

**FOUNDATION INVESTIGATION & DESIGN REPORTS
PROPOSED CULVERT (C5) REPLACEMENT
AT STATION 25+145 ON HIGHWAY 6
SOUTH OF DURHAM SOUTH TOWN LIMITS AND
NORTH OF GREY COUNTY ROAD 9, ONTARIO
G.W.P. 338-97-00
GEOCRES NO. 41A-199**

Prepared For:

UMA/AECOM ENGINEERING LIMITED

Prepared by:

SHAHEEN & PEAKER LIMITED

**Project: SPT1174B
June 6, 2008**



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G.W.P. 338-97-00**

1. INTRODUCTION

Shaheen & Peaker Limited (S&P) was retained by UMA/AECOM Engineering Limited (UMA) to conduct a foundation investigation for the proposed Highway 6 vertical realignment and culvert replacements and/or extensions from 1.1 km south of Grey County Road 9 (North Junction) at Station 21+100 through Village of Varney northerly to Township of Durham South Limits at Station 11+870 between the Counties of West Gray and North Wellington in Ontario.

As part of the detail design for the proposed improvements on Highway 6, a foundation investigation was required for the detail design of the replacement of the culvert structure (C5) at Station 25+145.

The Terms of Reference (TOR) for this investigation was outlined in the Request for Proposals (RFP) by the Ministry of Transportation (MTO) under Purchase Order Number 3004-E-0042 dated January 2005 and subsequent S&P proposal PO7413. The work was performed in accordance with Consultant Agreement No. 3004-E-0042.

The purpose of this investigation was to obtain subsurface information at the site by means of exploratory boreholes. This report presents the findings of the geotechnical investigation at this site.

2. PHYSIOGRAPHY

According to the Physiography of Southern Ontario (by Putnam & Chapman) and the Ontario Geological Survey Map P.2715, the study area lies in the area known as the Horseshoe Moraines. The Horseshoe Moraines has two main distinguishing features; i.e., irregular sand and gravel knobs and ridges (sand plain and kame moraine), and gravel or swamp-covered valleys. These granular deposits constitute aquifers associated primarily with kame deposits at or near the ground surface within a larger more extensive regional till plain. The existing gravel pit in Durham is part of the moraine spillway.

Existing subsurface information from Geocres database indicates that the overburden in this area primarily consists of sand and gravel. However, south of the CPR Railway (which runs

east-west) and east of CNR Railway limestone bedrock was encountered at about El. 1127 ft (344 ± m) during earlier geotechnical investigations.

According to Ontario Department of Mines Map 2039, entitled distribution of Limestone, Dolomite and Precambrian Pebbles in Gravels of Southern Ontario, the overburden (glacial drift), in this general area, is underlain by bedrock of predominately Guelph-Lockport-Amabel Formations with occasional Ancaster Chert beds. The bedrock composition generally consists of 90% dolomite, 3% limestone and 6% Pre-Cambrian rock. However, some shale and occasional gypsum and salt inclusions may also be found in the surrounding area.

Within the project limits, the grade of Highway 6 generally rises from about El. 377.4 m at Station 21+100 to about El. 386 m at Station 24+175, then it drops down to El. 384 m at Station 24+440 and generally rolls up to about El. 390 m at Station 24+700 and down to about El. 349 m at Station 10+700, and up to about El. 353.0 m at Station 10+870 (northern limit of contract), and up to El. 358 m at Station 11+175.

3. INVESTIGATION PROCEDURES

During the early phases of the projects, the existing Culvert C5 at Sta. 25+145 is a 0.91 x 0.91 m open bottom concrete structure was proposed to be extended to accommodate a new Northbound Passing Lane from Sta. 24+200 to 26+400. Accordingly, an extension on upstream of this culvert east of the existing highway was proposed, as well as the replacement of existing retaining walls. On that basis, four boreholes were drilled (all on the right side of the highway) for the proposed culvert extension and retaining walls. Later, it was decided to replace the structure (as well as extending it). Therefore, another borehole was drilled on the left side of the highway (for the replacement of the culvert).

The field investigation at this site was carried out during several periods from August 22, 2006 to May 16, 2007. The field investigation consisted of drilling and sampling of three boreholes for the culvert replacement/extension (Boreholes C5-1, C5-2 and C5-3) and two boreholes (Boreholes C5-RW1 and C5-RW2) for the associated retaining/wing walls, to a maximum depth of 9.6 m below the ground surface.

The initial four boreholes were drilled using solid stem or hollow stem augers run by truck and track mounted drill rigs owned and operated by Walker Drilling Limited. Borehole C5-3 which was put down in 2007 was advanced by Aardvark Drilling Inc. (for the supplementary investigation). All the boreholes were drilled under the full time supervision of geotechnical engineers from S&P.

Sampling in the boreholes was conducted at frequent intervals of depth by the Standard Penetration Test (SPT) method, as specified in ASTM D1586. This 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

(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 and this gives an indication of the consistency or the compactness condition of the soil deposit. Refusal was generally defined by reaching competent material for which the resistance measured by the Standard Penetration Test exceeds 100 blows per 0.3 m of penetration.

Water level observations in the open boreholes were made during drilling and at the completion of each borehole. In addition, piezometer was installed in Borehole C5-3. The piezometer allows monitoring of groundwater levels over time without undue interference/impact from surface water.

At the completion of drilling, all boreholes drilled were grouted and sealed using a cement/bentonite mixture. Borehole with the installed piezometer (C5-3) was sealed with bentonite above the slotted portion of the pipe and at ground surface.

The borehole locations were measured approximately by S&P field staff with reference to the local features, which were converted to station and offset measurements. The corresponding geodetic elevations and coordinates for the boreholes were provided to us by UMA.

A laboratory testing program, consisting of natural moisture content tests and grain-size analyses, was performed on selected soil samples.

The results of drilling, in-situ testing and water level measurements, as well as laboratory soil testing are summarized on the Record of Borehole Sheets in Appendix A.

The results of the laboratory tests are also presented separately in Appendix B.

4. SUBSURFACE CONDITIONS

From the information provided to us by UMA, the existing culvert at Sta. 25+145 is an open bottom concrete culvert, about 0.91 m high, 0.91 m wide and 22.9 m long. The invert elevation of the existing culvert is at El. 386.1 m on the upstream side and El. 385.9 m on the downstream side.

The soil conditions encountered at the location of Culvert C5 are discussed in Section 4.1 while the subsurface conditions encountered at the area of the originally proposed retaining walls are discussed in Section 4.2. Details of the stratigraphy encountered in the boreholes are presented on the Record of Borehole Sheets in Appendix A and on the soil strata drawings in Drawings 5B and 5C. The following paragraphs are only meant to complement and amplify these data.

4.1 CULVERT C5 SITE

4.1.1 EMBANKMENT FILL

Borehole C5-1, drilled on the right (east) shoulder of the highway from El. 388.2 m, contacted an approximately 3.0 m thick embankment fill. The top 0.4 m of the fill at the borehole location consists of granular pavement fill (i.e. sand & gravel). Below 0.4 m and extending to 1.7 m below the ground surface or to El. 386.5 m, the embankment fill was found to consist of sand with some gravel and silt. This is a granular (non-cohesive) material.

At 1.7 m depth (El. 386.5 m) an approximately 0.5 m thick organic clayey silt layer/pocket with some sand content was contacted to El. 386.0 m. This is a basically cohesive soil and based on an N-value of 6 blows/0.3 m, its consistency is described as firm. Due to its somewhat organic nature, it can be expected to have a relatively compressible structure.

At 2.2 m below the ground surface or at El. 386.0 m, another granular fill consisting of gravelly sand with traces of silt was contacted. This material was found to extend to 3.0 m or to El. 385.2 m. The grain-size distribution of a sample recovered from this lower fill layer was determined in the laboratory and the test yielded the following results:

Gravel	20%
Sand	72%
Silt and Clay	8%

As shown in Figure B5-1 in Appendix B, the tested material can be described as gravelly sand fill meeting the gradation requirements for Granular 'B' Type I.

A Standard Penetration test performed in the granular fill in Borehole C5-1 below 2.2 m depth yielded an N-value of 16 blows/0.3 m, indicating a compact condition.

4.1.2 TOPSOIL

Boreholes C5-2 and C5-3, which were put down from the bottom of the highway embankment, contacted a topsoil layer extending to a depth of approximately 0.2 m and 0.3m below the ground surface or to El. 386.5 and 385.6 m in Boreholes C5-2 and C5-3, respectively.

4.1.3 SANDY SILT (POSSIBLE FILL)

In Borehole C5-3, below the topsoil, a sandy silt deposit with traces of clay and gravel was encountered at a depth of 0.3 m below the ground surface. This deposit was found to extend to a depth of 3.3 m below the ground surface or to El. 382.6 m. From the presence of organics (e.g. topsoil) at a depth of 3.0 m, the deposit was identified as a possible fill

related to the construction activities when the existing culvert was constructed. Alternatively, the presence of organics may be due to its alluvial origin.

Standard Penetration Test performed in this deposit yielded N-values ranging from 4 to 5 blows/0.3 m, indicating a loose to very loose condition.

The measured natural moisture contents of samples recovered from this deposit range from 10% to 38%, mostly about 10%.

4.1.4 ORGANIC SILT

Underneath the topsoil layer in Borehole C5-2 and the embankment fill in Borehole C5-1, a layer of organic silt (mixed with alluvial sand and traces to some gravel in Borehole C5-2) was encountered. The thickness of the deposit was 0.4 m in Borehole C5-1 (i.e. beneath the embankment fill) and 3.5 m in Borehole C5-2. It was found to extend to El. 384.8 m and 383.1 m, respectively. It is possible that at Borehole C5-2 location the deposit was disturbed by the construction activities when the existing culvert was first built.

This is a basically fine-grained granular (i.e. cohesionless) material.

Standard penetration tests performed in this deposit yielded N-values ranging from 7 to 17 blows/0.3m, indicating a loose to compact but generally a loose condition.

The measured moisture contents for this material ranged from 16 to 53%.

4.1.5 SAND AND GRAVEL TO SANDY GRAVEL

Underlying the organic silt in Boreholes C5-2 and C5-3 at depths/elevations of 3.7 m/El. 383.1 m and 3.3 m/El. 382.6 m, a coarse granular deposit was contacted. The composition of the deposit ranges from sand and gravel to sandy gravel with traces to some silt. It was found to extend to depths of about 6.0 m (El. 380.8 m) and 6.9 m (El. 379.0 m) in Boreholes C5-2 and C5-3, respectively.

Grain-size analysis performed on two samples from Boreholes C5-2 and C5-3 yielded the following grain-size distribution (see Figures B5-2 and B5-3 in Appendix B).

Gravel	44 – 57%
Sand,	32 – 38%
Silt & Clay	11 – 18%

Standard Penetration tests performed in this deposit yielded N-values ranging from 3 to 55 blows/0.3 m, indicating a very loose condition near top and very dense condition for rest of this layer in Borehole C5-2 and dense to very dense condition at the top portion and compact condition at the bottom portion of the stratum in Borehole C5-3.

The measured natural moisture contents of this granular deposit range from 5 to 16%.

4.1.6 SILTY FINE SAND

Below the embankment fill and organic silt in Borehole C5-1, a deposit of silty fine sand was encountered at a depth of 3.4 m below the ground surface or at El. 384.8 m. The deposit was found to extend to a depth of 8.6 m below the ground surface or to El. 379.6 m. Its colour was noted to dark brown to brown and from this it is surmised that this is likely to be an alluvial soil containing traces of organic soil.

Standard Penetration tests performed in this deposit yielded N-values ranging from 5 to 7 blows/0.3 m in the upper $4 \pm$ m of the deposit (i.e. to about El. 381 m), indicating a loose condition. Below this depth an N-value of 62 blows/0.3 m was recorded which indicates a very dense relative density.

4.1.7 SANDY SILT

Underlying the surficial soils mentioned in the preceding paragraphs, all three boreholes contacted a sandy silt material. This deposit was contacted at depths/elevations of 8.6 m/El. 379.6 m (Borehole C5-1), 6.0 m/El. 380.8 m (Borehole C5-2) and 6.9 m/El. 379.0 m (Borehole C5-3) and extended to the termination of the boreholes.

This is a fine-grained granular (non-cohesive) material and Standard Penetration tests performed in the deposit yielded N-values ranging from 39 to in excess of 80 blows/0.3 m penetration, indicating a dense to very dense condition.

The measured natural moisture contents of this stratum range from 17 to 21%.

4.1.8 GROUNDWATER CONDITIONS

Groundwater levels in the open boreholes were observed during the drilling and at the completion of each borehole. In addition a piezometer installed in Borehole C5-3 to allow ground water monitoring over a prolonged period of time, without interference from surface water. The observations and recorded values are shown on the individual Record of Boreholes sheets presented in Appendix A.

The results indicate that free-standing water was found in the open boreholes upon their completion at depths/elevations of 7.6 m/El. 380.6 m and 6.3 m/380.4 m, Boreholes C5-1 and C5-2, respectively. These values may, however, not represent the stabilized groundwater levels, due to the fact that the boreholes were backfilled upon their completion (i.e. possible insufficient time for the water level to stabilize). The groundwater level in the piezometer installed in Borehole C5-3 was recorded at a depth of 5.1 m or at El. 380.8 m

about two days after the installation. Based on these observations, it is our opinion that the groundwater level at the site was at about El. 381 m at the time of our investigation.

It should also be pointed out that the groundwater is subject to seasonal fluctuations and fluctuations in response to major weather events. In addition, the water table at the site will be influenced by the water level in the water course.

4.2 ORIGINALLY PROPOSED RETAINING WALL BOREHOLES

In addition to the culvert boreholes (described above), two boreholes (C5-RW1 and C5-RW2) were drilled to a maximum of 6.7 m depth on the right side of the highway at the locations shown on the Borehole Location Plan Drawing No. 5A. These boreholes were advanced to evaluate the subsurface conditions in the area of the originally proposed retaining walls.

Boreholes C5-RW1 and C5-RW2, which were located just outside the primary floodplain (El. 387.6 and 386.7 m, respectively), encountered a surficial topsoil underlain by an essentially granular deposit consisting of sandy silt to silty sand till with occasional cobbles and boulders. This deposit is in turn underlain by a gravelly sand till which is in turn underlain by silty fine sand, followed by gravelly sand in Borehole C5-RW1.

4.2.1 TOPSOIL

At the location of Boreholes C5-RW1 and C5-RW2, the ground surface was covered by about 0.15 m of topsoil.

4.2.2 SANDY SILT TO SILTY SAND TILL

Below the topsoil in Boreholes C5-RW1 and C5-RW2, a sandy silt to silty sand till with occasional cobbles and boulders was encountered; extending to a depths of 2.2 m and 4.4 m respectively or to El. 385.4 m to El. 382.4 m.

Grain-size analyses performed on two samples from the deposit yielded the following grain-size distribution.

Gravel	10 - 20%
Sand,	40 - 41%
Silt & Clay	39 - 50%

as shown in Figure B5-4, in Appendix B.

Standard Penetration tests performed in this basically granular (i.e. non-cohesive) deposit yielded N-values ranging from 26 blows/0.3 m to 50 blows/0.08 m penetration, indicating compact to very dense but generally very dense condition.

4.2.3 GRAVELLY SAND TILL

Below topsoil and sandy silt to silty sand till in Boreholes C5-RW1 and C5-RW2, a coarser glacial till deposit was contacted at 2.2 m and 4.4 m below ground surface and extending to depths of about 4.5 m and 6.3 m (end of the borehole) in Boreholes C5-RW1 and C5-RW2 respectively or to El. 383.1 m and El. 380.5 m (end of the borehole), respectively.

This deposit is cohesionless (i.e. granular) soil. During the drilling, the presence of occasional cobbles and boulders was inferred in the deposit.

Standard Penetration tests performed in this coarse grained glacial deposit yielded N-values ranging from 68 blows/0.23 to 50 blows/0.08 m penetration, indicating a very dense condition.

The measured natural moisture contents samples recovered from this deposit generally range from 3 to 8%.

4.2.4 SILTY FINE SAND

Below the glacial deposits, at the location of Borehole C5-RW1, a silty fine sand layer (about 0.8 m in thickness) was contacted at about 4.5 m depth (El. 383.1 m) and extended to 5.3 m or to El. 382.4 m.

A Standard Penetration test performed in this deposit yielded an N-value of 9 blows/0.3 m penetration, indicating loose condition.

4.2.5 GRAVELLY SAND

Below the silty fine sand in Borehole C5-RW1, a gravelly sand deposit was encountered at 5.3 m depth (El. 382.4 m), extending to the termination of this borehole at a depth of 6.7 m (El. 380.9 m).

The measured N-values in this deposit are 33 blows/0.3 m and 50 blows/0.03 m penetration, indicating a compact to very dense condition.

The measured natural moisture contents range from 4 to 8%.

4.2.6 GROUNDWATER CONDITIONS

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


Both boreholes were dry upon their completion. This may, however, not represent the stabilized groundwater conditions.

It should also be pointed out that the groundwater is subject to seasonal fluctuations and fluctuations in response to major weather events. In addition, the water table at the site will be influenced by the water level in the water course.

SHAHEEN & PEAKER LIMITED


Ramon Miranda, P.Eng.




Z.S. Ozden, P.Eng.



Drawings

METRIC

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

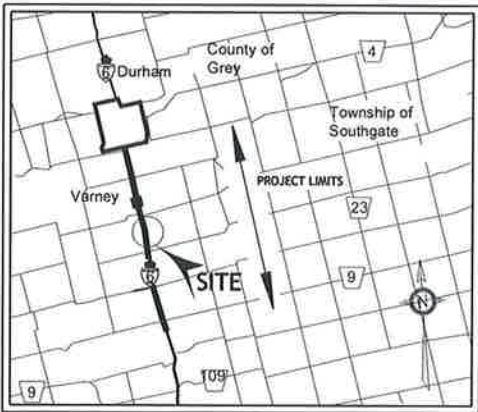
NOTES:
FOR DETAILED SUBSURFACE CONDITIONS
REFER TO RECORD OF BOREHOLE SHEETS.

CONT No.
GWP: 338-97-00

Highway 6, Durham
Culvert C5 @ Sta. 25+145
Borehole Location Plan



SHAHEEN & PEAKER LIMITED



KEY PLAN
N.T.S

LEGEND

Borehole

No.	ELEV.	CO-ORDINATES	
		NORTH	EAST
C5-1	388.2	4 886 284.1	200 505.5
C5-2	386.7	4 886 283.0	200 516.0
C5-RW1	387.6	4 886 263.0	200 511.5
C5-RW2	386.7	4 886 303.1	200 516.5
C5-3	385.9	4 886 296.3	200 490.4

NOTES

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

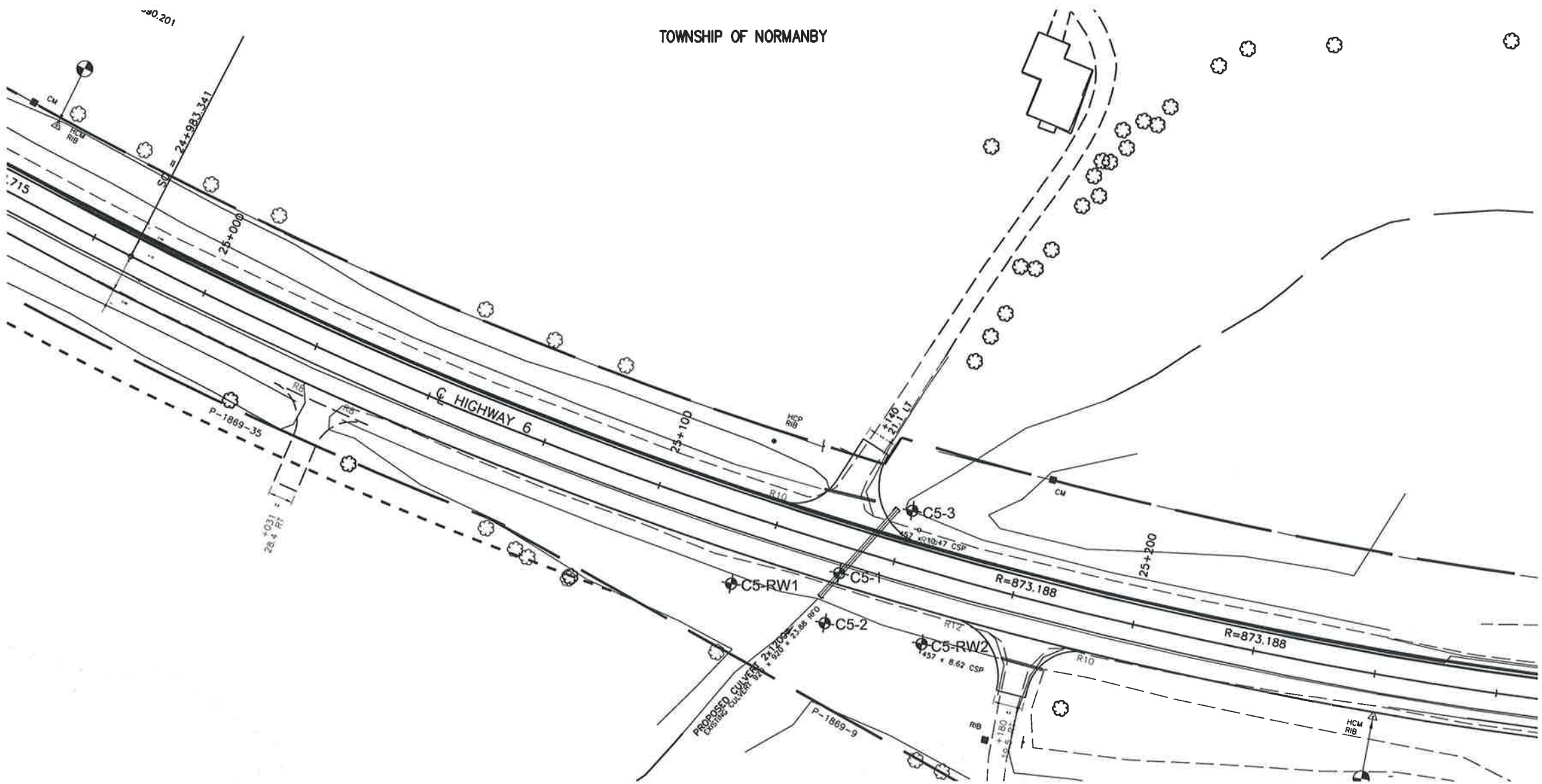
This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

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. 41A-199

SPT 1174			DIST
SUBM'D	CHECKED	DATE Jan., 2008	SITE
DRAWN SM	CHECKED RM	APPROVED ZO	DWG 5A



TOWNSHIP OF NORMANBY



BOREHOLE LOCATION PLAN



METRIC

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

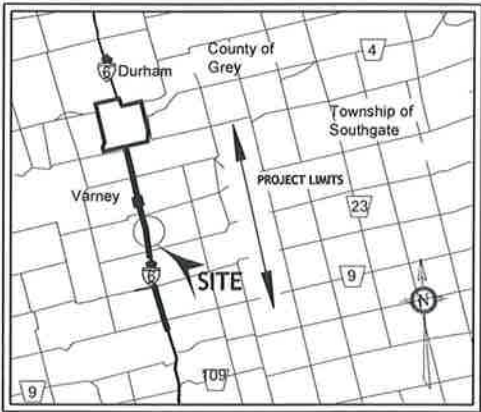
NOTES:
FOR DETAILED SUBSURFACE CONDITIONS
REFER TO RECORD OF BOREHOLE SHEETS.

CONT No.
GWP: 338-97-00

Highway 6, Durham
Culvert C5 @ Sta. 25+145
SOIL STRATIGRAPHY



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
C5-1	388.2	4 886 284.0	200 505.6
C5-2	386.7	4 886 283.0	200 516.0
C5-3	385.9	4 886 296.3	200 490.4

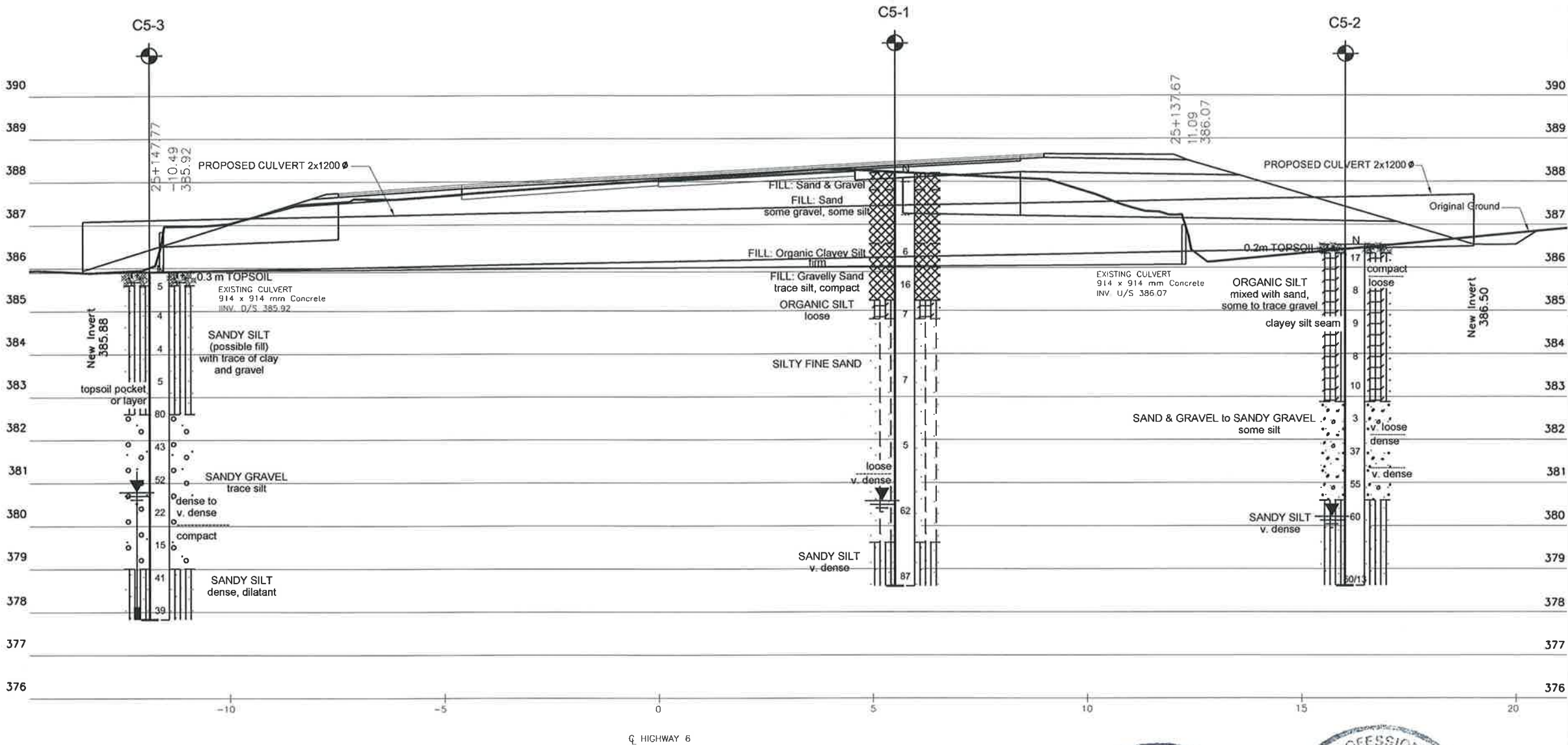
=NOTE=

- The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries assumed from geological evidence.
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REV.	DATE	BY	DESCRIPTION

Geocres No. 41A-199

SPT 1174			DIST
SUBM'D	CHECKED	DATE Jan., 2008	SITE
DRAWN SM	CHECKED RM	APPROVED ZO	DWG 5B



PROFILE ALONG CULVERT C5 @ STA. 25+140



Appendix A

Record of Borehole Sheets

RECORD OF BOREHOLE No C5-1

1 OF 1

METRIC

PROJECT SPT1174
BOREHOLE TYPE Hollow Stem Augers
DATUM Geodetic

LOCATION Hwy 6, Durham - Sta. 25+145, 5.5m Rt C/L
DATE 8/22/2006

ORIGINATED BY JL
COMPILED BY XS
CHECKED BY FS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W _p W W _L				GR SA SI CL				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%)								
388.2	Ground Surface						20	40	60	80	100										
0.0	FILL: Sand & Gravel brown, damp		1	AS	---																
387.8																					
0.4	FILL: Sand some gravel, trace to some silt, damp		2	AS	---																
386.5																					
1.7	FILL: Organic Clayey Silt some fine sand		3	SS	6																
386.0	dark brown, moist, firm																				
2.2	FILL: Gravelly Sand trace silt		4	SS	16																
385.2	brown, damp, compact																				
3.0	ORGANIC SILT black, moist, loose		5	SS	7																
384.8																					
3.4	SILTY FINE SAND dark brown																				
			6	SS	7																
			7	SS	5																
			8	SS	62																
379.6																					
8.6	SANDY SILT brown, wet																				
	very dense																				
	wet																				
			9	SS	87																
378.6																					
9.6	End of borehole.																				
	* Water level in open borehole at 7.6m (El. 380.6m) upon completion (not stabilized).																				

RECORD OF BOREHOLE No C5-2

1 OF 1

METRIC

PROJECT SPT1174 LOCATION Hwy 6, Durham - Sta. 25+140, 16m Rt. C/L ORIGINATED BY JL
 BOREHOLE TYPE Hollow Stem Augers DATE 10/3/2006 COMPILED BY HL
 DATUM Geodetic CHECKED BY FS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W _p W W _L				GR	SA	SI	CL
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%)							
386.7	Ground Surface						20	40	60	80	100									
386.6	0.2m TOPSOIL		1	SS	17															
0.2		compact																		
		loose	2	SS	8															
	ORGANIC SILT mixed with sand, some to trace gravel, black to dark brown, moist																			
		clayey silt seam	3	SS	9															
			4	SS	8															
		compact	5	SS	10															
383.1																				
3.7	SAND & GRAVEL TO SANDY GRAVEL some silt, brown, moist to wet		6	SS	3															
		very loose																		
		dense	7	SS	37															
		very dense	8	SS	55															
380.8																				
6.0	SANDY SILT oxidised brown, moist to wet very dense		9	SS	60															
378.8			10	SS	50/13															
7.9	End of borehole.																			
	* Water level in open borehole at 6.3m (El. 380.4 m) upon completion (not stabilized).																			

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

RECORD OF BOREHOLE No C5-3

1 OF 1

METRIC

PROJECT SPT1174 LOCATION Hwy 6, Durham - Sta. 25+151, 10.7 m Lt C/L ORIGINATED BY NE
 BOREHOLE TYPE Hollow Stem Augers DATE 5/16/2007 COMPILED BY XS
 DATUM Geodetic CHECKED BY NE

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
385.9	Ground Surface						20	40	60	80	100						
0.0 385.6 0.3	0.3 m TOPSOIL , trace gravel		1	SS	5												
	SANDY SILT (possible fill) with trace of clay and gravel brown, loose to very loose topsoil pocket or layer		2	SS	4												
			3	SS	4												
			4	SS	5												
382.6 3.3	SANDY GRAVEL trace silt, brown damp, dense to very dense compact, wet		5	SS	80												
			6	SS	43												
			7	SS	52												
			8	SS	22												
			9	SS	15												
379.0 6.9	SANDY SILT brown, dense, wet, dilatant		10	SS	41												
			11	SS	39												
377.8 8.1	End of borehole. Monitoring well installed to depth of 8.1 m. Water level inwell: May 18, 2007 — 5.1 m (El. 380.8 m).																

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

RECORD OF BOREHOLE No C5-RW1

1 OF 1

METRIC

PROJECT SPT1174 LOCATION Hwy 6, Durham - Sta. 25+120, 14m Rt C/L ORIGINATED BY JL
 BOREHOLE TYPE Solid Stem Augers DATE 10/3/2006 COMPILED BY XS
 DATUM Geodetic CHECKED BY FS

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT						PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa											WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE													
								20	40	60	80	100									
387.6	Ground Surface																				
387.6 0.2	0.15m TOPSOIL		1	SS	28		387							○							
	SANDY SILT to SILTY SAND TILL brown, moist compact very dense		2	SS	27		386							○							
		3	SS	63		385								○							
385.4 2.2		4	SS	50/13		384								○							
	GRAVELLY SAND TILL occasional cobble brown, moist to damp very dense		5	SS	72/23		383							○							
		6	SS	68/23		382								○							
383.1 4.5		7	SS	9		381								○							
382.4 5.3	GRAVELLY SAND trace to some silt brown, moist very dense to dense		8	SS	50/3									○							
		9	SS	33										○							
380.9 6.7	End of borehole. Borehole dry upon completion.																				

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

RECORD OF BOREHOLE No C5-RW2

1 OF 1

METRIC

PROJECT SPT1174 LOCATION Hwy 6, Durham - Sta. 25+160, 14.5m Rt C/L ORIGINATED BY JL
 BOREHOLE TYPE Solid Stem Augers DATE 10/3/2006 COMPILED BY HL
 DATUM Geodetic CHECKED BY FS

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 ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W _p W W _L				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%)				
						20 40 60 80 100					10 20 30						
386.7	Ground Surface																
386.6 0.2	0.15m TOPSOIL		1	SS	26		386							○			
	compact																
	very dense		2	SS	86/23cm									○			
	SANDY SILT to SILTY SAND TILL occasional cobble / boulder brown, moist		3	SS	50/13cm		385							○			
			4	SS	50/13cm		384							○			
			5	SS	50/8cm		383							○			
			6	SS	50/13cm									○			
			7	SS	50/13cm		382							○			
382.4 4.4	GRAVELLY SAND TILL some pebbles, occasional cobble / boulder brown, oxidised, moist very dense		8	SS	50/15cm		381							○			
380.5 6.3	End of borehole. Borehole dry upon completion.		9	SS	50/10cm									○			

Appendix B

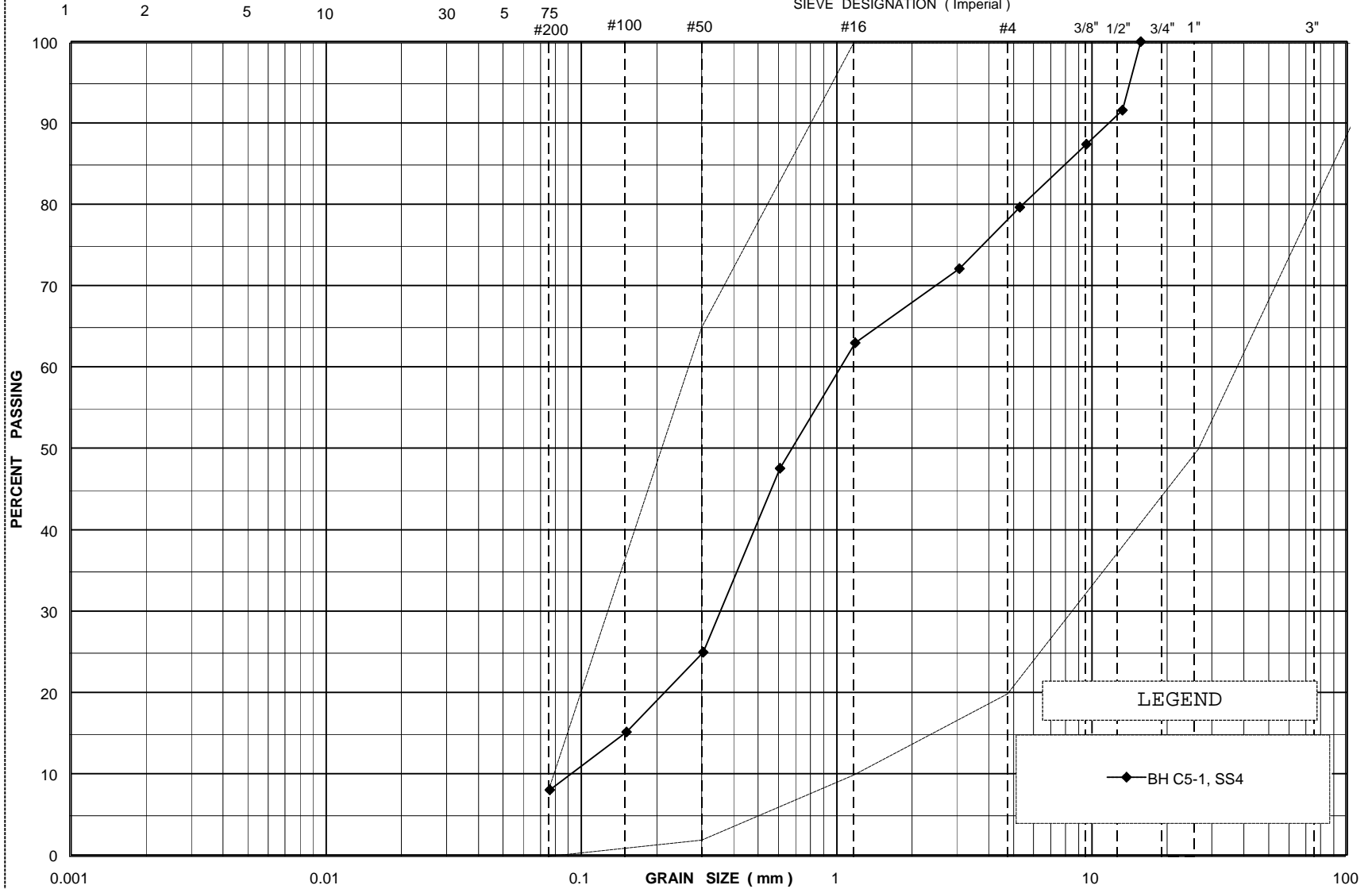
Laboratory Test Results

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT				SAND			GRAVEL	
				Fine	Medium	Coarse	Fine	Coarse

GRAIN SIZE IN MICROMETERS

SIEVE DESIGNATION (Imperial)



LEGEND

—◆— BH C5-1, SS4

SHAHEEN & PEAKER LIMITED

GRAIN SIZE DISTRIBUTION
GRAVELLY SAND FILL meeting the gradation requirements for Granular 'B'

FIGURE No. B5-1

G. W. P. 338-97-00

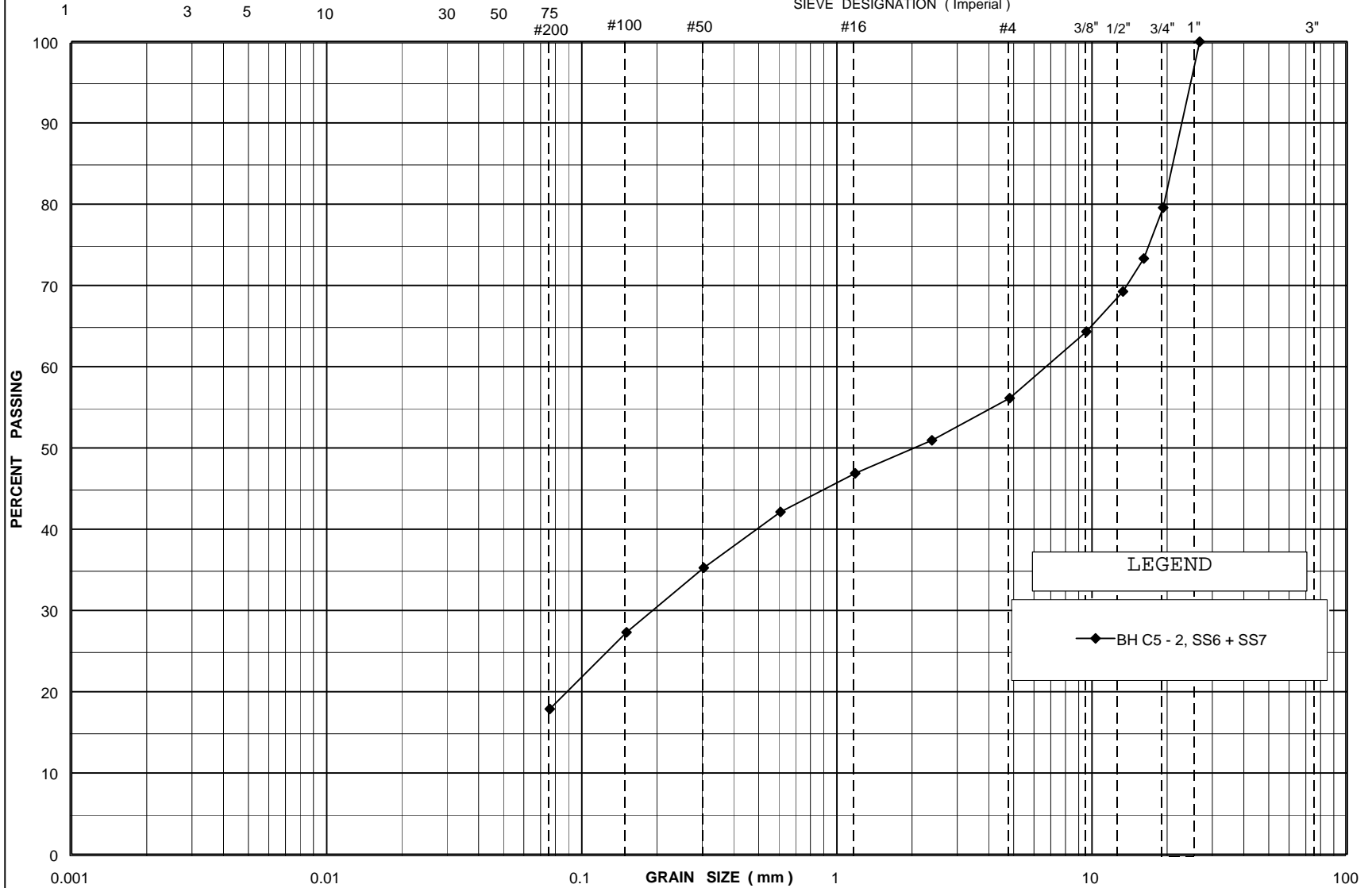
REF. No. SPT 1174

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse

GRAIN SIZE IN MICROMETERS

SIEVE DESIGNATION (Imperial)



LEGEND

—●— BH C5 - 2, SS6 + SS7

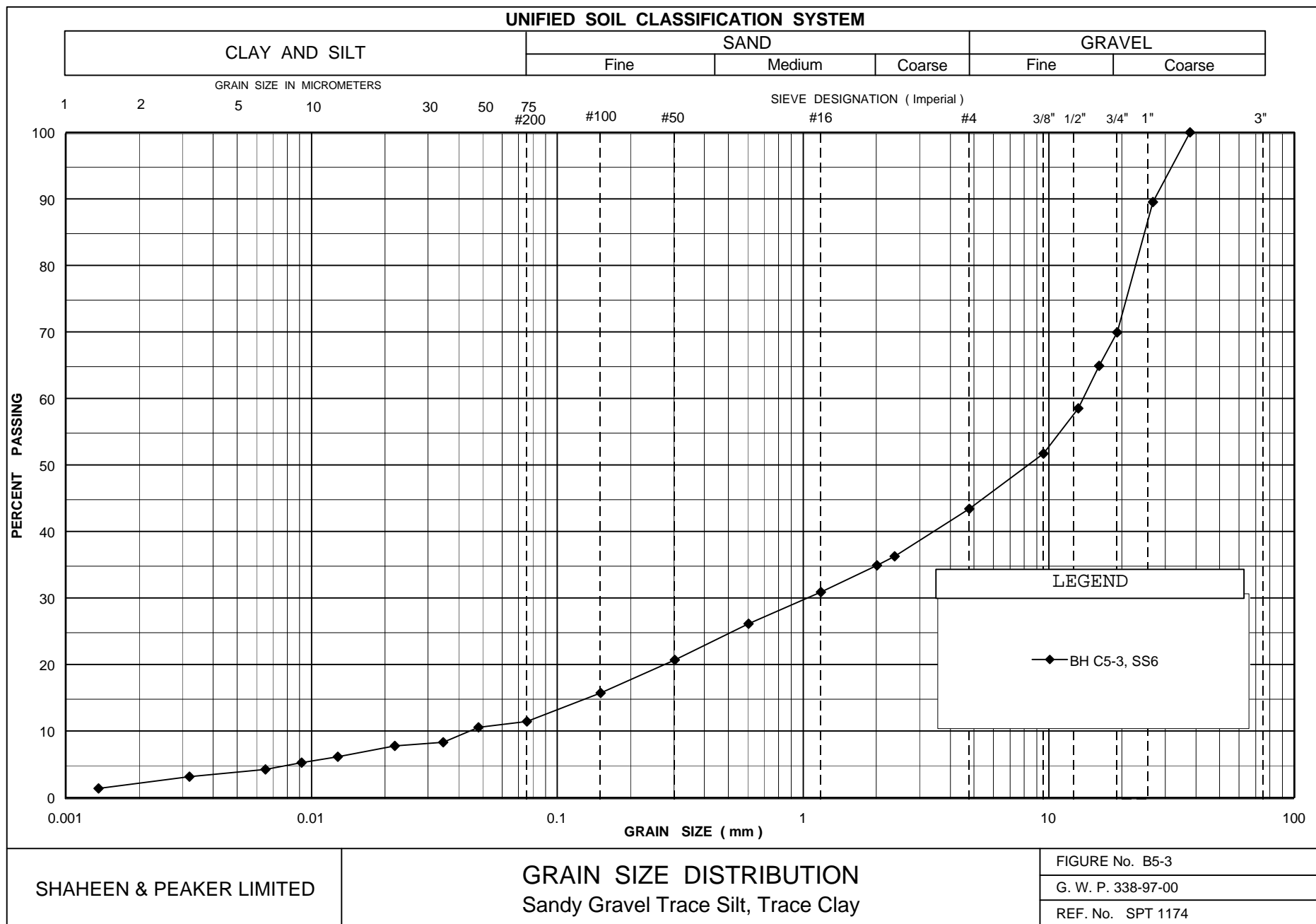
SHAHEEN & PEAKER LIMITED

GRAIN SIZE DISTRIBUTION
SAND & GRAVEL

FIGURE No. B5-2

G. W. P. 338-97-00

REF. No. SPT 1174



SHAHEEN & PEAKER LIMITED

GRAIN SIZE DISTRIBUTION

Sandy Gravel Trace Silt, Trace Clay

FIGURE No. B5-3

G. W. P. 338-97-00

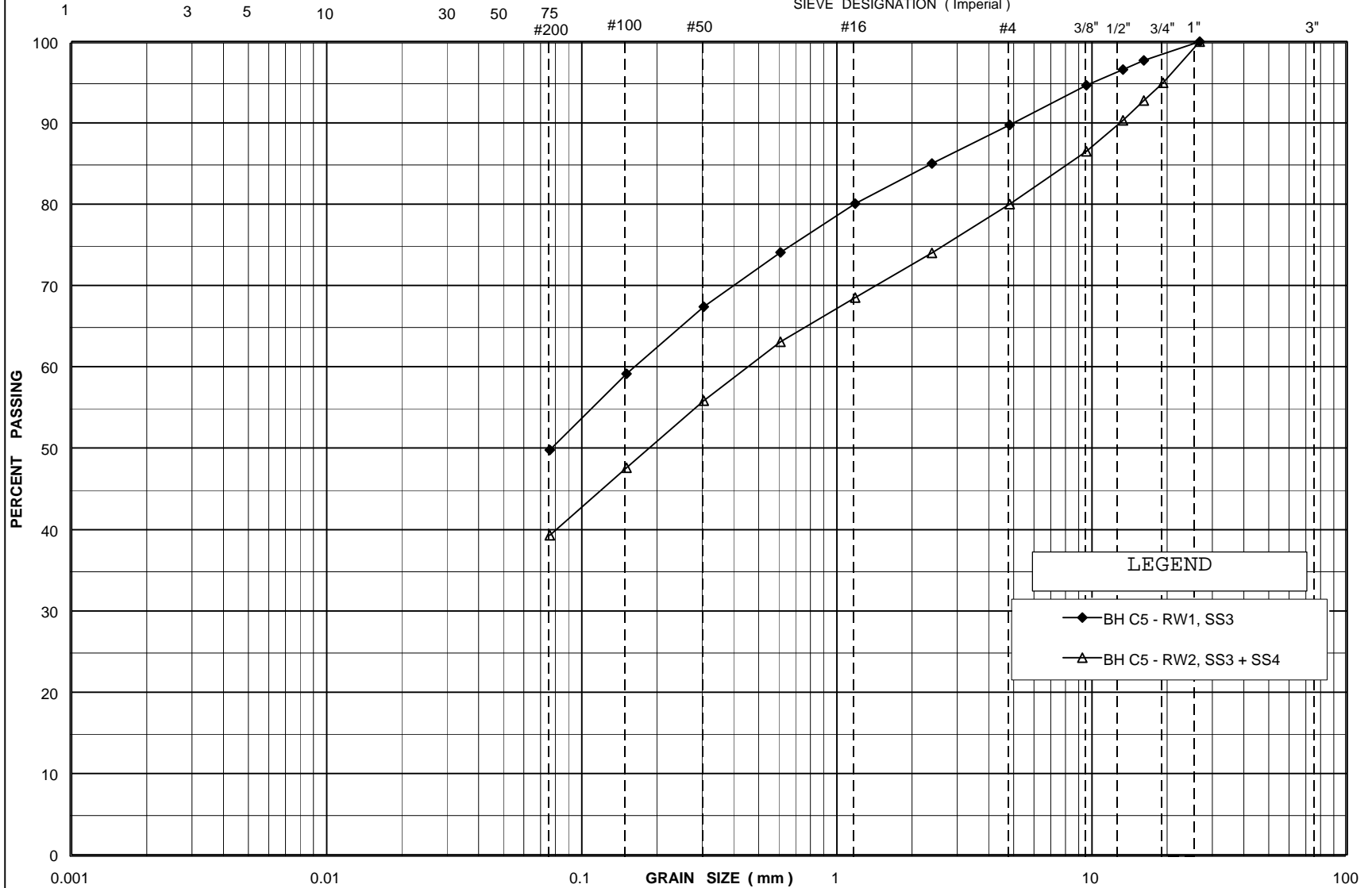
REF. No. SPT 1174

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse

GRAIN SIZE IN MICROMETERS

SIEVE DESIGNATION (Imperial)



LEGEND

- ◆— BH C5 - RW1, SS3
- △— BH C5 - RW2, SS3 + SS4

SHAHEEN & PEAKER LIMITED

GRAIN SIZE DISTRIBUTION
SANDY SILT to SILTY SAND TILL

FIGURE No. B5-3A

G. W. P. 338-97-00

REF. No. SPT 1174

Appendix C

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 \bar{N} .

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

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

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

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

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND 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
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	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
j_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
j_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
j	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
j_d	kN/m ³	UNIT WEIGHT OF DRY SOIL	I_p	%	PLASTICITY INDEX = $(W_L - W_p) / I_p$	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
j_{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
j'	kN/m ³	UNIT WEIGHT OF SUBMERGED SOIL						