coffey geotechnics
SPECIALISTS MANAGING THE EARTH

FOUNDATION INVESTIGATION REPORT HARMONY BEACH ROAD BRIDGE REPLACEMENT, HIGHWAY 7090, TOWNSHIP OF HAVILLAND, DISTRICT OF ALGOMA, ONTARIO G.W.P. 5430-06-00, SITE 38S-345 GEOCRES 41K-83

D.M. Wills Associates Limited

Project: TRANETOB01240AA
May 12, 2010

Coffey Geotechnics Inc.
20 Meteor Drive Etobicoke Ontario M9W 1A4 Canada

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

May 12, 2010

D.M. Wills Associates Limited
452 Charlotte Street
Peterborough, Ontario
K9J 2W3

Attention: Mr. Andy Staszak

Dear Sir:

RE: Foundation Investigation Report, Harmony Beach Road Bridge Replacement, Highway 7090, Township of Havilland, District of Algoma, Ontario, G.W.P.5430-06-00, Site 38S-345, GEOCRES No. 41K-83

Please find the attached Foundation Investigation Report for the above noted site.

For and on behalf of Coffey Geotechnics Inc.

Ramon Miranda, P.Eng.
Manager, Transportation Division

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TRANETOB01240AA

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FOUNDATION INVESTIGATION REPORT
HARMONY BEACH ROAD BRIDGE REPLACEMENT, HIGHWAY 7045
TOWNSHIP OF HAVILLAND, DISTRICT OF ALGOMA, ONTARIO
G.W.P. 5430-06-00, SITE 38S-345

1 INTRODUCTION

Coffey Geotechnics Inc. (Coffey) was retained by D.M. Wills Associates Limited (Wills) to carry out a foundation investigation for the proposed replacement of the Harmony Beach Road Bridge over the Harmony River on Highway 7045, in the Township of Havilland, approximately 1.3 km north east of Highway 17 junction with Harmon Beach Road (Highway 7045). The site is located within the District of Algoma and has MTO Site Number 38S-345.

The existing Harmony Beach Road Bridge is a five-span structure with a total length of about 19 m, which is supported by four sets of timber piers and timber abutments. It is our understanding that the original bridge was built as a two lane bridge and it was narrowed down to 4.1 m single lane centred on the structure after the rehabilitation in 2006.

The purpose of the investigation was to obtain information about the subsurface conditions at the site by means of boreholes, and to determine the engineering characteristics of the subsurface soils by means of field and laboratory tests.

The findings of the investigation are presented in this report.

2 SITE DESCRIPTION AND GEOLOGY

The site is located some 45 km north of Sault Ste. Marie at Harmony Beach on the Bachawana Bay (Lake Superior). The Harmony River flows into the Bachawana Bay which is about 120 m west of the proposed bridge replacement site (see site photographs, presented in Appendix D). A sand bar formation has developed at the mouth of the river discharging into the Bachawana Bay. The channel is clean, sand lined, and straight at the bridge site. North of the site the terrain is relatively flat. Based on the profile drawings supplied to us by Wills, to the south the land rises about 6 m within 150 m distance at a gradual slope. Water levels in the river would be subject to some fluctuations, both but would be largely regulated by the water level in Lake Superior.

According to the Quaternary Geology of Ontario (Map 2556), the site is located within a sand, gravelly sand and gravel glaciolacustrine deposit. Underlying the surficial granular deposit, thick silty clay to clay deposit is commonly encountered in this area. Bedrock underlying this area is low silicate basic volcanic rock according to Ontario Geologic Map 2108 (See Appendix E). As well, exposures of bedrock in this area are plentiful (as shown in Appendix D) and deposits of drift occur as thin, irregularly distributed patches.

The existing approach embankments, which are approximately up to 2.5 m high close to the bridge abutment, do not exhibit any apparent signs of slope instability or excessive erosion. As well, in the immediate vicinity of the existing bridge, there are no signs of excessive settlements/unusual cracking or deformations in the pavement.

* Highway 7045 has been changed to Highway 7090.

3 INVESTIGATION PROCEDURES

The fieldwork for the proposed replacement of Harmony Beach Road Bridge was performed during the period of July 21 through July 27, 2009. As agreed with MTO, the fieldwork consisted of drilling and sampling four boreholes (Boreholes B1 through B4) for the bridge structure, two boreholes for the approach embankments (Boreholes B5 and B6) and four boreholes (Boreholes B7 through B10) for determination of stripping depth at the toe area of the existing embankment, as well as performing field vane and Dynamic Cone Penetration tests (DCPT). The plan location of the boreholes is shown in Drawing No. 2. The following table summarizes the borehole locations and drilling depths.

Table 3.1: Borehole Locations and Drilling Depths

Borehole No.	Location	Drilling Depth Below Existing Ground Surface (m)	Dynamic Cone Penetration Tests	Piezometer
B1	10+180 (1.2 m Lt C/L)	18.5	No	No
B2	10+183 (6.3 m Rt C/L)	18.4	Yes	No
B3	10+213 (1.0 m Lt C/L)	15.5 (including 3.2 m rock coring)	Yes	No
B4	10+210 (5.1 m Rt C/L)	16.0 (including 3.0 m rock coring)	No	Yes
B5	10+169 (3.0 m Rt C/L)	11.1	No	No
B6	10+230 (1.0 m Lt C/L)	9.6	No	No
B7	10+189 (7.0 m Rt C/L)	1.2	No	No
B8	10+190 (11.5 m Lt C/L)	1.0	No	No
B9	10+206 (7.0 m Rt C/L)	1.0	No	No
B10	10+208 (6.5 m Lt C/L)	1.2	No	No

Landcore Drilling of Chelmsford, Ontario, carried out the drilling, testing and sampling work, under the direction and supervision of a Professional Engineer (Mr. Raid Khamis, P.Eng.) from Coffey. Deep boreholes (Boreholes B1 through B6) were advanced using a track-mounted drilling rig, outfitted with tools and equipment for soil sampling and testing. Drilling was effected using hollow-stem augers, however, in Boreholes B1, B2 and B3 wash boring methods were also utilized below a depth of 9 m. Coring was utilized to advance the borehole through the cobbles and boulders in Borehole B3. As well, bedrock was proven by rock coring in Boreholes B3 and B4. Shallow boreholes (Boreholes B7 through B10) were advanced by hand augering to figure out the extent of stripping at the toe area of the existing embankment.

Samples in the boreholes were taken at frequent intervals of depth by the Standard Penetration Test method (SPT), in general accordance with ASTM D1586. This test consists of freely dropping a 63.5 kg hammer a vertical distance of 0.76 m to drive a 51 mm O.D. split barrel (SS – split-spoon) sampler into the ground. The number of blows of the hammer required to drive the sampler into the relatively undisturbed ground by a vertical distance of 0.30 m is recorded as the Standard Penetration Resistance or the N-value of the soil which is indicative of the compactness condition of cohesionless granular soils (gravels, sands and silts) or the consistency of cohesive soils (clays and clayey soils).

In cohesive (clayey) deposits, where the consistency of the soil permitted, relatively undisturbed samples (TW) were taken with 50 mm (2") or 75 mm (3") diameter thin-walled (Shelby) tubes which were pushed into the bottom of the borehole by the application of static weight or using hydraulic pressure. The undrained shear strength of the soil was also measured in-situ by field vane tests. Where the consistency of clay permitted, a standard MTO type field vane was used to conduct the tests.

As mentioned above, in Boreholes B2 and B3, Dynamic Cone Penetration tests were performed. In Dynamic Cone Penetration Test (DCPT), a 51 mm diameter, 60 deg. apex cone point, screw-attached to the tip of A-size rods, is driven into the ground using the same driving energy as in the SPT method. By recording the number of blows to drive the cone/rod assembly into the soil every 0.3 m, a qualitative record of relative density/consistency is obtained. Although the interpretation of the test results is difficult because no samples can be obtained by the DCPT method and the penetration resistances are not necessarily equal to the N-values, useful information is gained by the continuity of the results and by the elimination of unbalanced hydrostatic effects which in many cases affect the SPT values, especially when fine-grained granular soils or cobbles/boulders are encountered.

Groundwater conditions in the boreholes were observed during drilling and upon completion in the open boreholes. In addition, a piezometer was installed in Borehole B4 to enable groundwater level monitoring in the borehole over a prolonged period of time without interference from surface water. The remaining boreholes were grouted upon their completion using a cement/bentonite mixture as per MTO procedures.

The borehole locations were established in the field by Coffey engineering staff, in relation to the existing features. The locations were then tied in and the geodetic elevations of the ground at the borehole locations were determined by the client's surveyors. This survey information was provided to us.

The soil and rock samples were transported to our geotechnical laboratory in Toronto for further examination and classification. A laboratory testing programme, consisting of natural moisture content and unit weight determinations, grain size analyses, one dimensional odeometer (consolidation) and Atterberg Limits tests, was performed on selected representative soil samples. Two rock core samples from Boreholes B3 and B4 were forwarded to the laboratory of Golder Associates where the samples were tested for their unconfined compressive strength (UCS), bulk and dry densities. The results of the laboratory tests are presented on the appropriate Record of Borehole Sheets (Appendix A) and also in Appendix B.

4 SUBSURFACE CONDITIONS

The sub-surface conditions were explored at ten boreholes (see Table 3.1 in Section 3) at the site. The plan locations of the boreholes are shown on Drawing No. 2 and details of sub-surface conditions encountered at each borehole location, including the results of in-situ testing, groundwater observations and laboratory test results, are presented on the Record of Borehole Sheets in Appendix A. A stratigraphic profile and sections at the bridge location are shown on Drawing Nos. 2 and 3. Detailed laboratory test results are enclosed in Appendix B. Rock core photographs are shown in Appendix E.

In general, the sub-surface stratigraphy comprises pavement (asphaltic concrete), granular pavement fill and embankment fill materials overlying a surficial sand deposit, which are in turn underlain by a 2.5 to 9.4 m thick deposit of silty clay to clay. This silty clay to clay is further underlain by lower granular soil deposits such as silty sand, sand, gravelly sand and gravel, followed by basic volcanic bedrock. Bedrock was proven by NQ coring in Boreholes B3 and B4.

4.1 Asphalt

A 40 to 80 mm thick asphalt layer was contacted in Boreholes B1, B2, B3 and B6. Boreholes B1 and B3 were drilled from the existing road pavement while Borehole B2 and B4 were drilled on the paved shoulder.

4.2 Embankment Fill

Boreholes B1, B2, B3, B4, B5 and B6 which were drilled from the existing paved road and shoulder area contacted a 0.2 to 0.3 m thick sand and gravel layer followed by gravelly sand, sand some gravel and sand fill materials extending to a depth of 1.1 to 3.5 m below the existing ground surface.

The grain-size distribution of a sample from the deposit from Borehole B3 is given in Figure B-1, in Appendix B. This indicates the following grain-size distribution.

Gravel:	61 %
Sand:	33 %
Silt & Clay:	6 %

Based on a recorded N-value of 5 to 30 blows/0.3 m, this basically granular pavement and embankment fill is considered very loose to compact but typically loose to compact.

4.3 Surficial Granular Soils

Underlying the fill, a surficial granular soil deposit consisting of sand to gravelly sand was contacted in Boreholes B1, B2, B5 and B6. This granular (non-cohesive) soil cap was found to extend to a depth of 1.8 to 4.0 m below the ground surface or to El. 183.4 to 181.1 m (i.e. 0.7 to 2.3 m thick).

The grain-size distribution of four samples from the deposit from Boreholes B1, B2 and B5 is given in Figure B-2, in Appendix B. This indicates the following grain-size distribution.

Gravel:	5-46%
Sand:	51-89%
Silt & Clay:	3-6%

From the grain-size distribution, the material is considered to be more pervious than the underlying silty clay to clay deposits. Also from the grain-size distribution curves, the estimated coefficient of permeability (k) of the samples tested is of the order of 1×10^{-2} to 1 cm/sec.

Standard Penetration tests performed in this granular (non-cohesive) soil deposit gave N-values which range from 3 to 12 blows/0.3 m indicating a very loose to compact relative density.

Boreholes B7 through B10 put down by hand augering to 1.0 to 1.2 m below the o.g. levels, near the toe of the existing embankments, to estimate stripping depths, contacted sand to gravelly sand within the depths explored.

It is believed that these surficial granular soils encountered at the site have been deposited by the River shortly before discharging into the Lake. These soils were not contacted in Boreholes B3 and B4. It is believed that this is due to disturbance and mixing of the existing surficial sand at these locations with the embankment fill, during the construction of the existing bridge structure.

4.4 Silty Clay to Clay

Underlying the non-cohesive deposits described in the previous sections, all the deep boreholes contacted a major cohesive deposit at depths ranging from 1.8 m to 4.0 m or El. 183.4 to 181.1 m. The following table summarizes the top and bottom elevations of the deposit, as encountered in the deep boreholes.

Borehole No.	Depth Below Ground Surface/ Elevation of the Top of the Deposit(m)	Depth of Below Ground Surface/ Elevation of the Bottom of the Deposit (m)
B1	4.0/181.4	13.4/172.0
B2	3.5/181.1	11.4/173.2
B3	3.5/182.0	8.5/177.0
B4	2.3/182.4	9.9/174.8
B5	1.8/183.4	11.1*/174.1*
B6	3.8/181.7	6.3/179.2

*End of borehole

The cohesive soil deposit consists of a reddish grey silty clay to clay and its thickness increases from south to north or from 2.5 m at Borehole B6 to more than 9.6 m at Borehole B5.

The grain-size distribution of seven samples from the deposit (from Boreholes B1 through B6) is given in Figure B-3. The results of the tests on the samples show the following grain-size distribution:

Gravel:	0 %
Sand:	0-2 %
Silt:	28-46 %
Clay:	52-72 %

Figure B-4 present the results of a grain-size analysis carried out on more silty zone (i.e. silty clay zone) in the deposit.

The results of Atterberg limits tests performed on nine samples recovered from the deposit are given in Figure B-5 in Appendix B. These tests yielded the following index values:

Liquid Limit: 54-71 %

Plastic Limit:	21-33 %
Plasticity Index:	29-42

These results indicate clay soils of high plasticity. As shown on the individual Record of Borehole Sheets, the measured natural moisture contents are near or typically in excess of the measured liquid limits which indicate the likelihood of a normally consolidated soil deposit.

The Atterberg Limits test results performed on two of the more silty zone in the clay deposit are presented in Figure B-6 in Appendix B. These indicate clayey soils of intermediate plasticity.

Standard Penetration tests conducted in the silty clay to clay deposit gave N-values which range from 0 to 4 blows/0.3 m but typically zero (i.e. sampler sank under own weight of the sampler and the drilling rods) which indicate a very soft to soft consistency. The undrained in-situ shear strengths of the deposit were measured in the field by means of field vane tests, using MTO type field vanes. The measured values range from 20 to 55 kPa, indicating a soft to firm consistency but typically soft. It should be kept in mind when analysing these results that the tests were performed in boreholes drilled from the top of the roadway. The undrained, in-situ shear strengths of the deposit beyond the influence of the embankment can be expected to be lower.

Figure C1 in Appendix C presents the measured undrained in-situ shear strengths versus elevation.

In Figures C2 through C5 in Appendix C, the variation of the measured in-situ vane strength values (i.e. in-situ undrained shear strengths) versus elevation is presented, for each of Boreholes B1, B2, B3 and B4. Also plotted on each figure is the effective overburden stress (P'_o), as well as the plot of 0.23 P'_o with elevation. It is commonly acknowledged that with Ontario clays if the measured undrained shear strengths are in excess of 0.23 P'_o line, the deposit may be somewhat over-consolidated. In this respect, about top 3 m portion of the silty clay to clay layer at north abutment location (Boreholes B1 and B2) and silty clay to clay at south abutment location (Boreholes B3 and B4) appear to be slightly over-consolidated. The silty clay to clay in Boreholes B1 and B2 appears to be normally consolidated below the upper±3 m zone.

Two oedometer (one dimensional consolidation) tests were performed in the laboratory on 76 mm (3") diameter Shelby tube (TW) samples. The results are presented in Figure B-7 and B-8 in Appendix B. These results show a possible pre-consolidation pressure that is similar to the existing overburden pressure which means this silty clay to clay deposit is probably normally consolidated. Compression index (C_c) of about 0.8 and recompression index (C_r) of about 0.15 are obtained.

There is some evidence that the lower zones of the deposit where it is thicker may still be consolidating under its own weight (i.e. may be underconsolidated).

The measured bulk unit weight of the TW samples range from 15.3 to 15.5 kN/m^3.

4.5 Basal Granular Soils

Underlying the silty clay to clay deposit, Boreholes B1, B2, B3, B4 and B6 encountered basal granular soils consisting of silty sand, sand, gravelly sand and gravel, with some cobbles and boulders. These lower granular soils were contacted at depths ranging from 6.3 m (Borehole B6) to 13.4 m (Borehole B1) below the ground surface or at Elevations 179.2 m (Borehole B6) to 172.0 m (Borehole B2). Borehole B5 was terminated within the clay deposit at 11.1 m depth or El. 174.1 m.

Boreholes B1, B2 and B6 were terminated in these lower granular deposits at depths ranging from 9.6 to 18.5 m below the ground surface or at El. 175.9 to 166.2 m. In Borehole B3 and B4, the boreholes were extended to the underlying bedrock at depths of 12.3 and 13.0 m or at El. 173.2 and 171.7 m, respectively.

The composition of these granular soils range from relatively finer silty sand to gravelly sand to coarse grained materials consisting of gravel with frequent cobble and boulder size particles (e.g. Boreholes B2 and B3).

The grain-size distribution of a sample from the relatively finer sand is given in Figure B-9 in Appendix B, while Figure B-10 shows the grain-size distribution of a layer of sand within a gravelly zone. These indicate the following grain-size distribution:

Gravel:	0 -2%
Sand:	86-87 %
Silt & Clay:	11-14 %

Figure B-11 shows the grain-size distribution of fine samples from the more prominent, relatively well-graded sand in the basal granular deposits. These indicate the following grain-size distribution:

Gravel:	12-28%
Sand:	40-61 %
Silt & Clay:	11-40 %

Figure B-12 shows the grain-size distribution of a relatively coarser gravelly sand layer within the basal granular deposits. The following grain-size distribution is indicated.

Gravel:	85 %
Sand:	12 %
Silt:	3 %

It should be pointed out that the presence of cobbles and boulders was noted in these deposits. In particular, boulders were contacted in Borehole B1, B2 and B3. Borehole B3 was advanced near the bedrock surface in between 10.0 and 12.3 m depths (El. 175.5 to 173.2 m) by coring through several boulders.

N-values recorded in these deposits range widely from 7 to in excess of 100 blows/0.3 m, indicating a loose to very dense compactness condition.

These basal granular deposits are water bearing and appeared to be under excess hydrostatic pressure.

4.6 Bedrock

In Boreholes B3 and B4, which were put down at the south abutment location, a reddish grey coloured basic volcanic rock (See the project site on Ontario Geologic Map 2108 in Appendix E) was contacted at depths of 12.3 m and 13.0 m or El. 173.2 and 171.7 m, respectively.

The percentage of rock core recovery was 72 to 100 % while the RQD values vary from 38 to 85 %. These results indicate a rock quality ranging from poor to good, but typically fair to good.

Unconfined compression tests were performed on selected intact rock samples and the tests yielded unconfined compressive strengths of about 161 to 188 MPa. These results indicate that the rock samples tested can be classified as being "very strong".

4.7 Groundwater Conditions

Groundwater conditions were observed in the open boreholes while drilling and upon completion of each borehole. In the deep boreholes (i.e. Borehole B1 through B6), where wash boring and NQ coring were used (i.e. water introduced into the boreholes), the on-completion water levels may not be reliable. The observations made in the boreholes are shown on the individual Record of Borehole Sheets and are summarized in the following table.

Table 4.7.1 Summary of Groundwater Level Measurements

Borehole No	Ground Surface Elevation (m)	Depth/Elevation of the Tip of Piezometer (m)	Water Level Measurement Depth/Elevation (m)	Date	Piezometers
B1	185.4	-	3.7/181.7*	Upon completion	No
B2	184.6	-	2.3/182.3*	Upon completion	No
B3	185.5	-	0.9/184.6*	Upon completion	No
B4	184.7	12.2/172.5	2.4/182.3	2 days after completion	Yes
B5	185.2	-	Dry*	Upon completion	No
B6	185.5	-	2.4/183.1*	Upon completion	No
B7	183.3	-	0.4/182.9*	Upon completion	No
B8	183.1	-	0.3/182.8*	Upon completion	No
B9	182.9	-	0.5/182.4*	Upon completion	No
B10	183.1	-	0.4/182.7*	Upon completion	No

* not stabilized

As shown in the above table a piezometer was installed in the basal granular deposit above the bedrock. The water level in the piezometer was measured at El. 182.3 m or close to the o.g. level. A previous investigation (1959, MTO Geocres 41K00-017 and 41K00-019) in the close vicinity of the existing bridge, shows an artesian conditions emanating from the basal granular deposits, a condition which frequently occurs due to an upward gradient the from confined pervious layer (the basal granular deposit at this site) between relatively impervious materials (i.e. silty clay to clay at top and bedrock at the bottom). However, an artesian condition was not encountered during our investigation but the water level was found at or very close to the o.g. levels. It is our opinion that an artesian condition might occur at the site depending on the water level in Lake Superior, located within about 120 m to the site. From the measured values, it is our opinion that groundwater level below the original grade (o.g.) at the time of investigation was at about El 182 to 183 m, while a perched water condition would likely occur due to the accumulation of the surface water in the fill materials and in the upper sand cap overlying the practically impervious clay deposit.

It should be pointed out that the water levels observed represent the conditions at the time of our investigation and that they would be subject to seasonal fluctuations as well as fluctuations due to weather events and the water level in the Harmony River which highly depends on the water level in Lake Superior (i.e. water level at the site would be largely regulated by the water level in Lake Superior), especially if there is a hydraulic connection through the water bearing, relatively pervious basal granular deposits underlying the site. We understand that the highest water level recorded in Lake Superior was 184.05 m, while the normal water level was 183.5 m (average of past five years).

For and on behalf of Coffey Geotechnics Inc.

Gwangha Roh, Ph.D.

LICENSED PROFESSIONAL ENGINEER
RAMON MIRANDA
PROVINCE OF ONTARIO

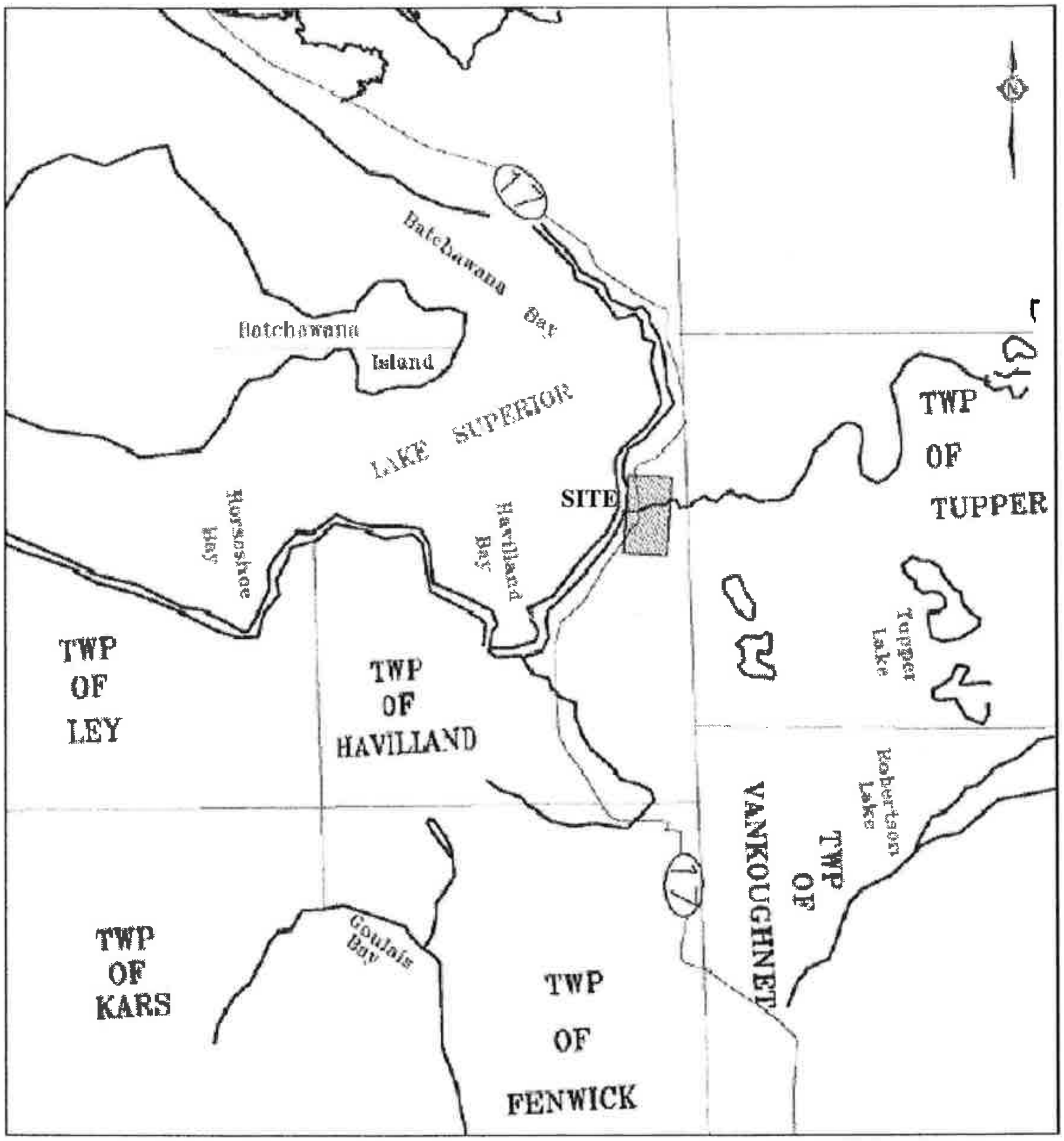
Ramon Miranda, P.Eng.

REGISTERED PROFESSIONAL ENGINEER
Z. S. OZDEN
PROVINCE OF ONTARIO

Zuhtu Ozden, P.Eng.

Drawings

Harmony Beach Road Bridge
Site No. 38S-345
Highway 17-7045



Drawing 1 Site Plan

CONT No.
GWP: 5430-06-00

SHEET

HARMONY BEACH ROAD BRIDGE
BOREHOLE LOCATION PLAN
AND SOIL STRATA (PROFILE)

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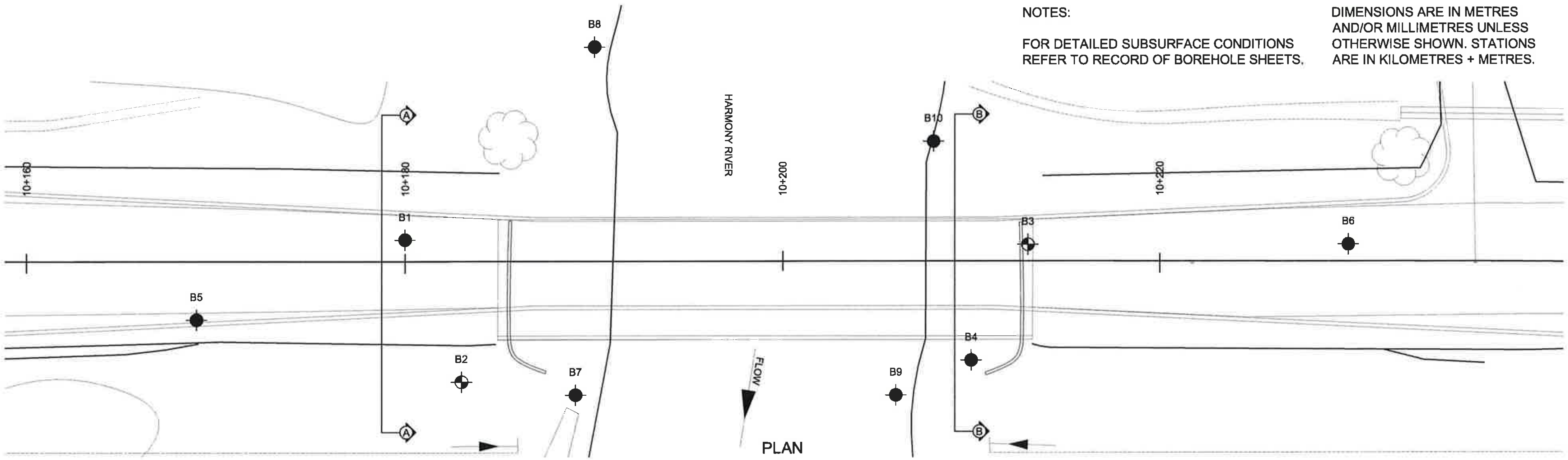
METRIC

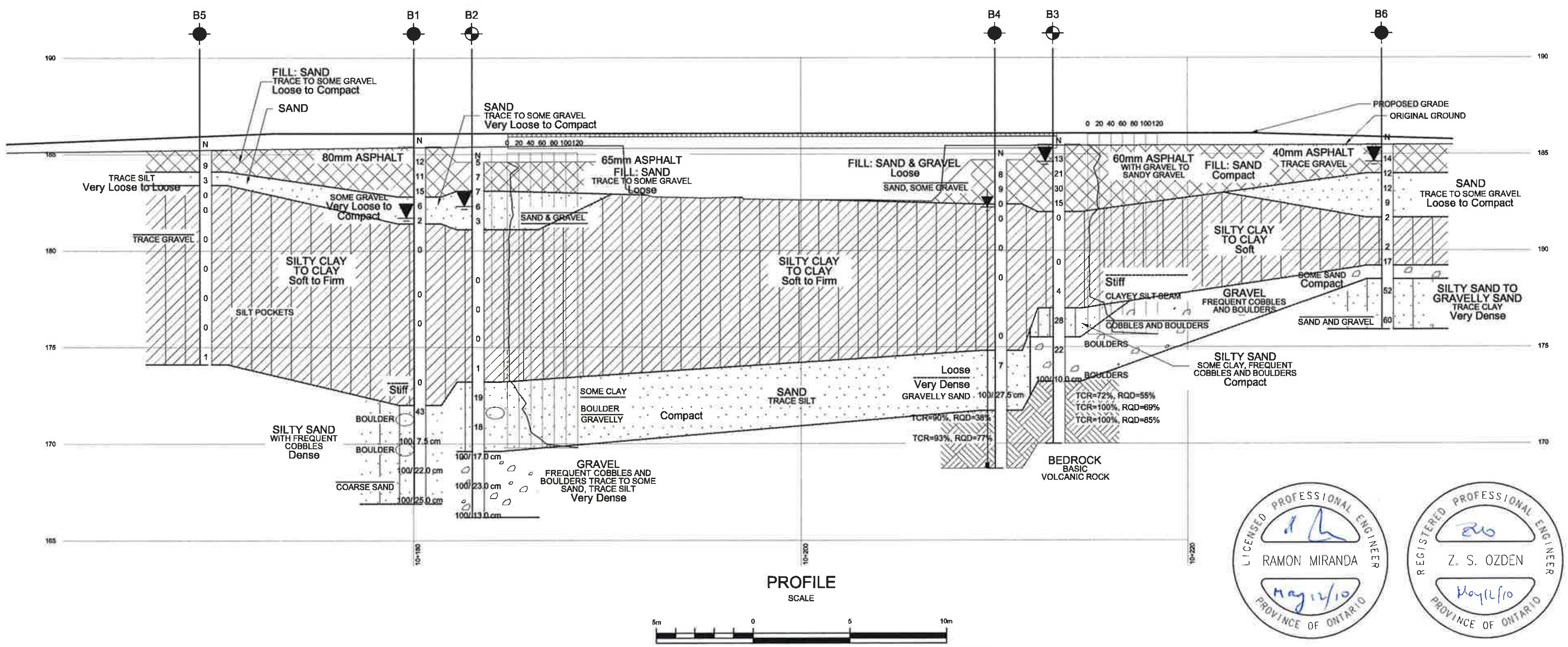
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES + METRES.

NOTES:

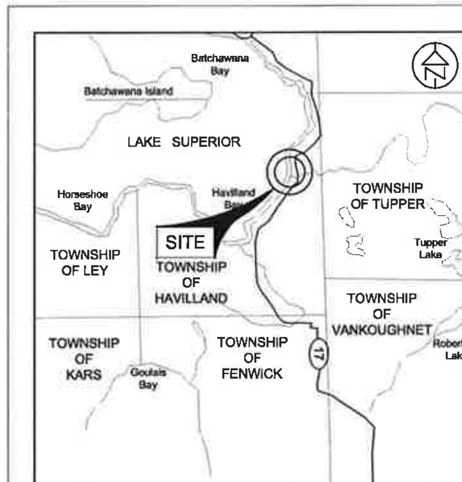
FOR DETAILED SUBSURFACE CONDITIONS REFER TO RECORD OF BOREHOLE SHEETS.



PLAN
SCALE



PROFILE
SCALE



KEY PLAN
N.T.S.

LEGEND

- Borehole
- Borehole & Cone
- N — Blows/0.3m (Std. Pen. Test, 475 J/blow)
- Water Level at Time of Investigation (W. L. NOT STABILIZED)
- Water Level in Piezometer
- Piezometer

No.	ELEVATION	NORTHING	EASTING
B1	185.3	5189580.7	276365.3
B2	184.6	5189578.8	276357.4
B3	185.4	5189548.1	276360.6
B4	184.7	5189551.9	276354.9
B5	185.1	5189592.2	276362.6
B6	185.5	5189531.2	276358.3
B7	183.3	5189572.9	276355.9
B8	183.1	5189569.5	276374.1
B9	182.9	5189556.1	276353.6
B10	183.1	5189552.3	276366.7

-NOTE-
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

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

REVISIONS	DATE	BY	DESCRIPTION

Geocres No 41K-63

TRANETOB01240AA			DIST
SUBM'D	CHECKED	DATE May 12, 2010	SITE 38S-345
DRAWN PHK	CHECKED RM	APPROVED ZO	DWG 2

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES + METRES.

NOTES:

FOR DETAILED SUBSURFACE CONDITIONS REFER TO RECORD OF BOREHOLE SHEETS.

CONT No.
GWP: 5430-06-00

SHEET

HARMONY BEACH ROAD BRIDGE
SOIL STRATA (SECTIONS)

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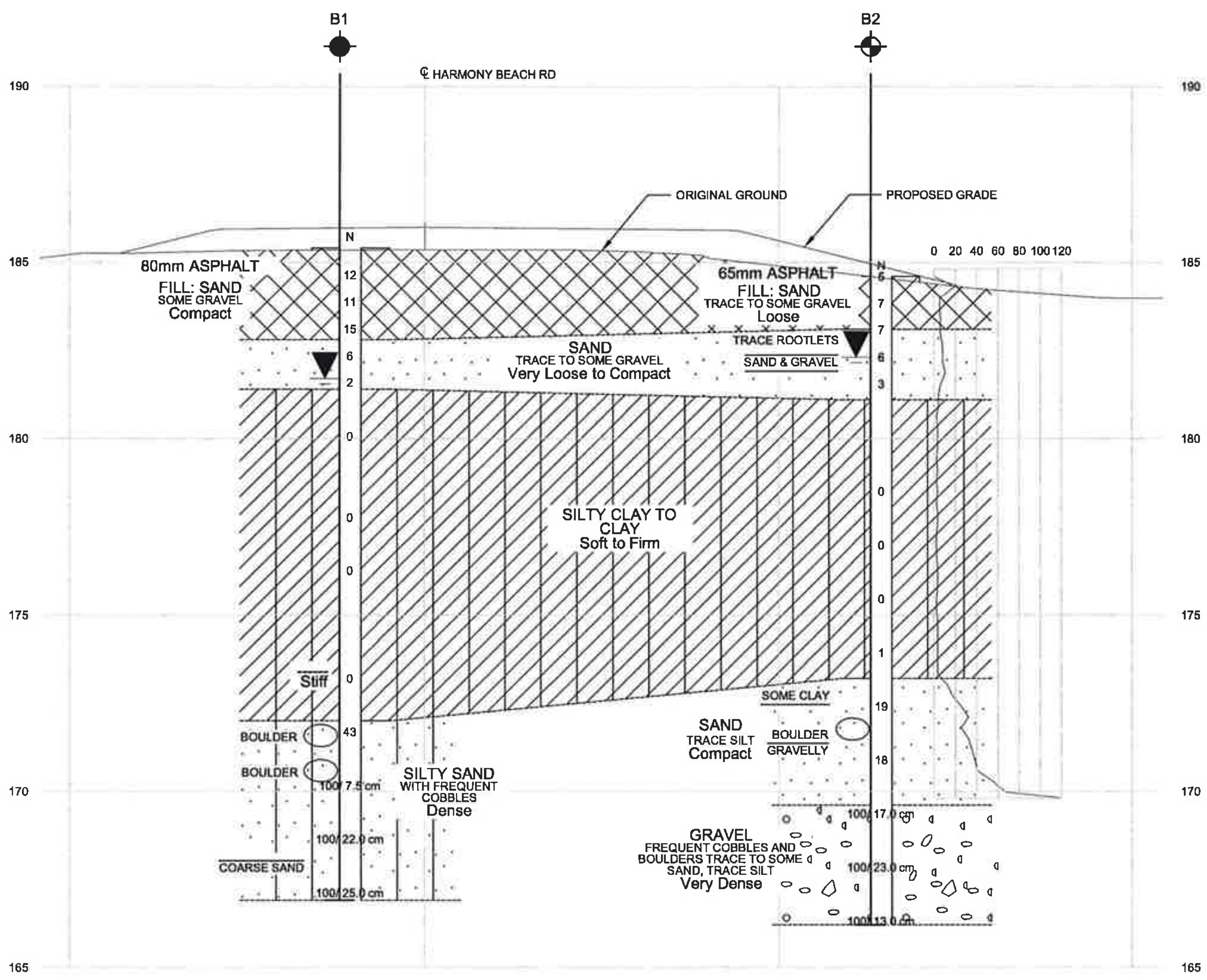
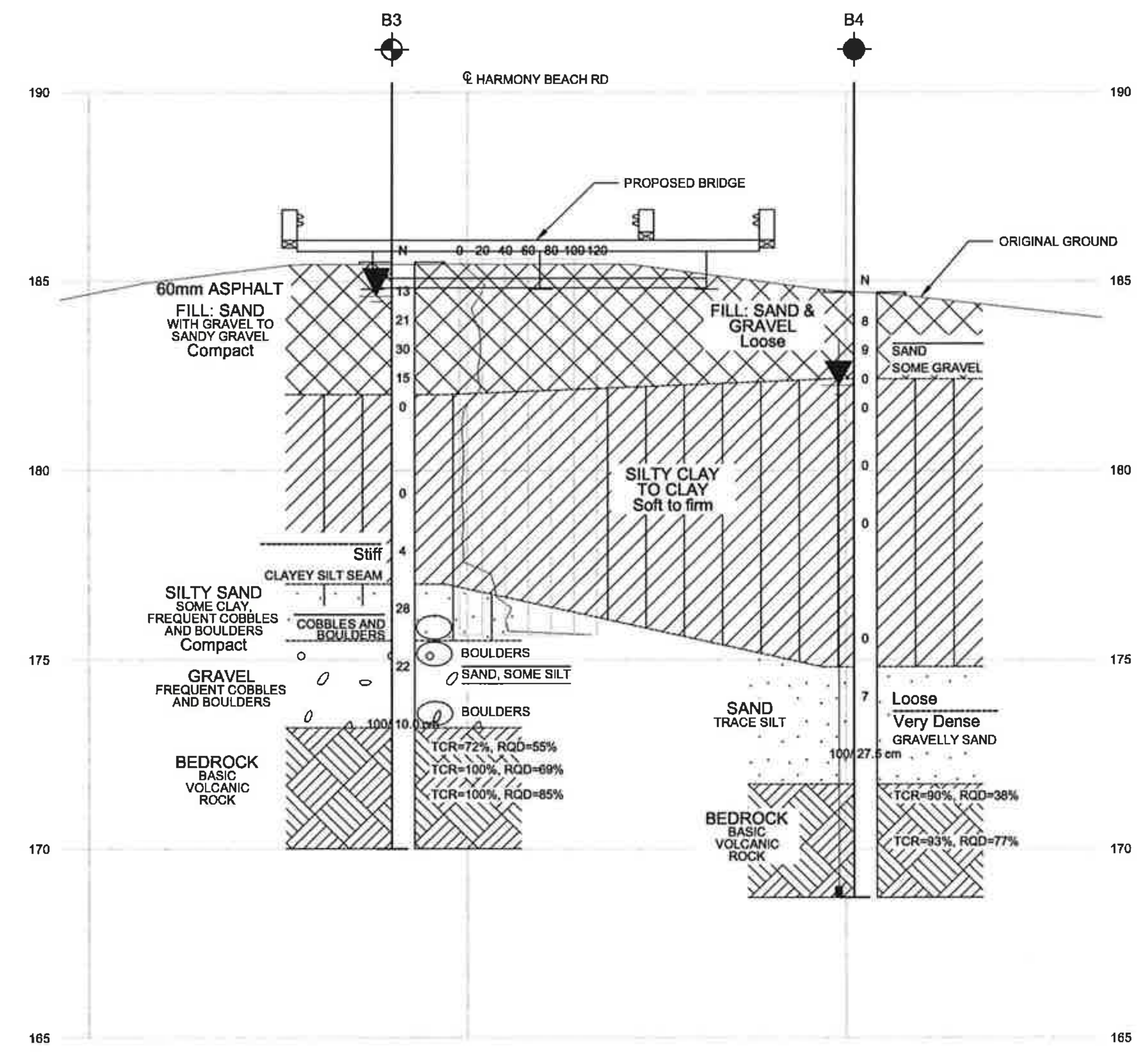


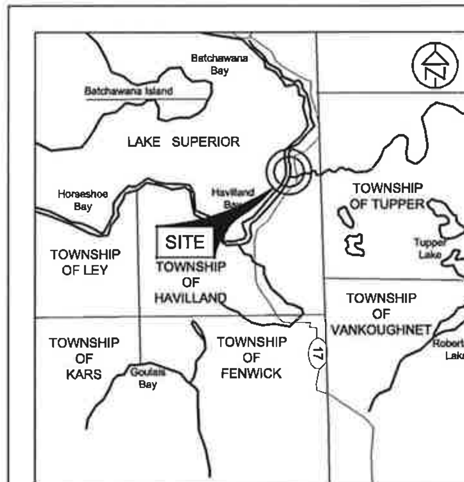
SECTION A-A



SECTION B-B

HORIZONTAL SCALE

2.5m 0 2.5 5m



KEY PLAN
N.T.S.

LEGEND

- Borehole
- Borehole & Cone
- N — Blows/0.3m (Std. Pen. Test, 475 J/blow)
- Water Level at Time of Investigation (W. L. NOT STABILIZED)
- Water Level in Piezometer
- Piezometer

No.	ELEVATION	STATION	OFFSET
B1	185.3	10+180	1.2m Lt C/L
B2	184.6	10+183	6.3m Rt C/L
B3	185.4	10+213	1.0m Lt C/L
B4	184.7	10+210	5.1m Rt C/L

-NOTE-
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

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

LICENSED PROFESSIONAL ENGINEER — RAMON MIRANDA — PROVINCE OF ONTARIO — May 12/10

REGISTERED PROFESSIONAL ENGINEER — Z. S. OZDEN — PROVINCE OF ONTARIO — May 12/10

REVISIONS	DATE	BY	DESCRIPTION

Geocres No 41K-83

TRANETOB01240AA			DIST
SUBM'D	CHECKED	DATE May 12, 2010	SITE 38S-345
DRAWN PHK	CHECKED RM	APPROVED ZO	DWG 3

Appendix A

Record of Borehole Sheets

Ministry of Transportation
Ontario

Foundation Design

TRANETOB01240AA: Harmony Beach Road Bridge

RECORD OF BOREHOLE No B1

METRIC

GWP 5430-06-00 LOCATION Sta: 10+180 ; 1.25 m Lt. C/L ORIGINATED BY RK

DIST HWY HWY 17 BOREHOLE TYPE Hollow Stem Augers, Wash boring COMPILED BY RK

DATUM Geodetic DATE 7/21/2009 CHECKED BY RM

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
185.4	GROUND SURFACE					
0.0	80 mm **ASPHALT** 0.2 m **FILL:** sand with gravel 0.3 m **FILL:** sand, some gravel	1	AS			
	FILL: sand, some gravel brown, compact, moist	2	SS	12		
		3	SS	11		
		4	SS	15		spoon wet
182.8 / 2.6	**SAND** some gravel brown, v. loose to compact, wet					5 89 (6)
						7 87 (6)
		5	SS	6	▼	
181.4 / 4.0	**SILTY CLAY to CLAY** reddish brown, soft to firm, wet	6	SS	2		
		7	TW	PM		consolidation test; unit weight 15.5
		8	SS	0		
		9	SS	0		0 1 28 71
		10	SS	0		
		11	TW	PM		consolidation test; unit weight 15.3
	stiff	12	SS	0		
172.0 / 13.4	**SILTY SAND** with freq. cobbles, dense, wet boulder	13	SS	43		auger refusal @ 14.2 m borehole further advanced using wash boring 20 40 26 14
170.4						

Elevation scale: 185, 184, 183, 182, 181, 180, 179, 178, 177, 176, 175, 174, 173, 172, 171

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH (kPa): O UNCONFINED + FIELD VANE ● POCKET PENETR. X LAB VANE; 20 40 60 80 100

Field vane sensitivity values plotted: 4.0, 4.0, 4.0, 4.0, 4.0, 7.0

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m^3

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity

20 / 15 ◆ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No B1

METRIC

GWP 5430-06-00 | LOCATION Sta: 10+180 ; 1.25 m Lt. C/L | ORIGINATED BY RK

DIST | HWY HWY 17 | BOREHOLE TYPE Hollow Stem Augers, Wash boring | COMPILED BY RK

DATUM Geodetic | DATE 7/21/2009 | CHECKED BY RM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH (kPa)	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
170.4 / 15.0	**SILTY SAND** with freq. cobbles, dense, wet; boulder		14	SS	100/7.5 cm		170				spoon bouncing on possible boulder, borehole advanced using coring
			15	SS	100/22.0 cm		169		o		21 58 (21)
	coarse sand		16	SS	100/25.0 cm		168 / 167				
166.9 / 18.5	End of Borehole Borehole caved-in @ 9.5 m upon completion Groundwater level in open borehole @ 3.7 m (not stabilized)* upon completion										

Legend: O UNCONFINED; + FIELD VANE; ● POCKET PENETR.; X LAB VANE. Plastic limit w_P, natural moisture content w, liquid limit w_L.

$+^3$, $\times^3$: Numbers refer to Sensitivity

15-⊕-5 (20 above, 10 below) (%) STRAIN AT FAILURE

TRANETOB01240AA: Harmony Beach Road Bridge

RECORD OF BOREHOLE No B2

 METRIC

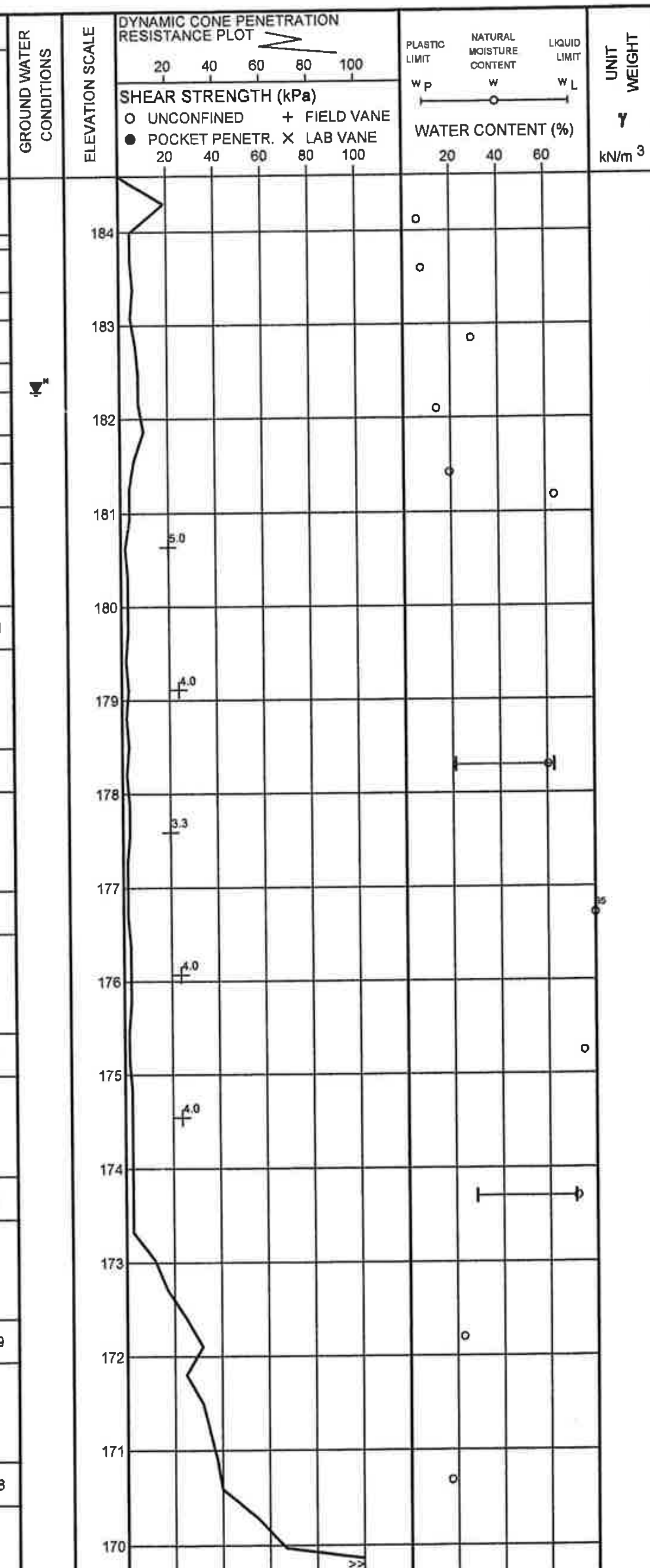
GWP 5430-06-00		LOCATION Sta: 10+183; 6.3 m Rt. C/L	ORIGINATED BY RK
DIST	HWY HWY 17	BOREHOLE TYPE Hollow Stem Augers, Wash boring	COMPILED BY RK
DATUM Geodetic		DATE 7/25/2009	CHECKED BY RM

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
184.6	GROUND SURFACE
0.0	65 mm **ASPHALT** **FILL:** sand tr. to some gravel brown, loose, moist
183.1 / 1.5	**SAND** tr. to some gravel tr. rootlets sand & gravel v. loose to loose, moist to wet
181.1 / 3.5	**SILTY CLAY to CLAY** reddish brown, soft, wet
173.2 / 11.4	**SAND** tr. silt, grey, compact, wet some clay boulder gravelly
169.6	

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	5	
2	SS	7	
3	SS	7	
4	SS	6	spoon wet 46 51 (3)
5	SS	3	
6	TW	PM	
7	SS	0	0 2 34 64
8	SS	0	
9	SS	0	
10	SS	1	
11	SS	19	auger refusal @ 13.1 m borehole further advanced using wash boring
12	SS	18	2 87 (11)



Continued Next Page

+3, ×3: Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

TRANETOB01240AA: Harmony Beach Road Bridge

RECORD OF BOREHOLE No B2

METRIC

GWP 5430-06-00 | LOCATION Sta: 10+183; 6.3 m Rt. C/L | ORIGINATED BY RK

DIST ____ HWY HWY 17 | BOREHOLE TYPE Hollow Stem Augers, Wash boring | COMPILED BY RK

DATUM Geodetic | DATE 7/25/2009 | CHECKED BY RM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH (kPa)	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
169.6 / 15.0	**GRAVEL** freq. cobbles and boulders tr. to some sand, tr. silt v. dense, wet	13	SS	100/ 17.0 cm		169				85	12	(3)	
		14	SS	100/ 23.0 cm		168							
		15	SS	100/ 13.0 cm		167							
166.2 / 18.4	End of Borehole Borehole caved-in @ 6.7 m upon completion DCPT performed adjacent to Borehole to 14.8 m (El. 169.8 m) Groundwater level in open borehole @ 2.3 m (not stabilized)* upon completion												

Legend: O UNCONFINED; + FIELD VANE; ● POCKET PENETR.; X LAB VANE. Plastic limit w_P, natural moisture content w, liquid limit w_L.

+3, X3: Numbers refer to Sensitivity

15-⊕-5 (20/10) (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No B3

METRIC

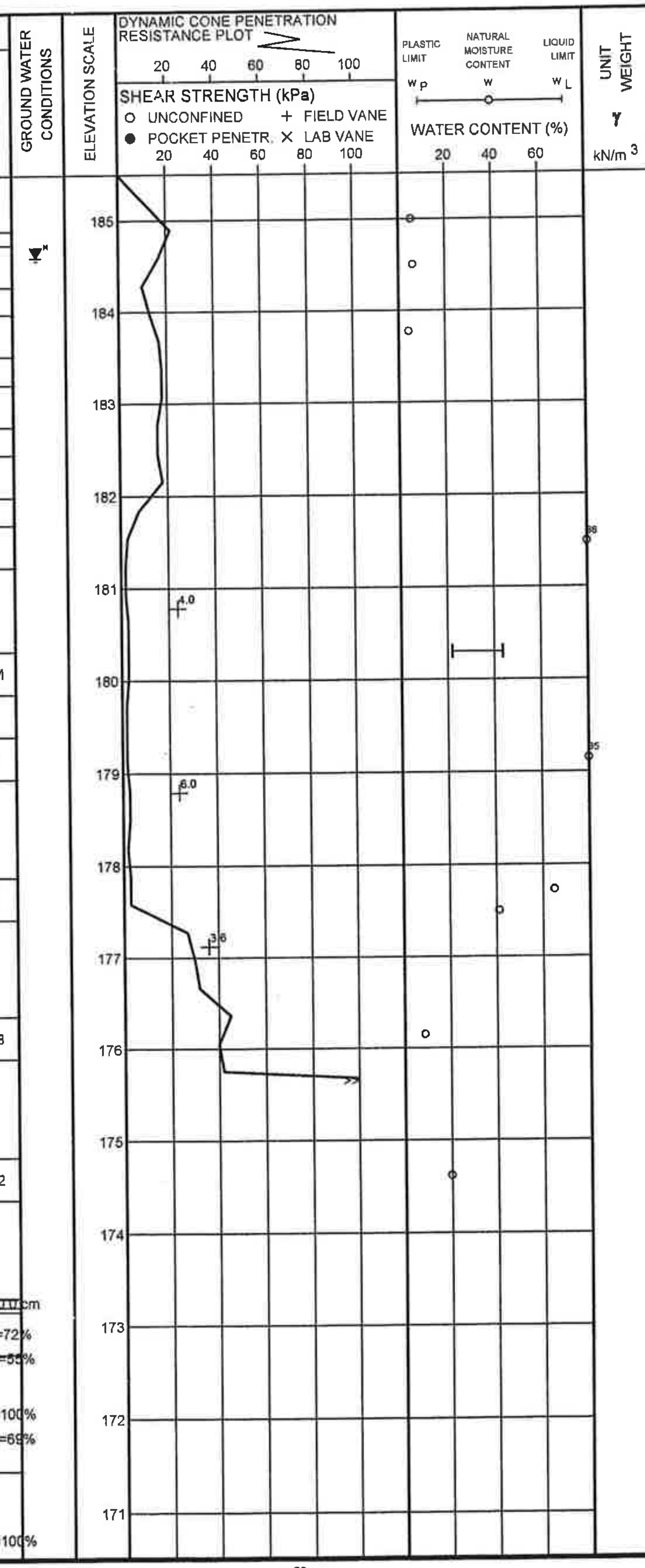
GWP 5430-06-00	LOCATION Sta: 10+213; 1.0 m Lt. C/L		ORIGINATED BY RK
DIST	HWY HWY 17	BOREHOLE TYPE Hollow Stem Augers, Wash boring, Rock coring	COMPILED BY RK
DATUM Geodetic		DATE 7/22/2009	CHECKED BY RM

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
185.5	GROUND SURFACE
0.0	60 mm **ASPHALT** 0.2 m **FILL:** sand & gravel 0.3 m **FILL:** sand, some gravel
184.1 / 1.4	**FILL:** sand with gravel to sandy gravel brown, compact moist wet
182.0 / 3.5	**SILTY CLAY to CLAY** reddish brown, soft, wet stiff, clayey silt seam
177.0 / 8.5	**SILTY SAND** some clay, freq. cobbles and boulders brown to reddish brown, compact, wet cobbles and boulders
175.5 / 10.0	**GRAVEL** freq. cobbles and boulders, wet boulders sand, some silt boulders
173.2 / 12.3	**BEDROCK** reddish grey basic volcanic rock
170.5	

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	AS		
2	SS	13	
3	SS	21	
4	SS	30	61 33 (6)
5	SS	15	spoon wet
6	SS	0	
7	TW	PM	0 0 47 53
8	SS	0	
9	SS	4	2 12 50 36
10	SS	28	12 48 29 11
11	RC		auger refusal @ 9.8 m borehole further advanced using wash boring
12	SS	22	0 86 (14)
13	RC		borehole advanced by coring
14	SS	100/ 10 cm	
15	RC	TCR=72% RQD=55%	UCS 161.5 MPa
16	RC	TCR=100% RQD=69%	
17	RC	TCR=100%	



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+3, X3: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

TRANETOB01240AA: Harmony Beach Road Bridge

RECORD OF BOREHOLE No B3

METRIC

GWP 5430-06-00 LOCATION Sta: 10+213; 1.0 m Lt. C/L ORIGINATED BY RK

DIST HWY HWY 17 BOREHOLE TYPE Hollow Stem Augers, Wash boring, Rock coring COMPILED BY RK

DATUM Geodetic DATE 7/22/2009 CHECKED BY RM

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) (O UNCONFINED, + FIELD VANE, ● POCKET PENETR., X LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
170.5 / 15.0	**BEDROCK** reddish grey basic volcanic rock				RQD=85%		170				
170.0 / 15.5	End of Borehole DCPT performed adjacent to Borehole to 9.9 m (El. 175.6 m) Borehole caved-in @ 6.6 m upon completion Groundwater level in open borehole @ 0.9 m (not stabilized)* upon completion										

$+^3, \times^3$: Numbers refer to Sensitivity

20 / 15 -○- 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No B4

METRIC

GWP 5430-06-00 LOCATION Sta: 10+210; 5.15 m Rt. C/L ORIGINATED BY RK

DIST HWY HWY 17 BOREHOLE TYPE Hollow Stem Augers, Rock Coring COMPILED BY RK

DATUM Geodetic DATE 7/27/2009 CHECKED BY RM

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
184.7	GROUND SURFACE					
0.0	FILL: sand & gravel brown, loose, moist	1	AS		184	
	sand, some gravel	2	SS	8		
		3	SS	9	183	
182.4 2.3	SILTY CLAY to CLAY reddish brown, soft to firm, wet	4	SS	0	182	spoon wet
		5	SS	0	181	0 0 33 67
		6	SS	0	180	
		7	SS	0	179, 178, 177, 176	
		8	SS	0	175	0 1 27 72
174.8 9.9	SAND tr. silt					augering slow
	reddish grey, loose	9	SS	7	174, 173	
	gravelly sand, brown, v. dense	10	SS	100/ 27.5 cm	172	22 61 (17)
171.7 13.0	BEDROCK reddish grey basic volcanic rock	11	RC	TCR=90% RQD=38%	171, 170	auger refusal @ 13.0 m UCS=186.3 MPa
169.7						

Shear strength (field vane) plotted values: 4.0 (≈180.8), 4.6 (≈179.3), 4.0 (≈177.7), 4.0 (≈176.6)

Water content: Sample 5 — W_P ≈ 27, W_L ≈ 58; Sample 8 — W_P ≈ 31, W_L ≈ 61; 33 (≈178.5)

Groundwater level ▼ at approx. 182.0

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH (kPa) O UNCONFINED + FIELD VANE ● POCKET PENETR × LAB VANE 20 40 60 80 100
PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L
WATER CONTENT (%) 20 40 60
UNIT WEIGHT γ kN/m³

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No B4

METRIC

GWP 5430-06-00	LOCATION Sta: 10+210; 5.15 m Rt. C/L		ORIGINATED BY RK
DIST	HWY HWY 17	BOREHOLE TYPE Hollow Stem Augers, Rock Coring	COMPILED BY RK
DATUM Geodetic		DATE 7/27/2009	CHECKED BY RM

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): O UNCONFINED, + FIELD VANE, ● POCKET PENETR., X LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
169.7 / 15.0	**BEDROCK** reddish grey basic volcanic rock		12	RC	TCR=93% RQD=77%		169				
168.7 / 16.0	End of Borehole Piezometer installed to 12.2 m Piezometer readings July 27 , 2009 4.1 m July 29, 2009 2.4 m										

+³, ×³: Numbers refer to Sensitivity

20 / 15-⊕-5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No B5

1 OF 1 **METRIC**

GWP 5430-06-00	LOCATION Sta: 10+169; 3.0 m Rt. C/L		ORIGINATED BY RK
DIST	HWY HWY 17	BOREHOLE TYPE Hollow Stem Augers	COMPILED BY WC
DATUM Geodetic		DATE 7/26/2009	CHECKED BY RM

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
185.2	GROUND SURFACE
0.0	0.3 m **FILL:** Sand & Gravel **FILL:** Sand tr. gravel, brown, loose, moist
184.1 / 1.1	**SAND** tr. silt, brown, v.loose to loose, moist
183.4 / 1.8	**SILTY CLAY TO CLAY** silt pockets, reddish brown soft, wet tr. gravel
174.1 / 11.1	End of Borehole. Borehole caved-in @ 10.0 m. Borehole was dry (not stabilized) upon completion.

SAMPLES

NUMBER	TYPE	"N" VALUES
1	AS	
2	SS	9
3	SS	3
4	SS	0
5	SS	0
6	SS	0
7	SS	0
8	SS	0
9	SS	0
10	SS	1

Field vane shear strength (sensitivity): 4.0, 3.5, 4.0, 3.5

REMARKS & GRAIN SIZE DISTRIBUTION (%)

GR	SA	SI	CL
29	68	(3)	
0	1	37	62

Column headings: GROUND WATER CONDITIONS; ELEVATION SCALE (185, 184, 183, 182, 181, 180, 179, 178, 177, 176, 175); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH (kPa) O UNCONFINED + FIELD VANE ● POCKET PENETR. X LAB VANE (20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60); UNIT WEIGHT γ kN/m³

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No B6

METRIC

GWP 5430-06-00 | LOCATION Sta. 10+230; 1.0 m Lt. C/L | ORIGINATED BY RK

DIST ____ HWY HWY 17 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY WC

DATUM Geodetic | DATE 7/23/2009 | CHECKED BY RM

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
185.5	GROUND SURFACE				
0.0	40 mm **ASPHALT** 0.3 m **FILL:** Sand & Gravel **FILL:** Sand tr. gravel, brown, compact, moist	1	AS		
		2	SS	14	
184.0 / 1.5	**SAND** tr. to some gravel, brown to grey loose to compact, wet	3	SS	12	
		4	SS	12	spoon wet
		5	SS	9	
181.7 / 3.8	**SILTY CLAY TO CLAY** reddish brown, soft, wet	6	SS	2	0 2 46 52
		7	SS	2	
179.2 / 6.3	**GRAVEL** some sand, grey, compact, wet	8	SS	17	
178.5 / 7.0	**SILTY SAND to GRAVELLY SAND** tr. clay, reddish brown v. dense, wet	9	SS	52	28 49 (23)
	sand and gravel	10	SS	60	
175.9 / 9.6	End of Borehole. Borehole caved in @ 6.7 m. Water level @ 2.4 m (not stabilized)* upon completion.				

Shear strength: 5.0 (at approx. elev. 181)

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH (kPa): O UNCONFINED + FIELD VANE ● POCKET PENETR. X LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m^3

ELEVATION SCALE: 185, 184, 183, 182, 181, 180, 179, 178, 177, 176

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No B7

METRIC

GWP 5430-06-00 LOCATION Sta: 10+189; 7.0 m Rt. C/L ORIGINATED BY RK

DIST HWY HWY 17 BOREHOLE TYPE Hand Auger COMPILED BY WC

DATUM Geodetic DATE 7/24/2009 CHECKED BY RM

ELEV DEPTH	SOIL PROFILE 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 ● POCKET PENETR. × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
183.3	GROUND SURFACE										
0.0	freq. cobble		1	AS							
	SAND tr. silt, tr. gravel, grey, wet		2	AS		▼	183				
			3	AS							
182.1 / 1.2	End of Borehole. Water level @ 0.4 m (not stabilized)* upon completion.										

$+^3, \times^3$: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No B8

METRIC

GWP 5430-06-00		LOCATION Sta: 10+190; 11.5 m Lt. C/L	ORIGINATED BY RK
DIST	HWY HWY 17	BOREHOLE TYPE Hand Auger	COMPILED BY WC
DATUM Geodetic		DATE 7/24/2009	CHECKED BY RM

ELEV DEPTH	SOIL PROFILE: 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 + FIELD VANE ● POCKET PENETR. × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
183.1	GROUND SURFACE										
0.0	**SAND** tr. gravel, some rootlets brown to grey, wet		1	AS		▼*	183				
			2	AS							
182.1 / 1.0	End of Borehole. Water level @ 0.3 m (not stabilized)* upon completion.										

+³, ×³: Numbers refer to Sensitivity

15-⊕-5 (20 above, 10 below) (%) STRAIN AT FAILURE

TRANETOB01240AA: Harmony Beach Road Bridge

RECORD OF BOREHOLE No B9

METRIC

GWP 5430-06-00 LOCATION Sta: 10+206; 7.0 m Rt. C/L ORIGINATED BY RK

DIST ______ HWY HWY 17 BOREHOLE TYPE Hand Auger COMPILED BY WC

DATUM Geodetic DATE 7/24/2009 CHECKED BY RM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	SAMPLE TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (kPa): O UNCONFINED, + FIELD VANE, ● POCKET PENETR., × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
182.9	GROUND SURFACE										
0.0	**GRAVELLY SAND** with cobble/rock pieces brown, wet		1	AS							
			2	AS		▼*					
181.9 / 1.0	End of Borehole. Water level @ 0.5 m (not stabilized)* upon completion.						182				

+³, ×³: Numbers refer to Sensitivity

15-⊕-5 (20 above, 10 below): (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No B10

METRIC

GWP 5430-06-00	LOCATION Sta. 10+208; 6.5 m Lt. C/L		ORIGINATED BY RK
DIST	HWY HWY 17	BOREHOLE TYPE Hand Auger	COMPILED BY WC
DATUM Geodetic	DATE 7/24/2009		CHECKED BY RM

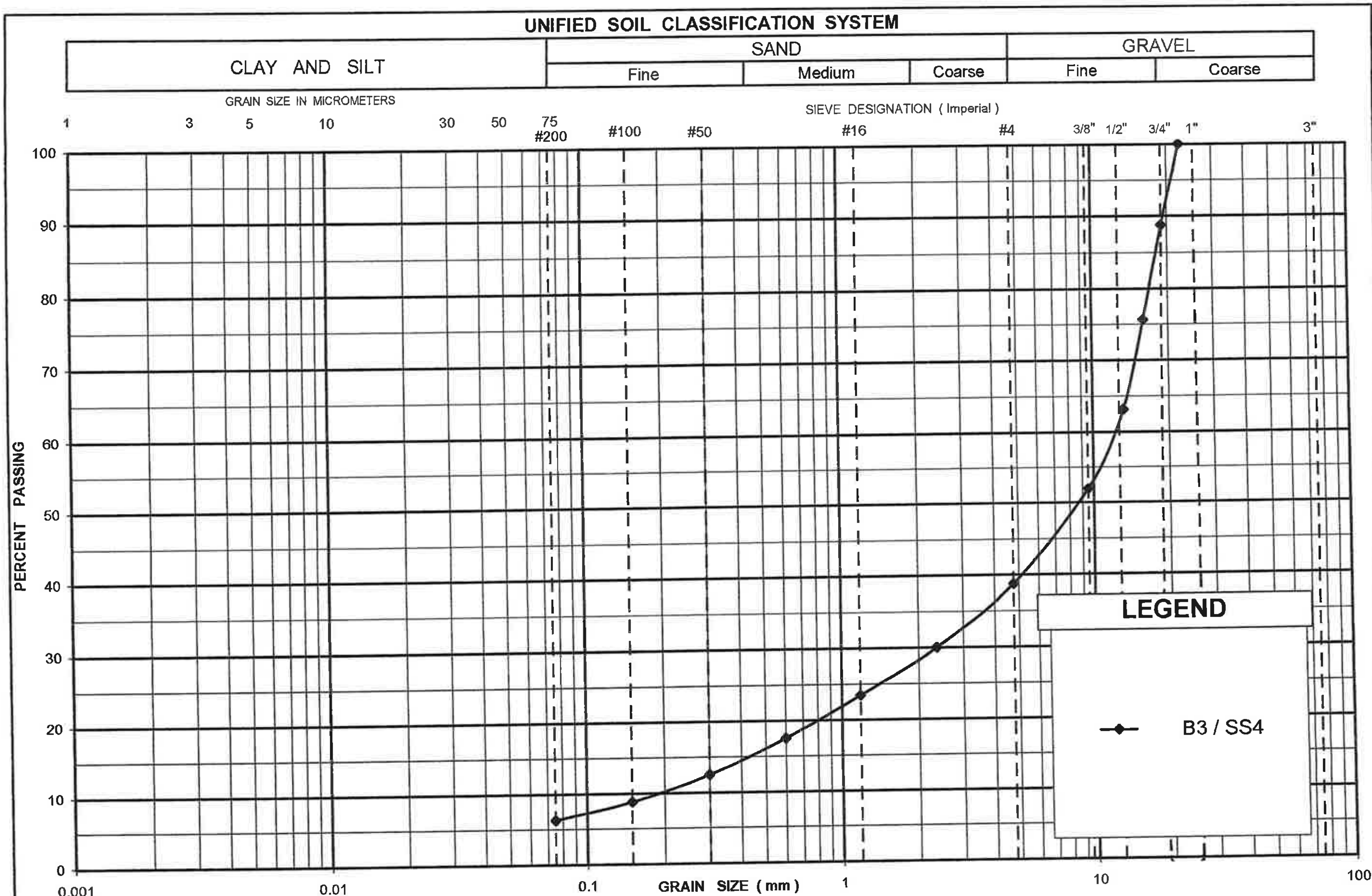
ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
183.1	GROUND SURFACE										
0.0	**SAND** some gravel and rock pieces/cobbles grey, wet		1	AS		▼*	183				
			2	AS							
181.9 / 1.2	End of Borehole. Water level @ 0.4 m (not stabilized)* upon completion.						182				

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Appendix B

Laboratory Test Results



coffey geotechnics
SPECIALISTS MANAGING THE EARTH

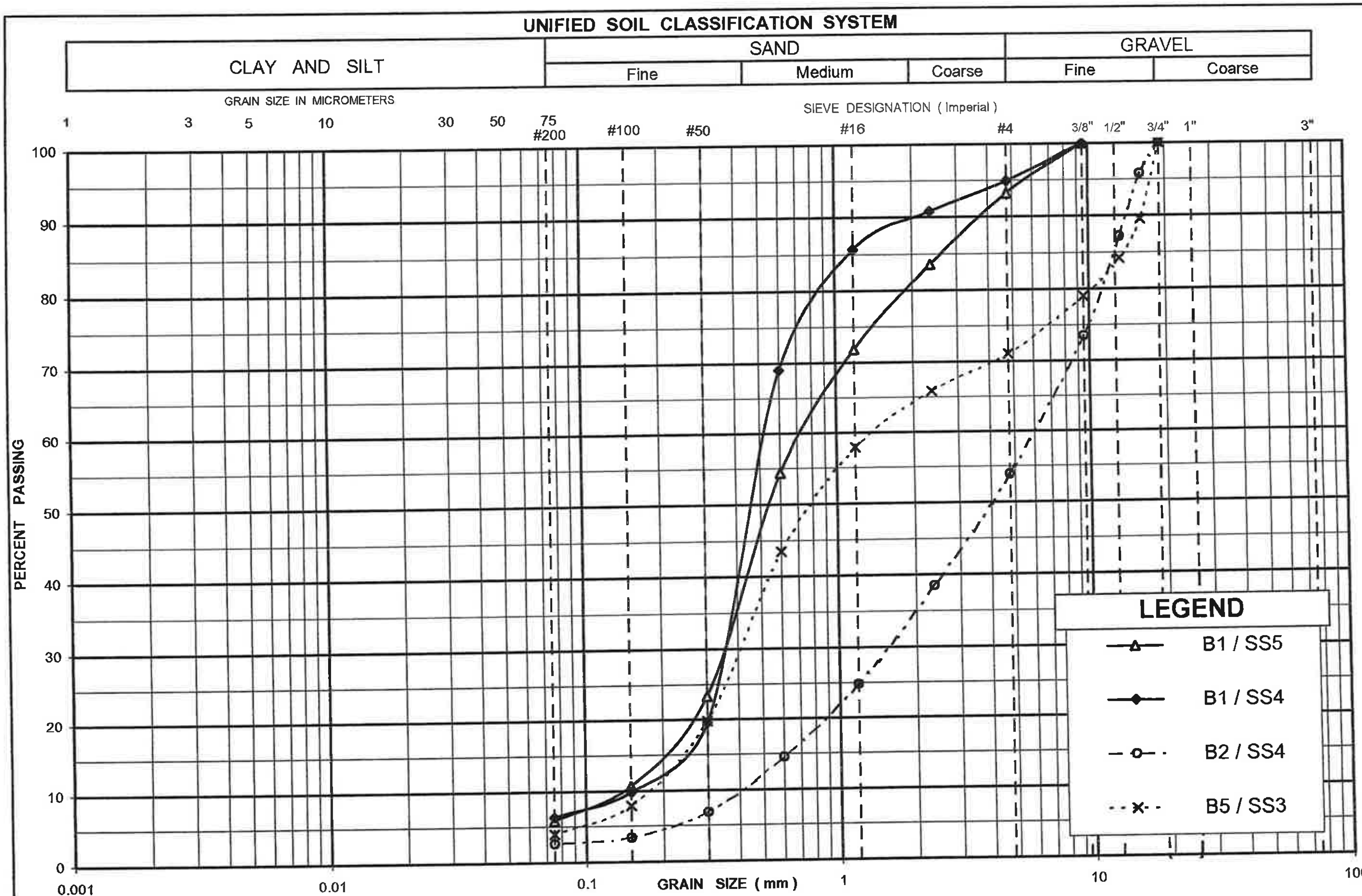
GRAIN SIZE DISTRIBUTION

EMBANKMENT FILL: Sandy Gravel

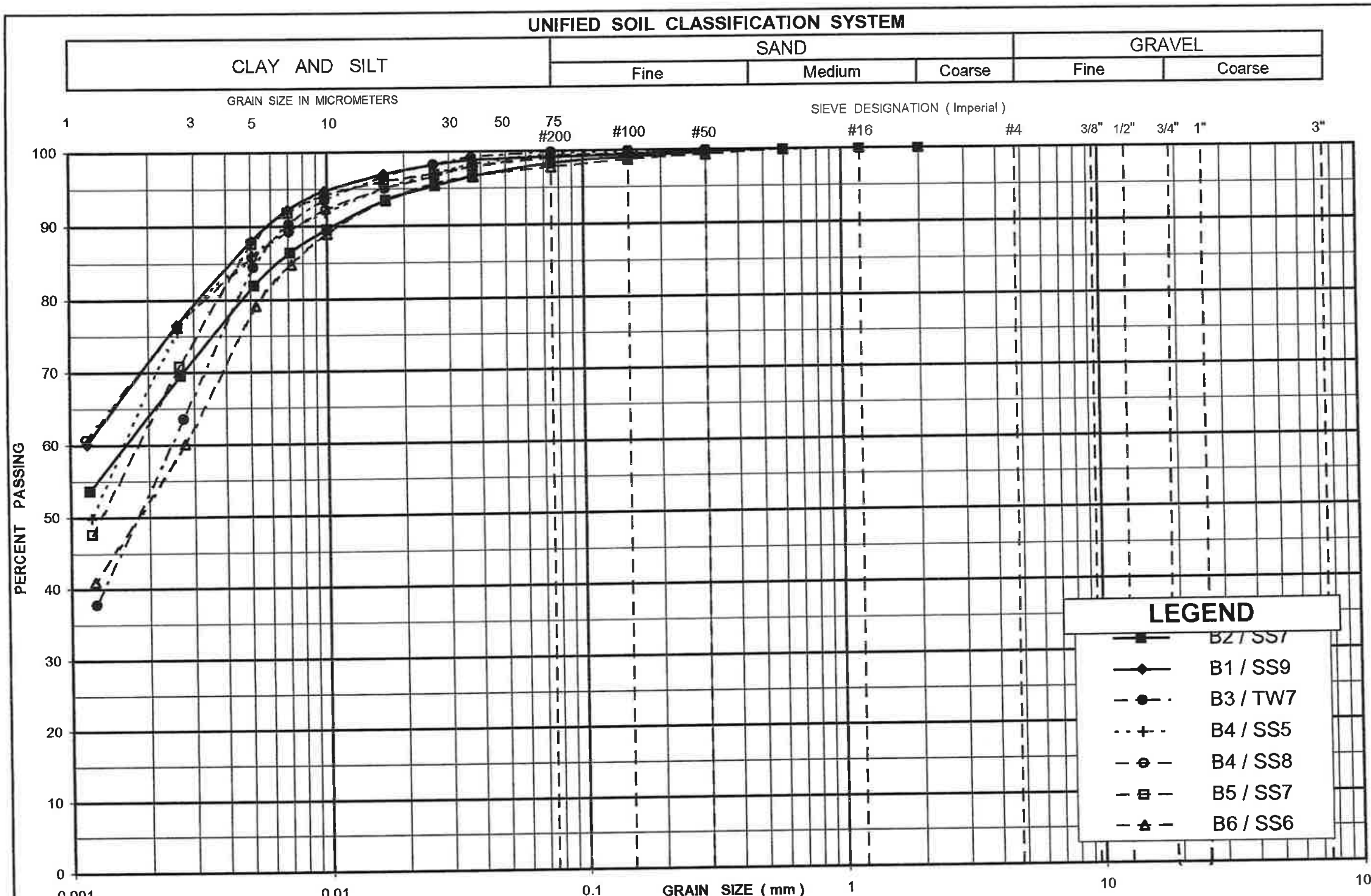
Figure No. B-1

PROJECT # : TRANETOB01240AA

DATE: October 09, 2009



coffey geotechnics SPECIALISTS MANAGING THE EARTH	GRAIN SIZE DISTRIBUTION SURFICIAL GRANULAR SOILS: Sand to Gravelly Sand	Figure No. B-2 PROJECT # : TRANETOB01240AA DATE: October 09, 2009

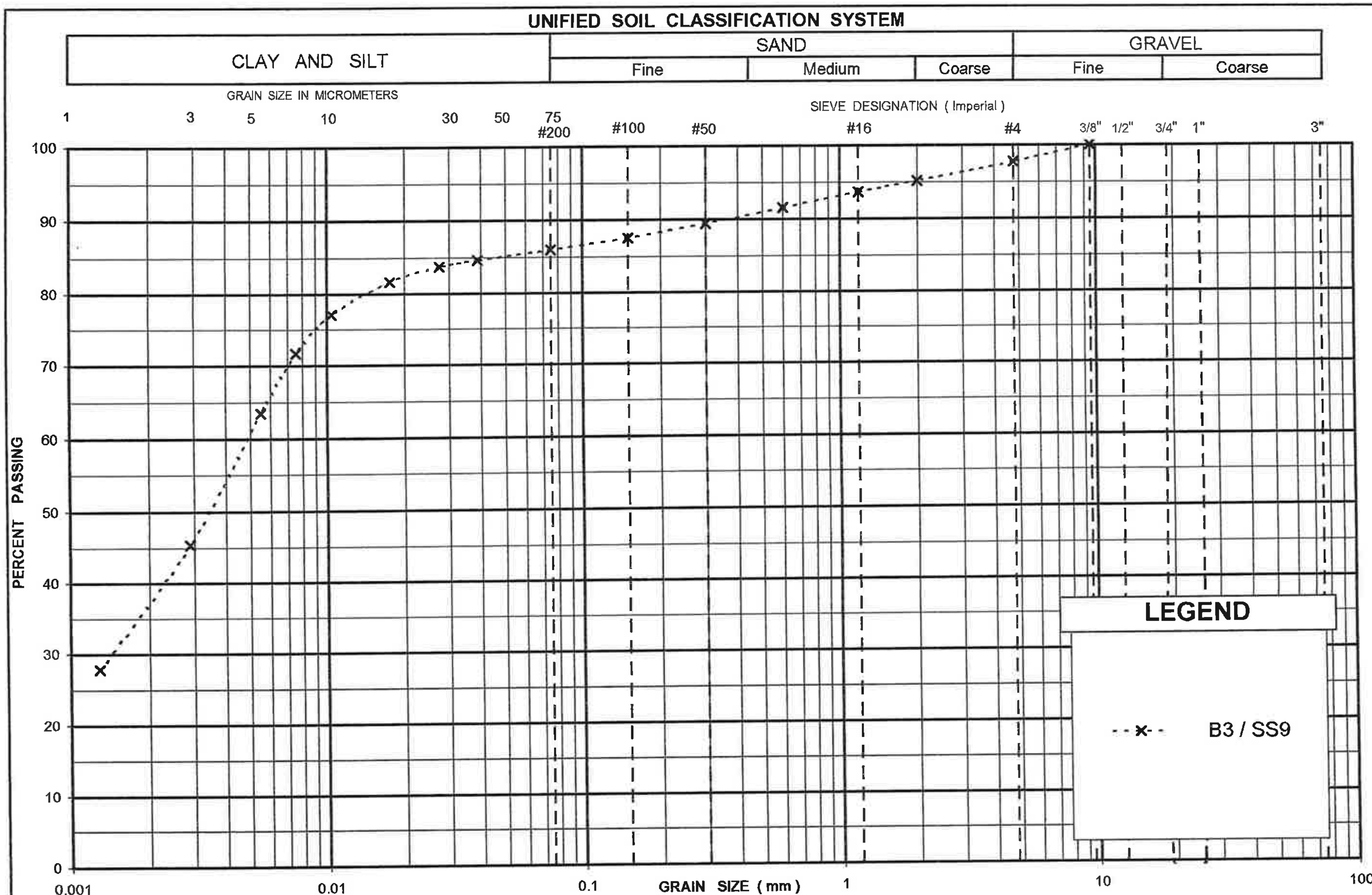


coffey geotechnics
SPECIALISTS MANAGING THE EARTH

GRAIN SIZE DISTRIBUTION

SILTY CALY to CLAY

Figure No.	B-3
PROJECT # :	TRANETOB01240AA
DATE:	October 09, 2009

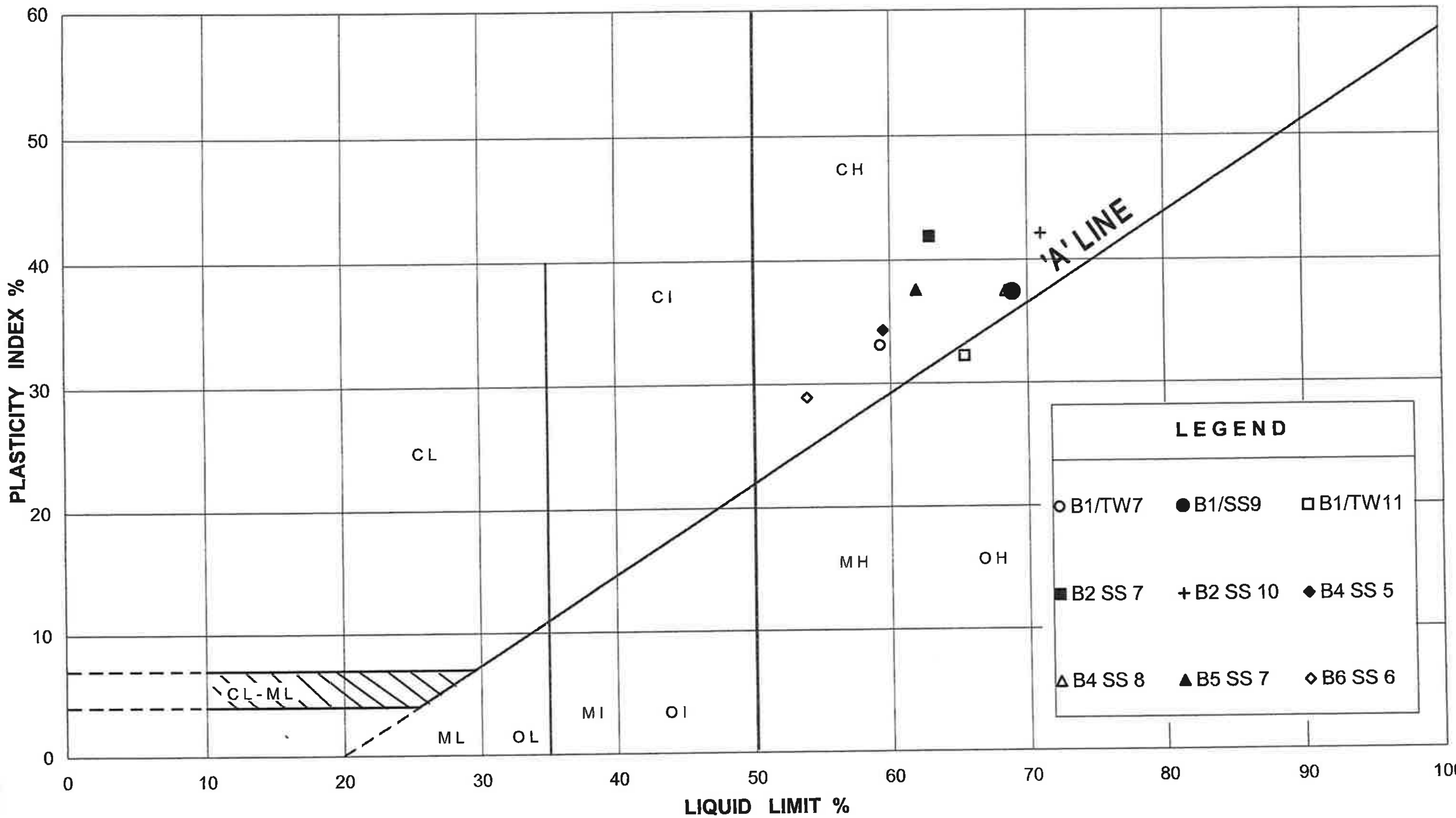


coffey geotechnics
SPECIALISTS MANAGING THE EARTH

GRAIN SIZE DISTRIBUTION

SILTY CLAY

Figure No. B-4	
PROJECT # :	TRANETOB01240AA
DATE:	October 09, 2009

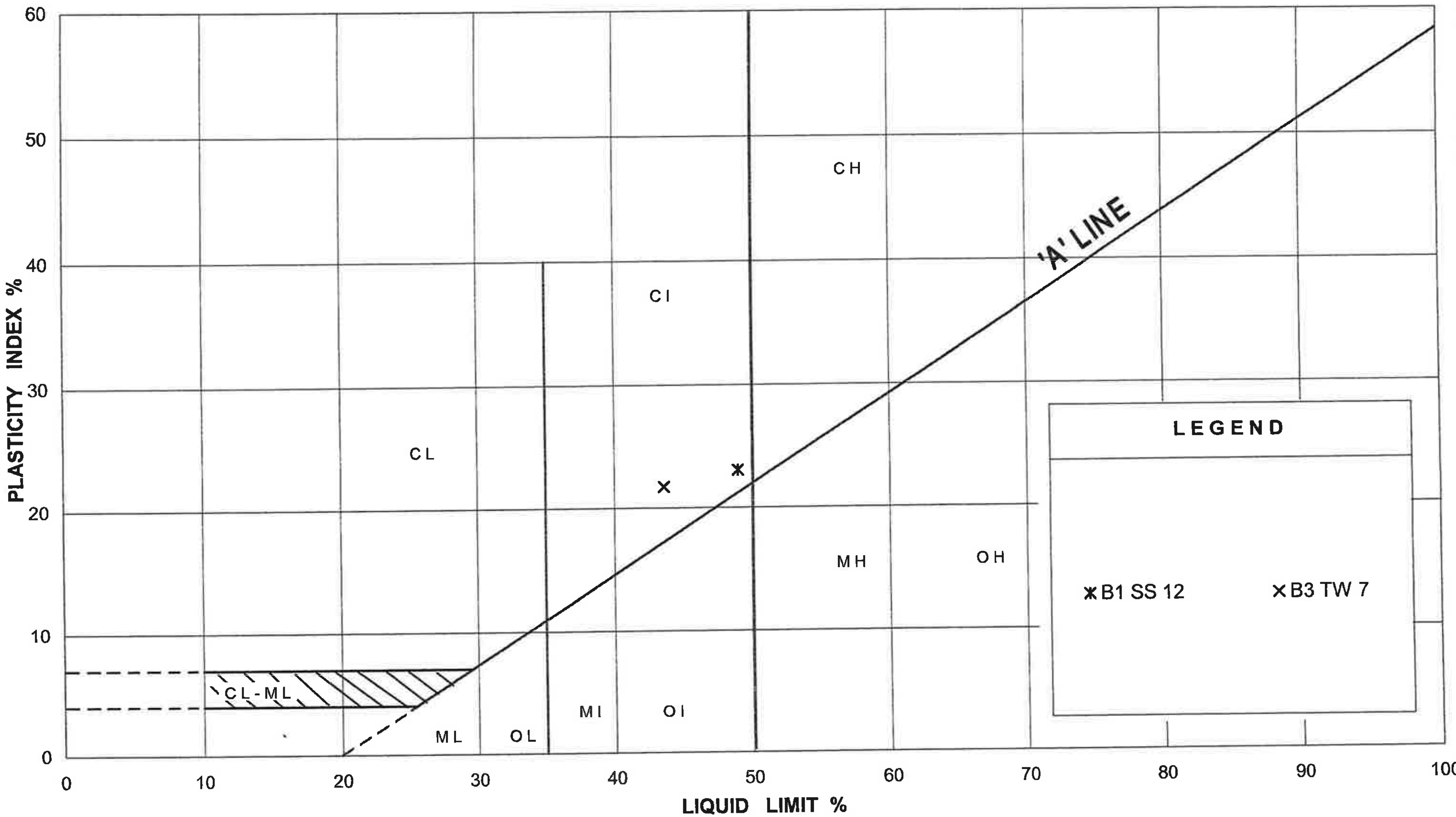


coffey geotechnics
SPECIALISTS MANAGING THE EARTH

PLASTICITY CHART

SILTY CLAY TO CLAY

Figure No. B-5	
Project No. TRANETOB01240AA	
DATE	Oct.16, 2009



coffey geotechnics
SPECIALISTS MANAGING THE EARTH

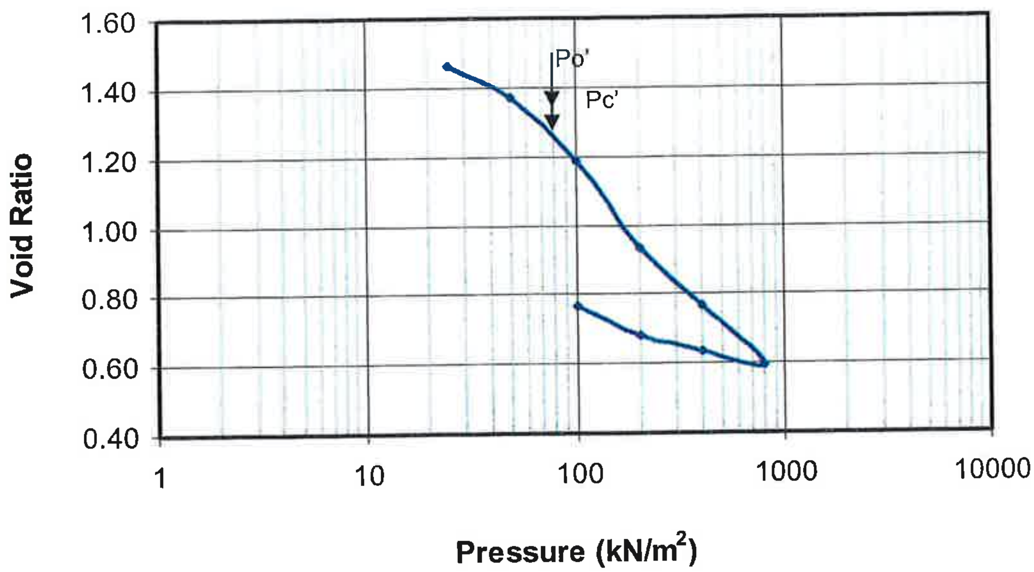
PLASTICITY CHART

SILTY CLAY

Figure No. B-6	
Project No. TRANETOB01240AA	
DATE	Oct.16, 2009

Figure B-7 Consolidation BH B1 TW7

Void Ratio versus Pressure



Coefficient of Consolidation vs. Pressure

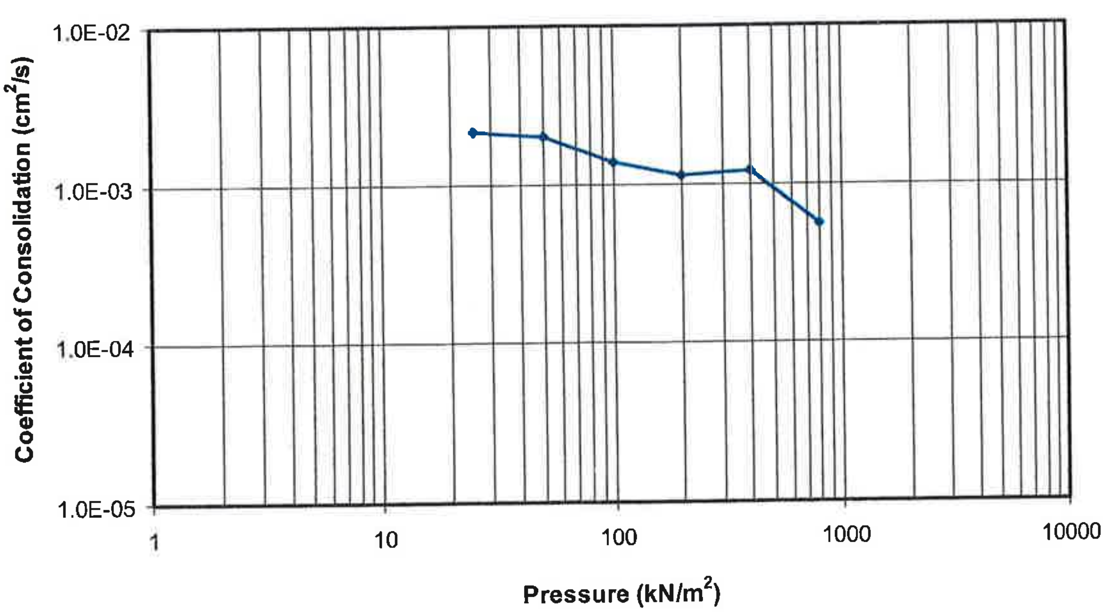
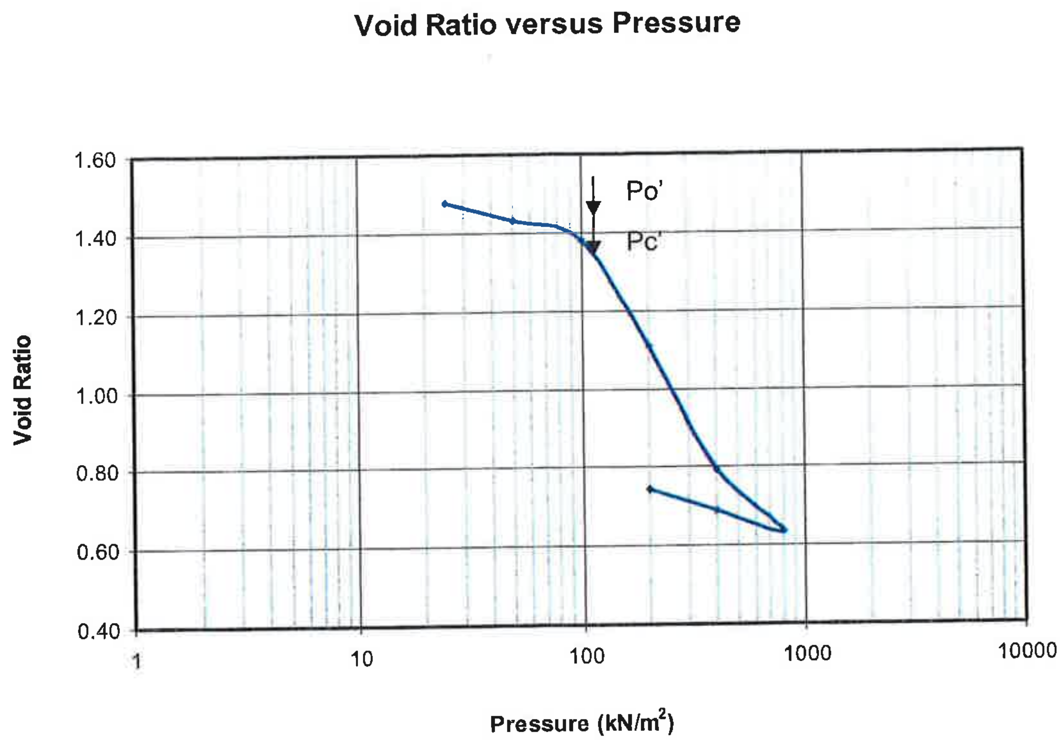
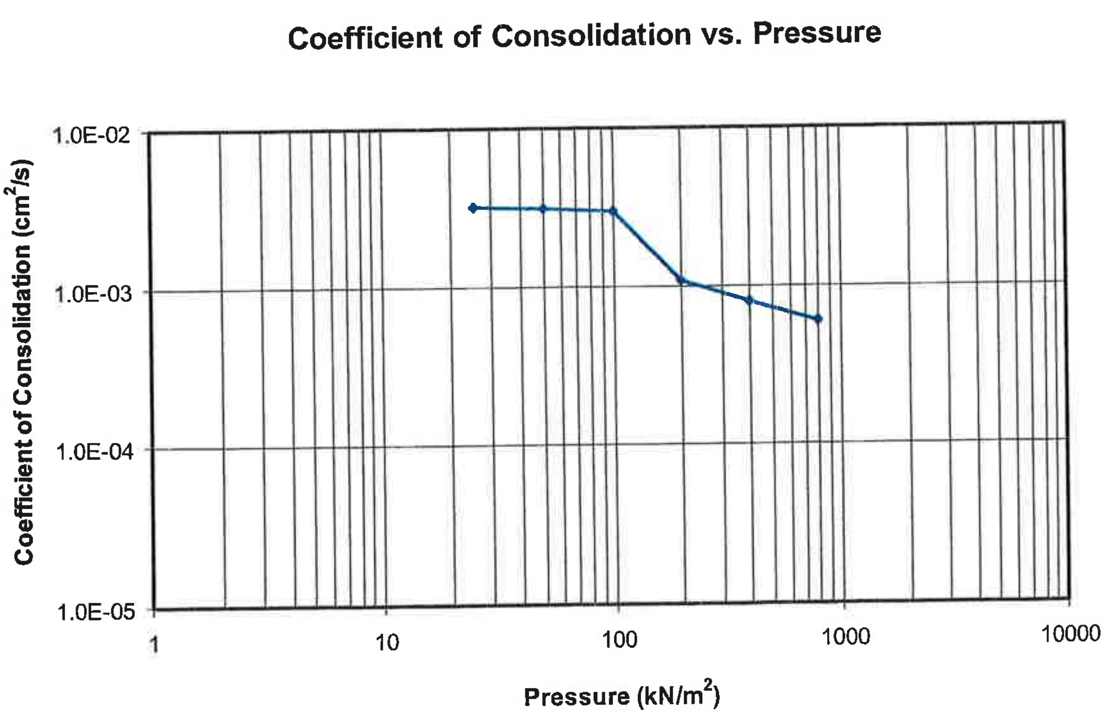
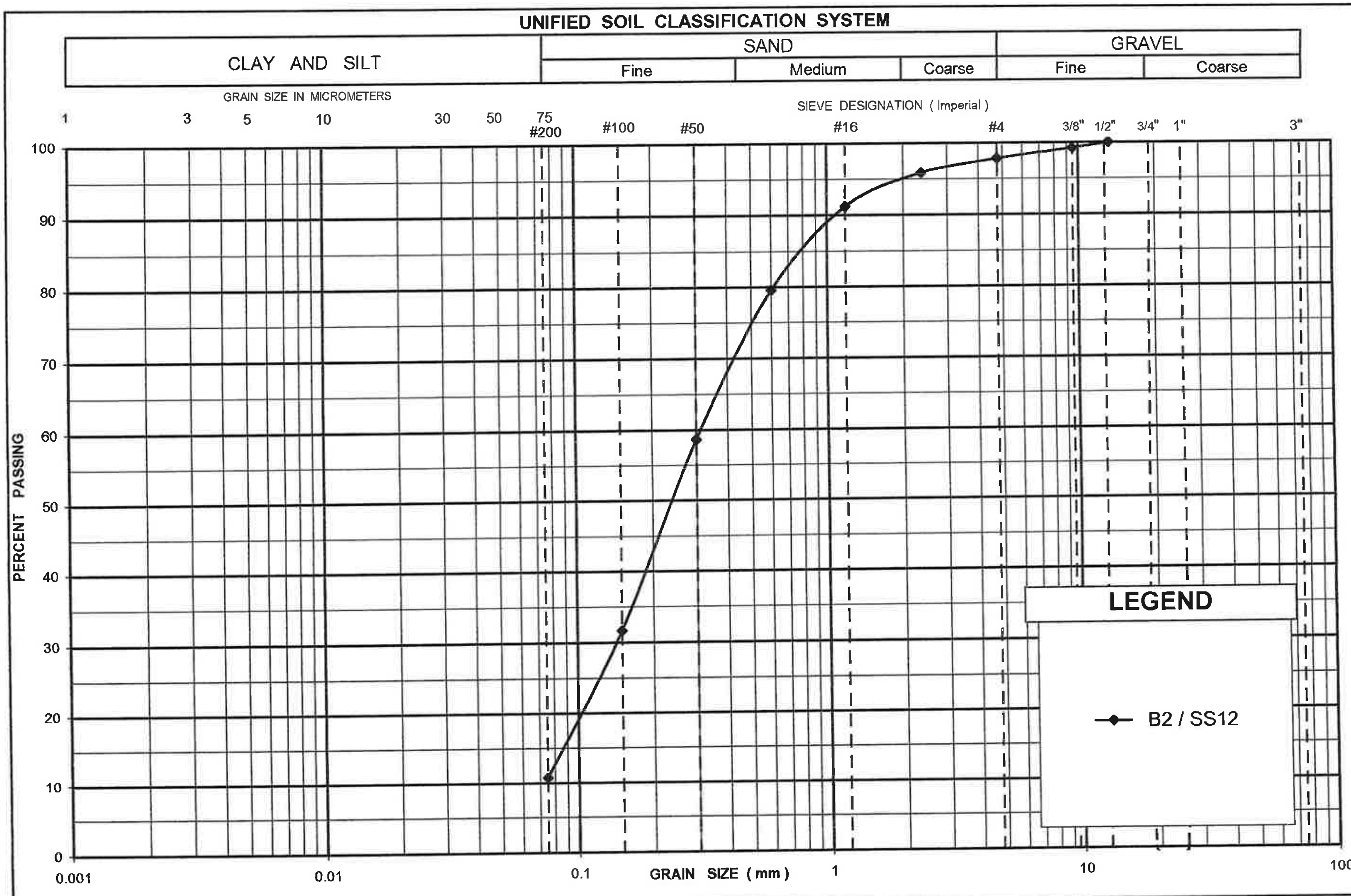


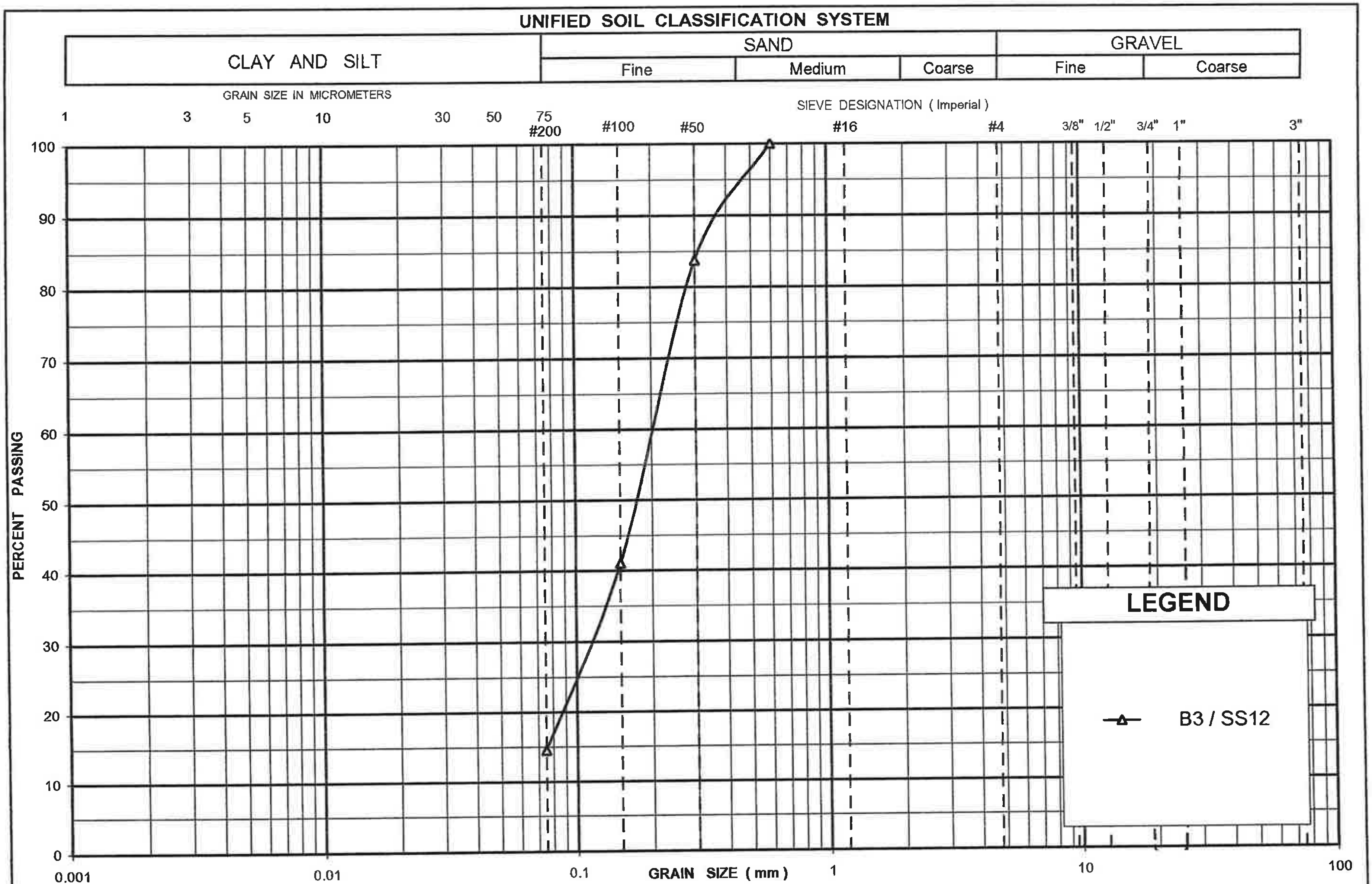
Figure B-8 Consolidation BH B1 TW11







coffey geotechnics SPECIALISTS MANAGING THE EARTH	GRAIN SIZE DISTRIBUTION BASAL GRANULAR SAND	Figure No. B-9 PROJECT # : TRANETOB01240AA DATE: October 09, 2009



coffey geotechnics
SPECIALISTS MANAGING THE EARTH

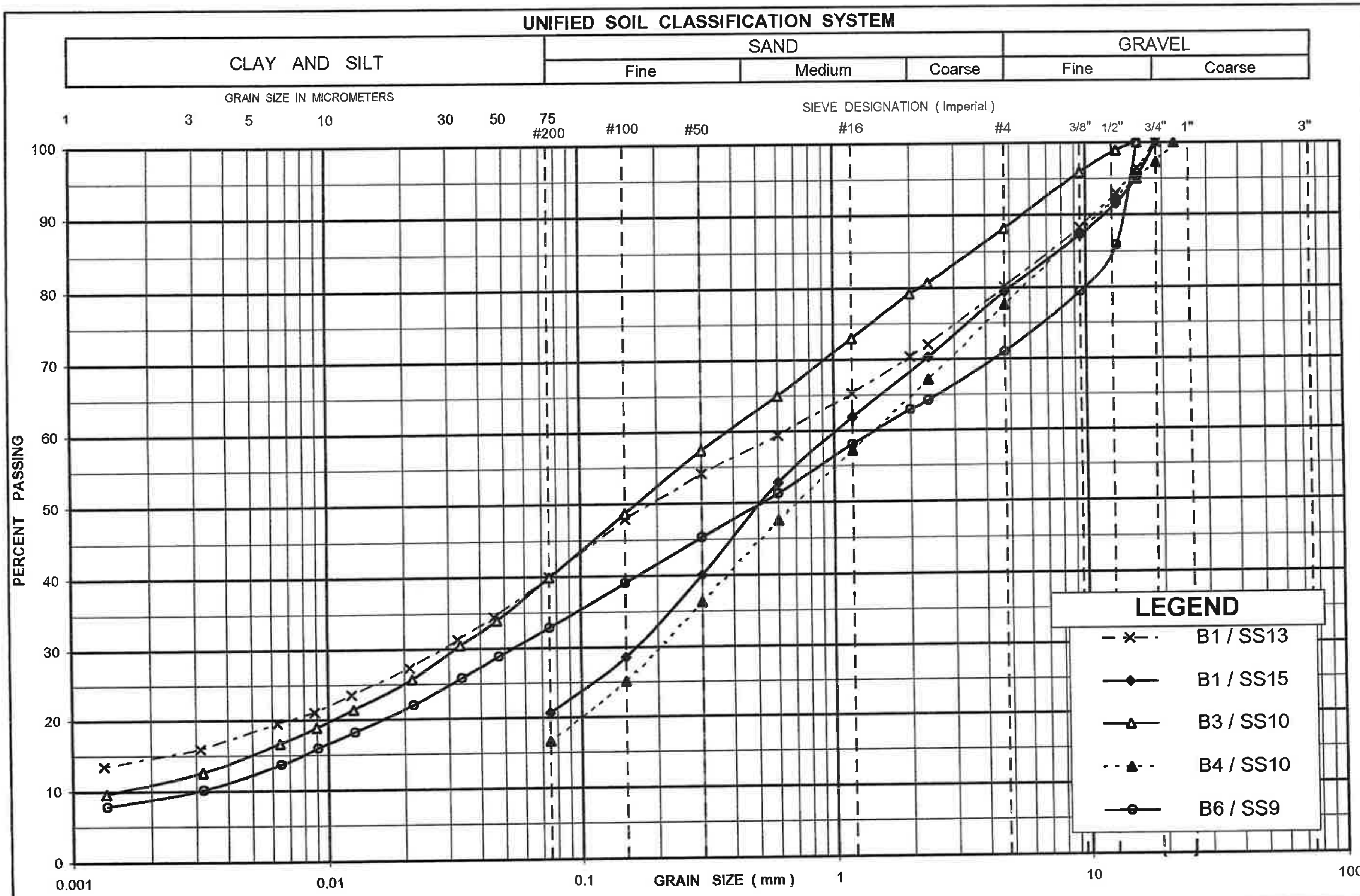
GRAIN SIZE DISTRIBUTION

BASAL GRANULAR SAND, Layer with gravelly soil

Figure No. B-10

PROJECT # : TRANETOB01240AA

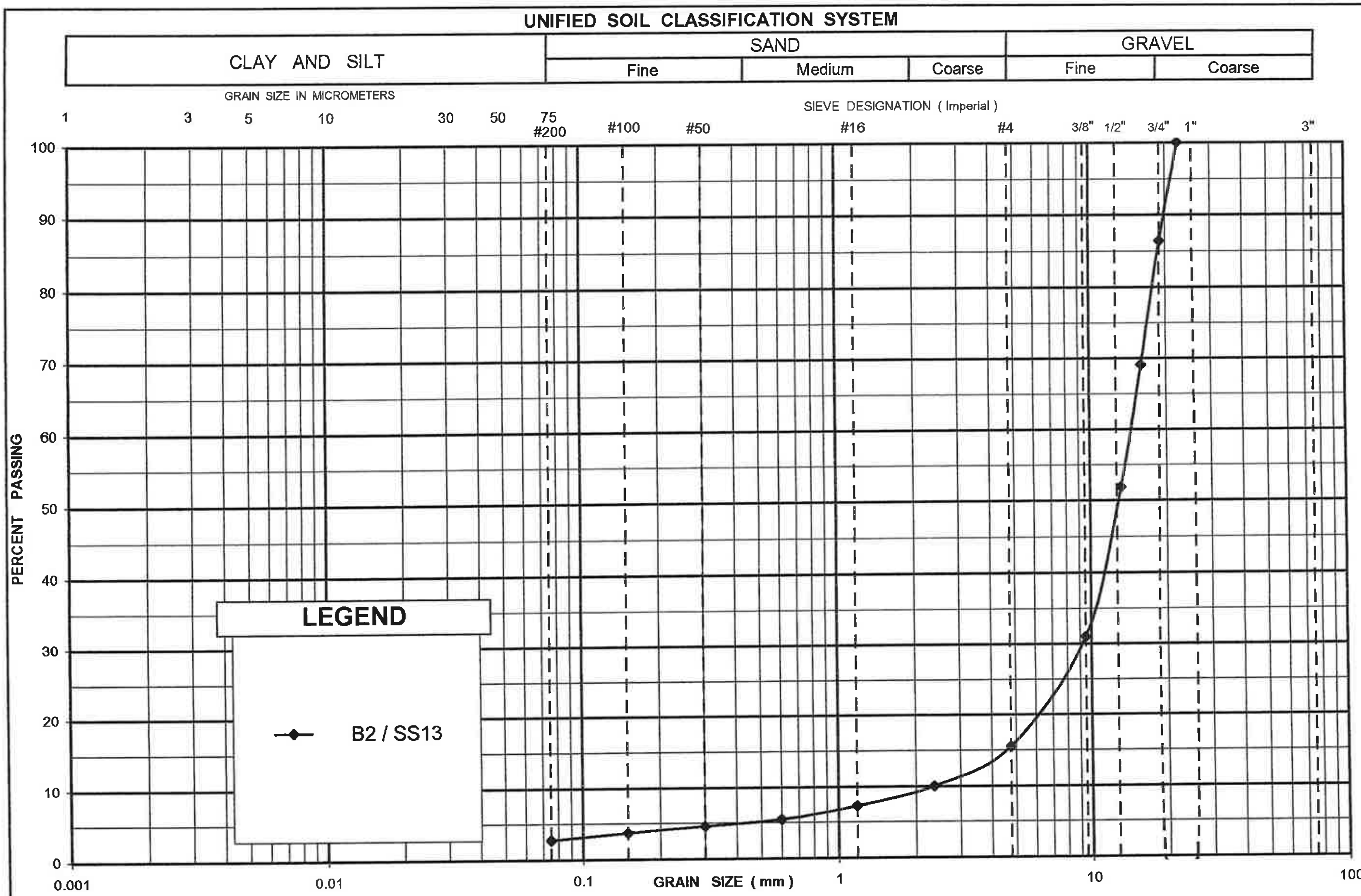
DATE: October 09, 2009



coffey geotechnics
SPECIALISTS MANAGING THE EARTH

GRAIN SIZE DISTRIBUTION
BASAL GRANULAR SILTY AND GRAVELLY SAND

Figure No.	B-11
PROJECT # :	TRANETOB01240AA
DATE:	October 09, 2009



coffey geotechnics
SPECIALISTS MANAGING THE EARTH

GRAIN SIZE DISTRIBUTION
BASAL GRANULAR SOIL: Gravelly Sand

Figure No. B-12	
PROJECT # :	TRANETOB01240AA
DATE:	October 09, 2009

Appendix C

Undrained Shear Strength Plots

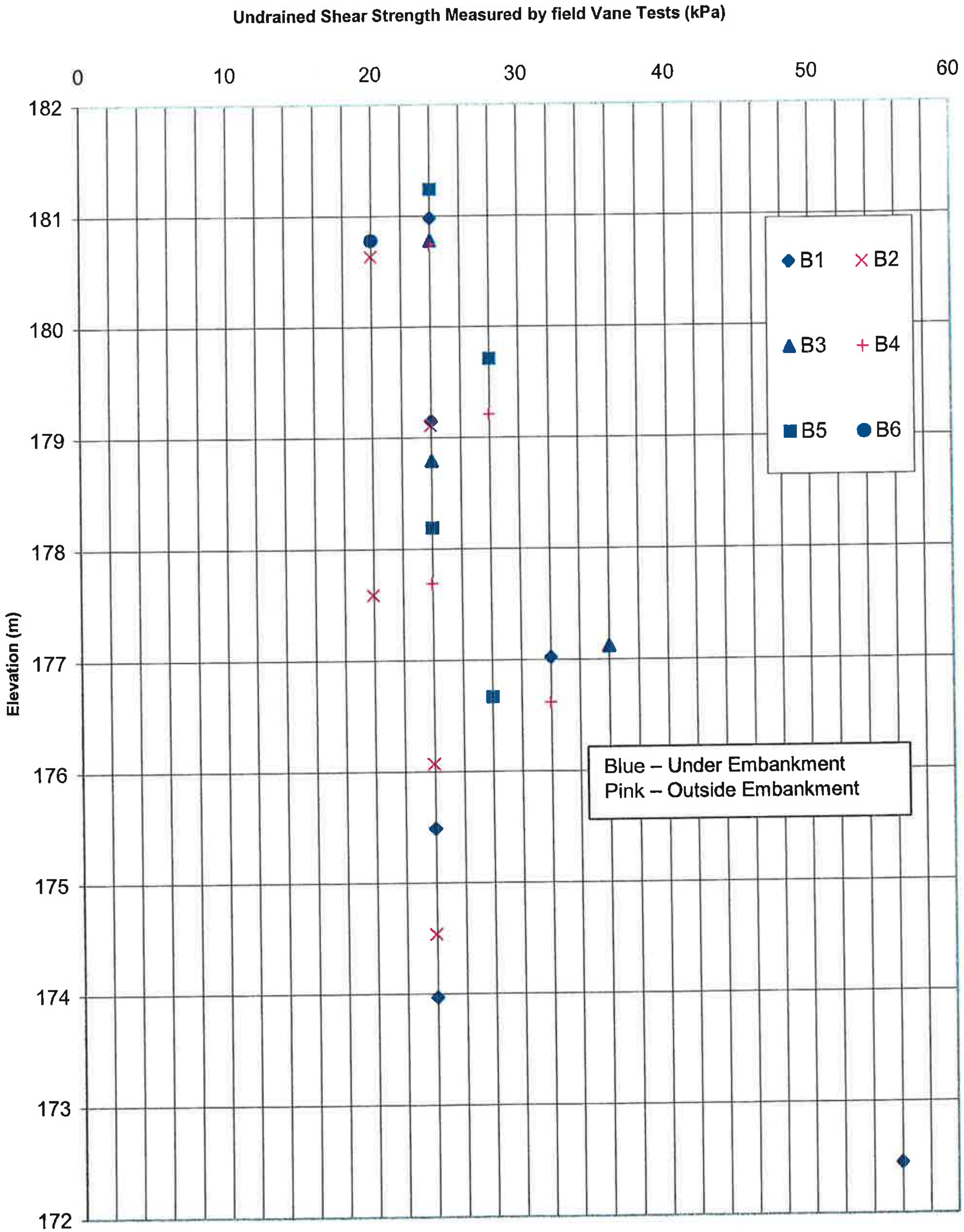


Figure C1. In-situ undrained Shear Strength versus Elevation

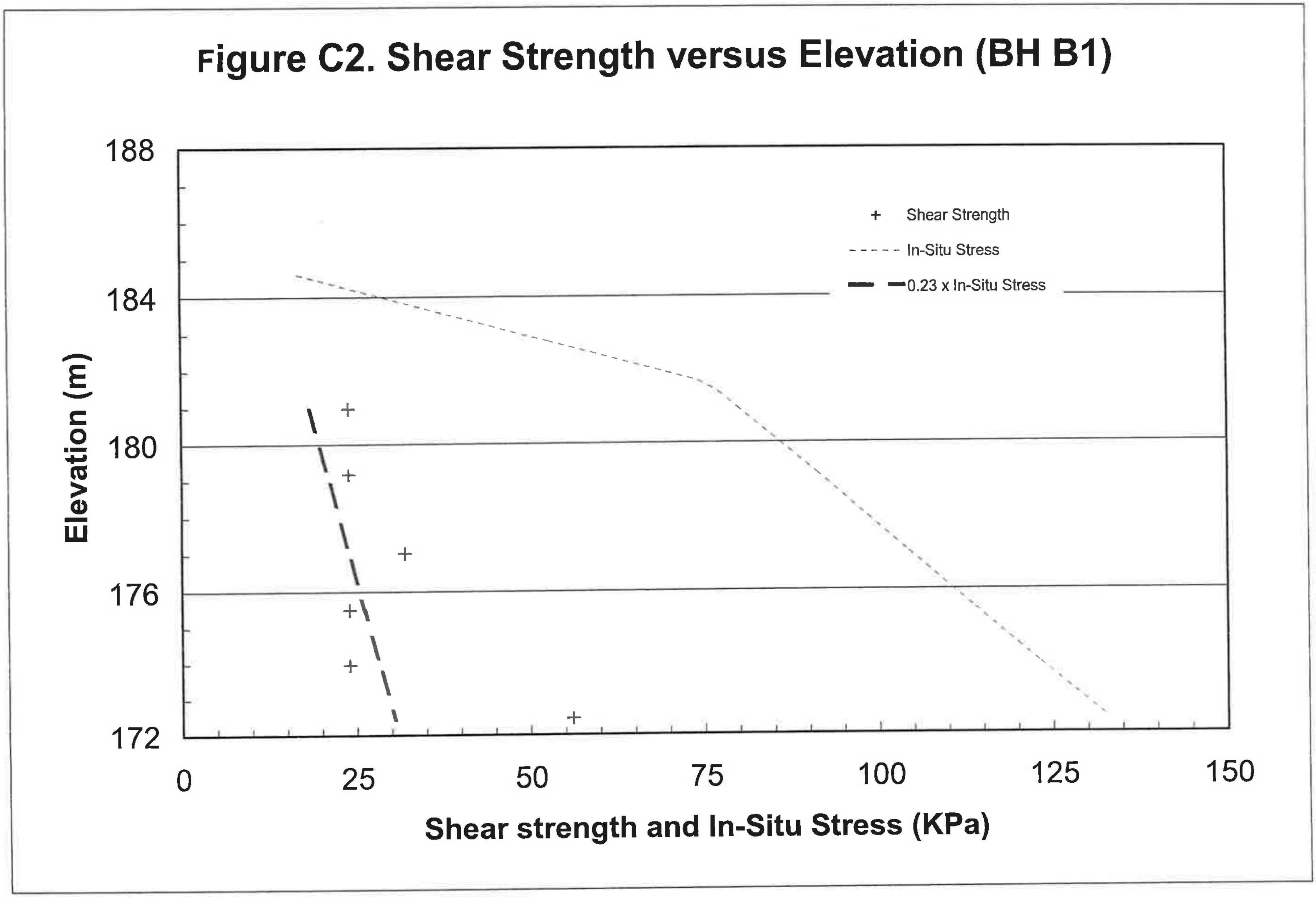


Figure C2. Shear Strength versus Elevation (BH B1)
188
184
180
176
172
0
25
50
75
100
125
150
Elevation (m)
Shear strength and In-Situ Stress (KPa)
Shear Strength
In-Situ Stress
0.23 x In-Situ Stress

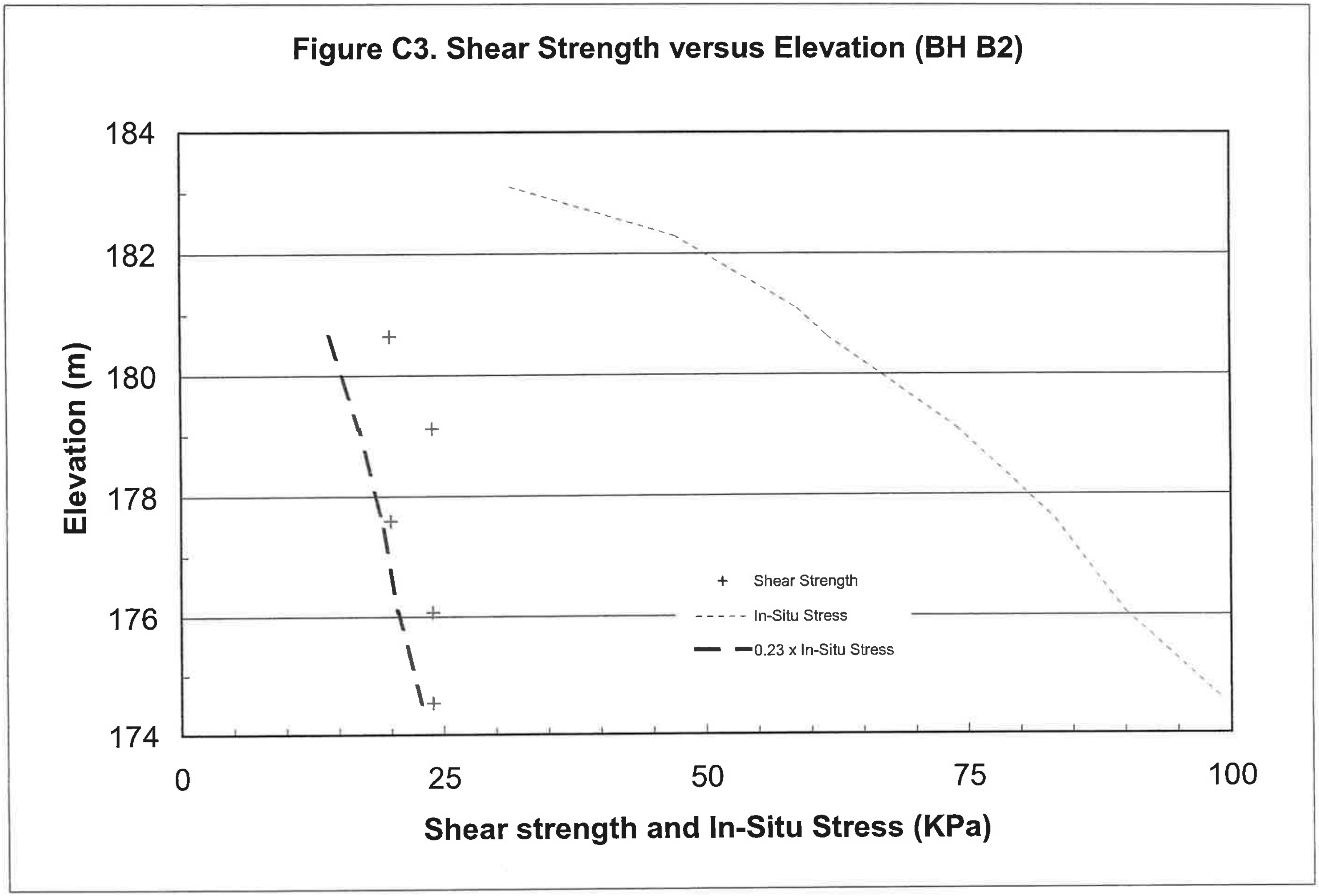


Figure C3. Shear Strength versus Elevation (BH B2)
184
182
180
178
176
174
Elevation (m)
0
25
50
75
100
Shear strength and In-Situ Stress (KPa)
Shear Strength
In-Situ Stress
0.23 x In-Situ Stress

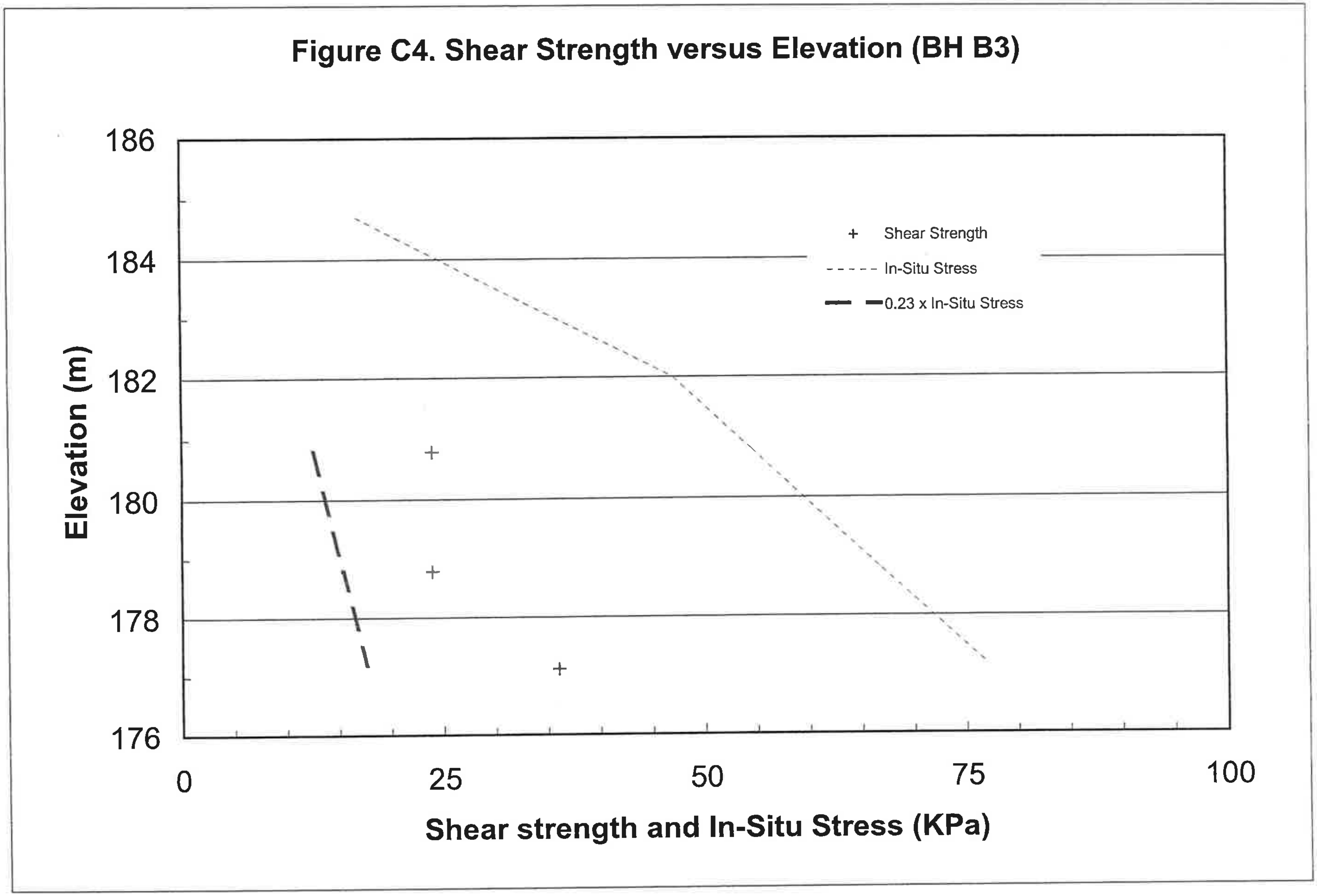
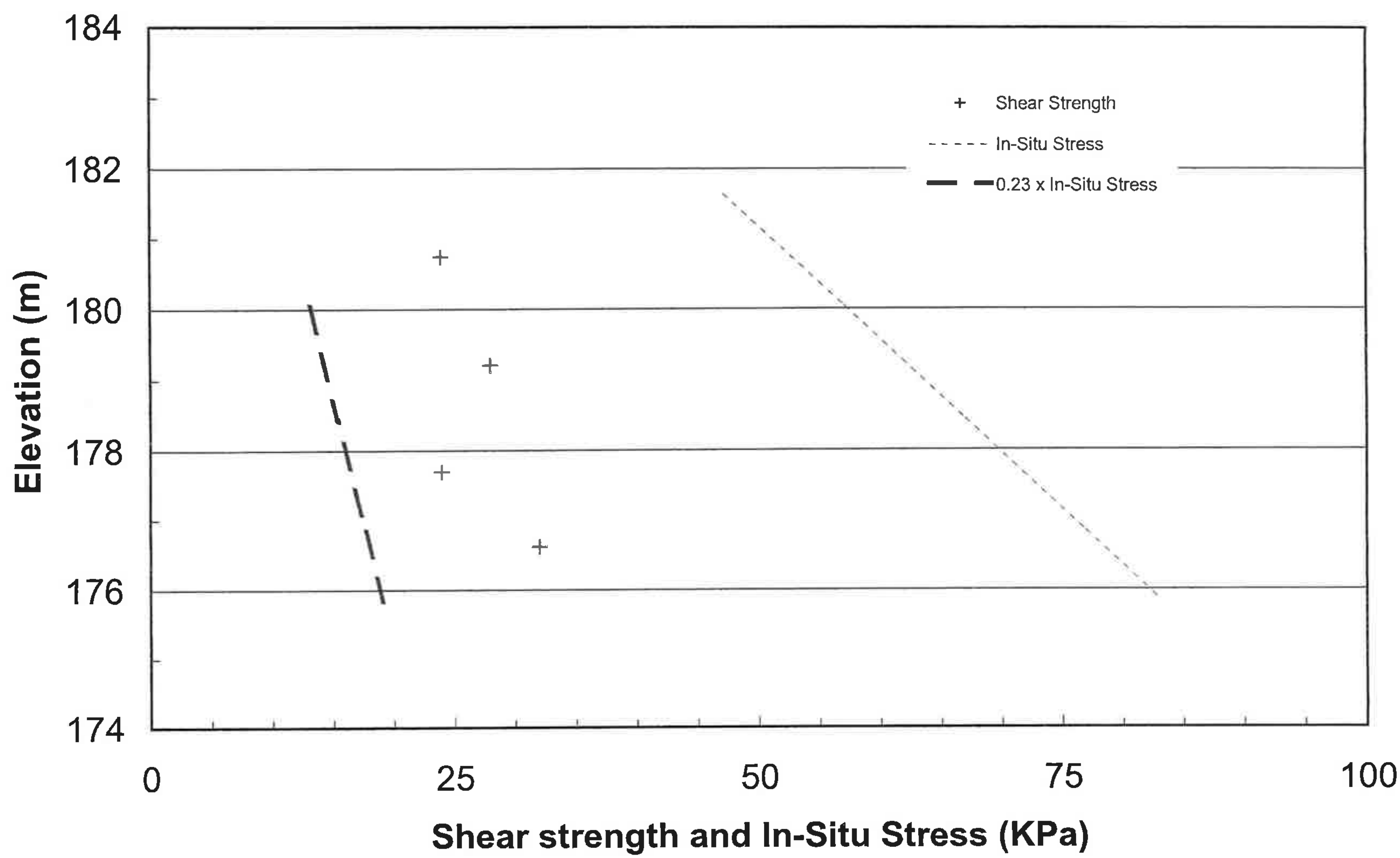


Figure C4. Shear Strength versus Elevation (BH B3)
Elevation (m)
186
184
182
180
178
176
0
25
50
75
100
Shear strength and In-Situ Stress (KPa)
Shear Strength
In-Situ Stress
0.23 x In-Situ Stress

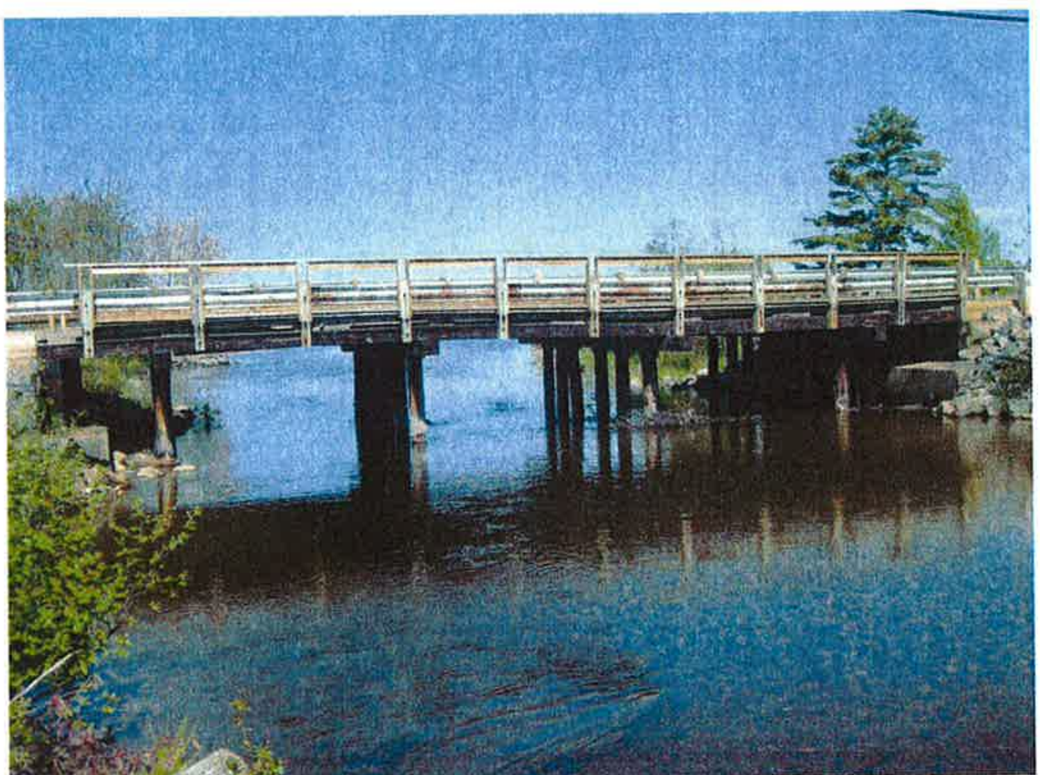
Figure C5. Shear Strength versus Elevation (BH B4)



Appendix D

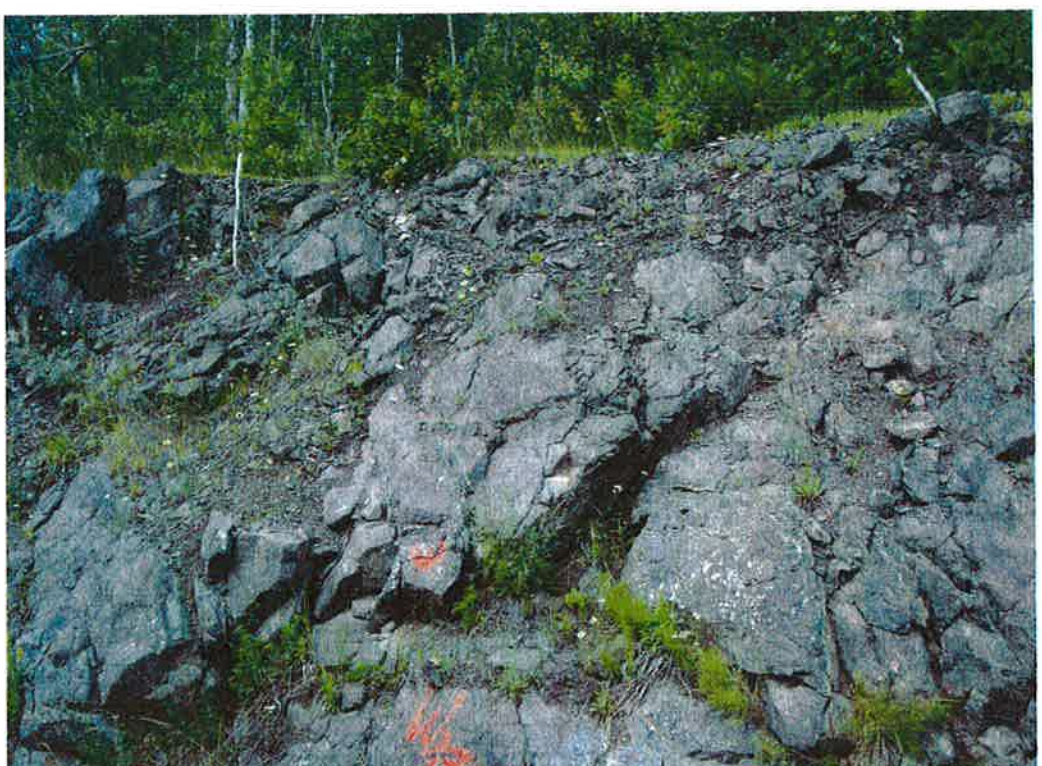
Site Photographs

Photograph D1. Harmony Beach Road Bridge (looking south)



Photograph D2. Harmony Beach Road Bridge (looking west)


Photograph D3. Existing Harmony Beach Road Bridge Foundations


Photograph D4. Exposed bedrock near the junction of Harmony Beach Road and Highway 17

Appendix E

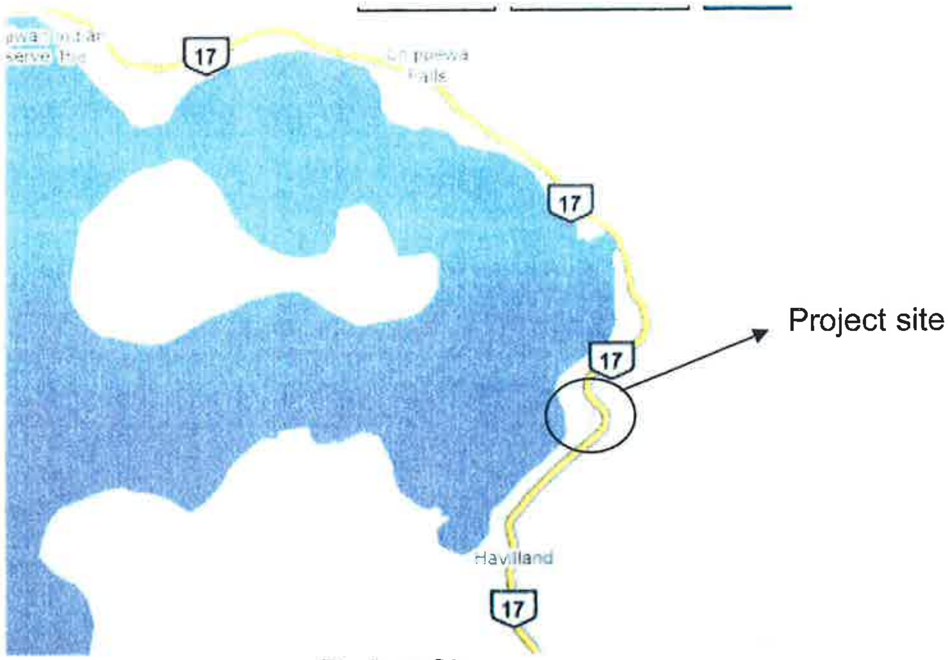
Rock Core Photographs and Geological Map

Photograph E1. Rock cores (RC11, BH B4)

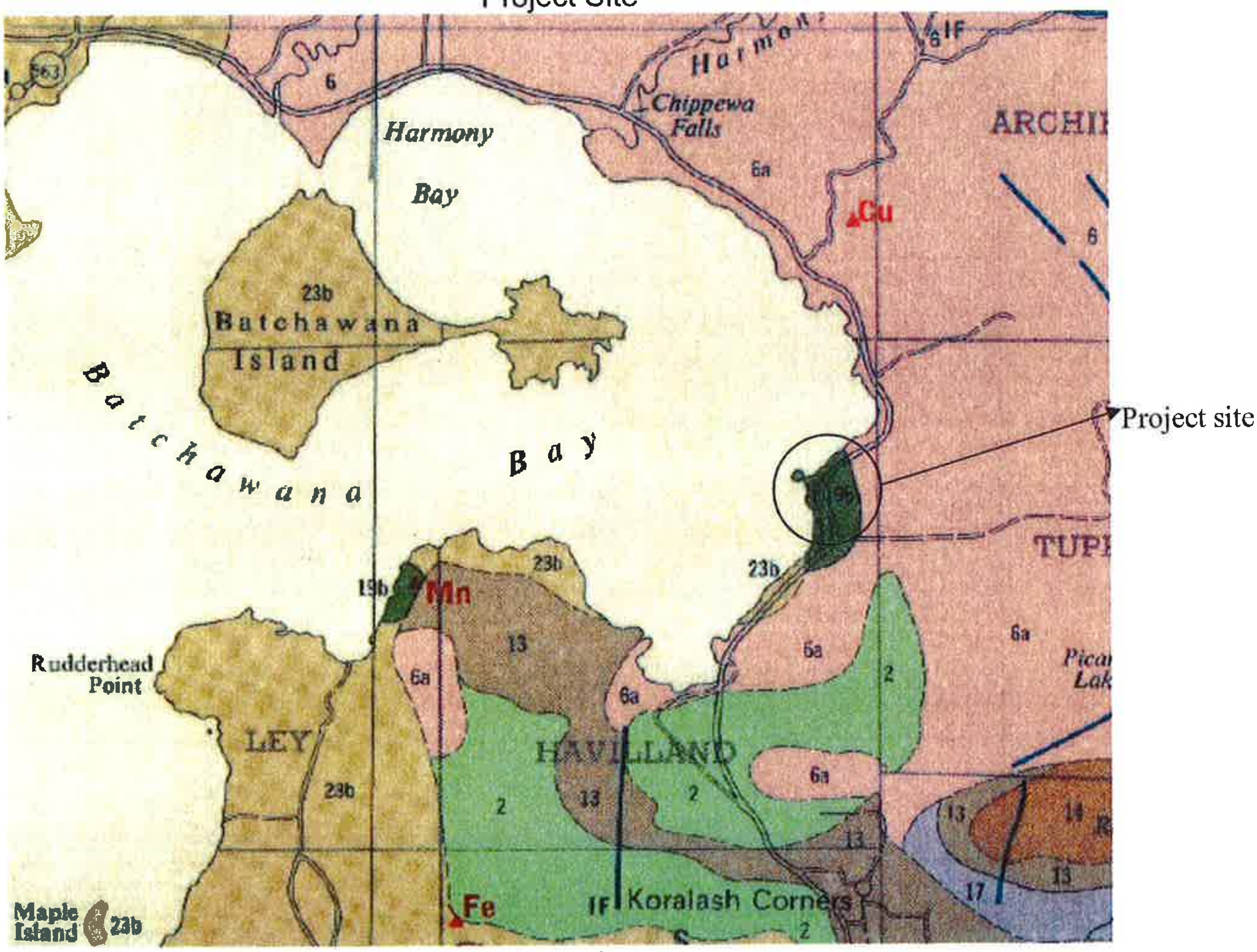
Photograph E2. Rock cores (RC12, BH B4)

Photograph E3. Rock cores (RC15 and 16, BH B3)

Photograph E4. Rock cores (RC17, BH B3)

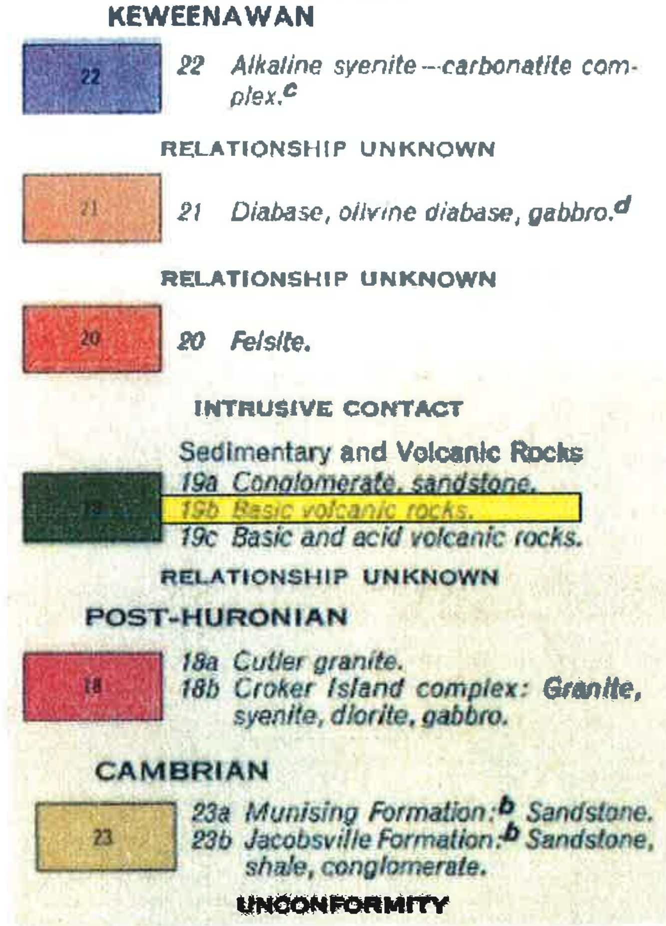


Project Site



Geological map

LEGEND



Basic volcanic rocks (low silicate) according to Ontario Geologic map m2108

Appendix F

Explanation of Terms Used in Report

EXPLANATION OF TERMS USED IN REPORT

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

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

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

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

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

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

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

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

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

JOINT AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_I, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ε	%	LINEAR STRAIN
$\varepsilon_1, \varepsilon_2, \varepsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICALL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
c_c	1	COMPRESSION INDEX
c_s	1	SWELLING INDEX
c_a	1	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = c_u / τ_r

PHYSICAL PROPERTIES OF SOIL

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