

**FOUNDATION INVESTIGATION AND  
DESIGN REPORTS  
CROOKED CREEK CULVERT AT  
HIGHWAY 66  
TOWNSHIP OF EBY, ONTARIO  
GWP 448-98-00**

**GEOCRES NO. 42A-71**

**Prepared For:**

**D.M. WILLS ASSOCIATES LIMITED**

**Prepared by:**

**SHAHEEN & PEAKER LIMITED**

**Project: SPT1201  
April 2, 2008**



**20 Meteor Drive  
Toronto, Ontario  
M9W 1A4  
Tel: (416) 213-1255  
Fax: (416) 213-1260  
EMAIL: [info@shaheenpeaker.ca](mailto:info@shaheenpeaker.ca)**

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### **DRAWINGS**

### **DRAWING NO.**

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**1,2 & 3**

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**FOUNDATION INVESTIGATION REPORT  
CROOKED CREEK CULVERT  
AT HIGHWAY 66  
TOWNSHIP OF EBY, ONTARIO  
G.W.P. 448-98-00**

**1. INTRODUCTION**

Shaheen & Peaker Limited (S&P) was retained by D.M. Wills Associates Limited (DMWA) to carry out a foundation investigation at the site of a proposed relining of the existing culvert under Highway 66 at Crooked Creek about 28 km south-west of Swastika in the Township of Eby.

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 PHYSIOGRAPHY**

The site is located approximately 7km south-west from the junction of Highway 66 with Highway 11 in the Township of Eby as shown in Drawing No. 1.

Surrounding area of Township of Eby (Kirkland Lake area) contains three major physiographic units: 1) Bedrock controlled landscape; 2) Sand plain; and 3) Clay plain. Project site is located in the physiographic region of clay plain which is topographically flat lying except where the clay thins against or is draped over bedrock. Additional relief exists where rivers have cut down into the sediments.

The continental drainage divide transects the area from east to west. Within this area rock knobs and ridges regularly protrude through the clay, illustrating the rugged nature of the bedrock topography.

Large tracts of the clay belt have a thin covering of organic material, evidence of the poor drainage network developed on the plains. In several instances, the poor drainage is due to rock sills which effectively act as dams. These sills prevent a significant amount of river incision and drainage development further upstream.

Drainage of this area is accomplished by: 1) the Englehart River; 2) the Blanche River network in addition to Crooked and Boston Creek; and 3) the Misena River. Creeks and rivers often make sharp bends to follow the trend of both regional and local bedrock faults.

According to the Quaternary Geology of Kirkland Lake Area (Ontario Geologic Survey Map 2649), this site is underlain by glaciolacustrine fine grained deposits which mainly consist of clay, varved clay and silt.

Bedrock in this area consists of early Precambrian (Archean) metavolcanic, metasedimentary and plutonic rocks.

### **3. PROCEDURES**

The fieldwork for this project was performed from Oct. 3 to Oct. 29, 2007 and consisted of drilling and sampling ten boreholes which were divided into three groups (i.e. C-series for culvert boreholes, S-series for possible temporary roadway protection (shoring) system boreholes and D-series for possible detour boreholes) to a depth of 6.6 m to 33.5 m below the ground surface. The locations of the boreholes at the site are given on the Borehole Location Plan Drawing No. 2.

The boreholes were advanced using a track-mounted drilling rig owned and operated by Landcore Drilling of Chelmsford, Ontario, under the full-time supervision of technical personnel from S&P. The boreholes were advanced using three different methods (i.e. continuous flight hollow-stem augers, wash boring drilling in the overburden and rock coring) depending the ground condition.

Samples in the boreholes were taken at frequent intervals of depth by the Standard Penetration Test method (SPT), in general accordance with ASTM D1586. The 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 granular (or cohesionless) soils (gravels, sands and silts) or the consistency of cohesive soils (clays and clayey soils).

In addition to SPT, where the consistency permitted, MTO field vane tests were performed to measure the undrained shear strength of the soil in situ. Relatively undisturbed samples of the cohesive soils were also taken by means of thin-walled (TW) samplers.

In some cases, the soil back-up in the boreholes was encountered with increasing depth of overburden in the boreholes. This necessitated wash boring with N-type casing. In C-series boreholes, rock cores were obtained by NQ rock coring method. Rock coring was also used in Borehole S1 to advance through rock fill between 3.1 and 4.3 m below the ground surface.

Dynamic Cone Penetration Tests (DCPT) were performed from the ground surface at Boreholes C1, C2, and C3, as well as from the bottom of the rest boreholes (i.e. Boreholes

S1, S2, D1, D2, D3, D4 and D5). In this test, a 51 mm diameter, 60-degree apex cone, screw attached to the tip of an A-size rod, is driven into the ground, using the same driving energy as the SPT method. By recording the number of blows of the hammer to drive the cone/rod assembly, into the soil every 0.3 m, a qualitative record of soil compactness condition is obtained. Although the interpretation of the test results is difficult because no samples are obtained by the DCPT 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 force effects which in some cases affect the SPT results.

The borehole locations were established in the field by S&P 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.

Groundwater conditions in the boreholes were observed during and on completion of drilling in the open boreholes. Upon their completion, Boreholes were grouted using a cement/bentonite mixture as per MTO procedures.

A laboratory testing programme, consisting of natural moisture content determinations, grain size analyses, Atterberg Limits tests, bulk unit weight and one-dimensional consolidation (oedometer) tests, was performed on selected samples. The results of the laboratory tests are presented on the appropriate Record of Borehole Sheets (Appendix A) and also in Appendix B.

#### **4. SUMMARIZED SUBSURFACE CONDITIONS**

The ground surface elevations range from 298.9 to 301.5 m for all the boreholes. The higher elevations (i.e. El. 301±) are for boreholes drilled from the top of the highway embankment, while the ground elevations of boreholes drilled from the bottom of the embankment (i.e. o.g. level) are typically 299 to 300 m.

Culvert boreholes (C-series boreholes) were drilled from 15.0 m south (Borehole C2) and 14.5 m north (Borehole C1) of the existing road centerline of Highway 66. Borehole C3 was drilled from existing Highway 66 road pavement. Boreholes C1 and C2 show, below a 0.15 m thick of topsoil, the presence of sand fill to depths/elevations of 1.8 m/297.6 m and 1.6 m/ 298.4 m, respectively, while in Borehole C3, a granular embankment fill was contacted to 4.3 m or to El. 297.0 m. Below these elevations, the boreholes contacted a silt deposit which attains a clayey silt nature with increasing depth and is further underlain by granitic bedrock at depths /elevations ranging from 23.7 m /El. 275.7 m to 31.7 m /El. 269.6 m.

Detour boreholes (D-series boreholes) were drilled along the north ditch of Highway 66 (11 m to 13 m north from the road centerline) and contacted 0.15 m to 0.2 m thick of topsoil layer, which is underlain by the major silt deposit. All the detour boreholes were terminated in the silt deposit at depths ranging from 6.6 m to 15.7 m below the ground surface.

Shoring (roadway protection-series) boreholes (Boreholes S1 and S2) were advanced from the existing road pavement of Highway 66 and encountered pavement and granular embankment fill to depths of 1.2 m (El. 300.0 m) to 3.1 m (El. 298.4 m). Borehole S1 contacted embankment rock fill below the pavement fill to a depth of 4.3 m (El. 297.2 m). Below these pavement and rock fills, Boreholes S1 and S2 encountered a 0.7 m to 1.0 m thick clayey silt layer which is further underlain by the major silt deposit. Borehole S2 was terminated in this silt deposit at a depth of 15.7 m (El. 285.5 m) while in Borehole S1, the silt deposit changes to clayey silt and the borehole was terminated in the clayey silt deposit.

Details of the subsurface conditions encountered in the boreholes are presented on the Record of Borehole Sheets in Appendix A. Inferred stratigraphic sections are shown in Drawings No. 2 and 3. The following description of the individual soil strata is to assist the designers of the project with an understanding of the anticipated subsurface conditions underlying the site. It should be noted that the soil and groundwater conditions may vary in between and beyond borehole locations.

#### 4.1 TOPSOIL

A 0.15 to 0.2 m thick topsoil layer was encountered in Boreholes C1, C2 and all detour boreholes.

#### 4.2 FILL

##### 4.2.1. ASPHALT AND GRANULAR PAVEMENT FILL

Boreholes S1, S2 and C3, which were drilled from the existing road pavement, contacted a 40 to 80 mm thick asphalt layer.

Underlying the asphalt, a granular pavement fill was encountered, which extended to 0.8 to 1.2 m below the road surface.

In Borehole S2, the recorded N-value in this granular fill is 61 blows/0.3 m which indicates a very dense condition and from this it appears that the pavement fill at this borehole location received systematic compaction when it was first placed.

##### 4.2.2. EMBANKMENT FILL

Underlying the pavement fill in Borehole C3, a 3.5 m thick sand fill layer (i.e. embankment fill) was contacted. This is a granular material and based on recorded N-values, which

range from 7 to 26 blows/0.3 m, the relative density of the fill is described as loose to compact. The higher N values of 21 to 26 were recorded at the top 2.0 m and this top portion appears to have received a systematic compaction, when the fill was first placed, while the lower portions of the fill appear to be uncompacted.

In Borehole S1, the pavement fill which extends to 0.8 m, is underlain by a granular embankment fill (i.e. sand and sandy gravel) to a depth of 3.1 m or El. 298.4 m. Based on N-values, which range from 46 to in excess of 50 blows/0.3 m, the relative density of this fill is described as dense to very dense and the fill appears to be well compacted. The granular pavement fill in this borehole is underlain by 1.2m thick rock fill to 4.3 m below the ground surface or to El. 297.2 m

#### 4.2.3. GRANULAR FILL

Boreholes C1 and C2, which were drilled beyond the toe of the existing road near the existing culvert, contacted an approximately 1.4 m to 1.6 m thick sand fill. The fill extends to El. 297.6 to 298.4m and is probably related the construction of the existing culvert. Standard Penetration tests performed in this granular deposit yielded N-values from 4 to 10 blows/0.3 m, which indicates a very loose to typically loose condition. This indicates that the fill was not properly compacted when it was first placed.

#### 4.3 UPPER CLAYEY SILT TO SILTY CLAY

At Boreholes S1 and S2 (i.e. shoring boreholes), 0.7 m to 1.0 m thick clayey silt was encountered below the pavement and rock fill. This clayey silt contains traces of organics. Standard Penetration tests performed in the basically cohesive deposit yielded N-values which ranged from 9 to 19 blows/0.3 m. These test results indicate a stiff to very stiff condition.

Below the topsoil in Borehole D5, a 1.0 m thick silty clay layer was contacted. From the recorded N-values which range from 3 to 6 blows/0.3 m, this cohesive deposit is considered to be soft to firm.

#### 4.4 SILT

Underlying the fill, the culvert boreholes (i.e. C1, C2 and C3) contacted a major silt deposit at depths from 1.6 to 4.3 m, corresponding to Elevations of 298.4 m and 297.0 m.

Underlying, the surficial clayey silt deposit, the shoring boreholes (S1 and S2) encountered the (same) silt deposit at depths from 2.2 to 5.0 m, corresponding to Elevations of 299.0 m and 296.5 m.

All the detour boreholes (D1 through D5) contacted the silt deposit below the topsoil and the surficial silty clay (Borehole D5 only) at depths of 0.15 to 1.2 m below the ground surface.



Many of the boreholes were terminated in this deposit except for the deep boreholes, as follows:

Borehole No.	Depth and bottom elevation of the silt deposit (m)
C1	16.6 / 282.8
C2	14.2 / 285.8
C3	18.3 / 283.0
S1	16.8 / 284.7

This silt deposit consists of a basically non-cohesive material but it contains occasional clay seams and zones in which the material attains a somewhat cohesive character. The silt was wet and dilatant.

The grain-size distribution of thirteen samples from the deposit is given in Figure B-1 (Appendix B).

The following grain-size distribution is indicated.

Gravel:	0%
Sand:	0-3%
Silt:	90-95%
Clay:	3-8%

Laboratory tests performed on three samples yielded the following index values (see Figure B-2 in Appendix B).

Liquid Limit:	18-20%
Plastic Limit:	Non-plastic
Plasticity Index:	Non-plastic

These results are characteristic of generally non-plastic (i.e. non-cohesive) silt. In addition to visual and tactile examination of the soil samples, from the fact that the measured natural moisture contents at certain depths are relatively higher than typical natural moisture contents measured (i.e. typically about 20%) of this deposit, it can be surmised that increased clay contents occur in the silt deposit in some zones.

N-values recorded in this basically fine grained granular (i.e. non-cohesive) deposit range from 1 to 18 blows/0.3 m. These values indicate a very loose to compact consistency but typically loose with typical N-values of between 5 and 10 blows/0.3 m. From the fact that clayey seams and zones are occasionally exist in this deposit, this can be described as being generally loose with occasional firm to stiff zones.

Field vane tests were performed in this deposit but due to the non-cohesive nature of the soil, these results are considered to be at most locations unreliable.

#### 4.5 BASAL CLAYEY SILT

At the culvert boreholes and Borehole S1 (which were drilled deeper), the silt layer is underlain by clayey silt, at depths of 14.2 m to 18.3 m below the ground surface (or below El. 285.8 m and 282.8 m). Borehole S1 was terminated in this layer. This clayey silt layer in culvert boreholes is 6.4 m to 12.2 m thick and extends to depths of 23.0 m to 30.5 m (or El. 276.4 m and 270.8 m)

This deposit is similar to (i.e. a continuation of) the overlying silt deposit except that it is finer and basically cohesive deposit and contains very soft to soft thin clay seams.

Atterberg Limits tests were performed on three samples from the deposit and these indicate the following index values (also see Figures B-5 in Appendix B):

Liquid Limit:	22 - 30%
Plastic Limit:	18 - 22%
Plasticity Index:	4 - 9
Natural moisture content:	32-39%

These results are characteristic of clayey soils of low plasticity. When analyzing these results, it should, however, be remembered that the soil tested is a mixture of several thin seams as the soil at many locations is thinly bedded. In fact, the sample from Borehole C2 shows a plasticity index of 4 and this indicates a low plasticity because the sample contained mostly silt seams.

The recorded N-values range from 0 to 4 blows/0.3 m, Field vane test results, gave undrained in-situ shear strengths of 36 to 68 kPa. Based on these results the consistency of this deposit is considered to be soft to stiff. In Borehole C3 an N-value of 13 blows/0.3 m was recorded below El. 274 m based on this and the dynamic cone penetration test results, the consistency of the soil in this borehole below El 274m is described as stiff to very stiff

Two consolidation tests were performed on selected Shelby tube samples from this deposit. The results are given in Figures B-3 and B-4 in Appendix B. The results indicate a small amount of preconsolidation (i.e.  $p_c - p_0$ ) of about 20 to 40 kPa.

#### 4.6 BEDROCK

Bedrock was encountered and cored in culvert boreholes (i.e.C1, C2 and C3), as follows:

Borehole No.	Ground Elevation (m)	Overburden Depth to the Surface of Bedrock (m)	Elevation of the Surface of Bedrock (m)
C1	299.4	23.7	275.7
C2	300.0	26.7	273.3
C3	301.3	31.7	269.6

The presence of a zone with rock fragments and boulders in a clayey silt matrix was inferred immediately overlying the surface of the bedrock. In Boreholes C1 and C2, this zone (layer) was found to be about 0.4 to 0.7 m thick, which in Borehole C3 was found to be thicker (i.e. 1.2 m thick).

The bedrock was identified as a granitic rock which may have been metamorphosed. Its colour is generally pink. The formation belongs to the Pre-Cambrian Era.

The rock core recovery (TCR) in the bedrock generally ranged from 72 to 100%, with Rock Quality Designation (R.Q.D.) values generally between 69 and 100% except for the upper 1 m of the rock cores obtained from Borehole C3. These results indicate a relatively sound rock with a fair to excellent rock quality except for the upper 1 m of the bedrock in Borehole C3 where poor to very poor rock quality is inferred. Photographs of rock cores from the bedrock are given in Appendix D.

From the table presented above the surface of the bedrock show significant variations (i.e. about 3.7 m within a borehole distance of about 17 m between Boreholes C2 and C3) and it seems to be dipping from Borehole C1 and C2 locations towards Borehole C3.

#### 4.7 GROUNDWATER CONDITIONS

Groundwater conditions in the open boreholes were observed during the drilling and at the completion of each borehole. The observations are shown on the individual Record of Borehole sheets.

However, due to relatively impervious nature of the soil and as well in culvert boreholes and Borehole S1 due to the fact that wash boring and coring was used owing to borehole back-up and rock coring, these observations may not represent stabilized conditions.

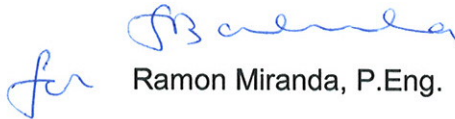
Based on the moisture contents of the soil samples, it is our opinion that the groundwater level at the site was generally about El. 296-298 m.

It should, however, be pointed out that the groundwater at the site would be subject to seasonal fluctuations as well as fluctuations due to weather events and the water level in the water course.

**SHAHEEN & PEAKER LIMITED**



Gwangha Roh, Ph.D., EIT

  
for

Ramon Miranda, P.Eng.



Z. S. Ozden, P.Eng.



ZO:tr/idrive

## Drawings





Drawing 1 – Site Plan



NOTES:  
FOR DETAILED SUBSURFACE CONDITIONS  
REFER TO RECORD OF BOREHOLE SHEETS.

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

CONT No.  
GWP: 448-98-00  
Hwy 66- Crooked Creek Culvert  
Town of Eby, ON  
BOREHOLE LOCATIONS



SHAHEEN & PEAKER LIMITED



KEY PLAN  
N.T.S

LEGEND

Borehole

No.	ELEV.	CO-ORDINATES	
		NORTH	EAST
C1	299.4	5322594.0	361406.8
C2	300.0	5322554.7	361411.1
C3	301.3	5322580.7	361412.3
D1	300.0	5322690.4	361499.9
D2	300.1	5322657.2	361469.5
D3	299.9	5322621.6	361434.2
D4	298.9	5322542.8	361362.0
D5	299.8	5322507.4	361329.5
S1	301.5	5322556.3	361390.2
S2	301.2	5322600.8	361434.9

NOTE

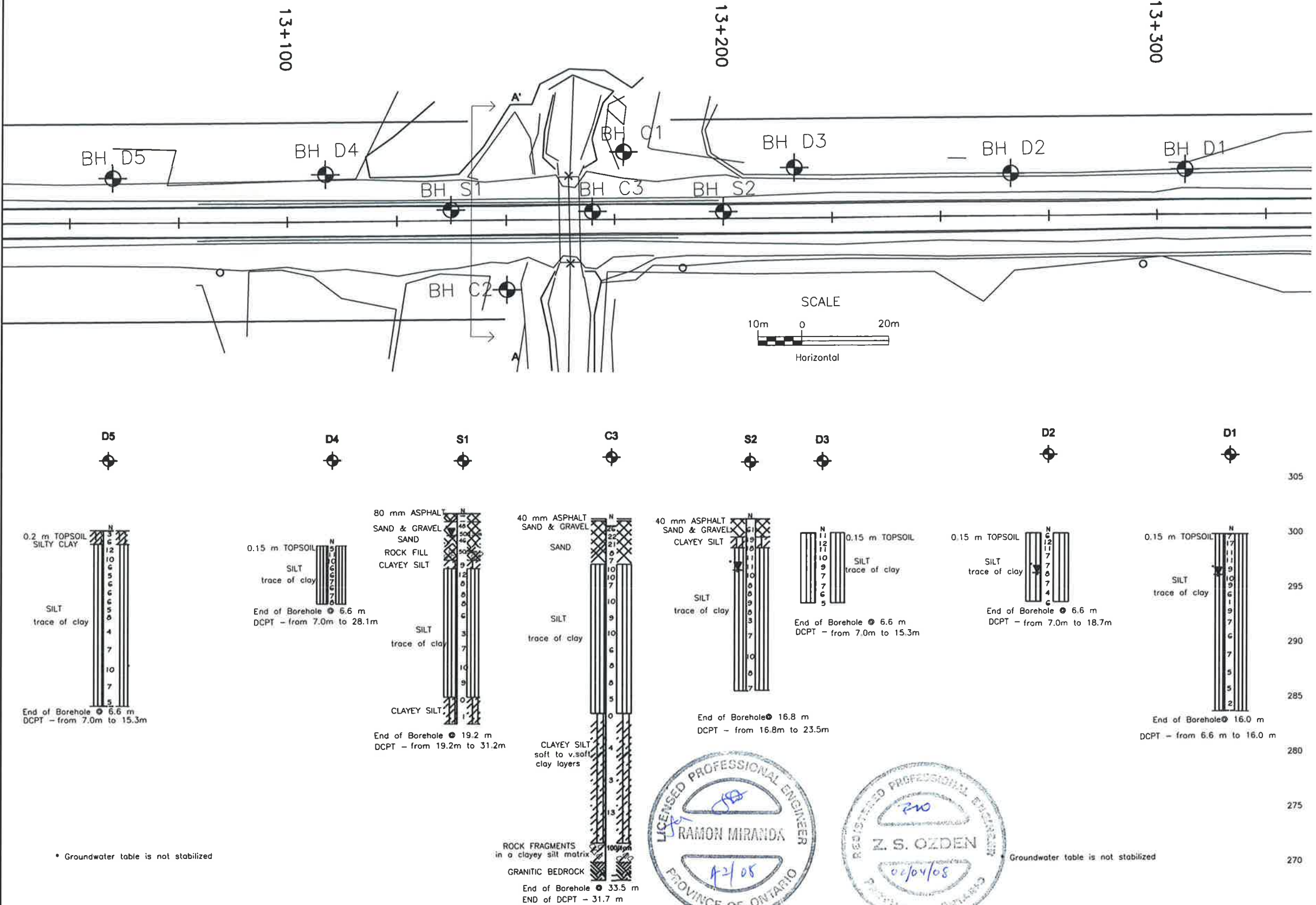
The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents are specifically excluded in accordance with the conditions of Section GC 2.01 of OPS Gen. Cond.

REV.	DATE	BY	DESCRIPTION
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Geocres No. 42A - 71

SPT 1201			DIST
SUBM'D	CHECKED	DATE Jan, 2008	SITE
DRAWN GR	CHECKED RM	APPROVED ZO	DWG 2



NOTES:  
FOR DETAILED SUBSURFACE CONDITIONS  
REFER TO RECORD OF BOREHOLE SHEETS.

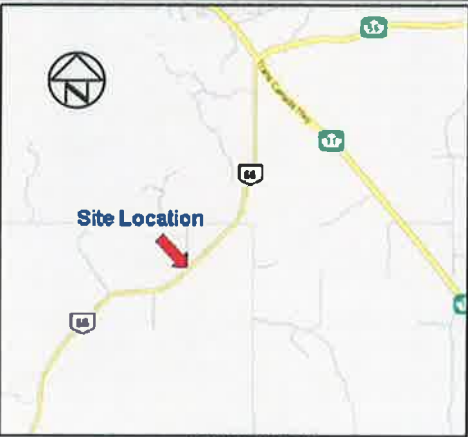
**METRIC**  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES UNLESS  
OTHERWISE SHOWN. STATIONS  
ARE IN KILOMETRES + METRES.

CONT No.  
GWP: 448-98-00

Hwy 66- Crooked Creek Culvert  
Township of Eby  
STRATIGRAPHIC SECTION

SHEET

SHAHEEN & PEAKER LIMITED



KEY PLAN  
N.T.S

LEGEND

- Borehole
- 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.	ELEV.	CO-ORDINATES	
		NORTH	EAST
C1	299.4	5322594.0	361406.8
C2	300.0	5322554.7	361411.1
C3	301.3	5322580.7	361412.3
D1	300.0	5322690.4	361499.9
D2	300.1	5322657.2	361489.5
D3	299.9	5322621.6	361434.3
D4	298.9	5322542.8	361362.0
D5	299.8	5322507.4	361329.5
S1	301.5	5322556.3	361390.2
S2	301.2	5322600.8	361434.9

NOTE

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

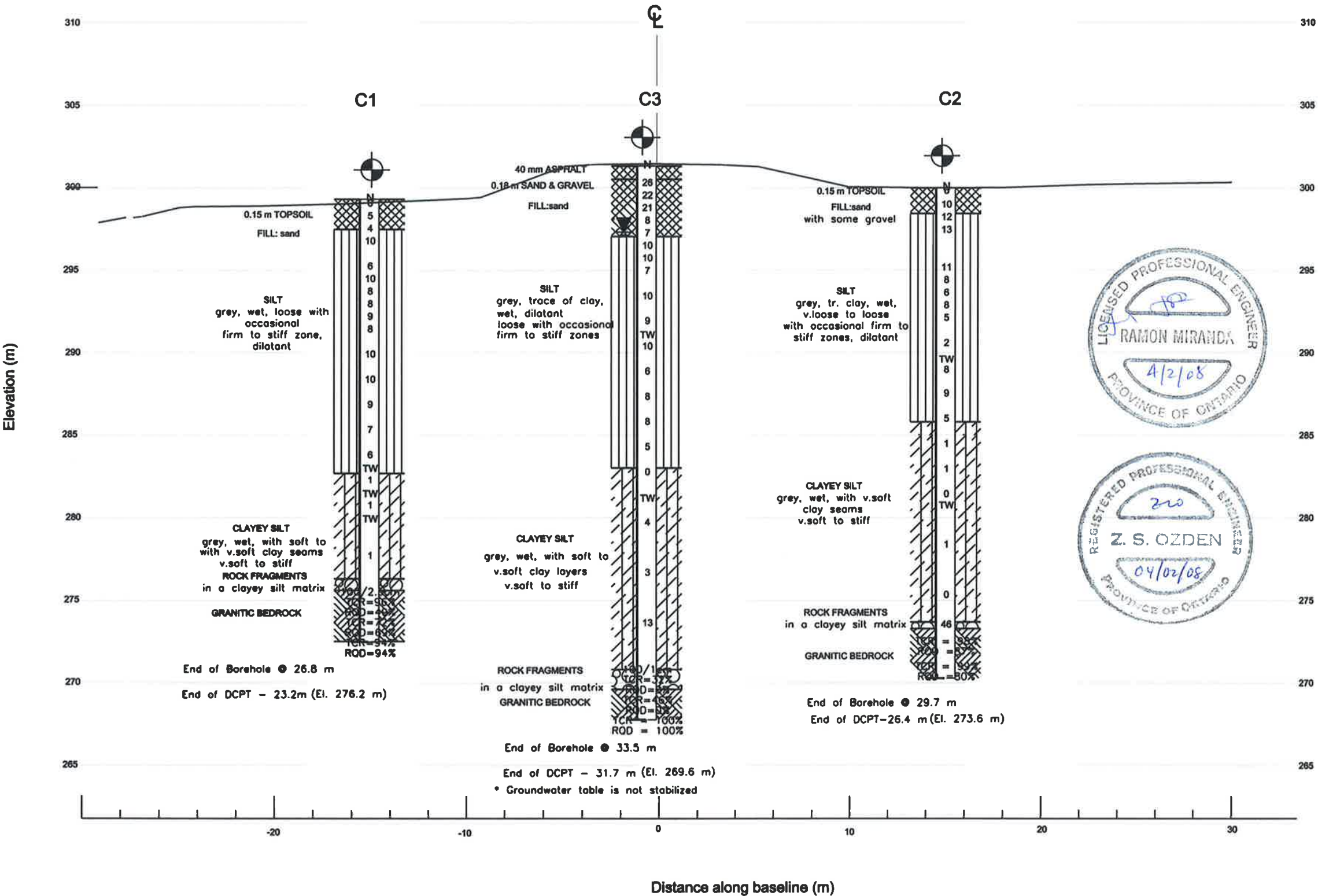
NOTE: This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents are specifically excluded in accordance with the conditions of Section GC 2.01 of OPS Gen. Cond.

REV.	DATE	BY	DESCRIPTION

Geocres No. 42A - 71

SPT 1201			DIST
SUBM'D	CHECKED	DATE Jan 2008	SITE
DRAWN GR	CHECKED RM	APPROVED ZO	DWG 3



STRATIGRAPHIC SECTION A -A'



# Appendix A

## Records of Borehole Sheets

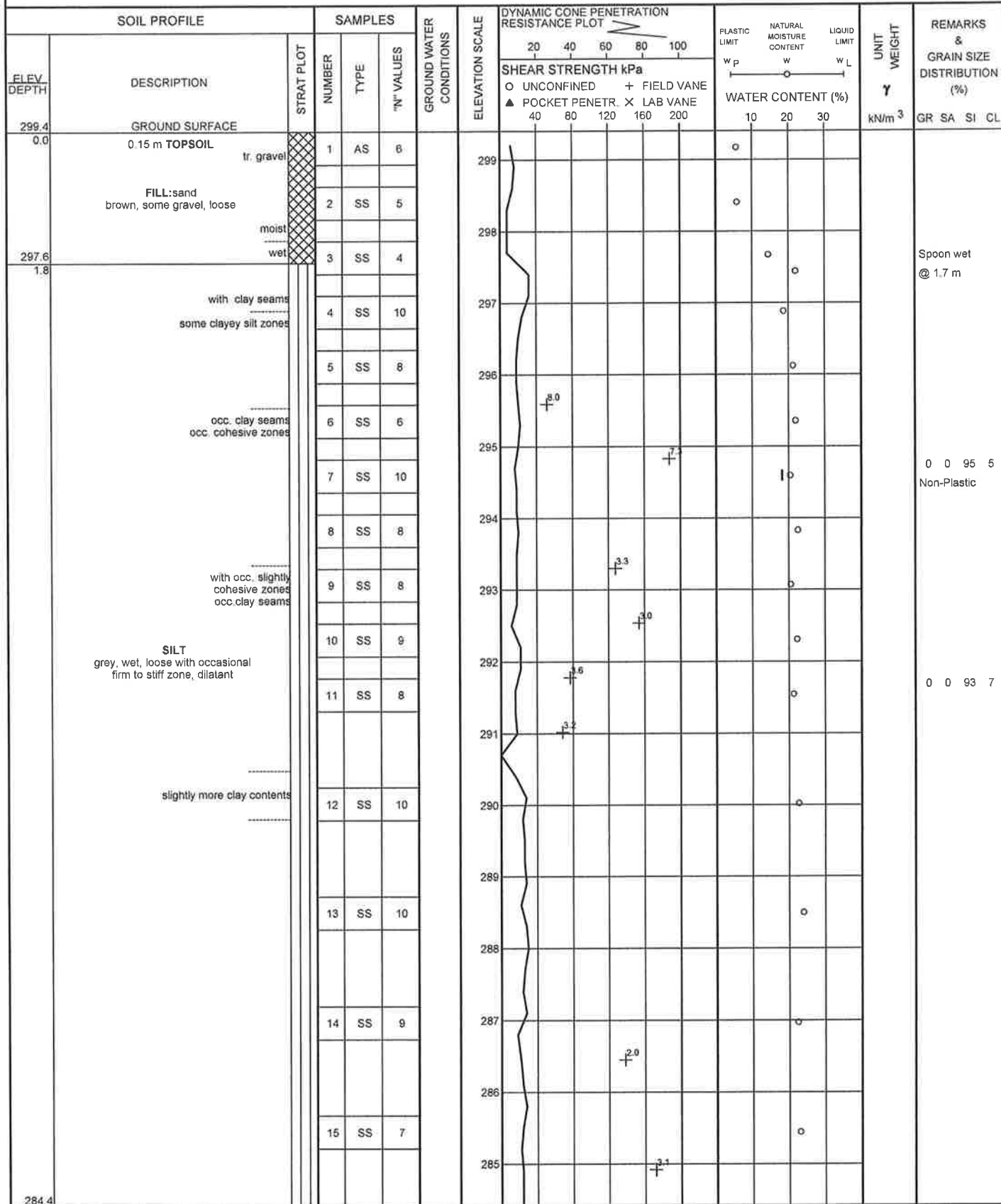
SPT 1201

# RECORD OF BOREHOLE No C1

1 OF 2

METRIC

GWP 448-98-00 LOCATION Crooked Creek Culvert - Sta. 13+176 14.5 m Lt C/L ORIGINATED BY ZI  
DIST HWY 66 BOREHOLE TYPE Hollow Stem Auger & N-type Wash Boring & NQ Coring COMPILED BY GR  
DATUM Geodetic DATE 10/3/2007 10/11/2007 CHECKED BY ZO



Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

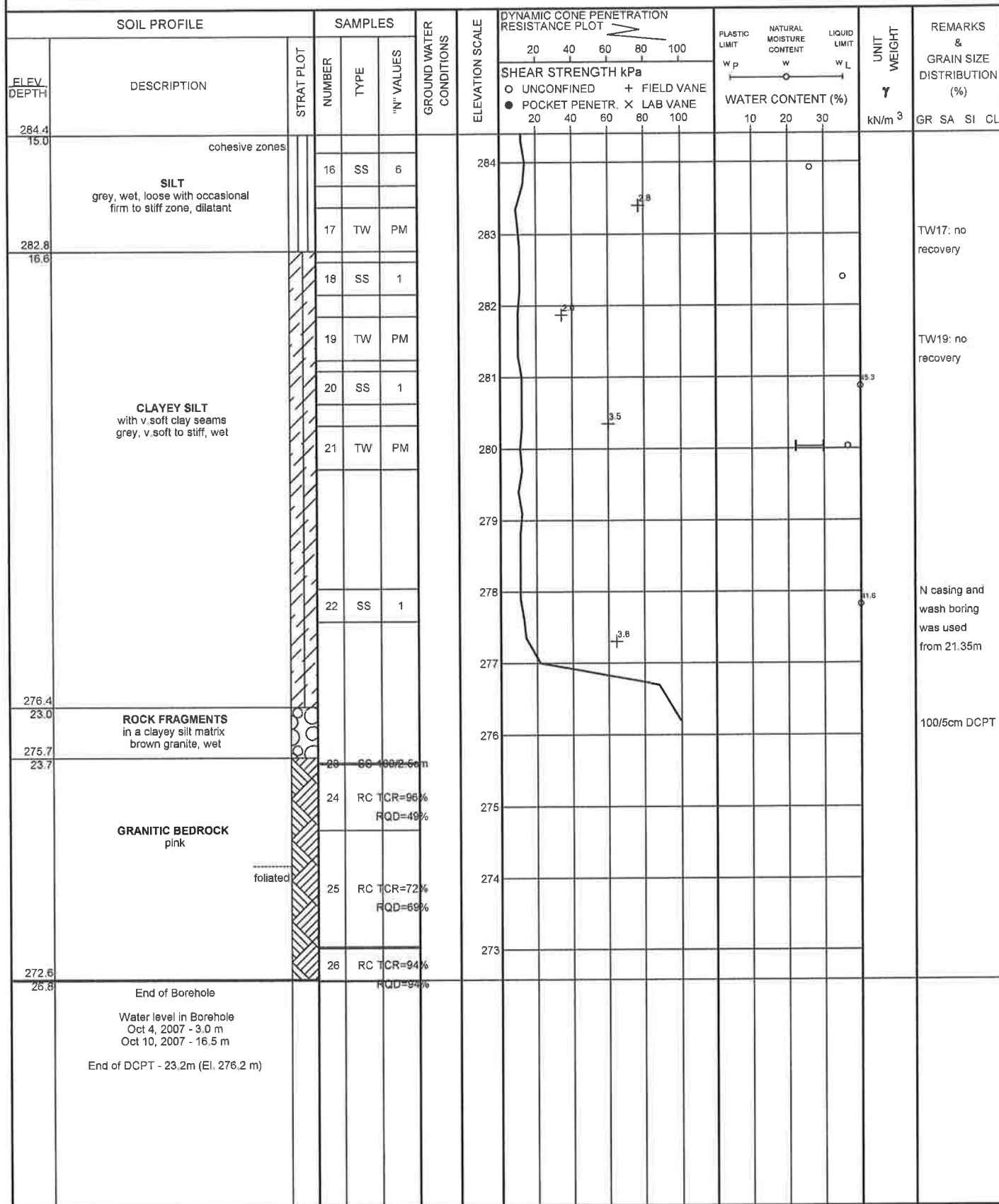
SPT 1201

# RECORD OF BOREHOLE No C1

2 OF 2

METRIC

GWP 448-98-00 LOCATION Crooked Creek Culvert - Sta. 13+176 14.5 m Lt C/L ORIGINATED BY ZI  
DIST HWY 66 BOREHOLE TYPE Hollow Stem Auger & N-type Wash Boring & NQ Coring COMPILED BY GR  
DATUM Geodetic DATE 10/3/2007 10/11/2007 CHECKED BY ZO



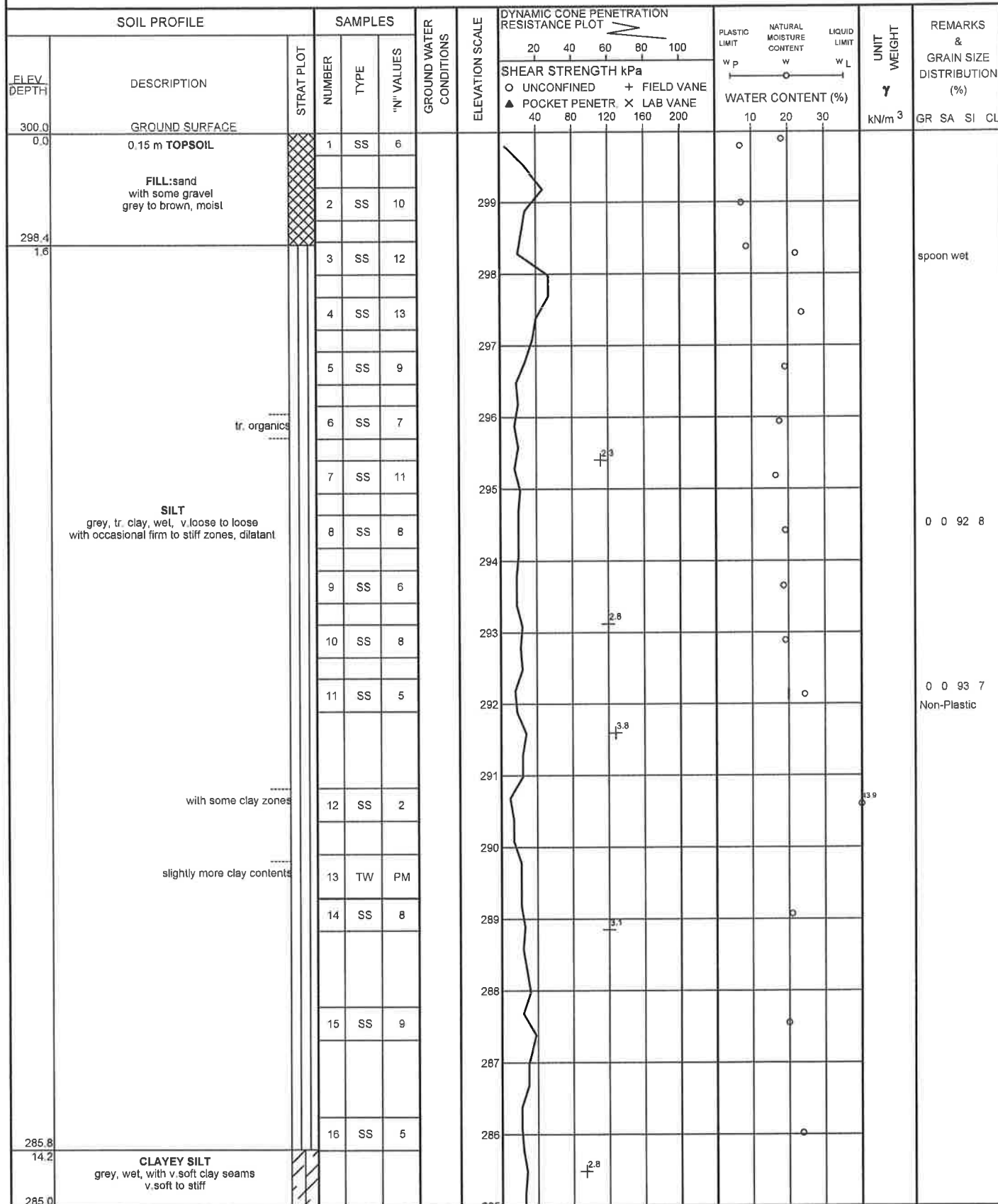
SPT 1201

# RECORD OF BOREHOLE No C2

1 OF 3

METRIC

GWP 448-98-00 LOCATION Crooked Creek Culvert - Sta. 13+150 15 m Rt C/L ORIGINATED BY ZI  
DIST HWY 66 BOREHOLE TYPE Hollow Stem Auger & N-type Wash Boring & NQ Coring COMPILED BY GR  
DATUM Geodetic DATE 10/25/2007 10/28/2007 CHECKED BY ZO



Continued Next Page

+ 3, X 3: Numbers refer to Sensitivity

20  
15 5  
10 (%) STRAIN AT FAILURE

SPT 1201

## 2 OF 3

METRIC

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

SPT 1201

## 3 OF 3

METRIC

GWP <u>448-98-00</u>		LOCATION <u>Crooked Creek Culvert - Sta. 13+150 15 m Rt C/L</u>	ORIGINATED BY <u>ZI</u>
DIST <u>          </u>	HWY <u>66</u>	BOREHOLE TYPE <u>Hollow Stem Auger &amp; N-type Wash Boring &amp; NQ Coring</u>	COMPILED BY <u>GR</u>
DATUM <u>Geodetic</u>	DATE <u>10/25/2007</u>	<u>10/28/2007</u>	CHECKED BY <u>ZO</u>

[illegible]

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

(%) STRAIN AT FAILURE

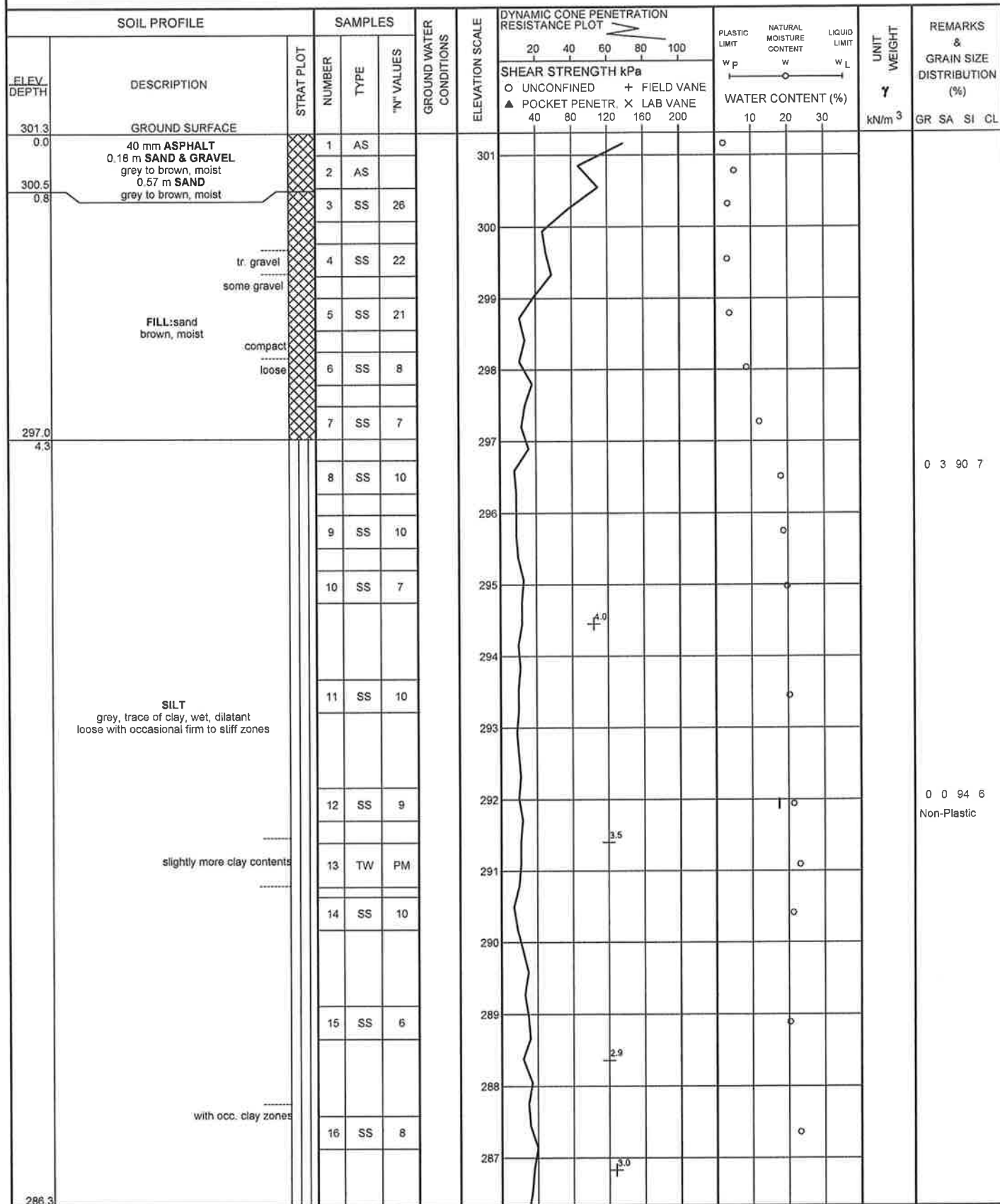
SPT 1201

# RECORD OF BOREHOLE No C3

1 OF 3

METRIC

GWP 448-98-00 LOCATION Crooked Creek Culvert - Sta. 13+170 1.5 m Lt C/L ORIGINATED BY  
DIST HWY 66 BOREHOLE TYPE Hollow Stem Auger & NQ Coring COMPILED BY  
DATUM Geodetic DATE 10/11/2007 10/14/2007 CHECKED BY



Continued Next Page

+ 3, X 3 Numbers refer to  
Sensitivity

20  
15 10 5  
(%) STRAIN AT FAILURE

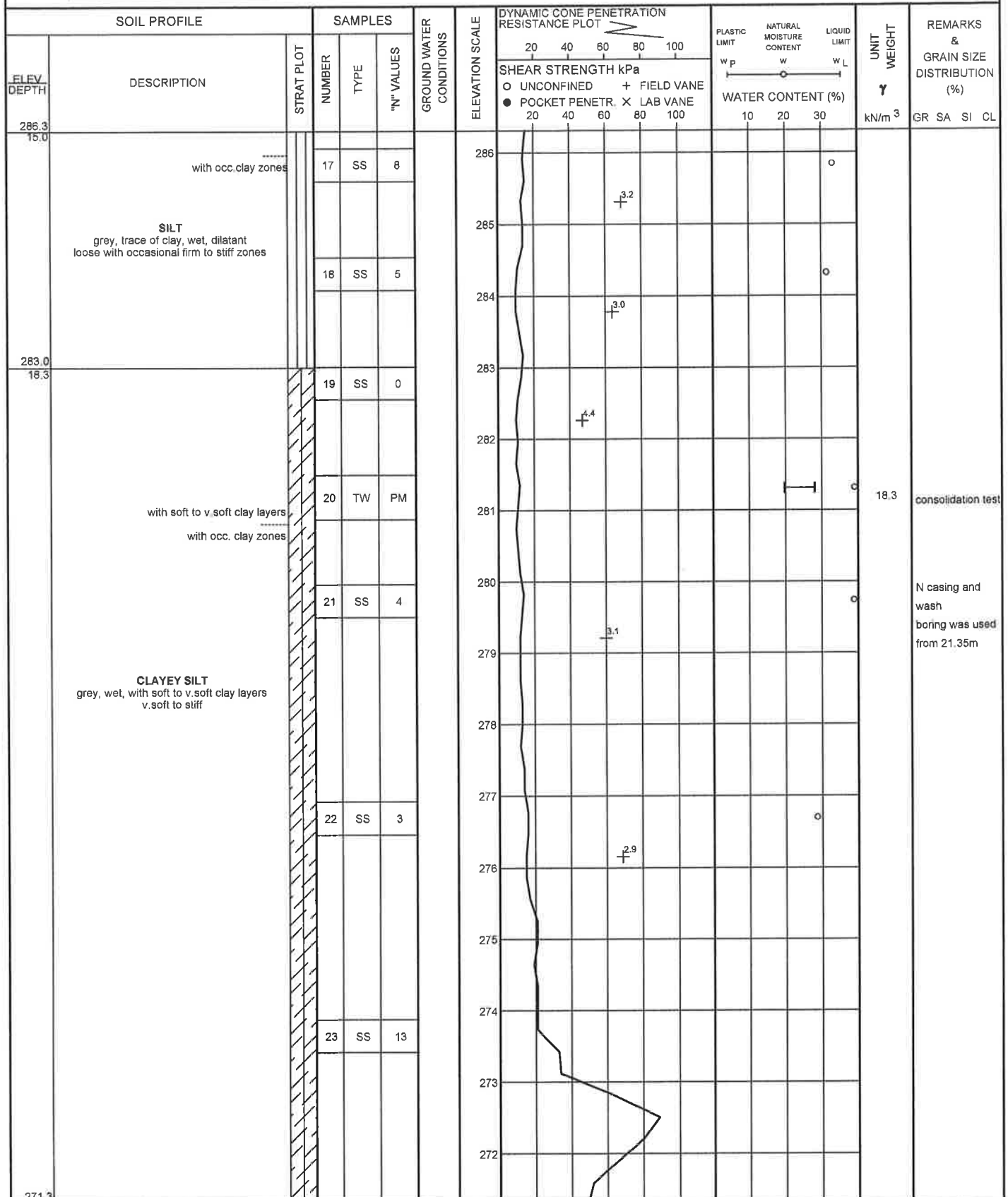
SPT 1201

# RECORD OF BOREHOLE No C3

2 OF 3

METRIC

GWP 448-98-00 LOCATION Crooked Creek Culvert - Sta. 13+170 1.5 m Lt C/L ORIGINATED BY  
DIST HWY 66 BOREHOLE TYPE Hollow Stem Auger & NQ Coring COMPILED BY  
DATUM Geodetic DATE 10/11/2007 10/14/2007 CHECKED BY



Continued Next Page

+ 3, X 3: Numbers refer to Sensitivity 20 15 10 5 (%) STRAIN AT FAILURE





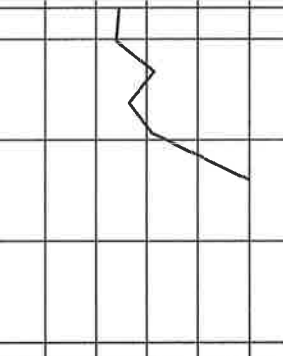
SPT 1201

# RECORD OF BOREHOLE No C3

3 OF 3

METRIC

GWP 448-98-00 LOCATION Crooked Creek Culvert - Sta. 13+170 1.5 m Lt C/L ORIGINATED BY \_\_\_\_\_  
 DIST \_\_\_\_\_ HWY 66 BOREHOLE TYPE Hollow Stem Auger & NQ Coring COMPILED BY \_\_\_\_\_  
 DATUM Geodetic DATE 10/11/2007 10/14/2007 CHECKED BY \_\_\_\_\_

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED    + FIELD VANE ● POCKET PENETR.    X LAB VANE							
271.3 30.0	CLAYEY SILT grey, wet		24	CC	100/100									100/7.6cm DCPT	
270.8 30.5			25	RC	TCR=32% RQD=0%										
269.6 31.7	GRANITIC BEDROCK pink  foliated	26	RC	TCR=48% RQD=0%											
267.8 33.5		27	RCT	TCR = 100% RQD = 100%											
End of Borehole  Water level in Borehole Oct 12, 2007 - 13.1 m Oct 15, 2007 - 4.0 m  End of DCPT - 31.7 m (El. 269.6 m)															

+<sup>3</sup>, X<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

SPT 1201

# RECORD OF BOREHOLE No D1

1 OF 2

METRIC

GWP 448-98-00 LOCATION Crooked Creek Culvert - Sta. 13+310 11 m Lt C/L / Sta 13+308 14 m Lt C/L ORIGINATED BY ZI  
DIST          HWY 66 BOREHOLE TYPE Hollow Stem Auger COMPILED BY GR  
DATUM Geodetic DATE 10/15/2007 10/29/2007 CHECKED BY ZO

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES								
300.0	GROUND SURFACE												
0.0	0.15 m TOPSOIL		1	SS	7								
			2	SS	17								
			3	SS	11								
	grey to brown		4	SS	11								
	grey		5	SS	9								
			6	SS	10								
			7	SS	9								
			8	SS	6								
			9	SS	1								
	occ. clay seams		10	SS	9								
	SILT wet, dilatant loose to compact		11	SS	7								
			12	SS	6								
			13	SS	7								
			14	SS	5								
			15	SS	5								
285.0													

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

SPT 1201

RECORD OF BOREHOLE No D1

2 OF 2

METRIC

GWP 448-98-00 LOCATION Crooked Creek Culvert - Sta. 13+310 11 m Lt C/L / Sta 13+308 14 m Lt C/L ORIGINATED BY ZI  
 DIST          HWY 66 BOREHOLE TYPE Hollow Stem Auger COMPILED BY GR  
 DATUM Geodetic DATE 10/15/2007 10/29/2007 CHECKED BY ZO

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT      NATURAL MOISTURE      LIQUID CONTENT      LIMIT		UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● POCKET PENETR.      X LAB VANE		WATER CONTENT (%)			
285.0 15.0	occ. clay seams							20   40   60   80   100	W <sub>P</sub> W      W <sub>L</sub>				
284.0 16.0	<b>SILT</b> wet, dilatant		16	SS	2			20   40   60   80   100	10   20   30	45.8			
	End of Borehole @ 6.6 m on Oct 16, 2007 Water level in borehole - 3.7m upon completion Borehole was moved and redrilled to 15.7 m on Oct 29, 2007							4.0					

+<sup>3</sup>, X<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
5  
(%) STRAIN AT FAILURE

SPT 1201

## 1 OF 2

METRIC

GWP	448-98-00	LOCATION	Crooked Creek Culvert - Sta. 13+265 11 m Lt C/L	ORIGINATED BY	ZI
DIST		HWY	66	BOREHOLE TYPE	Hollow Stem Auger
DATUM	Geodetic	DATE	10/16/2007	COMPILED BY	GR
				CHECKED BY	ZO

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

SPT 1201

## 2 OF 2

METRIC

GWP	448-98-00	LOCATION	Crooked Creek Culvert - Sta. 13+265 11 m Lt C/L	ORIGINATED BY	ZI
DIST		HWY	66	BOREHOLE TYPE	Hollow Stem Auger
DATUM	Geodetic	DATE	10/16/2007	CHECKED BY	ZO

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

SPT 1201

# RECORD OF BOREHOLE No D3

1 OF 2

METRIC

GWP 448-98-00 LOCATION Crooked Creek Culvert - Sta. 13+215 13 m Lt C/L ORIGINATED BY ZI  
DIST HWY 66 BOREHOLE TYPE Hollow Stem Auger COMPILED BY GR  
DATUM Geodetic DATE 10/16/2007 CHECKED BY ZO

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES								
299.9 0.0	GROUND SURFACE												
	0.15 m TOPSOIL		1	SS	11								
	moist / brown wet / grey		2	SS	12		299						
			3	SS	11		298						
			4	SS	10		297						
	SILT dilatant, loose to compact		5	SS	9		296						
			6	SS	7		295						
			7	SS	7		294						
			8	SS	6		293						
293.3 6.6	End of Borehole @6.6m		9	SS	5		292						
							291						
							290						
							289						
							288						
							287						
							286						
							285						

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

SPT 1201

# RECORD OF BOREHOLE No D3

2 OF 2

METRIC

GWP 448-98-00 LOCATION Crooked Creek Culvert - Sta. 13+215 13 m LI C/L ORIGINATED BY ZI  
DIST          HWY 66 BOREHOLE TYPE Hollow Stem Auger COMPILED BY GR  
DATUM Geodetic DATE 10/16/2007 CHECKED BY ZO

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)			
							20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>		
284.9																
284.6																
15.3	End of Borehole @6.6m Borehole dry upon completion (not stabilized) DCPT was performed from 7.0 m to 15.3 m					284										

+<sup>3</sup>, X<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

SPT 1201

# RECORD OF BOREHOLE No D4

1 OF 2

METRIC

GWP 448-98-00 LOCATION Crooked Creek Culvert - Sta. 13+108 13 m Lt C/L ORIGINATED BY ZI  
 DIST HWY 66 BOREHOLE TYPE Hollow Stem Auger COMPILED BY GR  
 DATUM Geodetic DATE 10/17/2007 CHECKED BY ZO

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>P</sub>	W	W <sub>L</sub>		
298.9 0.0	GROUND SURFACE							○ UNCONFINED + FIELD VANE ▲ POCKET PENETR. X LAB VANE						
	0.15 m TOPSOIL		1	SS	5									
			2	SS	11		298							0 2 91 7
			3	SS	10		297							
			4	SS	6		296							0 2 92 6
			5	SS	6		295							no recovery
			6	SS	7		294							
			7	SS	6		293							
			8	SS	7		292							no recovery
			9	SS	8		291							
292.3 6.6	End of Borehole @6.6m						290							
							289							
							288							
							287							
							286							
							285							
							284							

Continued Next Page

+ 3 . X 3: Numbers refer to  
Sensitivity

20  
15 5  
10 (%) STRAIN AT FAILURE





SPT 1201

# RECORD OF BOREHOLE No D5

1 OF 2

METRIC

GWP 448-98-00 LOCATION Crooked Creek Culvert - Sta 13+060 13 m Lt C/L / Sta 13+062 13 m Lt C/L ORIGINATED BY ZI  
 DIST          HWY 66 BOREHOLE TYPE Hollow Stem Auger COMPILED BY GR  
 DATUM Geodetic DATE 10/16/2007 10/29/2007 CHECKED BY ZO

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
299.8 0.0	GROUND SURFACE							20 40 60 80 100						
	0.2 m TOPSOIL		1	SS	3			40 80 120 160 200						
	SILTY CLAY brown, moist, soft to firm		2	SS	6		299							
298.6 1.2			3	SS	12		298							
		brown ----- grey	4	SS	10		297							
			5	SS	6		296							no recovery
			6	SS	5		295							
			7	SS	6		294							no recovery
			8	SS	6		293							
			9	SS	6		292							
	SILT trace of clay, wet loose to compact, dilatent		10	SS	5		291							
			11	SS	8		290							
			12	SS	4		289							
		tr. clay ----- -----	13	SS	7		288							
			14	SS	10		287							
			15	SS	7		286							
		tr. clay ----- -----					285							
284.8														

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

SPT 1201

RECORD OF BOREHOLE No D5

2 OF 2

METRIC

GWP 448-98-00 LOCATION Crooked Creek Culvert - Sta. 13+060 13 m Lt C/L / Sta 13+062 13 m Lt C/L ORIGINATED BY ZI  
DIST HWY 66 BOREHOLE TYPE Hollow Stem Auger COMPILED BY GR  
DATUM Geodetic DATE 10/16/2007 10/29/2007 CHECKED BY ZO

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT		LIQUID LIMIT	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● POCKET PENETR    x LAB VANE		W <sub>p</sub> W      W <sub>L</sub>					WATER CONTENT (%) 10    20    30			
284.8 15.0	SILT trace of clay, wet loose to compact, dilatent		16	SS	5			20	40	60	80	100						
284.1																15.7	284	3.6
End of Borehole @ 6.6 m - Oct 16, 2007 DCPT was performed from 7.0m to 15.3m -Oct 16, 2007 Borehole moved and redrilled from 7.2 m to 15.7 m -Oct 29, 2007																		

+<sup>3</sup>, X<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

SPT 1201

# RECORD OF BOREHOLE No S1

1 OF 3

METRIC

GWP 448-98-00 LOCATION Crooked Creek Culvert - Sta. 13+137 1.4 m Lt C/L ORIGINATED BY ZI  
DIST HWY 66 BOREHOLE TYPE Hollow Stem Auger & N-type Wash Boring COMPILED BY GR  
DATUM Geodetic DATE 10/2/2007 10/4/2007 CHECKED BY ZO

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
FLYV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
								20 40 60 80 100		W <sub>p</sub> W W <sub>L</sub>				
								40 80 120 160 200						
								UNCONFINED + FIELD VANE						
								POCKET PENETR. X LAB VANE						
301.5	GROUND SURFACE													
0.0	80mm ASPHALT		1	AS	---									
	0.19 m SAND & GRAVEL		2	AS	---		301							
	brown, moist													
300.8	0.48 m SAND		3	SS	48									
0.8	brown to grey, trace of gravel, moist													
	FILL:sand		4	SS	50/13cm		300							
	brown, trace of gravel													
298.8			5	SS	46		299							
2.8	FILL:sandy gravel													
298.4	brown, wet		6	SS	60/3cm									
3.1							298							
	FILL:rock		7	RC										
	granite, with some sand & gravel													
297.2							297							
4.3	CLAYEY SILT		8	SS	9									
	with some peat, trace of rootlets													
296.5	trace of sand, with some gravel, wet						296							
5.0			9	SS	12									
			10	SS	8		295							
			11	SS	8									
							294							
			12	SS	8									
							293							
			13	SS	6		292							
							291							
			14	SS	3									
							290							
			15	SS	7		289							
							288							
			16	SS	10									
							287							
286.5														

Continued Next Page

+<sup>3</sup>, X<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15 5  
10 (%) STRAIN AT FAILURE

SPT 1201

# RECORD OF BOREHOLE No S1

2 OF 3

METRIC

GWP 448-98-00 LOCATION Crooked Creek Culvert - Sta. 13+137 1.4 m Lt C/L ORIGINATED BY ZI  
DIST HWY 66 BOREHOLE TYPE Hollow Stem Auger & N-type Wash Boring COMPILED BY GR  
DATUM Geodetic DATE 10/2/2007 10/4/2007 CHECKED BY ZO

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE						
286.5 15.0	SILT grey, trace of clay, wet, dilatant loose with occasional firm to stiff zones		17	SS	9	286	+ 3.0			
284.7 16.8			18	SS	0					
282.3 19.2	CLAYEY SILT with v. soft clay layers		19	SS	1	284	+ 5.0			
								283		
						282				
						281				
						280				
						279				
						278				
						277				
						276				
						275				
						274				
						273				
						272				

Continued Next Page

+ 3 . X 3 Numbers refer to  
Sensitivity

20  
15 5  
10 (%) STRAIN AT FAILURE

Dynamic cone  
penetration  
blows are 0  
blows/feet  
from 19.2 to 23.2  
m.

SPT 1201

RECORD OF BOREHOLE No S1

3 OF 3

METRIC

GWP 448-98-00 LOCATION Crooked Creek Culvert - Sta. 13+137 1.4 m Lt C/L ORIGINATED BY ZI  
 DIST          HWY 66 BOREHOLE TYPE Hollow Stem Auger & N-type Wash Boring COMPILED BY GR  
 DATUM Geodetic DATE 10/2/2007 10/4/2007 CHECKED BY ZO

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE						
271.5							20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● POCKET PENETR. X LAB VANE	WP P W L WATER CONTENT (%) 10 20 30	kN/m <sup>3</sup>	GR SA SI CL
270.3						271				
31.2	End of Borehole @ 19.2 m DCPT was performed from 19.2 m to 31.2 m  Water level in Borehole Oct 02, 2007 - 3.2 m Oct 03, 2007 - 1.8 m									100/5cm DCPT

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15 5  
10 (%) STRAIN AT FAILURE

METRIC

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

SPT 1201

RECORD OF BOREHOLE No S2

2 OF 2

METRIC

GWP 446-98-00 LOCATION Crooked Creek Culvert - Sta. 13+200 1.5 m Lt C/L ORIGINATED BY ZI  
DIST HWY 66 BOREHOLE TYPE Hollow Stem Auger COMPILED BY GR  
DATUM Geodetic DATE 10/14/2007 CHECKED BY ZO

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					
286.2 15.0	SILT trace of clay, wet, dilatant loose to compact with occasional firm to stiff zones		15	SS	7	286	○ UNCONFINED	+					
285.5 15.7							● POCKET PENETR.	×					
277.7 23.5	End of Borehole @ 16.8 m DCPT was performed from 16.8 m to 23.5 m * Water level @ 4.3 m upon completion (not stabilized)					278							100/2.5cm DCPT

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE



# Appendix B

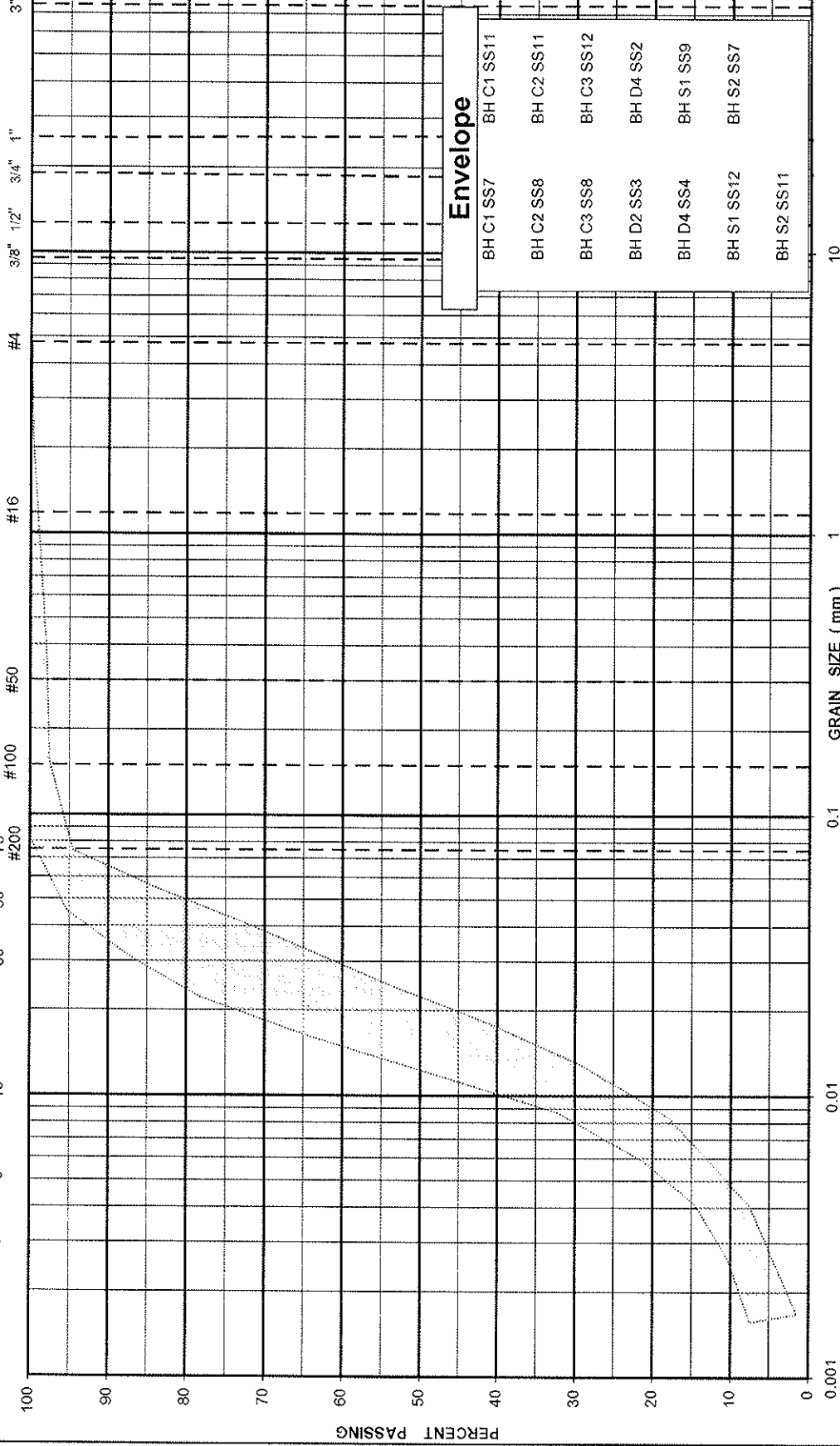
## Laboratory Test Results

# UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT			SAND			GRAVEL		
			Fine	Medium	Coarse	Fine	Coarse	

GRAIN SIZE IN MICROMETERS

SIEVE DESIGNATION ( Imperial )



## GRAIN SIZE DISTRIBUTION

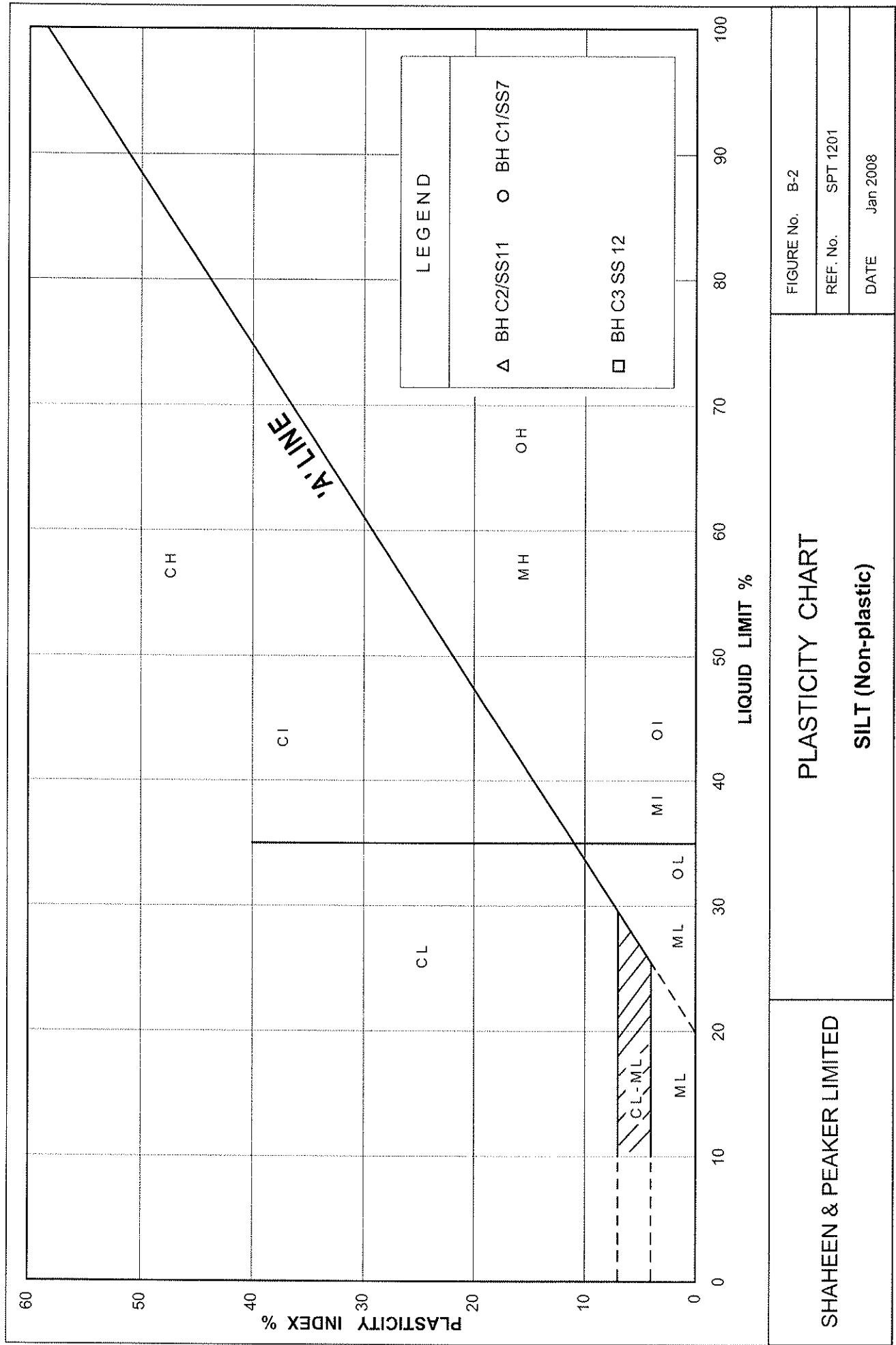
Silt, trace clay

SHAHEEN & PEAKER LIMITED

SAMPLE No: B-1

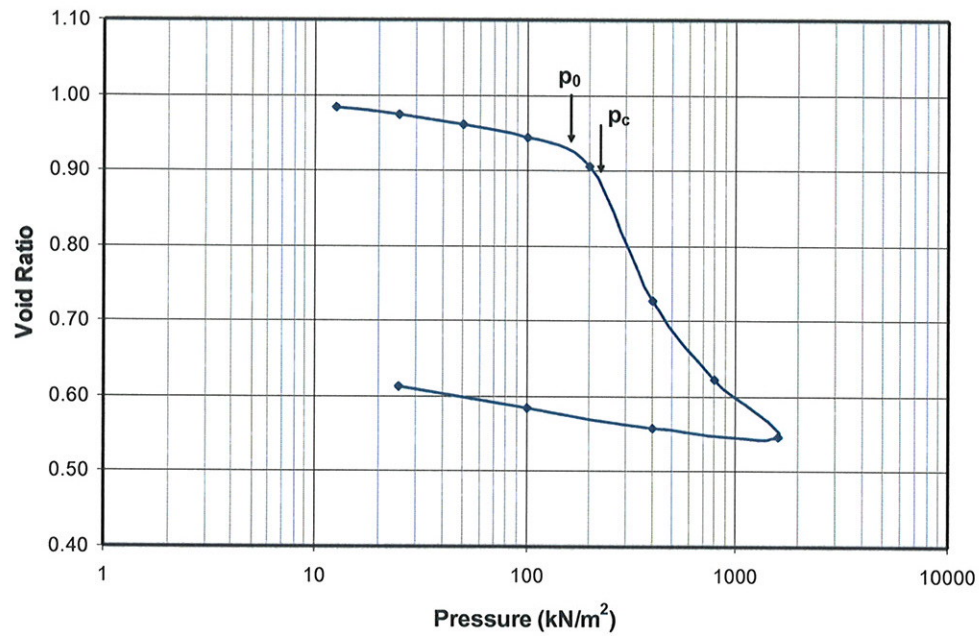
PROJECT No: SPT1201

Date: Jan., 2008



BH C2 TW 20 (18.9-19.5 m)

### Void Ratio versus Pressure



### Coefficient of Consolidation vs. Pressure

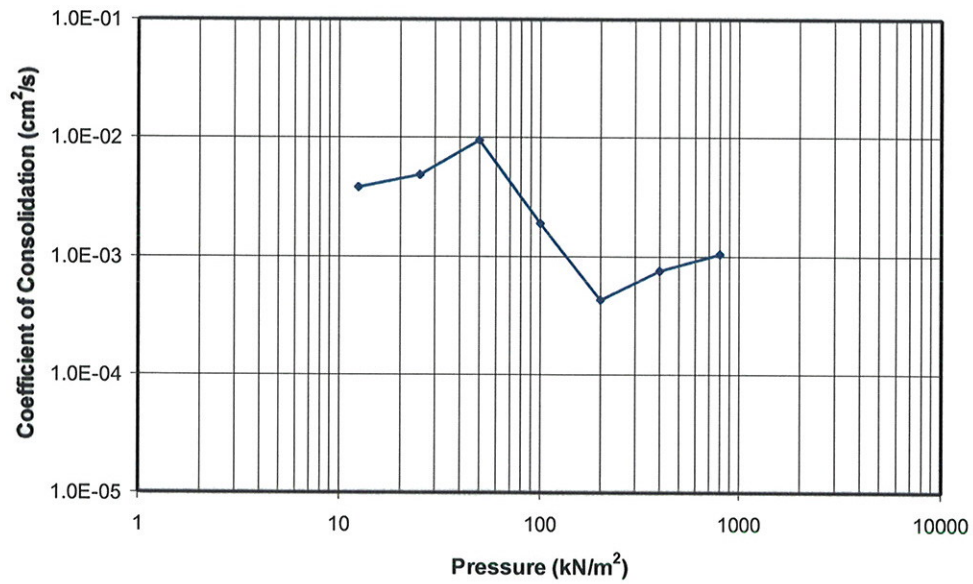


Fig B-3

BH C3 TW 20 (19.8-20.4m)

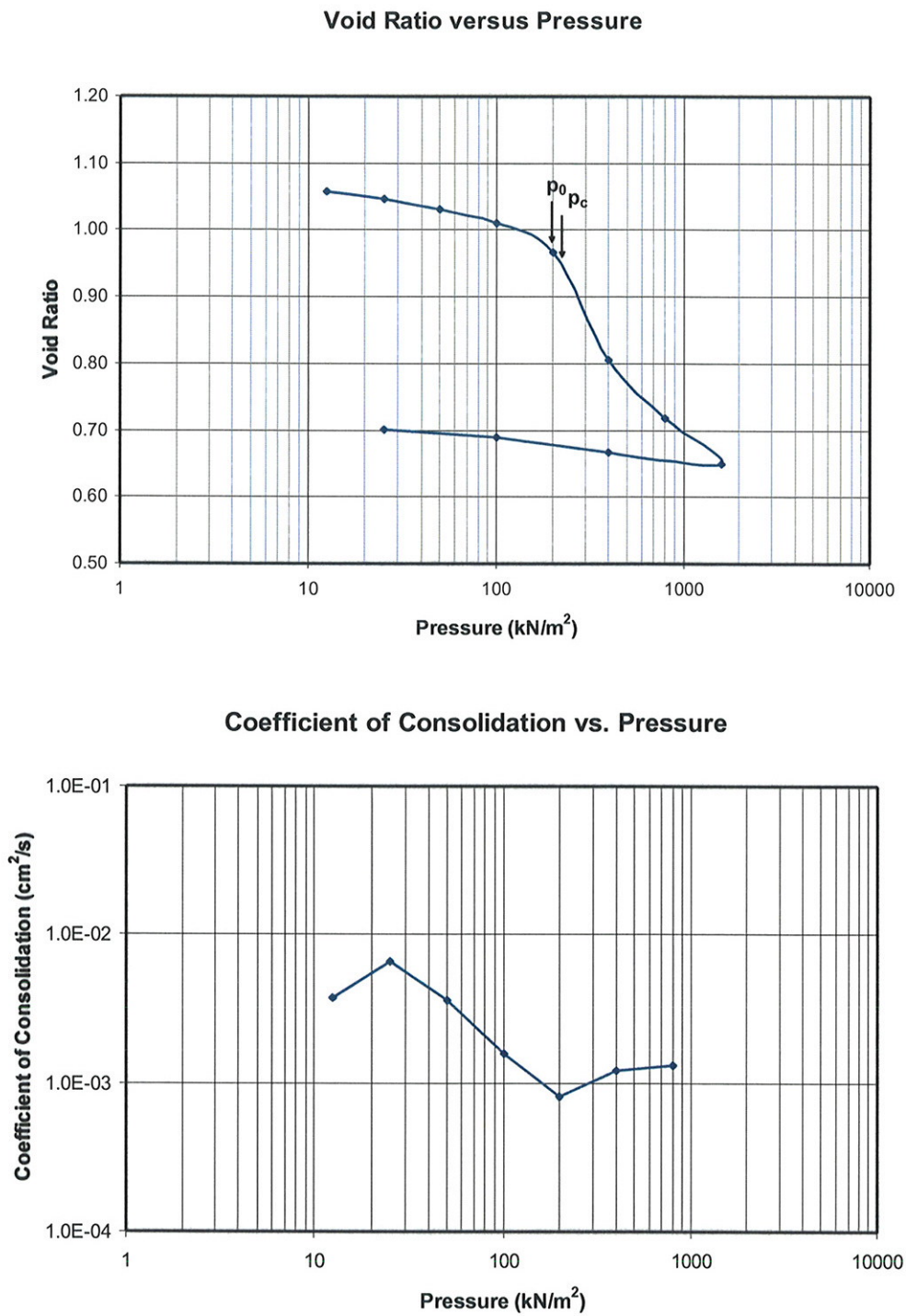
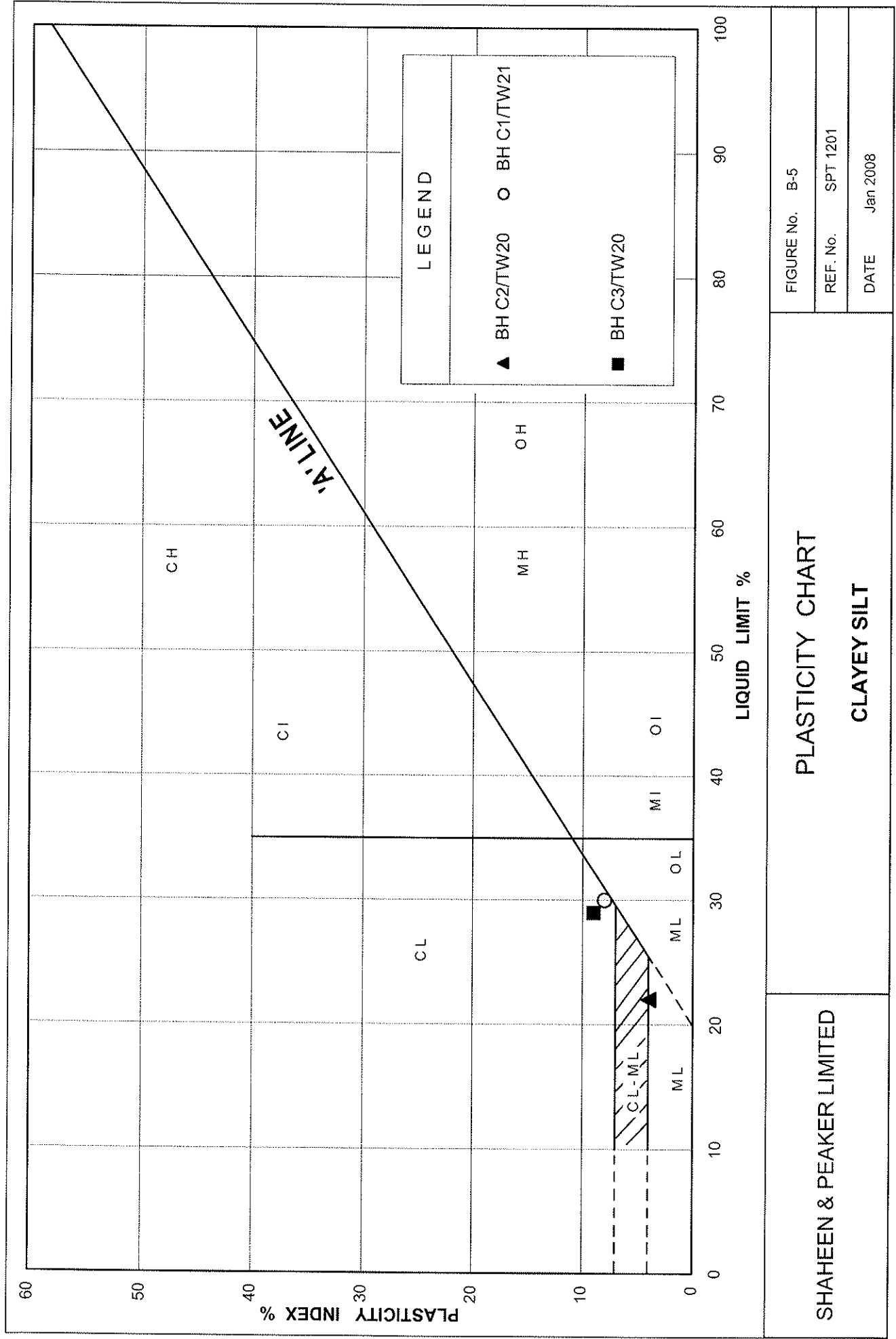


Fig B-4



# Appendix C

## Site Photographs





Photograph C-1 Crooked Creek Culvert





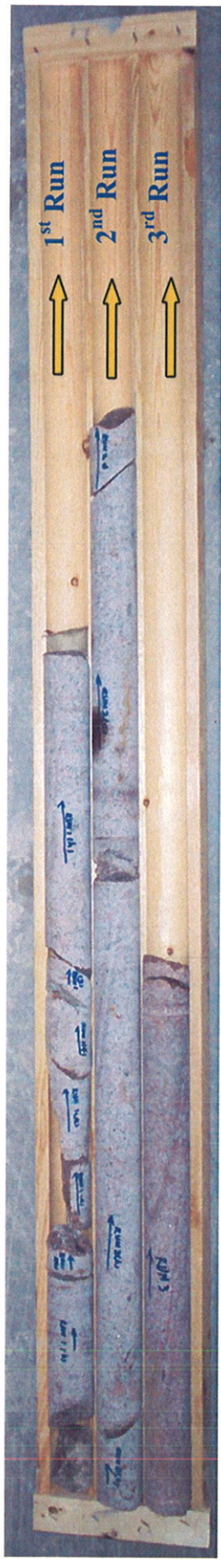
Photograph C-2 Crooked Creek Culvert

# Appendix D

## Rock Core Photographs



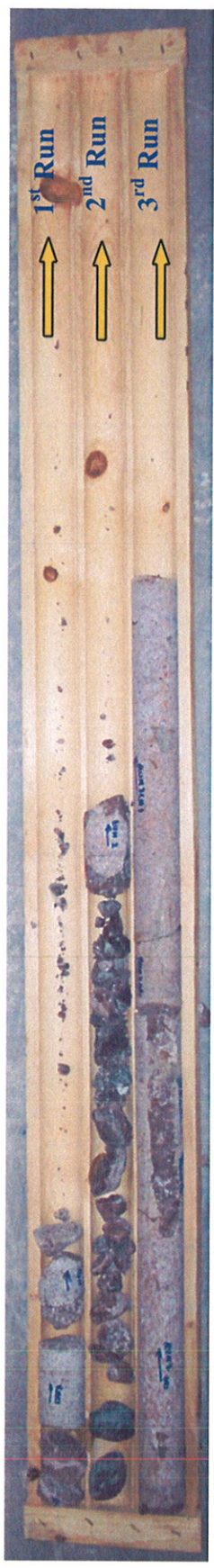
BH C1



BH C2



BH C3



Photograph D-1 Rock cores

# Appendix E

## 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 63.5 kg, 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 N.

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

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

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

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

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND/OR STRENGTH.

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

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

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

**JOINT AND BEDDING:**

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

## ABBREVIATIONS AND SYMBOLS

### FIELD SAMPLING

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

### STRESS AND STRAIN

$u_w$	kPa	PORE WATER PRESSURE
$r_u$	1	PORE PRESSURE RATIO
$\sigma$	kPa	TOTAL NORMAL STRESS
$\sigma'$	kPa	EFFECTIVE NORMAL STRESS
$\tau$	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
$\epsilon$	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
$\mu$	1	COEFFICIENT OF FRICTION

### MECHANICAL PROPERTIES OF SOIL

$m_v$	$\text{kPa}^{-1}$	COEFFICIENT OF VOLUME CHANGE
$c_c$	1	COMPRESSION INDEX
$c_s$	1	SWELLING INDEX
$c_a$	1	RATE OF SECONDARY CONSOLIDATION
$c_v$	$\text{m}^2/\text{s}$	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
$T_v$	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
$\sigma'_{vo}$	kPa	EFFECTIVE OVERBURDEN PRESSURE
$\sigma'_p$	kPa	PRECONSOLIDATION PRESSURE
$\tau_f$	kPa	SHEAR STRENGTH
$c'$	kPa	EFFECTIVE COHESION INTERCEPT
$\phi'$	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
$c_u$	kPa	APPARENT COHESION INTERCEPT
$\phi_u$	-°	APPARENT ANGLE OF INTERNAL FRICTION
$\tau_R$	kPa	RESIDUAL SHEAR STRENGTH
$\tau_r$	kPa	REMOULDED SHEAR STRENGTH
$S_r$	1	SENSITIVITY = $c_u / \tau_r$

### PHYSICAL PROPERTIES OF SOIL

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

**FOUNDATION DESIGN REPORT  
CROOKED CREEK CULVERT AT  
HIGHWAY 66  
TOWNSHIP OF EBY, ONTARIO  
G.W.P. 448-98-00**

**GEOCRES NO. 42A-71**

**Prepared For:**

**D. M. WILLS ASSOCIATES LIMITED**

**Prepared by:**

**SHAHEEN & PEAKER LIMITED**

**Project: SPT1201  
April 2, 2008**



**20 Meteor Drive  
Toronto, Ontario  
M9W 1A4  
Tel: (416) 213-1255  
Fax: (416) 213-1260  
EMAIL: [info@shaheenpeaker.ca](mailto:info@shaheenpeaker.ca)**

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### APPENDIX F: LIMITATIONS OF REPORT

**FOUNDATION DESIGN REPORT  
PROPOSED CROOKED CREEK CULVERT RELINING  
AT HIGHWAY 66  
TOWNSHIP OF EBY, ONTARIO  
G.W.P. 448-98-00**

## **5. DISCUSSION AND RECOMMENDATIONS**

The Crooked Creek, which flows southerly through the existing culvert under Highway 66, is located 7 km south-west of the junction of Highway 66 with Highway 11. Existing Crooked Creek structure is 26.2 m long structural plate corrugated steel pipe arch culvert (i.e. SPCSPA) which has cross section of 6220 mm span and 3960 mm rise.

According to data supplied by DMWA, the invert of the existing SPCSPA is at about El. 296.6 m at the inlet on the north side of the Highway, dropping to about El. 296.3 m at the outlet on the south side.

Drawing D-6844-P1, dated May 1970, prepared by MTO, shows that the culvert was designed to be constructed on a minimum 1'6" (0.45 m) thick granular bedding material.

Boreholes C1, C2, C3, S1 and S2, which were drilled in the immediate vicinity of the existing culvert show, underlying the culvert, the presence of a major silt deposit with occasional clayey silt zones and very thin clay seams. This deposit extends to El. 286-283 m. Standard Penetration tests performed in the silt deposit yielded N-values which range from 2 to 12 blows/0.3 m, but are typically between 5 and 10 blows/0.3 m. From this, the relative density of the soil can be described as loose with occasional firm to stiff cohesive zones. Below El. 286-283± m, the deposit attains a cohesive nature and is described as a cohesive (clayey silt) material. From the recorded N-values and field vane tests conducted, the consistency of this deposit is described as typically soft to stiff. This deposit contains some rock fragments and is more competent with a zone of about 0.4 to 1.2 m above the surface of the bedrock which was encountered at El. 275.7 to 269.6 m.

At the time of our investigation, the groundwater level was encountered at about El. 298-296 m, but would be subject to fluctuations. The groundwater level can also be expected to be controlled by the water level in the Crooked Creek.

### **5.1 REHABILITATION OF THE EXISTING CULVERT**

To rehabilitate the existing culvert, it is proposed to reline it. We understand that this will be accomplished by placing a 5050 x 3330 mm CSPA culvert inside the existing culvert. A clear space of minimum 40 mm and maximum 60 mm will be provided between the inside (liner) culvert and the outside (existing) culvert along the invert. Elsewhere a 70 mm minimum clear space will be provided between the two culverts. The space between the



outside and the liner culvert pipes will then be grouted. Adequate bracing will be provided within the liner and against the existing pipe to maintain line, grade and pipe liner during grouting operations.

We understand that the unit weight of the grout to be used will be  $2000 \text{ kg/m}^3$  and the liner pipe weight will be  $787 \text{ kg/m}$ . Based on the above, the estimated increase in weight per metre is about  $130 \text{ kN}$ . Assuming a granular bedding material of about  $0.45 \text{ m}$  thick and at least  $6.0 \text{ m}$ , the additional stresses on the surface of the silt subgrade would be about  $20 \text{ kPa}$ .

Based on these assumptions and the information obtained from the boreholes, field and laboratory tests, the estimated foundation settlement is about  $20 \text{ mm}$ . In our opinion, this amount of settlement should not cause an undue concern for the performance of the road.

The drawing prepared by MTO in 1970 (Drawing No. D-6844-P1) for the construction of the existing culvert shows that the Crooked Creek alignment was moved to the east and in this case if somewhere between  $1.2$  and  $2.0 \text{ m}$  of soil was removed for the new channel, additional loads of the magnitude quoted (i.e. of the order of  $20 \text{ kPa}$ ) should not represent a net stress increase in comparison with stress conditions that existed at that time. Theoretically, therefore, the settlements in the silt deposit would only represent a rebound and re-settlement. In the underlying clayey silt, these would similarly be in the 'pre-consolidated range'. In this situation, excessive settlements would not be expected (i.e. settlements may be between  $10$  and  $20 \text{ mm}$ ).

We have also estimated foundation settlements for a stress increase of  $25 \text{ kPa}$  and also for  $50 \text{ kPa}$ , over a  $6.0 \text{ m}$  width (i.e. the presence of a  $6.0 \text{ m}$  wide and  $0.45 \text{ m}$  thick compacted granular bedding material was assumed). With these assumptions and available borehole data, the estimated settlement for  $25 \text{ kPa}$  stress increase is about  $25 \text{ mm}$  and for a  $50 \text{ kPa}$  stress increase it is about  $60 \text{ mm}$ .

We recommend that during the construction the amount of grout pumped be checked and compared with calculated volumes and in the event of a discrepancy, the construction will need to be halted and the reason(s) for the discrepancy will need to be investigated.

We also recommend that the settlement (or heave) of the road surface be monitored before during and after the construction. Settlement monitoring could consist of paint mark points on the pavement along the centerline and edges of the culvert. Surface settlement points could also be installed beyond the paved portion (i.e. in the shoulder). The settlements will need to be monitored with reference to reliable, frost-free benchmark(s).

We recommend that a minimum of three sets of repeatable baseline readings be taken on all of the settlement points in advance of the start of construction. Settlement points should be conducted at least once daily during construction and twice daily during the grouting operations. After the construction, the frequency of the readings can be reduced to once

weekly for a month and a further reading one month later and another reading four months thereafter.

#### 5.1.1 EROSION PROTECTION

We recommend that the existing culvert be evaluated for the sufficiency of the existing erosion and scour measures and if observations show that they are deficient or if the realigning is expected to adversely affect erosion and scour potentials, further measures may be necessary. The following is a discussion of possible erosion measures.

Erosion and scour protection should be provided at the culvert inlet and outlet (including the slopes and sides). The erosion/scour protection should be designed by a specialist River Engineer/Scientist (as erosion and scour largely depend on the velocity of water in the watercourse and its regime) who is familiar with the findings of this report. The following are some general suggestions, considering that below some organic and alluvial deposits at the watercourse level the boreholes indicate that the native soils can be expected to consist of silt. The silt is considered to be a highly erodible and frost susceptible soil.

We recommend that concrete cut-off (apron) be constructed both at the inlet and outlet to prevent seepage beneath and around the culvert, especially through the granular bedding and granular backfill around the culvert. Beneath the culvert, the concrete cut-off wall should extend to a suitable depth (e.g. below any possible scour depth). Consideration may also be given to an impervious seal at the inlet and outlet.

At the inlet, consideration may also be given to the use of a clay seal. The purpose of the clay seal is to ensure that water flow is channeled through the culvert and does not seep through the backfill around the structure and from beneath the structure. The clay seal should therefore be continuous and is typically 0.6 m thick. It should comply with the material specifications given in OPSS 1205. It should be extended around the culvert from at least 0.5 m above the high water level in the watercourse down to the channel bed and up the other side in a continuous manner. It should be ensured that it extends to cover all the granular backfill materials to prevent any seepage through them. Typically, the clay seal is protected by laying a 0.6 m thick rock protection over it. The clay seal would generally be extended at about 8 m beyond the inlet.

At the outlet as well as at the inlet (if clay seal is not used), in addition to the concrete cut-off and/or impervious seal or in conjunction with these, a 0.6 m thick rock protection, consisting typically of 300 mm size rock can be considered. As the subgrade can be expected to consist of silt, a layer of granular or man-made filter material should be used. This would generally be extended about 8 m along the channel and the sides (to at least 0.3 m above the high water). The granular filter material underlying the rock protection can consist of a suitable granular material such as Granular 'A'. Alternatively, a suitable geotextile can be used underneath the rock fill, in lieu of the granular filter material. Another reference for consideration is OPSD 810.010 Rip-Rap Treatment for Culvert Outlets.

## 5.2 WING WALLS

It is unlikely that new wing walls will be required for the proposed method of rehabilitation but the following are provided for completeness.

Backfilling for any retaining (wing) walls should consist of suitable free-draining granular materials, compacted in accordance with the MTO standards and should conform to the applicable OPSD such as OPSD-803.010. For fills below the groundwater level or immediately below the roadway, it is recommended that Granular 'A' or 'B' materials be used. Where necessary, proper tapering as per MTO standards should be provided. The fill should be compacted in shallow lifts, not exceeding 200 mm loose thickness, to at least 98% of the material's Standard Proctor Maximum Dry Density (SPMDD). To avoid damaging or laterally dislocating the structure, care should be exercised when compacting fill adjacent to and immediately on top of the retaining wall structures. Compaction equipment should be restricted in size as per Ontario Ministry of Transportation (MTO) convention to prevent structural damage to the culvert.

Backfill behind any retaining (wing) walls should consist of Granular 'B' type materials in accordance with the MTO Standards. Free draining backfill materials, weepholes, etc. should be provided in order to prevent hydrostatic build-up, as shown on OPSD-3101.150.

Computation of earth pressures acting against rigid culvert walls and any wing walls should be in accordance with CHDBC. For design purposes, the following properties can be assumed for backfill.

### **Compacted Granular 'A' or Granular 'B' Type II**

Angle of Internal Friction  $\phi=35^\circ$  (unfactored)

Unit weight = 22 kN/m<sup>3</sup>

Coefficient of Lateral Earth Pressure:

Level Backfill	Backfill Sloping at 3H:1V	Backfill Sloping at 2H:1V
$K_a=0.27$	$K_a=0.34$	$K_a=0.40$
$K_b=0.35$	$K_b=0.44$	$K_b=0.50$
$K_o=0.43$	$K_o=0.56$	$K_o=0.62$
$K^*=0.45$	$K^*=0.60$	$K^*=0.66$

### **Compacted Granular 'B' Type I**

Angle of Internal Friction  $\phi=30^\circ$  (unfactored)

Unit Weight = 21 kN/m<sup>3</sup>

Coefficient of Lateral Earth Pressure:

Level Backfill	Backfill Sloping at 3H:1V	Backfill Sloping at 2H:1V
$K_a=0.33$	$K_a=0.42$	$K_a=0.54$
$K_b=0.41$	$K_b=0.52$	$K_b=0.64$
$K_o=0.50$	$K_o=0.66$	$K_o=0.76$
$K^*=0.57$	$K^*=0.74$	$K^*=0.86$

Note:

- $K_a$  is the coefficient of active earth pressure
- $K_b$  is the backfill earth pressure coefficient for an unrestrained structure including compaction efforts
- $K_o$  is the coefficient of earth pressure at rest
- $K^*$  is the earth pressure coefficient for a soil loading a fully restrained structure and includes compaction effects

These values are based on the assumption that the backfill behind the retaining structure is free-draining granular material and adequate drainage is provided.

The earth pressure coefficient adopted will depend on whether the retaining structure is restrained or some movement can occur such that the active state of earth pressure can develop. The effect of compaction should also be taken into account in the selection of the appropriate earth pressure coefficients. The use of vibratory compaction equipment behind the culvert and the retaining walls should be restricted in size as per current MTO practice.

As an alternative to conventional retaining walls, consideration could be given to MTO's Retained Soil System in which case the designer will have to include the geometric, performance and appearance requirements (i.e: medium performance and low to medium appearance).

Based on the results of Boreholes C1 and C2, strip footing foundations to support reinforced concrete retaining walls can be designed for the following geotechnical resistances, provided the footings are placed on undisturbed natural silt deposit in between El. 297.6 and 296.6 m.

Factored Bearing Resistance at U.L.S.	=	200 kPa
Bearing Resistance at S.L.S.	=	100 kPa

These values are based on a footing width of 1.8 m. Therefore if the project involves strip footing foundations, the foundation design and parameters should be discussed with S&P.

All footing excavations should be carefully inspected, evaluated and approved by the Geotechnical Engineer appointed by the QVE, who is familiar with the findings of this investigation.

Under inclined loading conditions, the bearing resistance at ULS should be reduced in accordance with CHBDC.

The structure will need to be checked against overturning and sliding, with an appropriate factor of safety. The unfactored horizontal resistance against sliding between poured concrete and approved silt subgrade surface can be calculated using a friction angle of 26 degrees

Due to the presence of high water table, dilatent nature of the subgrade silt (i.e. the founding subgrade can easily be disturbed during the construction) and the low geotechnical resistance values available, the site is not well suited for the construction of a reinforced concrete wall, especially a high wall (i.e. more than about 2 m high).

Consideration can be given to other wall types including RSS (Reinforced Soil System), etc. Gabion type or crib type walls may also be suitable if some lateral yielding would not be objectionable. These aspects can be discussed with us, if desired, once the details of the site project are known.

### 5.3 CONSTRUCTION COMMENTS

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA), Regulation 213/91, as well as the following specifications:

SP 105 S19 – Protection Systems

SP 902 S01 – Excavation and Backfilling to Structures

Although this is not expected, if excavations are required, the following soil classifications can be expected for temporary excavations in accordance with OHSA.

Fill and Topsoil : Type 3 soil above groundwater level and Type 4 soil below groundwater level.

Silt : Type 3 soil above groundwater level (or if the soil is dewatered) and Type 4 soil below groundwater level

Dewatering will be required to stabilize the soil and to facilitate construction if and where excavations are required. It is our opinion that in the silt deposit the groundwater can be controlled and depressed by about 0.5 m by means of strategically spaced and located filtered sumps. For deeper draw-down, vacuum well points will likely be required. It should be pointed out the silt is a dilatent material and as such it can easily be disturbed in the presence of water, as well it can expand, a condition which can be recognized by the liverish, jelly-like appearance of the soil. Any structures founded on unduly disturbed soil may undergo excessive settlements after the application of structural loads or backfilling.

In addition, the flow of water in the existing culvert will need to be controlled.

If excavations are anticipated, all bearing surfaces should be carefully evaluated and approved by the Geotechnical Engineer appointed by the QEV. Consideration can also be given to an NSSP for proper diversion of the creek flow inside the culvert and the dewatering of excavations (especially foundation excavations), with the responsibility assigned to the Contractor.

Allowance should be made to place a skim-coat of concrete (mud-slab) once the excavation is completed, inspected and approved, without any delay.

With the proposed method, roadway protection is unlikely be required but following brief comments are provided for the sake of completeness.

Locally temporary shoring systems generally consist of support provided by conventional soldier piles and timber lagging. For shallow excavations, the system can be designed as cantilever structures or supported by raker footings. They can also employ a soil anchor system, depending upon the depth of soil required and the performance criteria used. A tight interlocking steel sheet piling system is sometimes also used.

The suggested coefficient of lateral earth pressures based on Boreholes S1 and S2 are given in Table 5.3.1, for the design of the shoring system. The shoring system should be designed by a professional engineer, experienced in this type of work.

Table 5.3.1  
Recommended Unfactored Parameters for Temporary Shoring Design

Soil Type	$K_a$	$K_o$	$K_p$	$\gamma$ (kN/m <sup>3</sup> )
Granular Embankment Fill	0.3	0.45	3.3	21.5
Rock Fill	0.25	0.40	4.0	20.0
Upper Clayey Silt	0.38	0.55	2.7	17.5
Silt	0.36	0.53	2.8	18.0

It should be pointed out that the rock fill encountered in Borehole S1 can be expected to cause some problems during the installation of the caisson holes or the driving of steel sheet piling.

#### 5.4 EMBANKMENT FOR POSSIBLE DETOUR

The construction of a detour embankment is not expected with the proposed method of construction but the following are some brief comments for the construction of detour (if necessary) based on Boreholes D1 through D5.

If a detour is to be constructed it will probably match the existing Highway 66 embankment elevation (i.e. about El. 301.5 m) and since the o.g. levels typically range from 299 to 300 m the detour embankment can be expected to be 2.0 to 2.5 m high.

The boreholes show, after stripping the existing organics soils (about 0.1 to 0.2 m can be expected), the exposed subgrade soils can be expected to consist of silt (with the exception of Borehole D5 where the silt is overlain by an approximately 1.0 m thick surficial silty clay layer).

Based on the borehole data, no foundation failures are anticipated for up to about 2.5 m embankments. Normal 2H:1V side slopes can be used.

All organic and otherwise unsuitable soils should be removed within an envelope given by an imaginary slope no steeper than 1:1 from the toe of the proposed embankment. After stripping, the exposed subgrade should be inspected and approved. It should then be compacted, where feasible, from the surface using a suitable compactor.

Proper benching of the existing embankment slope should be implemented if and where abutting into existing embankments, as per MTO procedures and in accordance with OPSD 208.010.

The materials used for the construction of the embankment fills should consist of approved, acceptable earth fill. The embankment fill should be placed on the approved and properly rolled (where feasible) subgrade in lifts not exceeding 300 mm when loosely placed and each lift should be uniformly compacted to at least 95% of the material's Standard Proctor Maximum Dry Density. Embankment construction should be carried out in conformance with SP206S03

Embankment loadings would likely result in a settlement of the order of 45 mm (for an embankment height of 2.5 m) due to the settlement of natural foundation soils. About one-third of this settlement should take place within one month, with the majority of the remaining within the next six months.

In addition, the settlement of the new embankment fills under their own weight can be expected to occur. If the embankment is constructed to MTO standards, this should not exceed 20 mm. The time rate will depend on the material used for construction. However, if SSM or granular soils are used, about half of this settlement should be completed within one month and the remaining half substantially completed within one year.

As these settlements are not excessive, neither surcharging nor preloading is considered necessary for a detour embankment.

Proper erosion control measures should be implemented both during the construction and permanently. This can be achieved by prompt seed and cover (OPSS 572) or sodding (OPSS 571).

## 5.5 FROST PROTECTION

Design frost protection for the general area is 2.4 m. A permanent soil cover of at least 2.4 m or its thermal equivalent is therefore required for frost protection. In case of riprap (rock fill), only one half of the rock fill thickness should be assumed to be effective in providing frost protection.

## 6. CLOSURE

We recommend that once the details of the project are finalized, our recommendations be reviewed for their specific applicability.

The Limitations of Report, as quoted in Appendix F, are an integral part of this report.

### SHAHEEN & PEAKER LIMITED



Gwangha Roh, Ph.D., EIT



Zuhtu Ozden, P.Eng.



K. R. Peaker, Ph.D, P.Eng.



ZO:tr/idrive





# Appendix F

## Limitations of Report

## **LIMITATIONS OF REPORT**

The conclusions and recommendations given in this report are based on information determined at the testhole locations. The information contained herein in no way reflects on the environment aspects of the project, unless otherwise stated. Subsurface and groundwater conditions between and beyond the testholes may differ from those encountered at the testhole locations, and conditions may become apparent during construction, which could not be detected or anticipated at the time of the site investigation. The benchmark and elevations used in this report are primarily to establish relative elevation differences between the testhole locations and should not be used for other purposes, such as grading, excavating, planning, development, etc.

The design recommendations given in this report are applicable only to the project described in the text and then only if constructed substantially in accordance with the details stated in this report.

The comments made in this report on potential construction problems and possible methods are intended only for the guidance of the designer. The number of testholes may not be sufficient to determine all the factors that may affect construction methods and costs. For example, the thickness of surficial topsoil or fill layers may vary markedly and unpredictably. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusions as to how the subsurface conditions may affect their work. This work has been undertaken in accordance with normally accepted geotechnical engineering practices.

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Shaheen & Peaker Limited accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.