

**FOUNDATION INVESTIGATION & DESIGN REPORTS
PROPOSED CAMP CREEK CULVERT (C10)
REPLACEMENT AT STATION 28+050 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-195

Prepared For:

UMA/AECOM ENGINEERING LIMITED

Prepared by:

SHAHEEN & PEAKER LIMITED

**Project: SPT1174D
February 8, 2008**



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

**FOUNDATION INVESTIGATION REPORT
PROPOSED CAMP CREEK CULVERT (C10)
REPLACEMENT AT STATION 28+050 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-195

Prepared For:

UMA/AECOM ENGINEERING LIMITED

Prepared by:

SHAHEEN & PEAKER LIMITED

**Project: SPT1174D
February 8, 2008**



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

Table of Contents

| | |
|--------------------------------------------|----------|
| 1. INTRODUCTION | 1 |
| 2. PHYSIOGRAPHY | 1 |
| 3. INVESTIGATION PROCEDURES | 2 |
| 4. SUBSURFACE CONDITIONS | 3 |
| 4.1 Camp Creek Culvert (Culvert C10) | 3 |
| 4.1.1 Embankment Fill | 4 |
| 4.1.2 Topsoil | 4 |
| 4.1.3 Silty Sand to Sandy Silt Till | 4 |
| 4.1.4 Groundwater Conditions | 5 |
| 4.2 Proposed Detour Lane | 5 |
| 4.2.1 Topsoil | 6 |
| 4.2.2 Sandy Silt to Silty Sand Till | 6 |
| 4.2.3 Sandy Silt..... | 6 |
| 4.2.4 Groundwater Conditions | 7 |

| | |
|--------------------------------------------|--------------------|
| DRAWINGS | DRAWING No. |
| BOREHOLE LOCATION PLAN | 1 |
| SOIL STRATIGRAPHY ALONG CULVERT C10 | 2 |
| SOIL PROFILE ALONG PROPOSED DETOUR | 3 |

APPENDIX A: RECORD OF BOREHOLE SHEETS

APPENDIX B: LABORATORY TEST RESULTS

APPENDIX C: EXPLANATION OF TERMS USED IN REPORT

APPENDIX D: SITE PHOTOGRAPHS

**FOUNDATION INVESTIGATION REPORT
PROPOSED CAMP CREEK CULVERT (C10) REPLACEMENT
AT STATION 28+050 ON HIGHWAY 6
SOUTH OF DURHAM SOUTH TOWN LIMITS AND
NORTH OF GREY COUNTY ROAD 9, ONTARIO
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 detail design of the proposed culvert replacements on Highway 6 from 1.1 km south of Grey County Road 9 (North Junction) at Station 21+100 northerly through the Village of Varney to Township of Durham South Limits at Station 11+887 in Grey County, Ontario.

As part of the detail design for the proposed improvements on Highway 6, a foundation investigation was required for the detail design of Camp Creek concrete culvert structure and possible construction of a detour lane during construction.

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 P07413. 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, as well as general comments and recommendations for design and construction of the proposed replacement of Camp Creek culvert and possible construction of a detour embankment.

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.

Geological information indicates that the overburden (glacial drift), in this general area, may be underlain by bedrock at relatively shallow depths (i.e. less than 10 m). The culvert site is located near the interface of Upper Silurian Salina and Middle Silurian Guelph Formations, which are approximately 420 million years old. The Salina Formation (the younger of the two) consists of dolostone, shale, gypsum and salt while the Guelph Formation consists of dolostone.

Within the project limits, the grade of Highway 6 generally rises from about El. 377 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 m at Station 10+870 (northern limit of contract), and up to El. 356 m at Station 11+175.

3. INVESTIGATION PROCEDURES

Based on the scope of work outlined in RFP document and our proposal, the foundation field investigation for Camp Creek culvert (C10) consisted of a total of 7 boreholes to evaluate the subsurface conditions in the areas of the proposed culvert replacement and a possible detour construction.

The field investigation at this site was carried out during several periods from August 21 to November 20, 2006. The field investigation consisted of drilling and sampling of 3 boreholes for the culvert replacement and 4 boreholes for possible highway detour (around culvert C10 as discussed in the following sections of this report). For the proposed culvert replacement, three boreholes were drilled (C10-1, C10-2 and C10-3), one at each end of the culvert and one at the crest of the embankment for culvert replacement to a maximum depth of 6.0 m below the existing ground surface.

In addition, four boreholes were put down along a possible detour near Camp Creek culvert (C10-D1 through C10-D4) to a maximum of 6.2 m depth below the ground surface.

All the boreholes were advanced using solid stem, or hollow stem augers run by truck and track mounted drill rigs owned and operated by Walker Drilling Limited. 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.

Water level observations in the open boreholes were made during drilling and at the completion of each borehole. In addition, two piezometers were installed in selected boreholes. These piezometers allow 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. The boreholes with piezometers were sealed with bentonite and grout above the slotted portion of the pipes 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 all the borehole were provided to us by UMA.

A laboratory testing program consisting of natural moisture content, grain-size analyses (sieve and hydrometer), 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 in Appendix B.

4. SUBSURFACE CONDITIONS

The soil conditions are discussed in the following sections. Details of the stratigraphy encountered in the boreholes are presented on the Record of Borehole Sheets in Appendix A. The locations of the boreholes at the site are shown on the Borehole Location Plan Drawing No. 1. Stratigraphy along the culvert is given in Drawing No. 2 while Drawing No. 3 shows the soil profile along proposed detour.

4.1 CAMP CREEK CULVERT (CULVERT C10)

The existing structure at Camp Creek crossing at Station 28+050 is a 6.1 m wide x 1.52 high x 26.8 m long open bottom concrete culvert with an invert elevation of 336.33 to 336.06 m.

At this location three boreholes were drilled along the existing culvert. Borehole C10-1 was advanced on the west (left) side of Highway 6 near the downstream-end of the existing culvert. Boreholes C10-2 and C10-3 were put down on the east (right) side of Highway 6 on the gravel shoulder and adjacent to the east-end (upstream-end) of the existing culvert, respectively, as shown on Drawing No. 1 and Drawing No. 2.

Borehole C10-2, drilled from the shoulder of the highway, encountered a pavement and embankment fill to a depth of about 2.6 m or to El. 336.0 m. Boreholes C10-1 and C10-3, put down from the o.g. level contacted a 0.2 to 0.3 m thick topsoil layer. Underlying the topsoil (Boreholes C10-1 and C10-3) and pavement fill (Borehole C10-2), the boreholes contacted a glacial deposit consisting of sandy silt to silty sand till with silty sand/sandy silt layers.

4.1.1 EMBANKMENT FILL

Borehole C10-2 contacted a 0.3 m thick granular road shoulder fill, consisting of sand & gravel. Underlying this and to a depth of 2.6 m (El. 336.0 m), the embankment fill consists of sand to sandy silt with traces of gravel and topsoil. The presence of occasional shale fragments was noted. As well, the presence of cobbles was inferred during drilling.

From a recorded N-value of 9 blows/0.3 m and the observations made during drilling the compactness condition of this basically granular fill is described as loose to compact

4.1.2 TOPSOIL

Boreholes, which were located within the Creek's floodplain, contacted a 0.2 to 0.3 m thick topsoil layer. In addition, some organic staining was noted (immediately below the topsoil) in the upper 0.2 m of the underlying inorganic soil.

It should be pointed out the thickness of topsoil and other organic soils can be expected to be variable, especially in the low-lying areas and near water courses.

4.1.3 SILTY SAND TO SANDY SILT TILL

Underlying the topsoil and embankment fill all three boreholes contacted (below elevations ranging from 336.9 to 336.0 m) a glacial till deposit consisting of a heterogeneous mixture of sandy silt to silty sand with some gravel and traces of clay size particles. The presence of silty sand to sandy silt layers/seams, as well as cobbles, was also noted. In particular, in Borehole C10-1, augering below 2.5 m became very difficult and refusal was encountered at 3.1 m (El. 333.1 m). Refusal to augering was also contacted in Boreholes C10-2 and C10-3 at depths of 6.0 m and 4.6 m or at El. 332.6 m and 331.8 m, respectively. From this it appears that a zone of frequent cobbles and boulders exist below about El. 333.1 m, or possibly bedrock surface.

The grain-size distribution of a sample from the deposit is given in Figure B10-1. The following grain-size distribution is indicated from the curve presented.

| | |
|---------|-----|
| Gravel: | 26% |
| Sand: | 28% |
| Silt: | 41% |
| Clay: | 5% |

The measured natural moisture contents of the basically granular (i.e. non-cohesive) deposit range from 7 to 19%, but are typically 9 to 11%. The higher moisture contents can be attributed to the silty sand and sandy silt layers.

Standard Penetration tests performed in this unit yielded N-values which ranged from 15 blows/0.3 m to 150 blows/0.08 m. These results indicate a compact to very dense relative density.

4.1.4 GROUNDWATER CONDITIONS

Groundwater conditions were observed during the drilling and upon completion of each open borehole. In addition, piezometers were installed in Boreholes C10-1 and C10-3.

Upon completion of the boreholes water levels were recorded at depths ranging from 0.6 to 0.8 m below o.g. or between Elevations 335.8 and 335.3 m. In the piezometer installed in Borehole C10-1 the water level in about a month later rose to 0.2 m or El. 335.9 m.

4.2 PROPOSED DETOUR LANE

Boreholes C10-D1, C10-D2, C10-D3 and C10-D4 were put down along the east side of the existing Highway 6 embankment between Stations 27+950 and 28+150 to investigate the subsurface conditions for a possible detour lane embankment which would be used during the construction of the culvert. The borehole locations are shown on Drawing No. 1 and a stratigraphic profile on Drawing No. 3.

The boreholes put down for the investigation were extended to depths ranging between 4.3 and 6.2 m below the ground surface adjacent to the highway embankment. A track mounted drilling rig equipped with standard soil testing and rock coring equipment was used to advance the boreholes. As shown on Drawing No. 1, Boreholes C10-2 and C10-3, drilled at the culvert location also provide subsurface information along the proposed detour lane route.

In the boreholes, Standard Penetration testing (SPT) was utilized to obtain soil samples and to obtain 'N'-values of the soil.

In general, the boreholes show, below some topsoil, the presence of a sandy silt to silty sand till deposit with some sandy gravel to sandy silt layers/lenses.

Details of the subsurface conditions encountered in the boreholes are given on the Record of Borehole Sheets and the individual strata are briefly described in the following paragraphs.

4.2.1 TOPSOIL

The boreholes show the presence of a surficial topsoil layer with a recorded thickness of 0.15 to 0.3 m at the borehole locations (generally 0.3 m).

It should be pointed out that the thickness of topsoil and other organic soils can be expected to be variable in between and beyond borehole locations, especially near watercourses and in low-lying areas.

4.2.2 SANDY SILT TO SILTY SAND TILL

The site is underlain, within the depths investigated, by a major glacial deposit consisting of silty sand to sandy silt till.

The deposit was encountered in the majority of the boreholes (except for Boreholes C10-D1 and C10-D3) immediately underlying the surficial topsoil layer. In Borehole C10-D1, the topsoil is underlain by a 0.2 m thick sand layer and the till was encountered at 0.5 m below the ground surface underlying this surficial sand layer. Similarly, in Borehole C10-D3, the topsoil is underlain by a 2.1 m thick gravel layer (consisting of angular dolostone fragments) with some sand and silt, below which the glacial till was contacted at 2.4 m depth.

The glacial till consists of a heterogeneous mixture of sandy silt to silty sand with some gravel. The grain-size distribution of a typical sample from the till is presented in Figure B10-1 in Appendix B. Visual examination of the soil samples showed that the till attains with increasing depth a typically somewhat coarser (silty sand till) nature with increased dolostone fragment (gravel) content. The presence of cobbles was also noted. The boreholes were typically terminated at 4.3 to 6.2 m below the ground surface upon encountering refusal to further augering probably on boulders or possibly on bedrock (hence the increase dolostone fragments with increased depth).

N-values recorded in the till ranges from 10 blows/0.3 m to 50 blows/0.08 m. These results indicate that the compactness condition of the soil deposit ranges from compact to very dense.

4.2.3 SANDY SILT

In addition to occasional thin interbeds/lenses of silt/silty sand in the glacial till, a 1.6 m thick layer/lense of sandy silt was contacted in Borehole C10-D4 from 1.4 m below the ground surface to 3.0 m below the ground surface.

Standard Penetration tests in the sandy silt yielded N-values of 7 and 10 blows/0.3 m, which indicate a loose condition. A visual examination of the soil samples recovered from the deposit indicated that it is a dilatant material and it was in a wet condition.

4.2.4 GROUNDWATER CONDITIONS

Groundwater conditions were observed in the open boreholes during drilling and upon completion of each borehole. The recorded levels, shown on the individual Record of Borehole Sheets, are not believed to represent the stabilized groundwater levels due to insufficient time available for the observations. In the piezometer installed in Borehole C10-3 (located immediately adjacent to the creek), the stabilized groundwater level was recorded at 0.6 m below the ground surface. Based on this, along with observations made during drilling of the boreholes, it is our opinion that at the time of our investigation the groundwater level was generally 0.6 to 1.5 m below the ground surface.

It should be pointed out that the groundwater level would be subject to seasonal fluctuations and variations in response to major weather events. It would also be controlled by the water level in the Creek.

SHAHEEN & PEAKER LIMITED


Ramon Miranda, P.Eng.


Z.S. Ozden, P.Eng.

ZO:tr/idrive



Drawings

METRIC

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

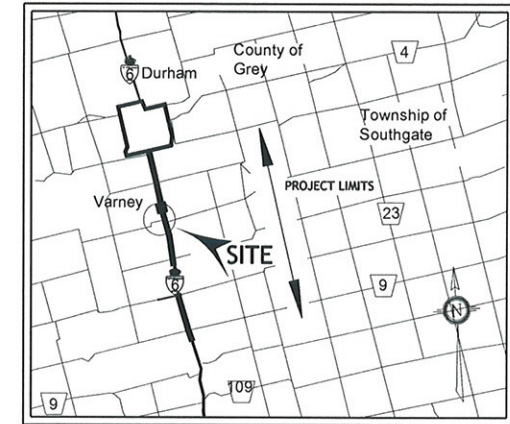
NOTES:
FOR DETAILED SUBSURFACE CONDITIONS
REFER TO RECORD OF BOREHOLE SHEETS.

CONT No.
GWP: 338-97-00

Highway 6, Durham
Camp Creek Culvert (C10) @ Sta. 28+050
BOREHOLE LOCATIONS



SHAHEEN & PEAKER LIMITED



KEY PLAN
N.T.S

LEGEND

Borehole

| No. | ELEV. | CO-ORDINATES | |
|--------|-------|--------------|-----------|
| | | NORTH | EAST |
| C10-1 | 336.1 | 4 889 144.6 | 199 985.0 |
| C10-2 | 338.6 | 4 889 154.1 | 200 008.6 |
| C10-3 | 336.4 | 4 889 150.5 | 200 016.4 |
| C10-D1 | 341.2 | 4 889 051.6 | 200 031.4 |
| C10-D2 | 338.5 | 4 889 101.1 | 200 024.2 |
| C10-D3 | 337.9 | 4 889 194.2 | 200 005.2 |
| C10-D4 | 336.2 | 4 889 252.1 | 199 999.5 |

NOTE

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

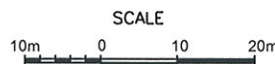
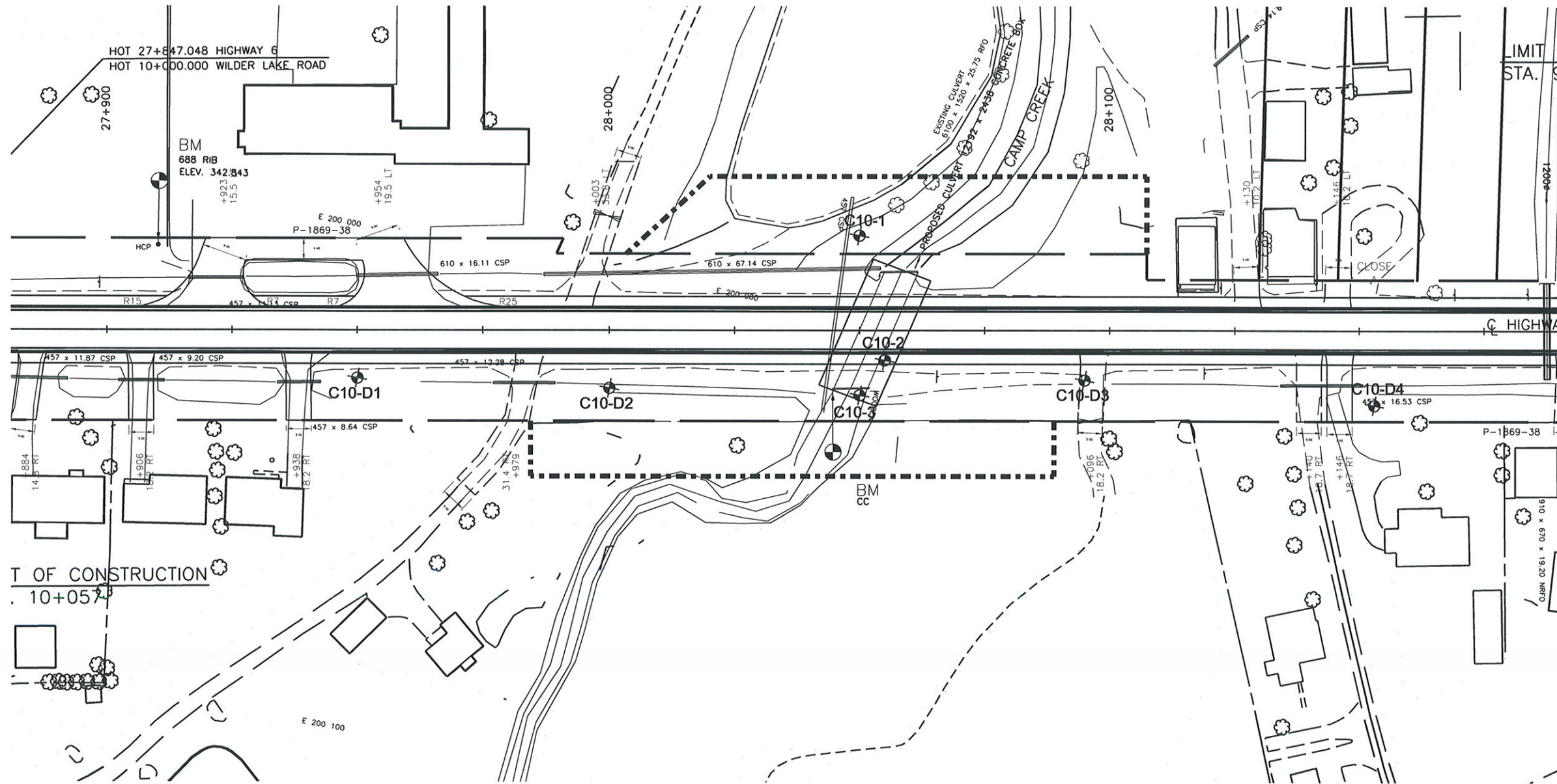
NOTE: This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

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. 41A-195

| SPT 1174 | | | DIST |
|----------|------------|---------------|-------|
| SUBM'D | CHECKED | DATE Jan 2008 | SITE |
| DRAWN SM | CHECKED RM | APPROVED ZO | DWG 1 |



PLAN



METRIC

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

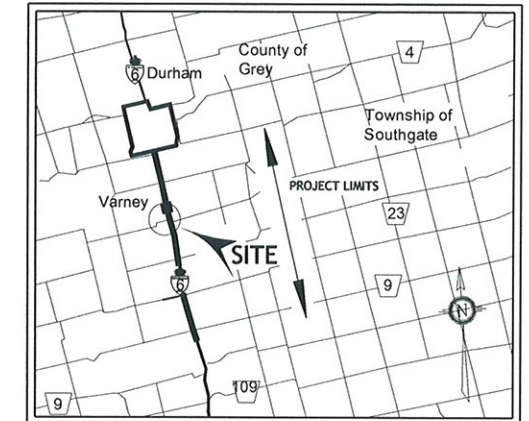
NOTES:
FOR DETAILED SUBSURFACE CONDITIONS
REFER TO RECORD OF BOREHOLE SHEETS.

CONT No.
GWP: 338-97-00

Highway 6, Durham
Camp Creek Culvert (C10) @ Sta. 28+050
SOIL STRATA



SHAHEEN & PEAKER LIMITED



KEY PLAN
N.T.S

LEGEND

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

| No. | ELEV. | CO-ORDINATES | |
|-------|-------|--------------|-----------|
| | | NORTH | EAST |
| C10-1 | 336.1 | 4 889 144.6 | 199 985.0 |
| C10-2 | 338.6 | 4 889 154.1 | 200 008.6 |
| C10-3 | 336.4 | 4 889 150.5 | 200 016.4 |

=NOTE=

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

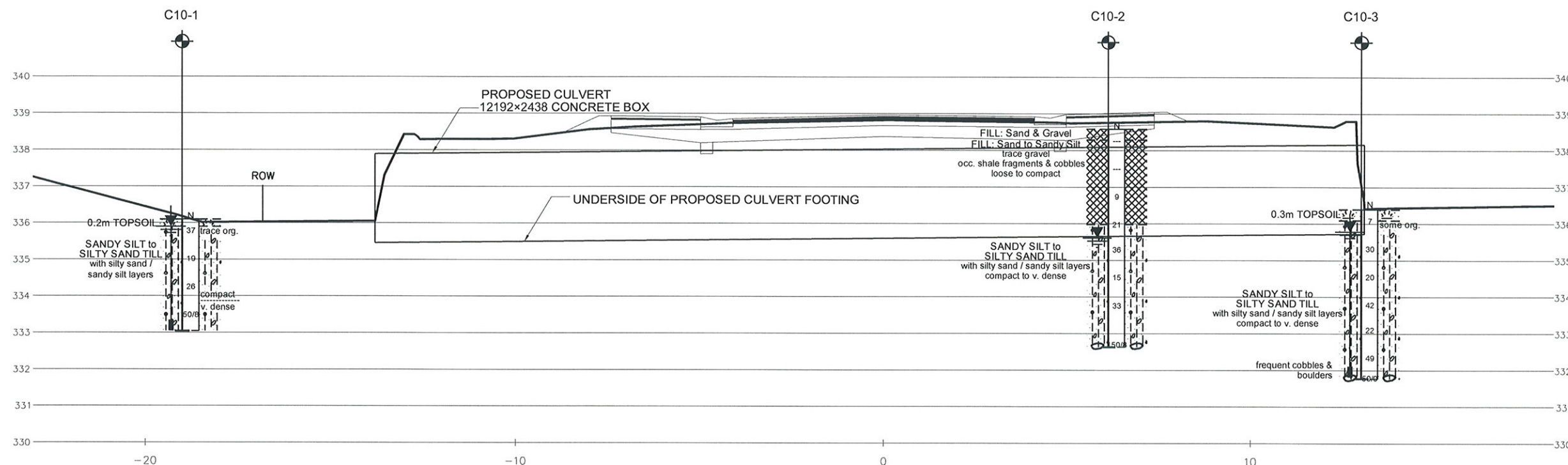
NOTE: This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

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. 41A-195

| SPT 1174 | | | DIST |
|----------|------------|---------------|-------|
| SUBM'D | CHECKED | DATE Jan 2008 | SITE |
| DRAWN SM | CHECKED RM | APPROVED ZO | DWG 2 |

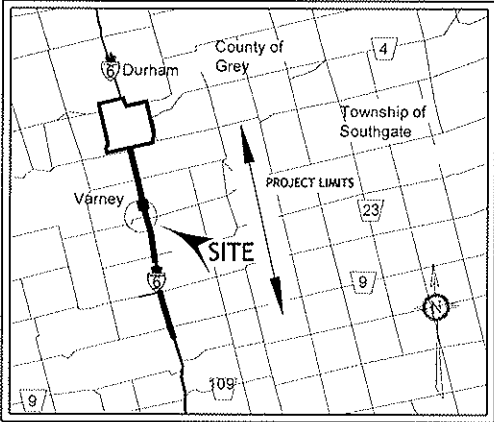


SCALE
1m 0 1 2m VERT
1m 0 1 2m HOR

STRATIGRAPHIC SECTION ALONG CULVERT C10 @ STA. 28+053



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

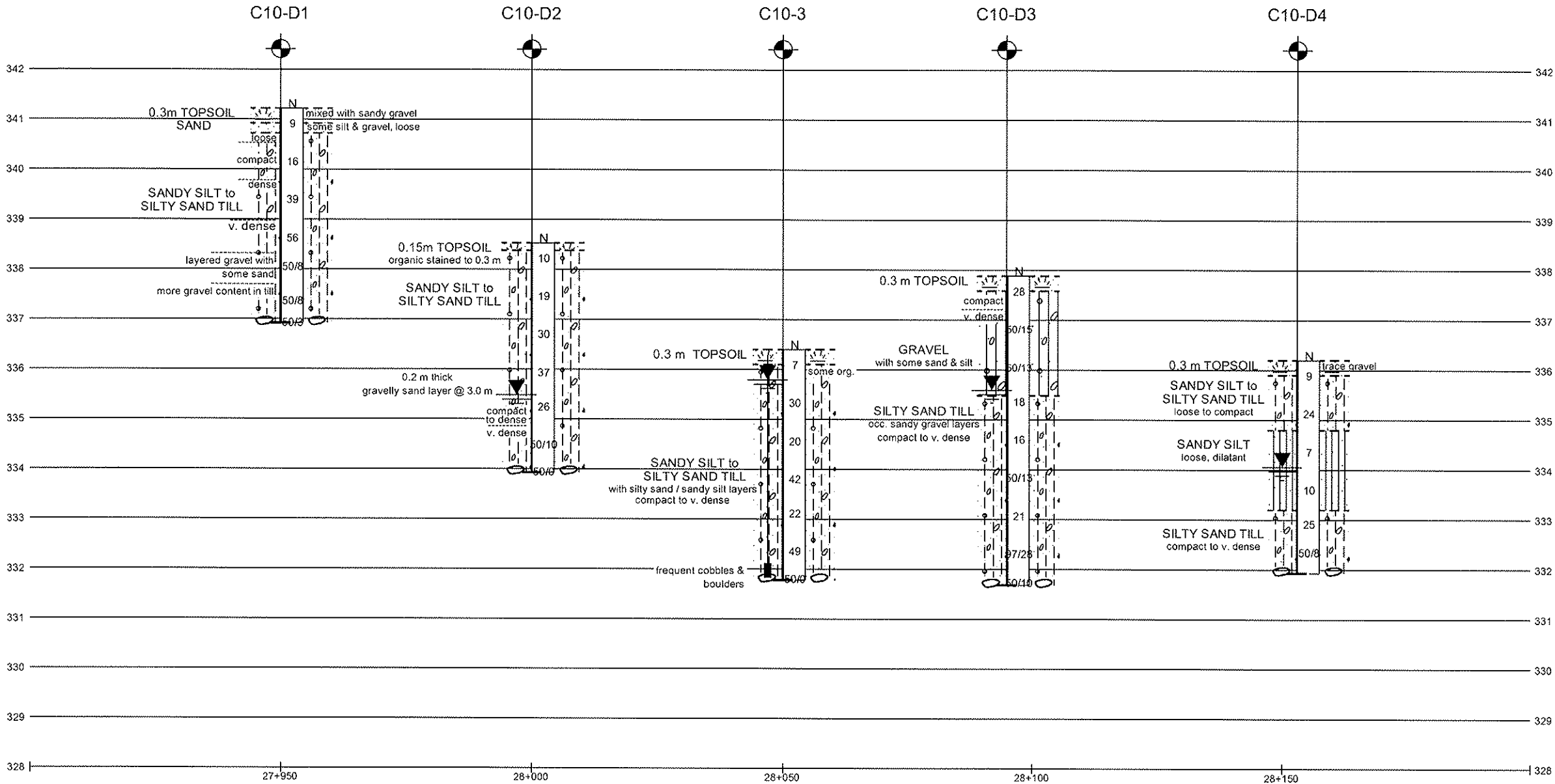
| No. | ELEV. | CO-ORDINATES | |
|--------|-------|--------------|-----------|
| | | NORTH | EAST |
| C10-D1 | 341.2 | 4 889 051.6 | 200 031.4 |
| C10-D2 | 338.5 | 4 889 101.1 | 200 024.2 |
| C10-3 | 336.4 | 4 889 150.5 | 200 016.4 |
| C10-D3 | 337.9 | 4 889 194.2 | 200 005.2 |
| C10-D4 | 336.2 | 4 889 252.1 | 199 999.5 |

=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. 41A-195 | | | |
| SPT 1174 | | | DIST |
| SUBM'D | CHECKED | DATE Jan 2008 | SITE |
| DRAWN SM | CHECKED RM | APPROVED ZO | DWG 3 |



SOIL PROFILE ALONG PROPOSED DETOUR



Appendix A

Record of Borehole Sheets

SPT1174

RECORD OF BOREHOLE No C10-1

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 28+050, 19m Lt C/L ORIGINATED BY JL
 DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers COMPILED BY XS
 DATUM Geodetic DATE 10/19/2006 CHECKED BY FS

| SOIL PROFILE | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|--------|------|----------------------------|-----------------|---------------------------------------------|----|----|----|-----|-------------------------------------------------|---------------------------------------------------|
| ELEV. DEPTH | DESCRIPTION | STRAT. PLOT | NUMBER | TYPE | "N" VALUES | | 20 | 40 | 60 | 80 | 100 | | |
| 336.1 | | | | | | | | | | | | | |
| 330.9 0.2 | 0.2 m TOPSOIL trace org. | | 1 | SS | 37 | | | | | | | | |
| | | | 2 | SS | 19 | | | | | | | | |
| | SANDY SILT to SILTY SAND TILL with silty sand / sandy silt layers brown to grey, moist to wet | | 3 | SS | 26 | | | | | | | | |
| | compact very dense | | 4 | SS | 50/8 | | | | | | | | |
| 333.1 3.1 | End of borehole. Very difficult augering below 2.5 m. Auger refusal at 3.1 m. Equipment damaged, probably due to cobbles and boulders. Water level at 0.8 m upon completion, cave at 3.1 m. Piezometer installed to depth of 3.0 m. Water level in piezometer: Oct. 19, 2006 ---0.8 m (El. 337.4 m) Nov. 21, 2006 ---0.2 m (El. 337.9 m) | | | | | | | | | | | | |

+ 3, x 3: Numbers refer to
Sensitivity

20
15 5
10 (%) STRAIN AT FAILURE

SPT1174

RECORD OF BOREHOLE No C10-2

1 OF 1

METRIC

GWP 338-97-00

LOCATION Hwy 6, Durham - Sta. 28+055, 6m Rt C/L

ORIGINATED BY JL

DIST HWY 6

BOREHOLE TYPE Hollow Stem Augers

COMPILED BY XS

DATUM Geodetic

DATE 8/21/2006

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 | | | | | | | | | | | | | |
| | | | | | | | | ○ UNCONFINED + FIELD VANE | | | | | | | | | | | | | |
| | | | | | | | | ● POCKET PENETR. × LAB VANE | | | | | | | | | | | | | |
| | | | | | | | WATER CONTENT (%) | | | | | | | | | | | | | | |
| | | | | | | | 20 40 60 80 100 | | | | | 10 20 30 | | | | | | | | | |
| 338.6 | | | | | | | | | | | | | | | | | | | | | |
| 0.0 | FILL: Sand & Gravel | | 1 | AS | --- | | 338 | | | | | | | | | | | | | | |
| 338.3 | FILL: Sand to Sandy Silt trace gravel occasional shale fragments & cobbles brown, moist loose to compact | | 2 | AS | --- | | | | | | | | | | | | | | | | |
| 0.3 | | | 3 | SS | 9 | | 337 | | | | | | | | | | | | | | |
| | | | 4 | SS | 21 | | 336 | | | | | | | | | | | | | | |
| 336.0 | SANDY SILT to SILTY SAND TILL with silty sand / sandy silt layers brown, moist compact to very dense | | 5 | SS | 36 | | 335 | | | | | | | | | 26 28 41 5 | | | | | |
| 2.6 | | | 6 | SS | 15 | | 334 | | | | | | | | | | | | | | |
| | | | 7 | SS | 33 | | 333 | | | | | | | | | | | | | | |
| 332.6 | | | 8 | SS | 150/8 | | | | | | | | | | | possible boulder | | | | | |
| 6.0 | End of borehole. Auger refusal at 5.9 m, probably on a boulder. * Water level in open borehole at 3.0 m (El. 335.6 m) upon completion (not stabilized). | | | | | | | | | | | | | | | | | | | | |

+ 3, x 3

Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

SPT1174

RECORD OF BOREHOLE No C10-3

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 28+050, 13m Rt C/L ORIGINATED BY JL
DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers COMPILED BY XS
DATUM Geodetic DATE 10/18/2006 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 | | | | | WATER CONTENT (%) | | | |
| | | | | | | 20 | 40 | 60 | 80 | 100 | W _p | W | W _L | | | |
| 336.4 | | | | | | | | | | | | | | | | |
| 336.0 | 0.3 m TOPSOIL | | 1 | SS | 7 | | | | | | | | | | | |
| 0.3 | some organics | | 2 | SS | 30 | | | | | | | | | | | |
| | SANDY SILT to SILTY SAND TILL with silty sand / sandy silt layers grey, wet compact to very dense | | 3 | SS | 20 | | | | | | | | | | | |
| | | | 4 | SS | 42 | | | | | | | | | | | |
| | | | 5 | SS | 22 | | | | | | | | | | | |
| | | | 6 | SS | 49 | | | | | | | | | | | |
| | | | 7 | SS | 50/0 | | | | | | | | | | | |
| 331.8 | frequent cobbles & boulders | | | | | | | | | | | | | | | |
| 4.6 | End of borehole. Auger refusal @ 4.6 m. Borehole relocated 1.5 m south and redrilled but auger refusal encountered again @ 4.6 m, possible boulder or bedrock. Water level at 0.6m upon completion. Piezometer installed to depth of 4.6 m. Water level in piezometer: Oct. 18, 2006 --- 0.6 m (El. 335.8 m) | | | | | | | | | | | | | | | |

SPT1174

RECORD OF BOREHOLE No C10-D1

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 27+950, 9.6m Rt C/L
DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers
DATUM Geodetic DATE 11/14/2006
ORIGINATED BY ZI
COMPILED BY XS
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 | | | 20 40 60 80 100 | 20 40 60 80 100 | 10 20 30 | | | | | |
| 341.2 | GROUND SURFACE | | | | | | | | | | | | | | |
| 340.9 | 0.3 m TOPSOIL mixed with sand & gravel | | 1 | SS | 9 | | 341 | | | | | | | | |
| 0.3 | SAND, some silt & gravel, brown, loose | | | | | | | | | | | | | | |
| 340.7 | loose | | | | | | | | | | | | | | |
| 0.5 | | | 2 | SS | 16 | | 340 | | | | | | | | |
| | compact | | | | | | | | | | | | | | |
| | dense | | 3 | SS | 39 | | 339 | | | | | | | | |
| | SANDY SILT to SILTY SAND TILL | | | | | | | | | | | | | | |
| | brown, moist to wet | | 4 | SS | 56 | | 338 | | | | | | | | |
| | very dense | | | | | | | | | | | | | | |
| | layer of gravel with some sand | | 5 | SS | 50/8 | | 337 | | | | | | | | |
| | more gravel content in till | | 6 | SS | 50/8 | | | | | | | | | | |
| 336.9 | End of borehole. | | 7 | SS | 50/3 | | | | | | | | | | |
| 4.3 | Auger refusal @ 4.3 m possibly on a boulder. | | | | | | | | | | | | | | |
| | No free-standing water in open borehole upon completion. | | | | | | | | | | | | | | |

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

SPT1174

RECORD OF BOREHOLE No C10-D2

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 28+000, 11.6m RI C/L
DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers ORIGINATED BY JL
DATUM Geodetic DATE 11/14/2006 COMPILED BY XS
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 ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE | | | | | | | | |
| 338.5 | GROUND SURFACE | | | | | | 20 | 40 | 60 | 80 | 100 | 10 | 20 | 30 | | |
| 338.4 | 0.15 m TOPSOIL | | | | | | | | | | | | | | | |
| 0.2 | organic stained to 0.3 m | | 1 | SS | 10 | | | | | | | | | | | |
| | | | 2 | SS | 19 | | | | | | | | | | | |
| | SANDY SILT to SILTY SAND TILL | | 3 | SS | 30 | | | | | | | | | | | |
| | | | 4 | SS | 37 | | | | | | | | | | | |
| | 0.2 m thick gravelly sand layer @ 3.0 m | | 5 | SS | 26 | | | | | | | | | | | |
| | compact to dense | | 6 | SS | 50/10 | | | | | | | | | | | |
| | very dense | | 7 | SS | 50/0 | | | | | | | | | | | |
| 333.9 | End of borehole. | | | | | | | | | | | | | | | |
| 4.6 | Auger refusal @ 4.6 m possibly on a boulder. | | | | | | | | | | | | | | | |
| | Borehole caved-in @ 4.3 m. | | | | | | | | | | | | | | | |
| | * Water level at 3.1 m (El. 335.4 m) in the open borehole upon completion (not stabilized). | | | | | | | | | | | | | | | |

+ 3 × 3: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No C10-D3

1 OF 1

METRIC

GWP 338-97-00 LOCATION Hwy 6, Durham - Sta. 28+095, 10m Rt C/L ORIGINATED BY JL
DIST HWY 6 BOREHOLE TYPE Hollow Stem Augers COMPILED BY XS
DATUM Geodetic DATE 11/20/2006 CHECKED BY FS

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | 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 ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE | | | | | | WATER CONTENT (%) W P W W L PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT | | | |
| 337.9 | GROUND SURFACE | | | | | | | 20 | 40 | 60 | 80 | 100 | | | | | |
| 0.0 | 0.3 m TOPSOIL | | 1 | SS | 28 | | | | | | | | | | | | |
| 337.6 | | compact | | | | | | | | | | | | | | | |
| 0.3 | | very dense | 2 | SS | 50/15 | | 337 | | | | | | | | | | |
| | GRAVEL with some sand & silt, greyish | | 3 | SS | 50/13 | | 336 | | | | | | | | | | |
| | | moist | | | | | | | | | | | | | | | |
| 335.5 | | wet | 4 | SS | 18 | | 335 | | | | | | | | | | |
| 2.4 | | | 5 | SS | 16 | | 334 | | | | | | | | | | |
| | SILTY SAND TILL occasional sandy gravel layers brown, compact to very dense | | 6 | SS | 50/13 | | 333 | | | | | | | | | | |
| | | | 7 | SS | 21 | | | | | | | | | | | | |
| | | | 8 | SS | 97/28 | | | | | | | | | | | | |
| 331.7 | | | 9 | SS | 50/10 | | 332 | | | | | | | | | | |
| 6.2 | End of borehole. Auger refusal @ 6.2 m. Borehole caved-in @ 6.1 m upon completion. • Water level at 2.3 m (El. 335.6 m) in the open borehole upon completion (not stabilized). | | | | | | | | | | | | | | | | |

+³, ×³: Numbers refer to Sensitivity

20
15
10
(%) STRAIN AT FAILURE



SPT1174

RECORD OF BOREHOLE No C10-D4

1 OF 1

METRIC

GWP 338-97-00

LOCATION Hwy 6, Durham - Sta. 28+153, 15m RI C/L

ORIGINATED BY JL

DIST HWY 6

BOREHOLE TYPE Solid Stem Augers

COMPILED BY XS

DATUM Geodetic

DATE 11/20/2006

CHECKED BY FS

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | 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 ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE | | | | | | WATER CONTENT (%) w _p w w _L | | | | |
| 336.2 | GROUND SURFACE | | | | | | | 20 | 40 | 60 | 80 | 100 | | | | | | |
| 335.9 0.3 | 0.3 m TOPSOIL trace gravel | | 1 | SS | 9 | | 336 | | | | | | | | | | | |
| 334.8 1.4 | SANDY SILT to SILTY SAND TILL brown, loose to compact | | 2 | SS | 24 | | 335 | | | | | | | | | | | |
| | SANDY SILT brown, loose, wet, dilatant | | 3 | SS | 7 | | 334 | | | | | | | | | | | |
| 333.2 3.0 | SILTY SAND TILL brown, moist to wet compact to very dense | | 4 | SS | 10 | | 333 | | | | | | | | | | | spoon wet @ 2.3 m no recovery |
| | | | 5 | SS | 25 | | | | | | | | | | | | | |
| 331.9 4.3 | End of borehole. Auger refusal @ 4.3 m. Borehole caved-in @ 4.0 m upon completion. * Water level at 2.1 m (El. 334.1 m) in the open borehole upon completion (not stabilized). | | 6 | SS | 50/8 | | 332 | | | | | | | | | | | difficult augering |

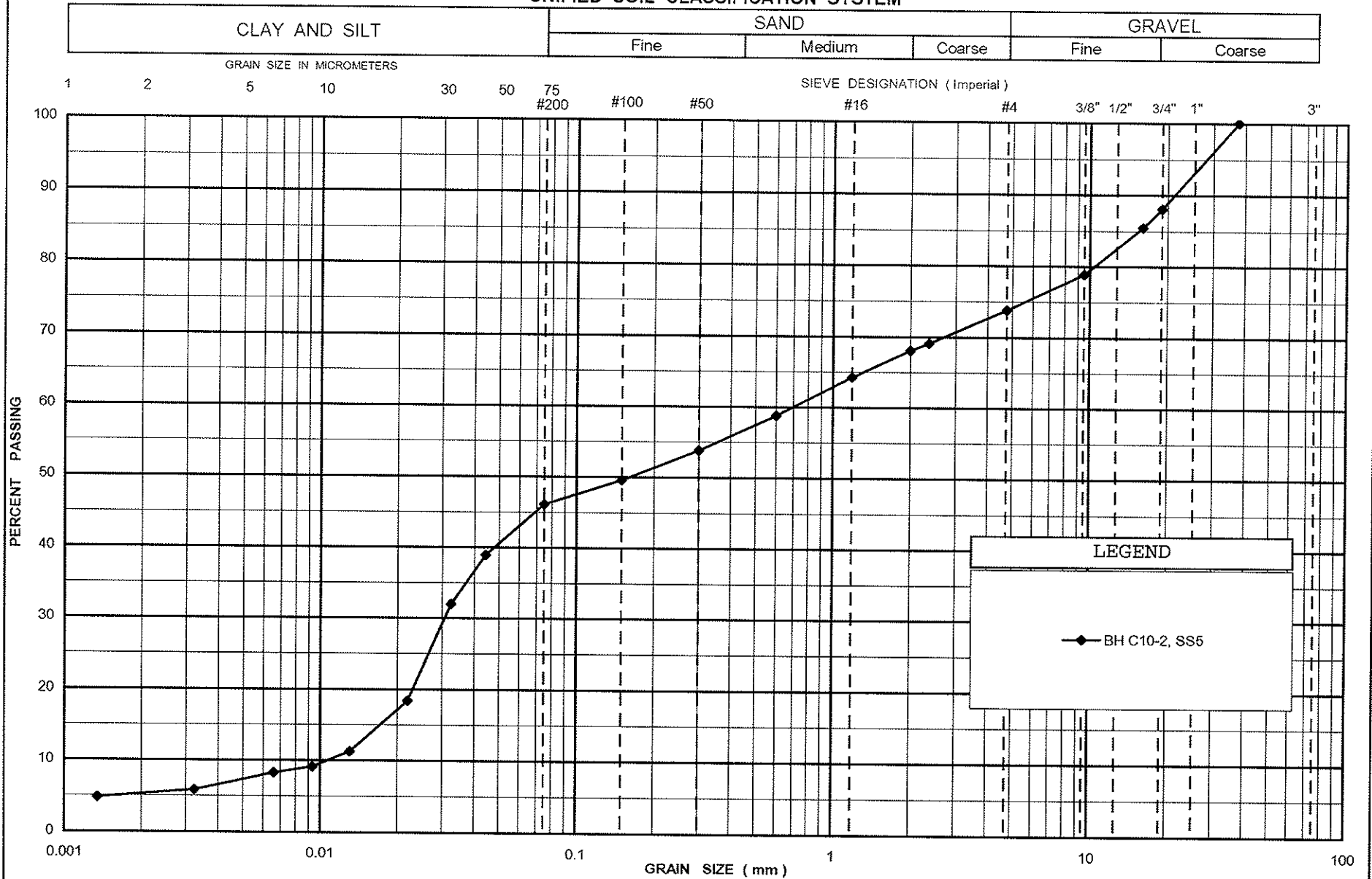
+ 3 x 3 : Numbers refer to
Sensitivity

20
15 5
10 (%) STRAIN AT FAILURE

Appendix B

Laboratory Test Results

UNIFIED SOIL CLASSIFICATION SYSTEM



SHAHEEN & PEAKER LIMITED

GRAIN SIZE DISTRIBUTION
SANDY SILT to SILTY SAND TILL

FIGURE No. B10-1

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 |

MECHANICAL 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 | | | | | | |

Appendix D

Site Photographs

Foundation Investigation Report of Culvert C10 on Highway 6: GWP 338-97-00



Photo (1): Culvert C10 at Station 28+050 on Highway 6, West end view



Photo (2): Culvert C10 at Station 28+050 on Highway 6, East end view

**FOUNDATION DESIGN REPORT
PROPOSED CAMP CREEK CULVERT (C10)
REPLACEMENT AT STATION 28+050 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-195

Prepared For:

UMA/AECOM ENGINEERING LIMITED

Prepared by:

SHAHEEN & PEAKER LIMITED

**Project: SPT1174D
February 8, 2008**



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

Table of Contents

| | |
|-----------------------------------------------------------|-----------|
| 5. DISCUSSION AND RECOMMENDATIONS | 8 |
| 5.1 Camp Creek Culvert Replacement | 8 |
| 5.1.1 Culvert Foundations | 8 |
| 5.1.2 Backfilling and Lateral Earth Pressures..... | 9 |
| 5.1.3 Construction..... | 11 |
| 5.1.4 Erosion Protection..... | 13 |
| 5.2 Proposed Detour Lane | 14 |
| 6. CLOSURE | 15 |

APPENDIX E: LIMITATIONS OF REPORT

**FOUNDATION DESIGN REPORT
PROPOSED CAMP CREEK CULVERT (C10) REPLACEMENT
AT STATION 28+050 ON HIGHWAY 6
SOUTH OF DURHAM SOUTH TOWN LIMITS AND
NORTH OF GREY COUNTY ROAD 9, ONTARIO
G.W.P. 338-97-00**

5. DISCUSSION AND RECOMMENDATIONS

As part of the rehabilitation of Highway 6, Camp Creek Culvert (C10) at Station 28+050 on Highway 6 is proposed to be replaced, possibly with the construction of a detour.

5.1 CAMP CREEK CULVERT REPLACEMENT

The existing open bottom concrete culvert at Station 28+050 (Camp Creek crossing) is a 6.1 m wide x 1.5 m high x 26.8 m long structure. It will be replaced with a wider, higher and slightly longer structure at Station 28+055. The new structure, which will measure 12.2 x 2.4 x 27.4 m, will be an open bottom concrete culvert and the invert level is expected to be at about El. 336.2 m (i.e. essentially the same as the existing).

Borehole C10-1, C10-2, C10-3, drilled at the site, show below some topsoil or embankment fill, the presence of a sandy silt to silty sand till with silty sand to sandy silt layers. As well, the deposit contains cobbles and boulders. The Standard Penetration test results show that the material is in a compact to very dense condition. The groundwater level at the time of our investigation was found near the o.g. level but would be subject to seasonal fluctuations and fluctuations due to major weather events and water level in the Creek itself.

The undisturbed till deposit encountered at the site is suitable to support both CSP and concrete box or concrete open bottom culverts. But since the structure has already been designed as precast concrete hy-span culvert with cast-in-place concrete footings, this option will be discussed in the following sections.

5.1.1 CULVERT FOUNDATIONS

The boreholes show that the sandy silt to silty sand till in its undisturbed state is suitable to support the proposed structure.

The following table summarizes the recommended highest founding depths/elevations at the borehole locations.

Table 5.1.1

| Borehole No. | Existing Ground Surface Elevation (m) | Recommended Highest Founding Level (Bottom of Footing) m | Elevation (m) | Subgrade Material |
|--------------|---------------------------------------|----------------------------------------------------------|---------------|-------------------------------------------------------------------------------|
| C10-1 | 336.1 | 0.4 | 335.7 | dense to compact silty sand to sand silt till with silty sand to sandy layers |
| C10-2 | 338.6 | 2.7 | 335.9 | dense to compact silty sand to sand silt till with silty sand to sandy layers |
| C10-3 | 336.4 | 0.7 | 335.7 | compact silty sand to sand silt till with silty sand to sandy layers |

The following geotechnical resistances can be used for footings to be placed on undisturbed, competent sandy silt to silty sand till.

| | |
|-------------------------------------|---------|
| Factored Bearing Resistance at ULS: | 300 kPa |
| Geotechnical Resistance at SLS: | 180 kPa |

Provided that the bearing subgrade is not unduly disturbed during the construction, with the recommended serviceability resistance value, the total and differential settlements should not exceed 25 mm and 20 mm, respectively. As will be discussed in Section 5.1.3 of this report, good construction techniques, including dewatering, will be required to achieve this. As well, all bearing surfaces must be inspected, evaluated and approved by a Geotechnical Engineer who is familiar with the findings of this investigation.

Frost and scour depths need to be considered when choosing the footing elevations.

Under inclined loading conditions, the bearing resistance at ULS should be reduced in accordance with Clause 6.7.4 of the CHBDC (Canadian Highway Bridge Design Code – CAN/CSA-S6-06).

The unfactored horizontal resistance against sliding between poured concrete and approved till surface can be calculated using a friction angle of 28 degrees, although lateral resistance is unlikely to be a problem for culvert foundation.

5.1.2 BACKFILLING AND LATERAL EARTH PRESSURES

Backfilling for the culvert replacement 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-803.01. 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). The Granular 'A'

or 'B' materials should be compacted to 100% of their SPMDD's. To avoid damaging or laterally dislocating the structure, care should be exercised when compacting fill adjacent to and immediately on top of the culvert structure. Compaction equipment should be restricted in size as per MTO convention to prevent structural damage to the culvert. The backfilling operation should be carried out simultaneously on both sides of the culvert as per MTO specifications.

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

Computation of earth pressures acting against rigid culvert walls and any wing walls should be in accordance with CHDBC. Suggested backfill properties are given below.

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

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

Unit weight = 22 kN/m³

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/m³

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).

5.1.3 CONSTRUCTION

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

SP 105 S01 – Protection Systems

SP 902 S01 – Excavation and Backfilling to Structures

The boreholes show that the excavations for the construction of the culvert can be expected to extend through basically granular embankment fill, underlying topsoil or other organic mixed layer into the sandy silt to silty sand till with silty sand to sandy silt layers. These soils can be classified as follows:

| | |
|-------------------------------|---------------------------------|
| Granular Pavement Fill | Type 2 soil (above water level) |
| Topsoil and Organic Rich Soil | Type 3 above water level |
| | Type 4 below water level |
| Sandy silt to silty sand till | Type 2 above water level |
| | Type 3 below water level |
| Silty sand to sandy silt | Type 2 above water level |
| | Type 4 below water level |

Depending on the site conditions at the time of construction, dewatering will likely be required to stabilize the soil and to prevent its disturbance and dilatation. It is our opinion that the groundwater level can be lowered by up to about 0.5 m by means of gravity drainage and pumping from strategically located filtered sumps. Closely spaced deep filtered sumps may be required if deeper water level lowering is required. For more than about 0.8 m water lowering, well points or deep wells may be required. For this reason, we

recommend that, if possible, the construction be carried out during a dry period. As well, care should be taken to avoid disturbing the foundation soils by minimizing construction traffic (including foot traffic) and minimizing vibrations. If deep wells and/or well points are required, the zone of cobbles or boulders and/or possible bedrock surface (i.e. refusal to augering encountered in all three boreholes at El. 333.1 m – 331.8 m) should be taken into consideration.

We recommend that the water flow in the existing watercourse be diverted away from the culvert so that the construction can be carried out in sufficiently dry conditions. Alternatively, if feasible, the existing culvert can remain in place during the construction of the new culvert. It can then be removed after the completion of the new culvert. In this instance, care will need to be exercised not to disturb the new foundations when removing the existing structure.

Where weak, organic or otherwise unsuitable soils are encountered at the foundation subgrade level, they should be removed and replaced with lean concrete or Granular 'A' type material compacted to not less than 100% of the material's Standard Proctor Maximum Dry Density (SPMDD). In this instance, because of the high water table, the use of lean concrete is recommended to raise the foundation grades. All founding subgrades should be inspected and evaluated by the Quality Verification Engineer (QVE), at the time of construction.

It is expected that temporary shoring will be required to support the excavations. Locally, temporary shoring systems generally consist of support provided by conventional soldier piles and timber lagging. Shoring system should be designed so that the lateral movement of any portion of the roadway protection system will not exceed the established criterion for the structural performance level. In this case, the required performance level is considered 2. The coefficient of lateral earth pressures given in Table 5.1.3 can be used for the design of the temporary shoring system.

Table 5.1.3
Recommended Unfactored Parameters for Temporary Shoring Design

| Soil Type | K_a | K_o | K_p | Unit Weight (kN/m^3) |
|-------------------------------|-------|-------|-------|------------------------------------|
| Granular Embankment Fill | 0.30 | 0.45 | 3.3 | 21.5 |
| Organic Topsoil | 0.41 | 0.58 | 2.4 | 15.0 |
| Sandy silt to silty sand till | 0.28 | 0.44 | 3.6 | 21.0 |
| Silty sand to sandy silt | 0.3 | 0.45 | 3.3 | 20.5 |

We recommend that the Contract Documents should include an NSSP to flag the contractor about the presence of cobbles and boulders in the overburden, encountered during the field investigation.

5.1.4 EROSION PROTECTION

Erosion and scour protection should be provided at the culvert inlet and outlet including the side slopes, as well as inside the open bottom culvert structure. The erosion/scour protection should be designed by a specialist River Engineer/Scientist who is familiar with the findings of this investigation.

The boreholes indicate that below some surficial materials deposited by the Creek, the predominant soil type at the site consists of sandy silt to silty sand till. In addition to the soil types, the particular design depends on other considerations such as water velocity in the Creek at the culvert locations, fisheries, etc. Typically, concrete cut-off (apron) walls and head walls are constructed both at the inlet and the outlet to prevent scour and to inhibit seepage around the culvert, particularly through the granular backfill.

Clay seal can be used at the inlet in lieu of or in addition to the concrete cut-off and head walls. 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 or from beneath the structure. The clay material 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, across the channel bed and up to the side, in a continuous manner. It must be ensured that the seal extends to cover all the granular backfill to prevent seepage through these granular backfill materials. The clay seal should be protected by laying a 0.6 m thick rock protection over it. The clay seal should be extended to at least 6 m beyond the inlet.

At the outlet (and also if clay seal is not provided at the inlet), in addition to the concrete cut-off and head walls, a 0.6 m thick layer of rock protection, consisting of 300 mm diameter size rock, can be considered. This should be underlain by a 0.3 m thick layer of granular filter material. The granular filter can consist of a suitable granular soil, such as Granular 'A' (OPSS Form 1010). Alternatively, a suitable geotextile can be used underneath the rock fill, in lieu of the granular filter. The rock fill protection should extend a suitable distance from the outlet and the inlet (e.g. at least 6 m) and at least 0.3 m above the high water level.

A suitable erosion/scour protection scheme will be needed inside the open bottom culvert, such as the rock protection described above.

Another reference for consideration is OPSD 810.010 Rip-Rap Treatment for Culvert Outlets.

5.2 PROPOSED DETOUR LANE

The construction of the new culvert may possibly involve the widening of the existing embankment on the east (right) side, to provide a temporary detour lane.

We understand that the height of the new embankment (widening) will be 2 to 3 m above original grades (o.g.). Boreholes drilled from the o.g. level along the toe of the existing embankment showed the presence of a topsoil layer (typically 0.3 m thick), underlain in general by a compact to very dense silty sand to sandy silt till which attains a silty sand till character with increasing depth. The presence of some dolostone gravel to gravelly sand/sand and sandy silt interbeds/lenses was also noted.

Based on this information, no instability problems due to foundation conditions are anticipated and for the widening standard 2H:1V side slopes are considered acceptable provided that the construction proceeds as per conventional MTO procedures, as follows.

Proper benching of the existing embankment slope should be implemented when widening the embankment, as per MTO procedures and in accordance with OPSD 208.01.

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 as per MTO standards. After stripping, the exposed subgrade should be inspected and approved. It should then be compacted, where feasible, from the surface using a suitable compactor.

The materials used for the construction of the embankment fills should consist of approved, acceptable earth fill (e.g. select subgrade materials or Granular 'B' – OPSS 1010). In as much as possible, the fill used should match the existing embankment fill, within the frost zone, especially if the widening will remain in place after the construction of the culvert. The embankment fill should be placed on the approved and properly rolled 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 loadings would likely result in a settlement of the order of 15 to 20 mm due to the settlement of foundation soils and the existing embankment. About one-half of this settlement should take place within one month, with the majority of the remaining within the next three to six months.

In addition, a settlement of the order of 20 mm can be expected due to the settlement of the fill placed for the widening, bringing the total to about 35 to 40 mm. Such settlements are considered acceptable. The time rate of settlement of the embankment fill (20 mm) under its own weight would depend on the materials used, but if SSM is used, the rate of settlement would be similar to rates quoted above.

As these settlements are not excessive, surcharging is not considered necessary.

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

6. CLOSURE

We recommend that once the details of the culverts and retaining walls are finalized, our recommendations be reviewed for their specific availability. The Limitations of Report, as quoted in Appendix E, are an integral part of this report.

SHAHEEN & PEAKER LIMITED


Ramon Miranda, P.Eng.



ZO:tr/ldrive


Z.S. Ozden, P.Eng.



Appendix E

Limitations of Report

LIMITATIONS OF REPORT

This report is intended solely for the Client named. The material in it reflects our best judgment in light of the information available to Shaheen & Peaker Limited at the time of preparation. Unless otherwise agreed in writing by Shaheen & Peaker Limited, it shall not be used to express or imply warranty as to the fitness of the property for a particular purpose. No portion of this report may be used as a separate entity, it is written to be read in its entirety.

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.