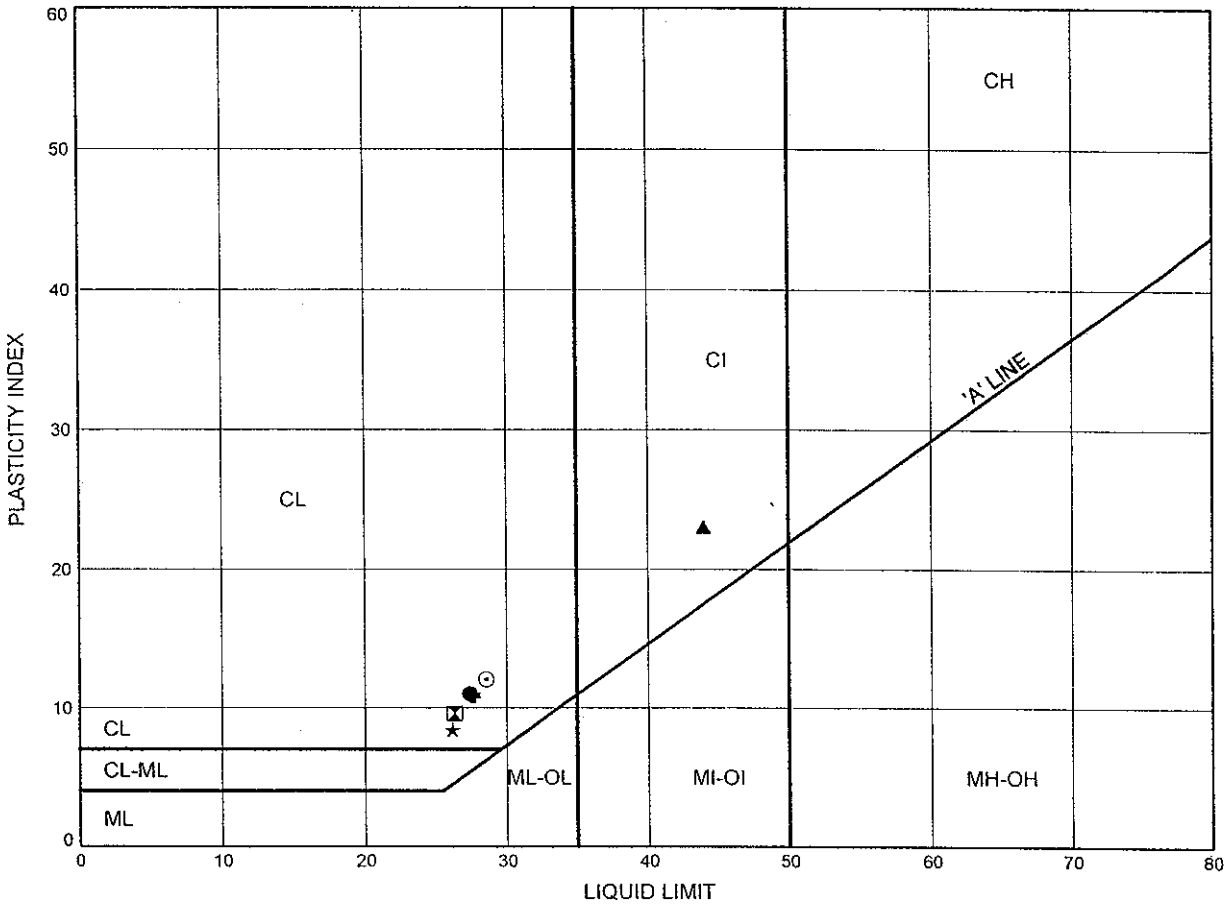
ALTR 1-09-4135 TN BRIDGE.GPJ 05/18/10

# ATTERBERG LIMITS TEST RESULTS

FIGURE B13

## SILTY CLAY




| SYMBOL | BOREHOLE | DEPTH (m) | ELEVATION (m) |
|---|---|---|---|
| ● | TN3 | 9.3 | 174.8 |
| ⊠ | TN3 | 13.9 | 170.2 |
| ▲ | TN4 | 2.5 | 181.5 |
| ★ | TN4 | 4.0 | 180.0 |
| ⊙ | TN4 | 5.5 | 178.5 |
| ✿ | TN4 | 9.3 | 174.7 |

Date May 2010

Project 1-09-4135

Prep'd DB

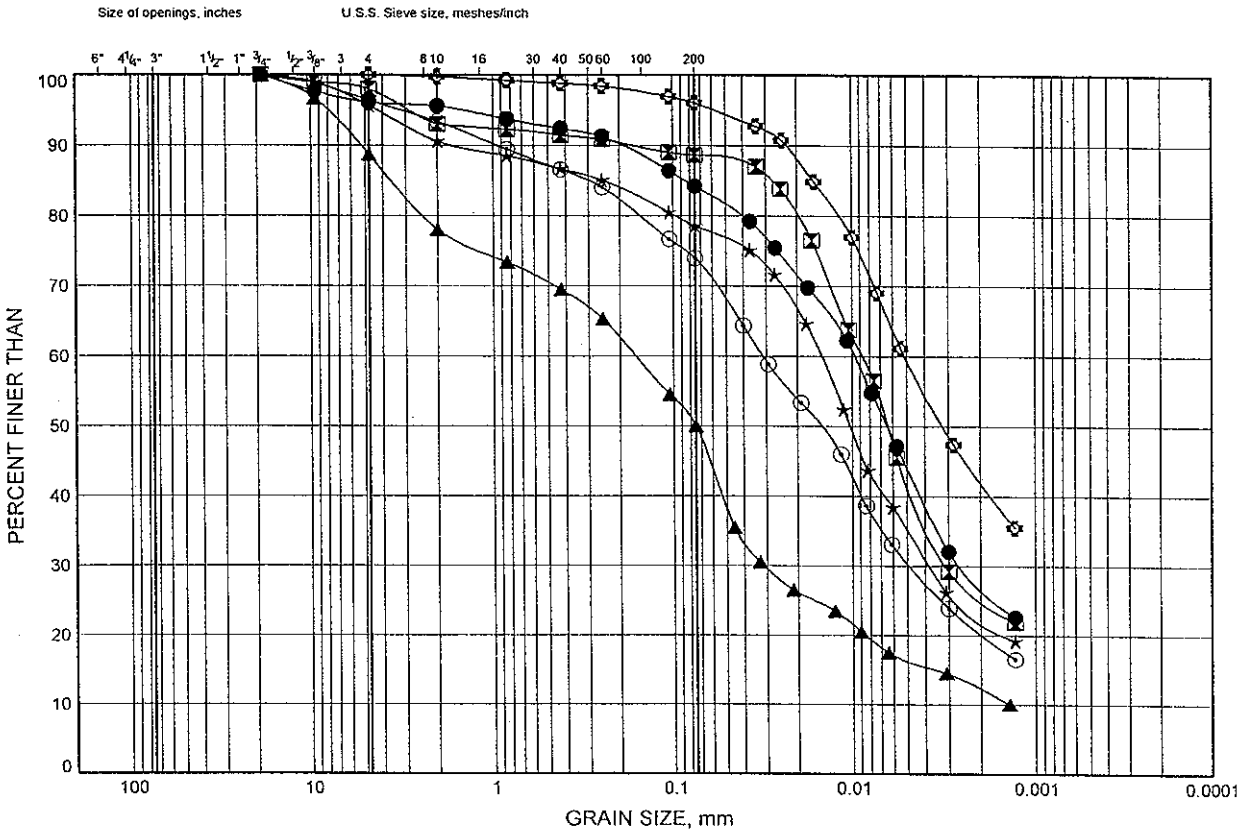
Chkd. MP

ALTR 1-09-4135 TN BRIDGE.GPJ 05/18/10

# GRAIN SIZE DISTRIBUTION

FIGURE B14

## SILTY CLAY TO CLAYEY SILT TILL




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

| SYMBOL | BOREHOLE | DEPTH (m) | ELEVATION (m) |
|---|---|---|---|
| ● | TN1 | 15.4 | 168.1 |
| ⊠ | TN2 | 15.4 | 168.8 |
| ▲ | TN2 | 26.1 | 158.1 |
| ★ | TN3 | 17.0 | 167.1 |
| ⊙ | TN4 | 17.0 | 167.0 |
| ✿ | TN4 | 27.6 | 156.4 |

Date May 2010

Project 1-09-4135

Prep'd DB

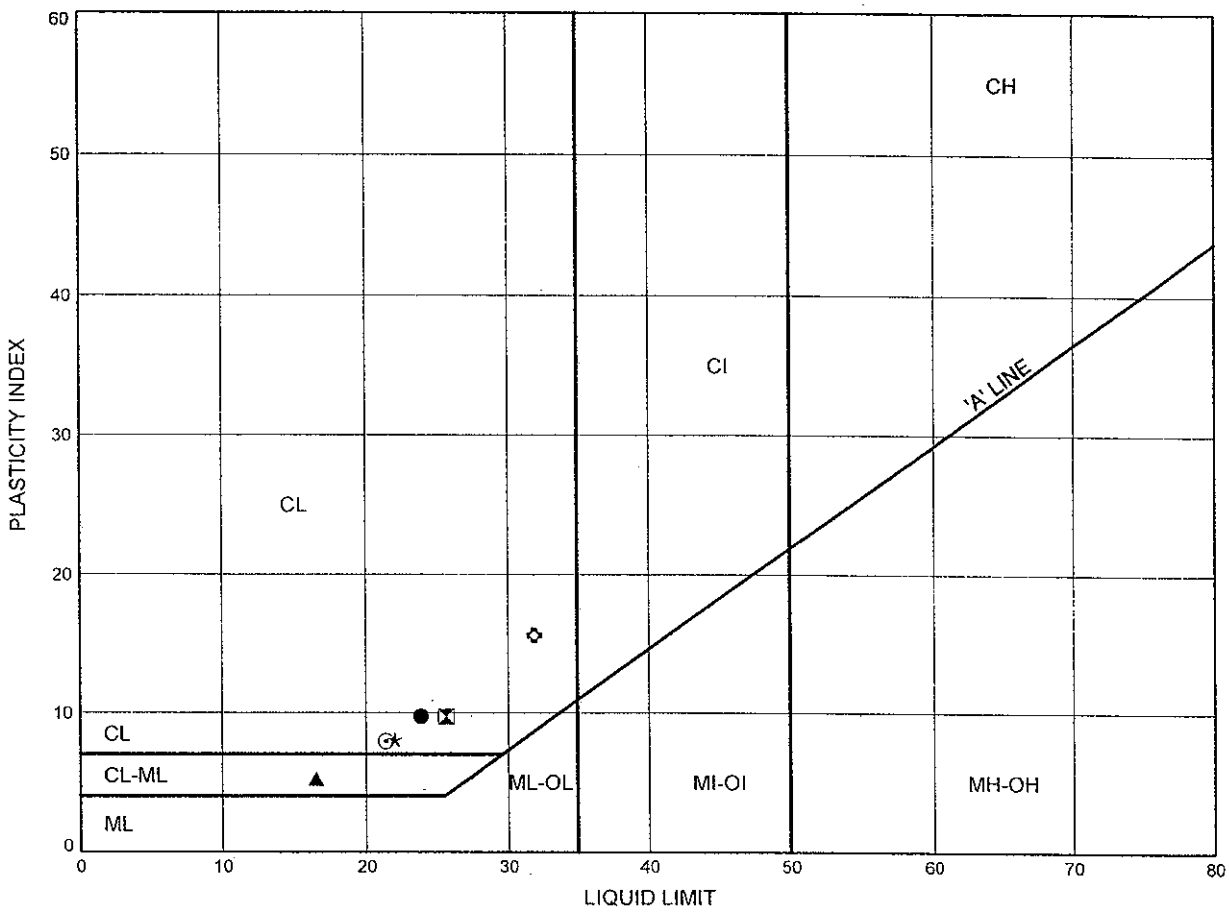
Chkd. MP

GSD 1-09-4135 TN BRIDGE.GPJ 05/18/10

# ATTERBERG LIMITS TEST RESULTS

FIGURE B15

## SILTY CLAY TO CLAYEY SILT TILL




| SYMBOL | BOREHOLE | DEPTH (m) | ELEVATION (m) |
|---|---|---|---|
| ● | TN1 | 15.4 | 168.1 |
| ⊠ | TN2 | 15.4 | 168.8 |
| ▲ | TN2 | 26.1 | 158.1 |
| ★ | TN3 | 17.0 | 167.1 |
| ⊙ | TN4 | 17.0 | 167.0 |
| ✿ | TN4 | 27.6 | 156.4 |

Date May 2010

Project 1-09-4135

Prep'd DB

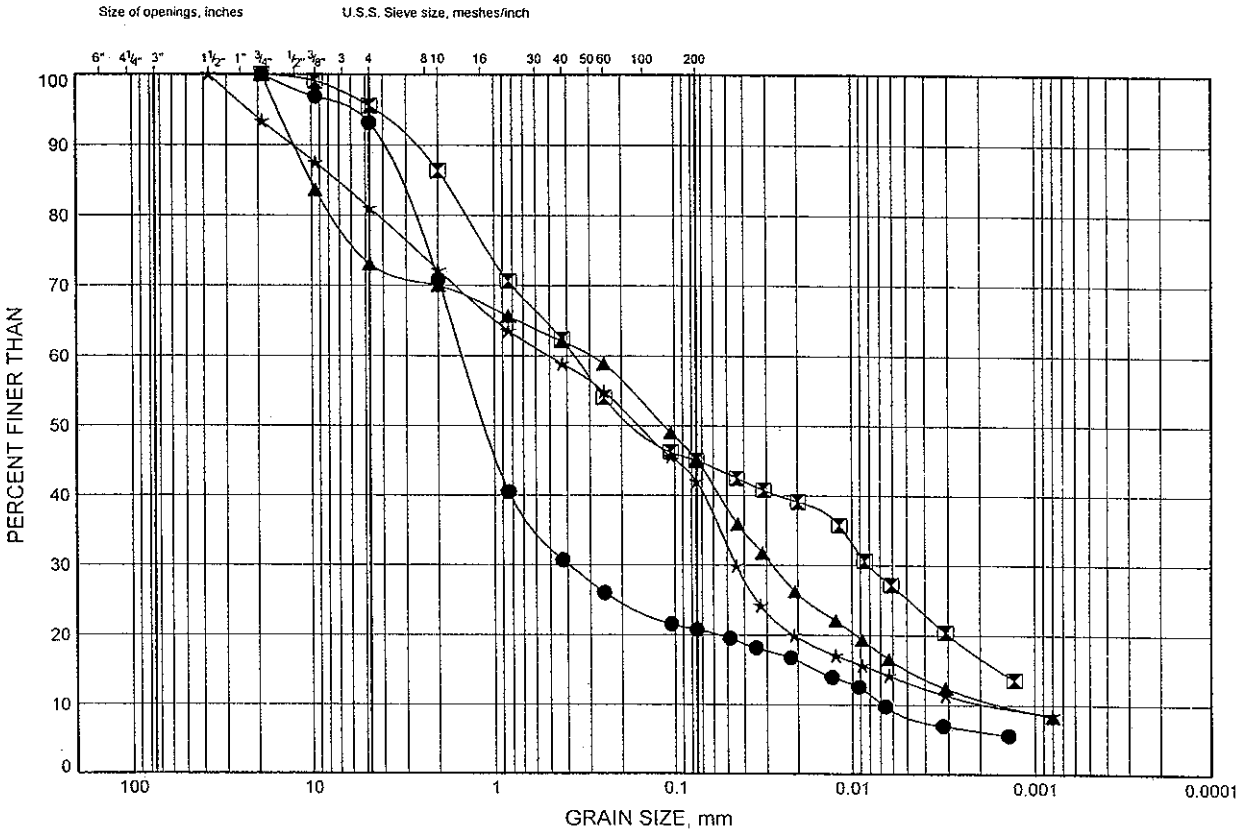
Chkd. MP

ALTR 1-09-4135 TN BRIDGE.GPJ 05/18/10

# GRAIN SIZE DISTRIBUTION

FIGURE B16

## SILTY SAND TO SANDY SILT TILL




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

| SYMBOL | BOREHOLE | DEPTH (m) | ELEVATION (m) |
|---|---|---|---|
| ● | TN1 | 20.0 | 163.5 |
| ⊠ | TN1 | 24.6 | 158.9 |
| ▲ | TN4 | 21.5 | 162.5 |
| ★ | TN4 | 29.2 | 154.8 |

Date May 2010

Project 1-09-4135

Prep'd DB

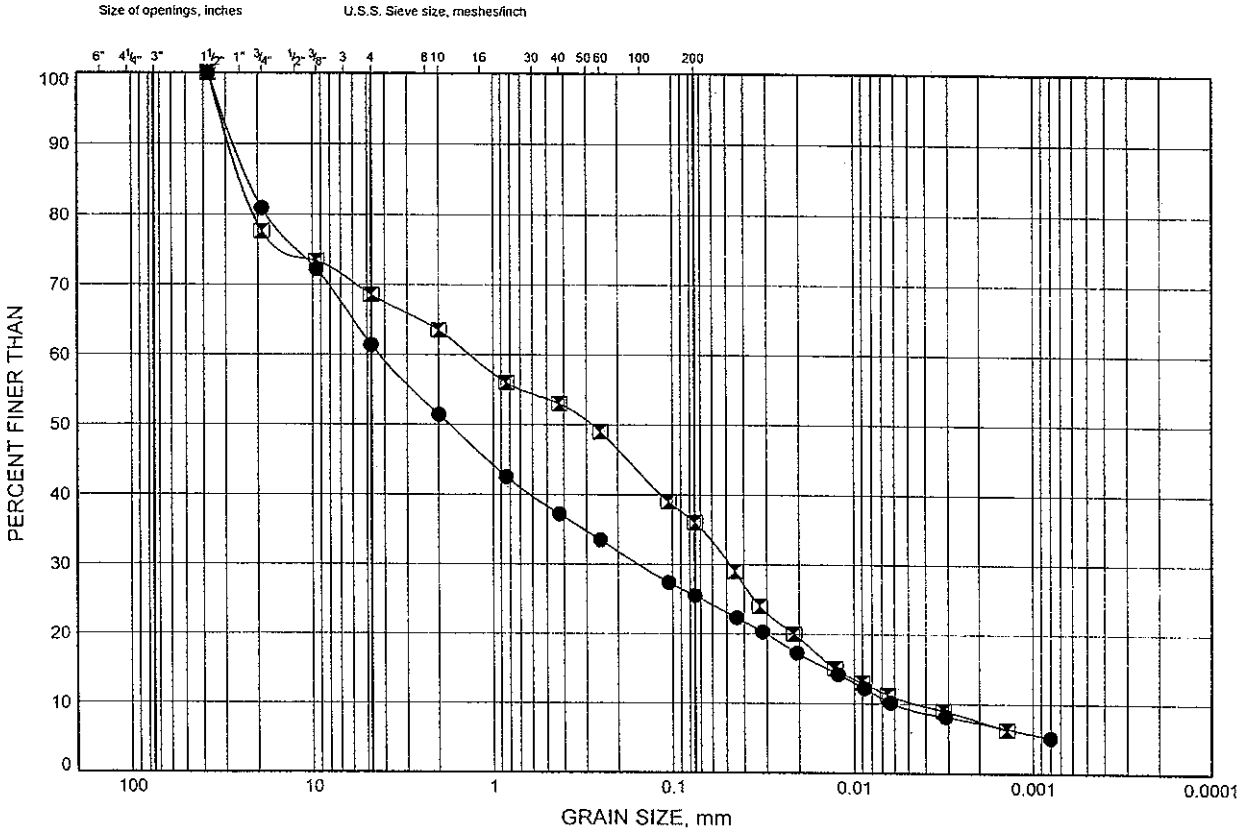
Chkd. MP

GSD 1-09-4135 TN BRIDGE.GPJ 05/18/10

# GRAIN SIZE DISTRIBUTION

FIGURE B17

## SAND AND GRAVEL TILL




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

| SYMBOL | BOREHOLE | DEPTH (m) | ELEVATION (m) |
|---|---|---|---|
| ● | TN2 | 29.2 | 155.0 |
| ⊠ | TN3 | 29.2 | 154.9 |

Date May 2010

Project 1-09-4135

Prep'd DB

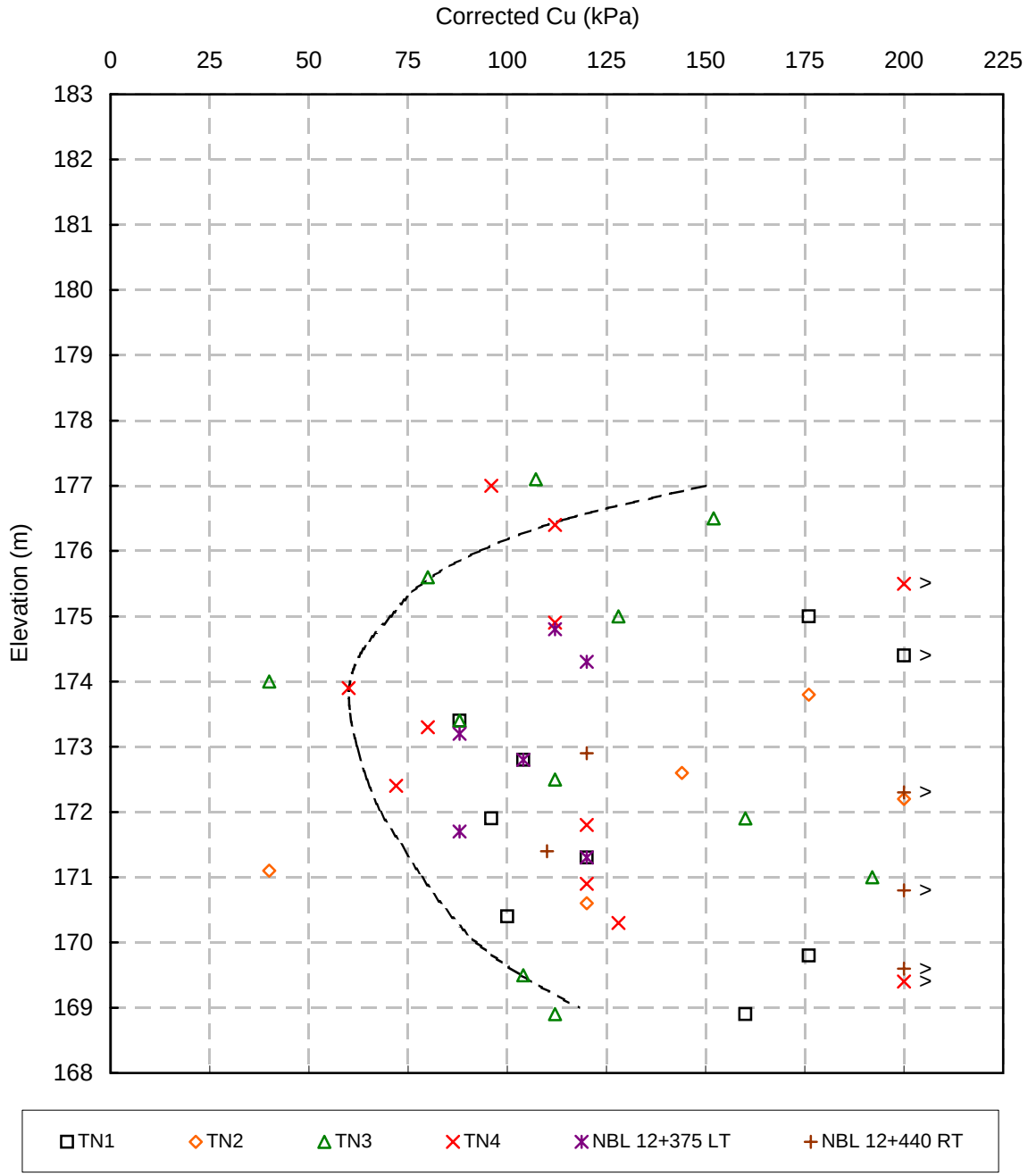
Chkd. MP

GSD 1-09-4135 TN BRIDGE.GPJ 05/18/10

| CORRECTED UNDRAINED SHEAR STRENGTH | FIGURE B18 |
|---|---|

HWY 406 TWINNING - TRILLIUM OVERHEAD (NBL)

Silty Clay




**Field Shear Vane Correction**

Morris & Williams (1994)

($\mu$ = 1.18 EXP(-0.08 Ip) + 0.57)

Applied Correction Factors

0.89 (Elev.>177m) 1.00 (Elev.<177m)

Project No. : 1-09-4135

Date : September, 2010

Terraprobe Inc.

Prepared By : HW

Checked By : RA

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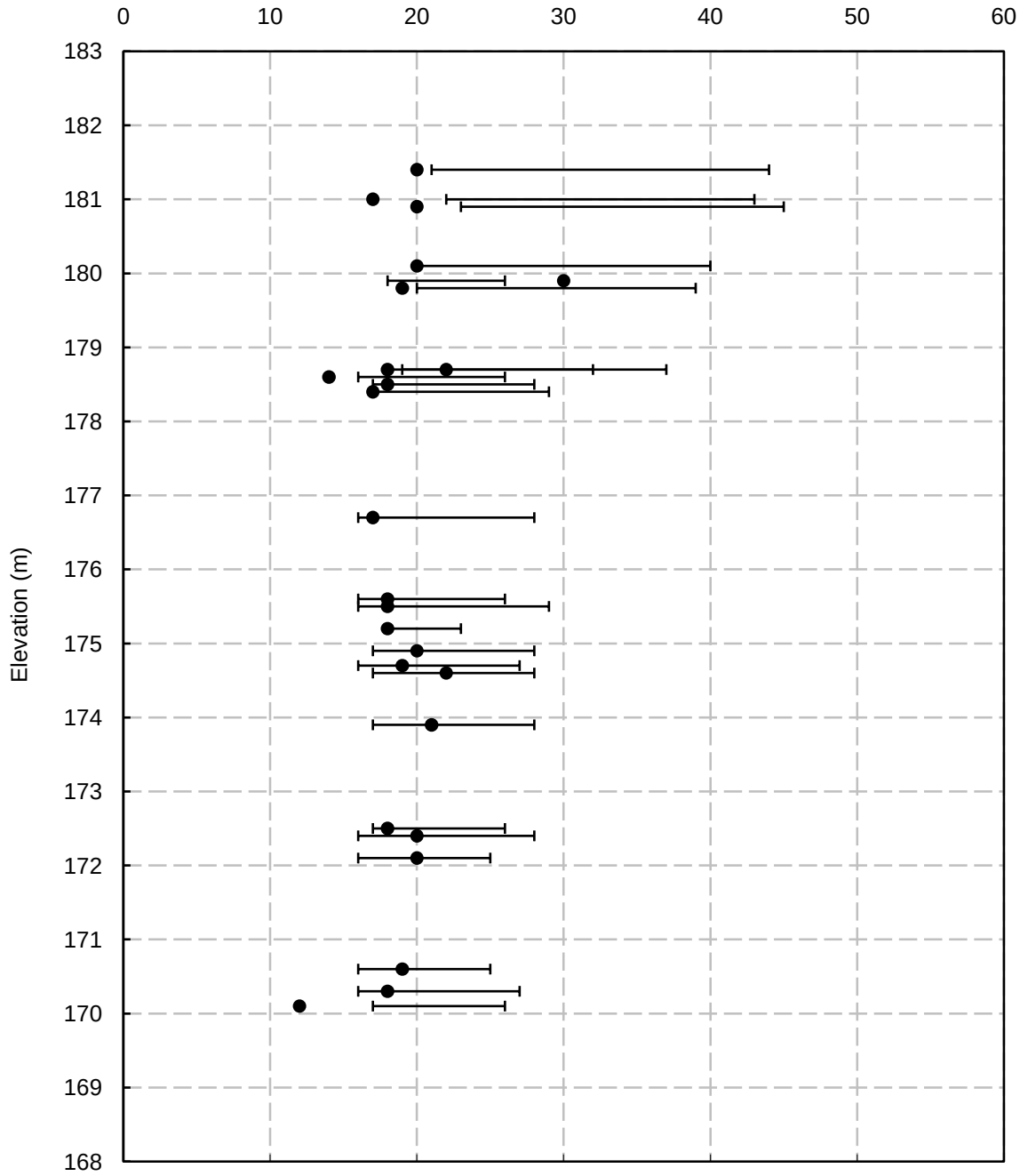
| ATTERBERG LIMITS AND WATER CONTENTS | FIGURE B19 |
|---|---|

HWY 406 TWINNING - TRILLIUM OVERHEAD (NBL)

Silty Clay

Atterberg Limits & Water Contents (%)




Project No. : 1-09-4135

Date : September, 2010

Terraprobe Inc.

Prepared By : HW

Checked By : RA

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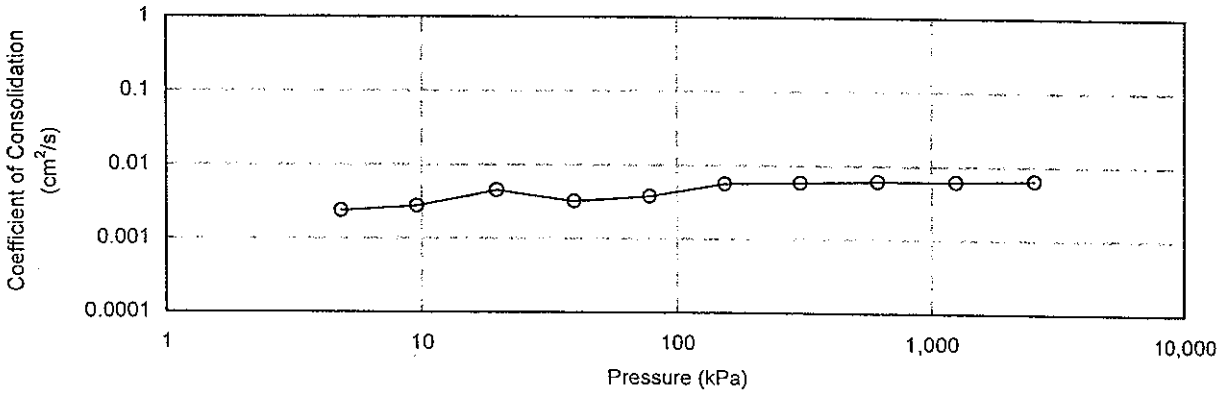
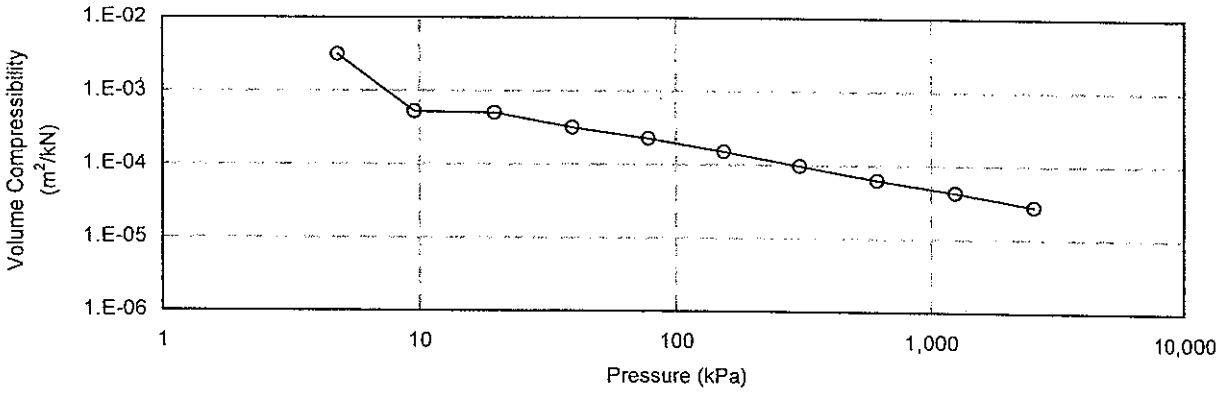
| HWY 406 TWINNING - TRILLIUM RAILWAY NORTH | FIGURE B20 |
|---|---|

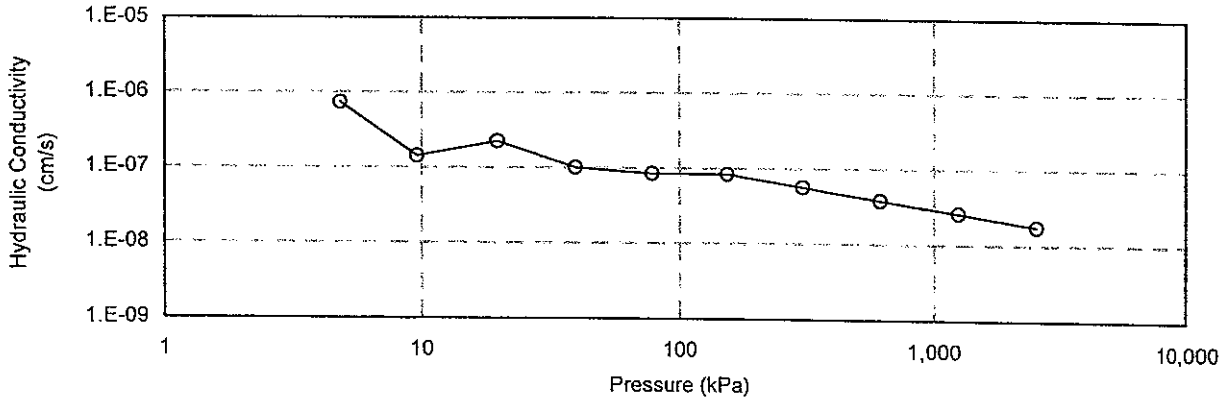
CONSOLIDATION TEST
Cv vs Pressure
NBL 12+375 LT, TW9




CONSOLIDATION TEST
mv vs Pressure
NBL 12+375 LT, TW9




CONSOLIDATION TEST
k vs Pressure
NBL 12+375 LT, TW9




Project No. : 1-09-4135
Date : May 2010

Terraprobe Inc.

Prepared By : HW
Checked By : RA

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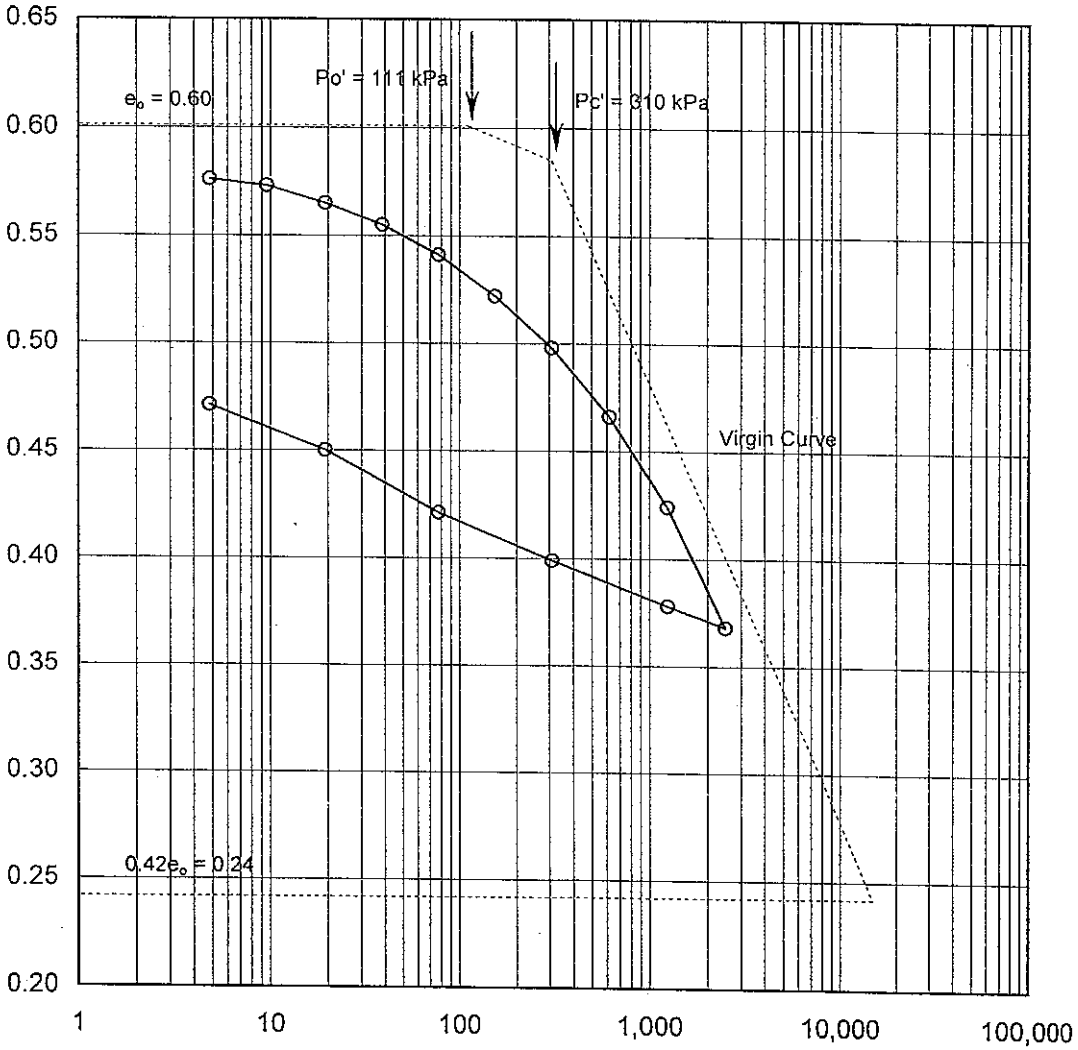
| HWY 406 TWINNING - TRILLIUM RAILWAY NORTH | FIGURE B21 |
|---|---|

CONSOLIDATION TEST
e vs Pressure
NBL 12+375 LT, TW9




| Soil Type : | Silty Clay | | | | |
|---|---|---|---|---|---|
| $e_o$ = | 0.60 | $\omega_L$ = | 28% | Po' = | 111 kPa |
| $\omega$ = | 21% | $\omega_P$ = | 16% | Pc' = | 310 kPa |
| $\gamma$ = | 20.6 kN/m$^3$ | PI = | 12% | Cc = | 0.204 |
| Gs = | 2.77 | | | Cr = | 0.036 |

Project No. : 1-09-4135
Date : May 2010

Terraprobe Inc.

Prepared By : HW
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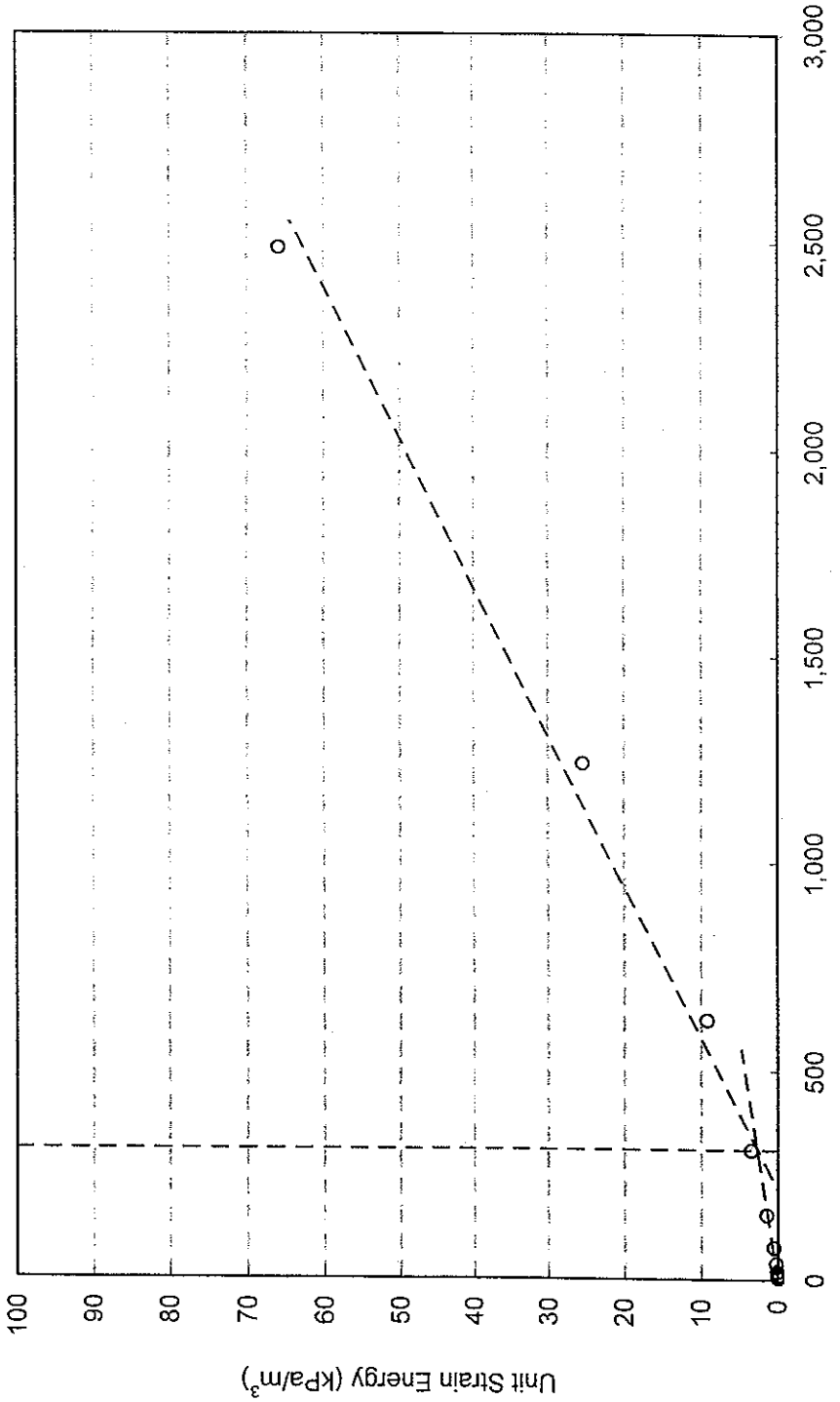
HWY 406 TWINNING - TRILLIUM RAILWAY NORTH

FIGURE B22

CONSOLIDATION TEST
Unit Strain Energy vs Pressure
NBL 12+375 LT, TW9




Project No. : 1-09-4135

Date : May 2010

Terraprobe Inc.

Prepared By : HW

Checked By : RA

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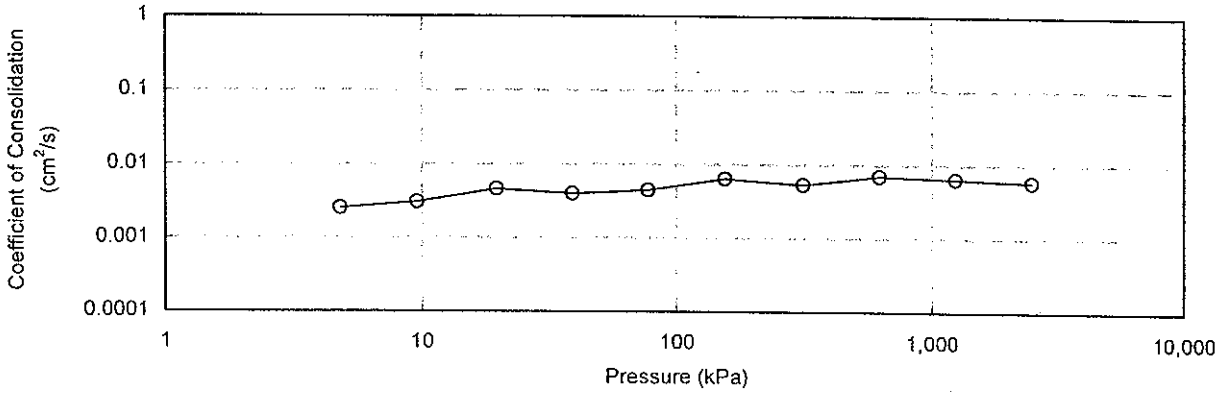
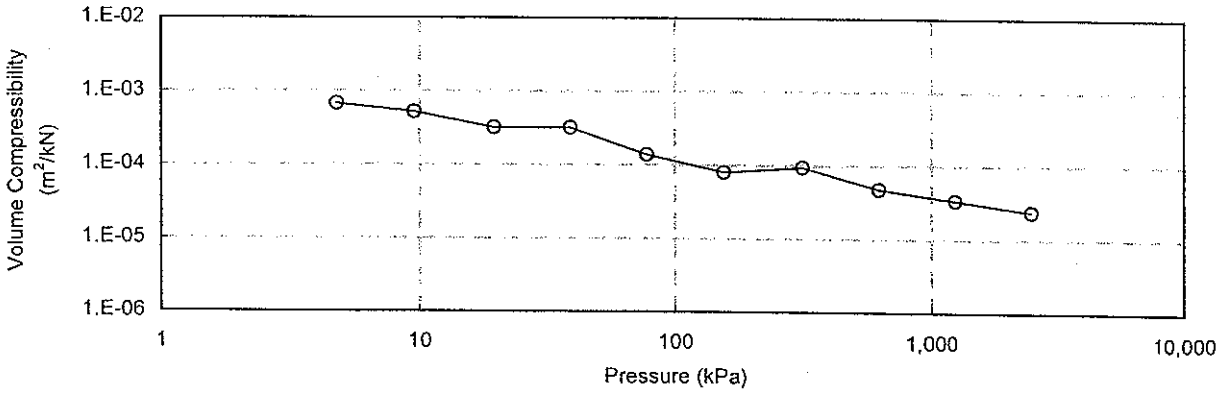
## HWY 406 TWINNING - TRILLIUM RAILWAY NORTH

**FIGURE B23**

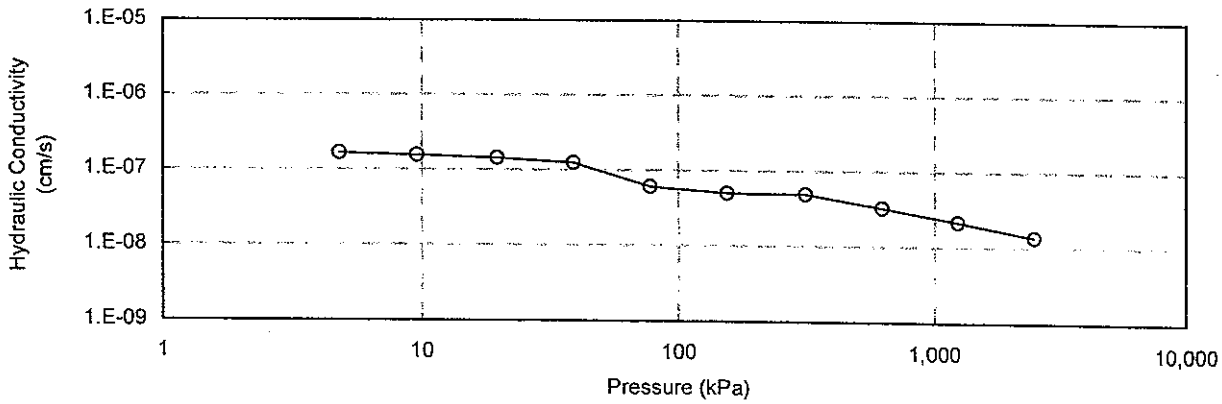
CONSOLIDATION TEST
Cv vs Pressure
NBL 12+440 RT, TW10




CONSOLIDATION TEST
mv vs Pressure
NBL 12+440 RT, TW10




CONSOLIDATION TEST
k vs Pressure
NBL 12+440 RT, TW10

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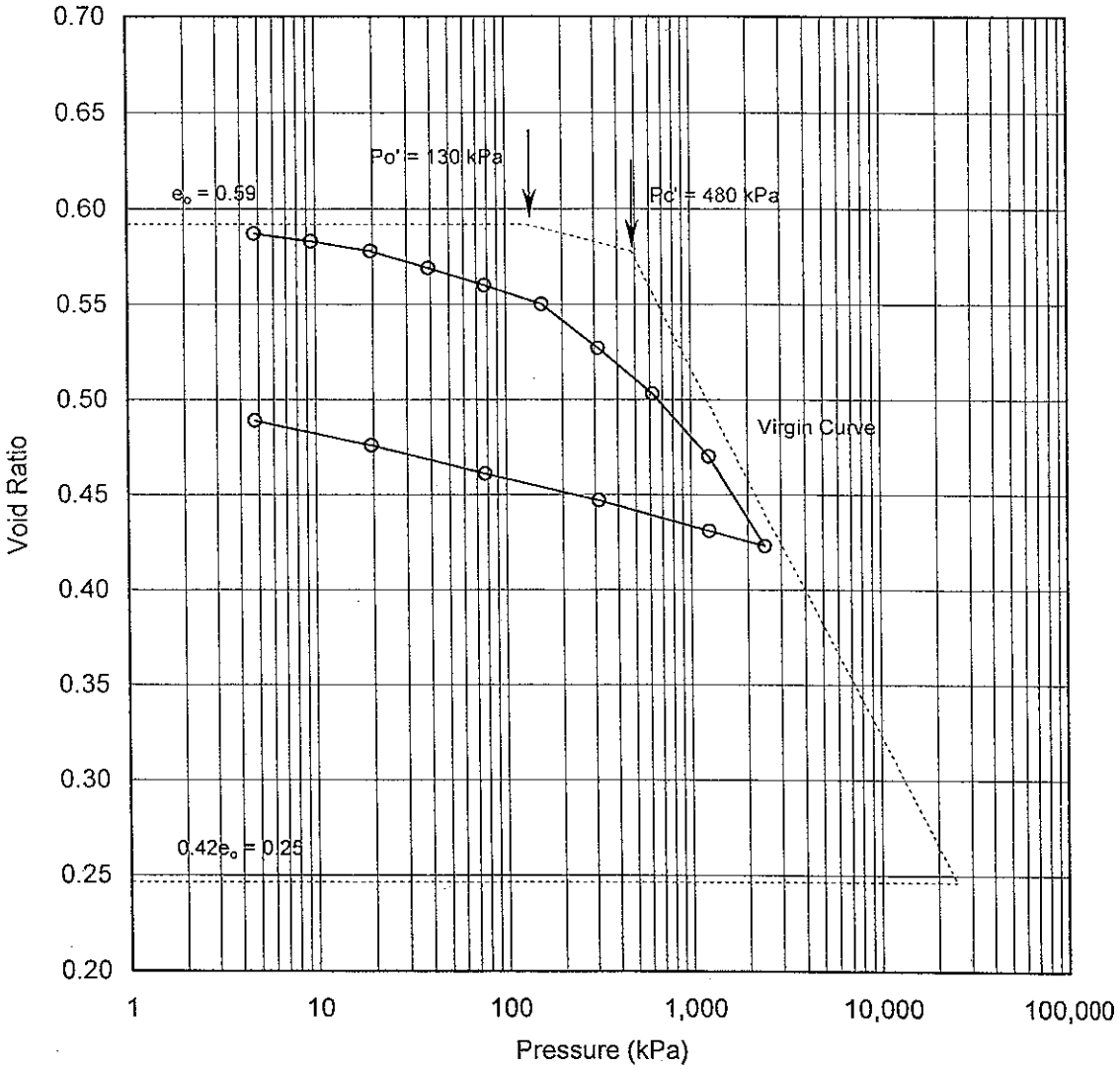
Project No. : 1-09-4135
Date : May 2010

**Terraprobe Inc.**

Prepared By : HW
Checked By : RA

| HWY 406 TWINNING - TRILLIUM RAILWAY NORTH | FIGURE B24 |
|---|---|

CONSOLIDATION TEST
e vs Pressure
NBL 12+440 RT, TW10




| Soil Type : | Silty Clay | | | | |
|---|---|---|---|---|---|
| $e_o$ = | 0.59 | $\omega_L$ = | 25% | Po' = | 130 kPa |
| $\omega$ = | 21% | $\omega_P$ = | 15% | Pc' = | 480 kPa |
| $\gamma$ = | 20.7 kN/m$^3$ | PI = | 10% | Cc = | 0.193 |
| Gs = | 2.79 | | | Cr = | 0.025 |

Project No. : 1-09-4135
Date : May 2010

Terraprobe Inc.

Prepared By : HW
Checked By : RA

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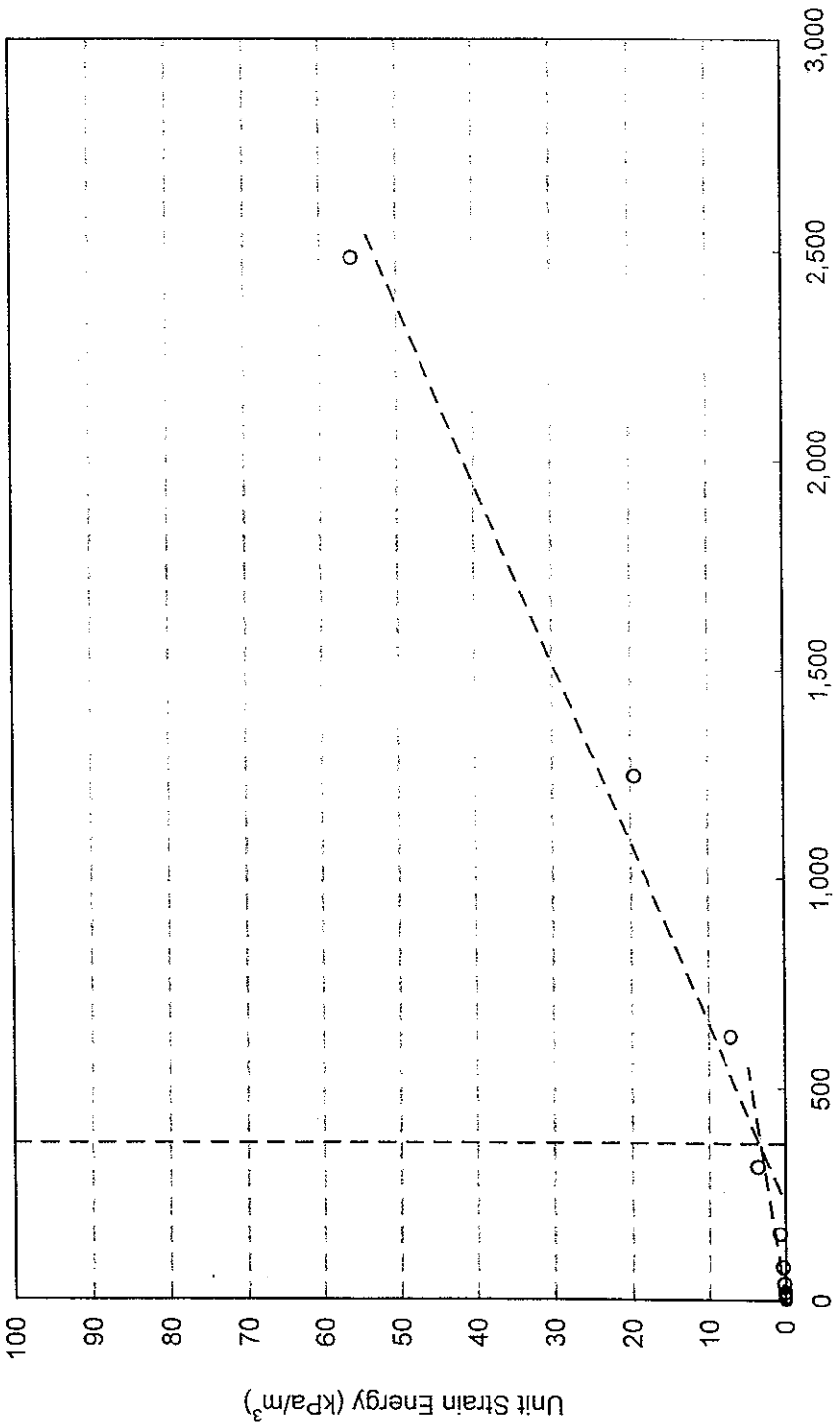
HWY 406 TWINNING - TRILLIUM RAILWAY NORTH

FIGURE B25

CONSOLIDATION TEST
Unit Strain Energy vs Pressure
NBL 12+440 RT, TW10




Project No. : 1-09-4135

Date : May 2010

Terraprobe Inc.

Prepared By : HW

Checked By : RA

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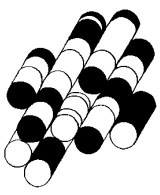
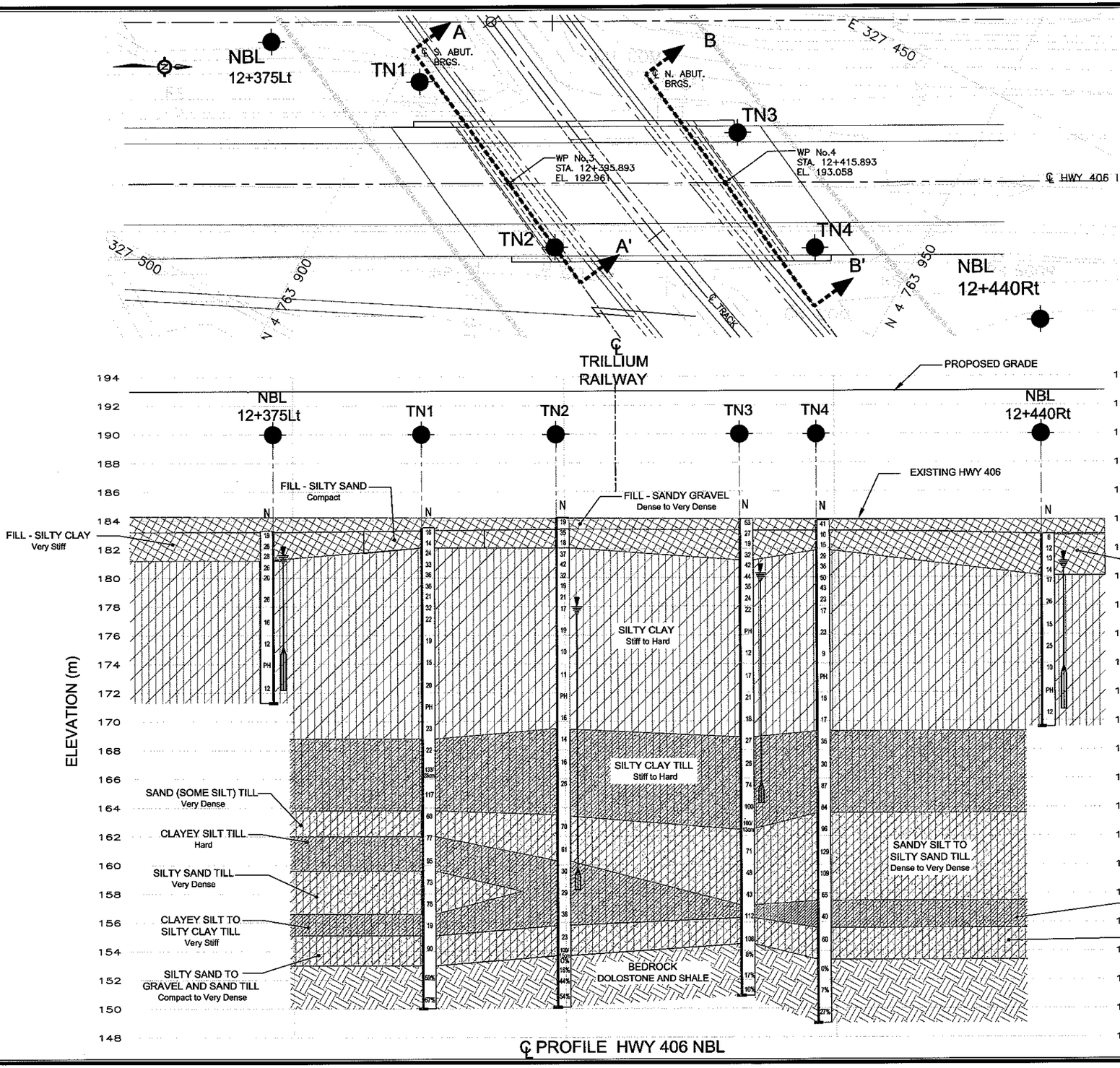
# APPENDIX C

TERRAPROBE INC.






℄ PROFILE HWY 406 NBL

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

REGISTERED PROFESSIONAL ENGINEER
M. TANOS
03/09/2010
PROVINCE OF ONTARIO

PLAN SCALE 5m 2.5 0 2.5 5m

LICENSED PROFESSIONAL ENGINEER
R.A. ABDUL
Sept 03/2010
PROVINCE OF ONTARIO

SCALE
HORIZONTAL 5m 2.5 0 2.5 5m
VERTICAL 4m 4m

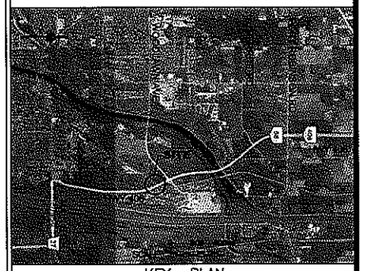
CONT No
WP No 280-99-00

HIGHWAY 406
TRILLIUM RAILWAY OVERHEAD
HWY 406 NBL
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET 1 OF

Giffels Associates Limited
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 (MAY 2010) |
| | Piezometer |
| 90% | Rock Quality Designation |
| A/R | Auger Refusal |

| No | ELEV. | COORDINATES | |
|---|---|---|---|
| | | NORTHING | EASTING |
| TN1 | 183.5 | 4 763 901.884 | 327 473.410 |
| TN2 | 184.2 | 4 763 920.110 | 327 481.066 |
| TN3 | 184.1 | 4 763 930.031 | 327 463.726 |
| TN4 | 184.0 | 4 763 941.375 | 327 469.753 |
| NBL 12+375Lt | 183.3 | 4 763 888.095 | 327 476.584 |
| NBL 12+440Rt | 183.0 | 4 763 962.851 | 327 465.805 |

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 information only. Surface details and features are for conceptual illustration.

| REVISIONS | | | |
|---|---|---|---|
| DATE | BY | DESCRIPTION | |
| DESIGN R.A | CODE CHBDC2006 | LOAD | DATE SEPT. 2010 |
| DRAWN K.C | CHK R.A | STRUCT | GEOCRES 30M3-255 |

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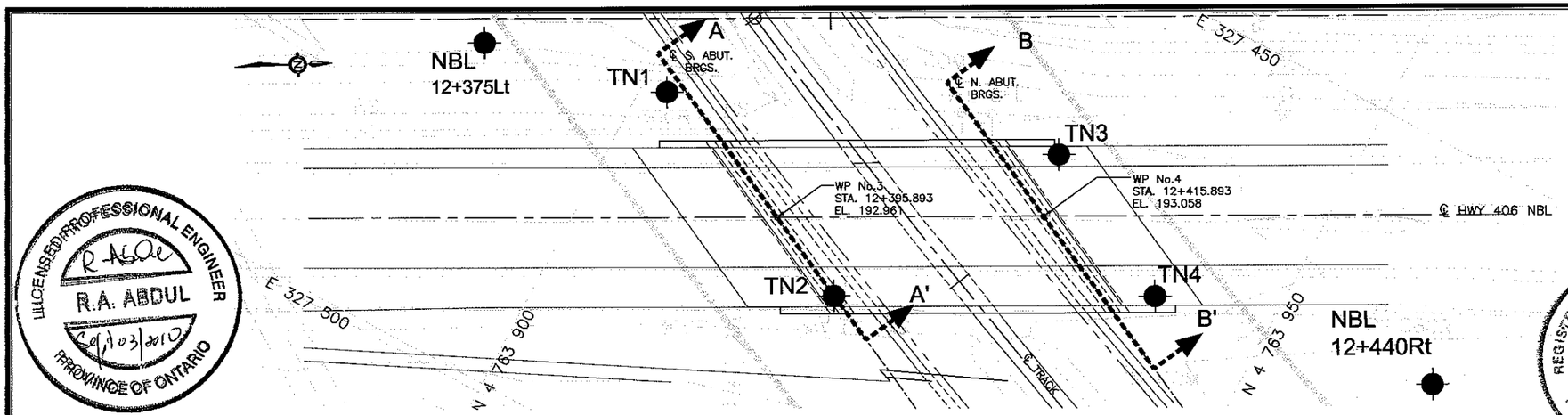
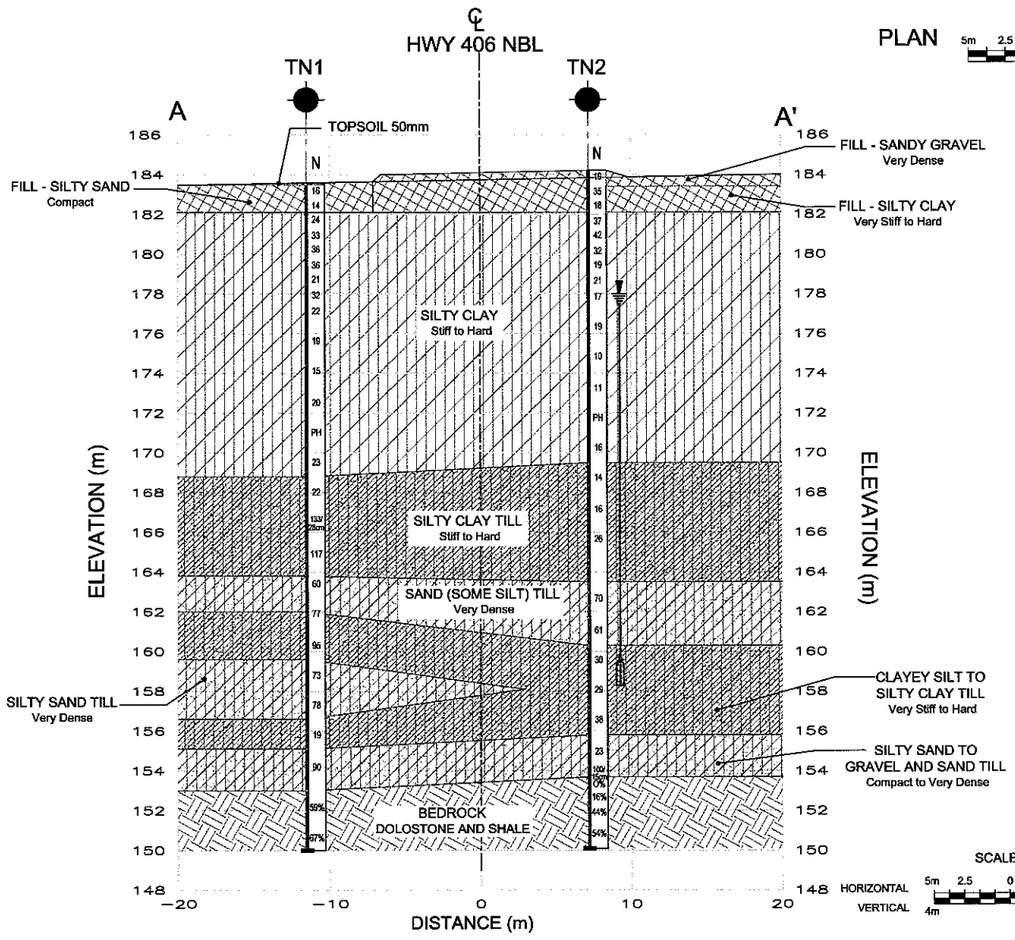
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETERS UNLESS OTHERWISE SHOWN



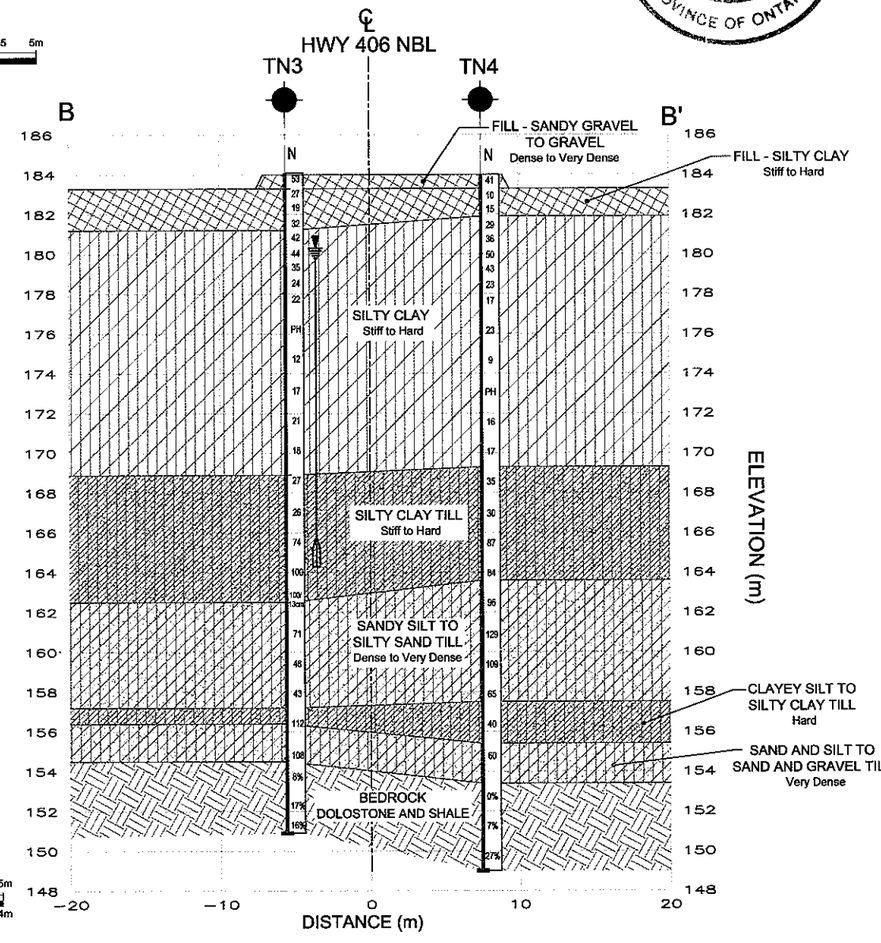





PLAN
SCALE 5m 2.5 0 2.5 5m




SECTION A-A'




SECTION B-B'

SCALE
HORIZONTAL 5m 2.5 0 2.5 5m
VERTICAL 4m 4m

CONT No
WP No 280-99-00

HIGHWAY 406
TRILLIUM RAILWAY OVERHEAD
HWY 406 NBL
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET 1 OF

Giffels Associates Limited
Consulting Engineers and Architects
An IBI Group Company

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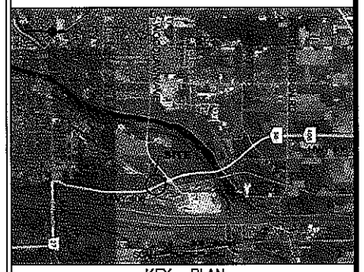
Consulting Geotechnical & Environmental Engineering
Construction Materials Engineering, Inspection & Testing
10 Bram Court - Brampton Ontario L6W 3R8 (905) 796-2650



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 (MAY. 2010) |
| | Piezometer |
| 90% | Rock Quality Designation |
| A/R | Auger Refusal |

| No | ELEV. | COORDINATES | |
|---|---|---|---|
| | | NORTHING | EASTING |
| TN1 | 183.5 | 4 763 901.884 | 327 473.410 |
| TN2 | 184.2 | 4 763 920.110 | 327 481.066 |
| TN3 | 184.1 | 4 763 930.031 | 327 463.726 |
| TN4 | 184.0 | 4 763 941.375 | 327 469.753 |
| NBL 12+375Lt | 183.3 | 4 763 888.095 | 327 476.584 |
| NBL 12+440Rt | 183.0 | 4 763 962.851 | 327 465.805 |

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 information only. Surface details and features are for conceptual illustration.

| REVISIONS | DATE | BY | DESCRIPTION |
|---|---|---|---|
| | | | |

| | | | |
|---|---|---|---|
| DESIGN R.A | CODE CHBDC2006 | LOAD | DATE SEPT. 2010 |
| DRAWN K.C | CHK R.A | STRUCT | GEOCRES 30M3-255 |

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