coffey geotechnics
SPECIALISTS MANAGING THE EARTH

FOUNDATION INVESTIGATION AND DESIGN REPORTS PROPOSED NEW CULVERTS (STATIONS 9+845 SOUTH SERVICE ROAD-SITE 30-682C AND 28+430 NEW HIGHWAY 26 - SITE 30+680C) TOWNSHIP OF CLEARVIEW, ONTARIO, G.W.P. 630-91-00, GEOCRES NO. 41A-211

Delcan Corporation

Project: TRANETOB01232AA-AB
March 01, 2010

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

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

March 01, 2010

Delcan Corporation
625 Cochrane Drive, Suite 500
Markham, Ontario
L3R 9R9

Attention: Mr. Sam Dinatolo, P.Eng.

Dear Sirs:

RE: Foundation Investigation and Design Reports, Proposed New Culverts (Stations 9+845 South Service Road – Site 30-682C and 28+430 Highway 26 – Site 30-680C), Township of Clearview, Ontario, G.W.P. 630-91-00, GEOCRES No. 41A-211

Please find attached the Foundation Investigation and Design Reports relating to the above noted site.

For and on behalf of Coffey Geotechnics Inc.

Ramon Miranda, P. Eng.
Manager, Transportation Division

Attachment

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

FOUNDATION INVESTIGATION REPORT PROPOSED NEW CULVERTS (STATIONS 9+845 SOUTH SERVICE ROAD - SITE 30-682C AND 28+430 NEW HIGHWAY 26 - SITE 30+680C) TOWNSHIP OF CLEARVIEW, ONTARIO, G.W.P. 630-91-00, GEOCRES NO. 41A-211

Delcan Corporation

Project: TRANETOB01232AA-AB
March 01, 2010

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

CONTENTS

CONTENTS

Appendices

FOUNDATION INVESTIGATION REPORT
PROPOSED NEW CULVERTS
(STATIONS 9+845 SOUTH SERVICE ROAD AND 28+430 NEW HIGHWAY 26)
TOWNSHIP OF CLEARVIEW, ONTARIO
G.W.P. 630-91-00

1 INTRODUCTION

As part of the realignment of Highway 26, from the Township of Wasaga Beach to Collingwood, Coffey Geotechnics Inc. (Coffey) was retained by Delcan Corporation (Delcan) to carry out a foundation investigation at the site of proposed two new culverts at the following locations in the Township of Clearview, Ontario.

Station	Site	Township	Remark
9+845 (South Service Road)	30-682C	Clearview	New culvert
28+430 (New Highway 26 alignment)	30-680C	Clearview	New culvert

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

The findings of the investigation are presented in this report.

2 PHYSIOGRAPHY

Highway 26, in the area of the project, crosses the western extremity of the Nottawasaga Basin. According to the Physiography of Southern Ontario by L.J. Chapman and D.F. Putnam, 1984, the basin is located within the Physiographic Region known as the Simcoe Lowlands. The area contains some rolling and some broad flatlands such as the Minesing Flats. The area is drained by the Nottawasaga River and its tributaries.

The Nottawasaga Basin was covered by the Georgian Bay Lobe of the Laurentide Ice Sheet which formed the Edenvale Moraine east of the project area and the Cornhill Moraine south of the project area. This ice sheet deposited sandy, silty ground moraine till over most of the basin. Sandy, silty tills with boulders and cobbles were laid down south of the project area on the slope of the Niagara Escarpment as well as within the project area. During the occupation of the area by lake waters, sand and gravel beaches were formed along the shorelines and on hillsides. On the Niagara Escarpment slope, shore cliffs were formed by wave action of lake waters. The Nottawasaga River deposited a large sandy delta as it entered Glacial Lake Nipissing and the current Georgain Bay. Sand with some gravel and silt were deposited along the shore forming the current Wasaga Beach.

In the project area, the bedrock is known to consist of the Collingwood member of the Middle Ordovician Lindsay Formation. It is comprised of interbedded, black, organic-rich limestone and highly calcareous and fossiliferous black shales. Southwest of the project area, at the lower part of the Niagara Escarpment, blue-grey, non-calcareous, fissile shales of the late Ordovician Blue Mountain Formation are found. These are overlain by the Georgian Bay Formation, a blue-grey shale with light grey to cream coloured limestone and dolostone. The deposition of these formations occurred within an approximate time period between 550 and 500 million years before the present. During the wave erosion process of the Niagara Escarpment, rock from these formations contributed clay, boulders and cobbles to the till deposit of the project site.

The western and central part of the project area is underlain by a sandy, silty till with cobbles and boulders of mainly carbonate rocks, except near the present lakeshore, where sand and gravel beaches dominate.

3 INVESTIGATION PROCEDURES

The fieldwork for this project was performed during the period from November 6 to 11, 2008 and consisted of drilling and sampling a total of eight boreholes; five CS-series boreholes were drilled for the South Service Road culvert at Station 9+845 and three C-series boreholes were drilled for the new Highway 26 culvert at Station 28+430 as shown in Drawing 1.

At the South Service Road culvert location, CS-series boreholes were advanced to depths of 10.8 to 11.1 m (Elevations 181.7 to 183.4 m) close to the location of the proposed new culvert as listed in Table 3.1. The locations of the boreholes at the site are given on the Borehole Location Plan, Drawing No A1-1.

Table 3.1: Borehole Locations and Drilling Depths (Station 9+845, South Service Road)

Borehole No.	Location	Depth of Borehole Below Existing Ground Surface (m)	Piezometer
CS1	9+831	10.8	Yes
CS2	9+843	10.9	No
CS3	9+833	10.8	No
CS4	9+872	10.9	No
CS5	9+828	11.1	No

Along the new Highway 26 alignment, three C-series boreholes were drilled for the proposed culvert at Station 28+430 as detailed in Table 3.2, below. The boreholes were advanced to depths of 11.1 to 12.7 m (Elevations 179.3 to 177.6 m). The locations of the boreholes at the site are given on the Borehole Location Plan in Drawing No A2-1.

Table 3.2: Borehole Locations and Drilling Depths (Station 28+430, New Highway 26)

Borehole No.	Location	Depth of Borehole Below Existing Ground Surface (m)	Piezometer
C1	28+418	12.7	Yes
C2	28+440	11.1	No
C3	28+400	11.1	No

The boreholes were advanced using a track-mounted drilling rig owned and operated by Eastern Soil Investigations of Courtice, Ontario, under the full-time supervision of a Professional Engineer from Coffey. These boreholes were advanced using continuous flight solid-stem augers; however, in Borehole CS2 wash boring methods using NW casing were utilized below a depth of 3.0 m.

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

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

Groundwater conditions in the boreholes were observed during and on completion of drilling in the open boreholes. Upon their completion, the boreholes were grouted using a cement/bentonite mixture as per MTO procedures. Standpipe piezometers were installed in Boreholes CS1 and C1 on completion.

A laboratory testing programme, consisting of natural moisture content determinations, Atterberg Limits test and grain size analyses, was performed on selected samples. The results of the laboratory tests are presented on the appropriate Record of Borehole Sheets (Appendices A1 and A2) and in Appendices B1 and B2.

In 2002 – 2003, Golder Associates Limited (Golder) carried out a geotechnical investigation at the sites of the proposed culverts. The findings of the investigation were presented in a report entitled "Foundation Investigation Report, Proposed New Culverts, Highway 26, G.W.P. 630-91-00, Agreement Number 3005-A-000164", dated February 2006. The investigation included two boreholes at the proposed South Service Culvert site at Station 9+845 (Boreholes 1 and 2) and two boreholes for the proposed new culvert at the realignment of Highway 26 at Station 28+430 (Boreholes 3 and 4). The boreholes put down by Golder at Stations 9+845 and 28+430 were used to supplement the boreholes by Coffey at these sites. The locations of these boreholes are shown on the Borehole Location Plans, Drawing Nos. A1-1 and A2-1.

4 SUBSURFACE CONDITIONS

Details of the subsurface conditions encountered in the boreholes are presented on the Record of Borehole Sheets in Appendices A1 and A2, including boreholes by Golder Associates Limited. An inferred stratigraphic section and profile based on Coffey boreholes at each culvert location is also presented in Appendices A1 and A2. Previous investigation report for these proposed new culverts (prepared by Golder, 2002) is also included in Appendix D of this report.

The following description of the individual soil strata (based on Coffey boreholes at Stations 9+845 and 28+430) is to assist the designers of the project with an understanding of the anticipated subsurface conditions underlying the site. It should be noted that the soil and groundwater conditions may vary in between and beyond borehole locations.

4.1 Culvert at Station 9+845 (South Service Road) – Site 30-682C

Boreholes CS1 through CS5 were put down at the proposed South Service Road. At the borehole locations, the ground surface elevations range from 192.6 to 194.2 m. Boreholes CS1 and CS3, which were drilled from the shoulder area of the existing service road, encountered an embankment fill extending to depths/elevations of 2.0 m/192.1 m and 2.3 m/191.9 m, respectively. Of the remaining boreholes, which were drilled from original ground (o.g.) levels, Boreholes CS4 and CS5 encountered 0.4 m thick topsoil at the ground surface. Below the topsoil, Boreholes CS4 and CS5 contacted a surficial clayey silt deposit to depths of 2.1 to 3.3 m (El. 192.1 – 190.9 m), respectively. Borehole CS2 contacted a 1.4 m thick, surficial granular soil to Elevation 191.2 m. Below these surficial deposits, all boreholes encountered a major sandy silt till deposit. Boreholes CS1, CS3 and CS5 were terminated in this glacial sandy silt till deposit at depths of 10.8 to 11.1 m (El. 183.4 – 183.1 m), while in Boreholes CS2 and CS4 a lower sand deposit was contacted at depths of 8.6 and 10.0 m or at El. 184.0 and 184.2 m. These two boreholes were terminated in this water bearing sand deposit after penetrating it 0.9 to 2.3 m or at El. 183.3 and 181.7 m.

Details of the subsurface conditions encountered in the boreholes are presented on the Record of Borehole Sheets in Appendix A. Inferred stratigraphic section at the culvert location is also presented in Drawing No. A1-2. The following description of the individual soil strata is to assist the designers of the project with an understanding of the anticipated subsurface conditions underlying the site. It should be noted that the soil and groundwater conditions may vary in between and beyond the borehole locations.

4.1.1 Topsoil

Boreholes CS4 and CS5 encountered a 0.4 m thick topsoil at ground surface.

4.1.2 Fill

Boreholes CS1 and CS3 were advanced from near the shoulder of the existing service road and contacted embankment fill to depths of 2.0 m and 2.3 m respectively or to El. 192.1 m and 191.9 m. In Borehole CS1, underlying a 0.2 m thick topsoil, the fill was found to consist of clayey silt with some sand and traces of gravel.

The grain size distribution of a sample from the deposit is given in Figure B1-1 in Appendix B-1. The curve indicates:

Gravel:	2%
Sand:	25%
Silt:	47%
Clay:	26%

Standard Penetration tests performed in this primarily cohesive fill material yielded N-values of 5 to 7 blows/0.3 m, indicating a firm consistency.

In Borehole CS3 the embankment fill was found to consist of sand with silt and clay size soil particles. This is basically granular (i.e. non-cohesive) material and from the recorded N-values, which range from 5 to 7 blows/0.3 m, its relative density is described as loose.

Figure B1-2 shows the grain size distribution of this primarily granular embankement fill and the following grain size distribution is indicated.

Gravel:	0%
Sand:	78%
Silt & Clay:	22%

From the recorded N-values these fill materials do not appear to have received a systematic compaction when they were first placed.

4.1.3 Clayey Silt

Below the topsoil, Boreholes CS4 and CS5 contacted a 2.9 and 1.7 m thick clayey silt deposit, extending to El. 190.9 m and 192.1 m, respectively. This clayey silt deposit contains some sand and traces of gravel size particles and could possibly be of glacial origin.

The grain-size distribution of samples from this deposit was determined in the laboratory and the resulting curves are given in Figure B1-3 in Appendix B1. The following grain-size distribution is indicated.

Gravel:	0-4%
Sand:	7-29%
Silt:	32-40%
Clay:	27-61%

The results of Atterberg Limits tests performed on samples recovered from this deposit are given on the individual Record of Borehole Sheets and also on the plasticity chart presented in Figure B1-4 in Appendix B1. The following index values were obtained:

Liquid Limit:	18-23%
Plastic Limit:	11-13%
Plasiticity Index:	7-10

These results are characteristic of cohesive soils of low plasticity.

Standard Penetration tests, performed in this cohesive deposit, yielded N-values of between 1 and 21 blows/0.3 m, indicating very soft to very stiff consistency.

4.1.4 Surficial Sand & Gravel

Borehole CS2 contacted at the ground level a 1.4 m thick surficial granular deposit which consists of sand & gravel with traces to some silt and clay size particles.

Standard Penetration tests, performed in this basically granular (non-cohesive) soil deposit, yielded N-values of 9 and 16 blows/0.3 m, indicating loose to compact relative density.

4.1.5 Sandy Silt Till

Underlying the embankment fill in Borehole CS1 and CS3, sand & gravel in Borehole CS2, clayey silt in Boreholes CS4 and CS5, all boreholes encountered a major sandy silt till deposit at depths of 1.4 to 3.3 m (El. 192.1 to 190.9 m). Boreholes CS1, CS3 and CS5 were terminated within this deposit at depths of 10.8 to 11.1 m (El. 183.4 to 183.1 m), while in Boreholes CS2 and CS4, it extends to 8.6 and 10.0 m (EI. 184.0 and 184.2 m) where it is underlain by a sand deposit. The deposit consists of an unsorted, heterogeneous mixture of sandy silt with traces of gravel and clay size particles and is interbedded with occasional thin silt/silty sand seams. The presence of cobbles was inferred while drilling and broken cobble pieces were noted between about El. 186 and 190 m in Boreholes CS1, CS3 and CS5.

The grain-size distribution of nine samples from this deposit was determined in the laboratory and the resulting curve is given in an envelope form in Figure B1-5 in Appendix B1. The following grain-size distribution is indicated.

Gravel:	5-9%
Sand:	33-44%
Silt:	37-45%
Clay:	10-18%

N-values recorded in this basically non-cohesive (granular) deposit range from 16 blows/0.3 m to in excess of 50 blows/0.3 m. These results indicate a compact to very dense relative density, but very dense below about EI. 189.0 m.

Due to their mode of deposition, the presence of cobbles and boulders should always be anticipated in the glacial till deposits.

4.1.6 Lower Sand

Underlying the sandy silt till in Boreholes CS2 and CS4, a lower sand deposit was contacted at depths of 8.6 and 10.0 m or at EI. 184.0 m and 184.2 m, respectively. The boreholes were terminated after penetrating it a vertical distance of 0.9 and 2.3 m at EI. 183.3 and 181.7 m respectively. The upper portion of this sand deposit in Borehole CS2 contains some gravel. This granular (i.e. non-cohesive) soil deposit contains traces to some silt and traces of clay.

Grain size analysis tests performed on two samples of the upper portion of this deposit yielded the following grain-size distribution, as shown in Figure B1-6 in Appendix B1.

Gravel:	6-22%
Sand:	59-79%
Silt & Clay:	15-19%

Measured N-values in excess of 50 blows/0.3 m were obtained, indicating a very dense compactness condition.

4.1.7 Groundwater Conditions

Groundwater levels in the open boreholes were observed during the drilling and at the completion of each borehole. In addition, a piezometer was installed in Borehole CS1 to allow groundwater monitoring over a prolonged period of time, without interference from surface water. The observations and recorded values are shown on the individual Record of Borehole sheets.

The observations show that Boreholes CS1, CS3 and CS5 were dry on completion. In Borehole CS4 a water level was recorded at 9.8 m below grade, or at Elevation 184.4 m, while in Borehole CS2, in which water was used to advance the borehole, the water level was recorded at 0.2 m below the ground surface. It should be noted that the water levels had not stabilized and unlikely represent the actual (stabilized) groundwater table, especially in Borehole CS2 where wash boring method was used (i.e. water introduced into the borehole). A piezometer was installed within the sandy silt till in Borehole CS1, near the bottom of the borehole at El. 183.3 m. A measured water level of 8.0 m (Elevation 186.1 m) was obtained about five weeks after the installation, which is likely the stabilized water level, at the time our investigation.

The change of the colour of the soil from brown to grey was noted typically at a depth of about 2 m below the ground surface or between El. 192 and 191 m. Based on the above observations, the groundwater at the time of our investigation was at about Elevation 186 m, but could fluctuate between Elevation 192 and 184 m. In addition, a perched water table could occur due to the accumulation of surface water in the suficial sand fill, or sand & gravel deposits (i.e. Boreholes CS2 and CS3). The groundwater table would also be subject to fluctuations due to changes in the water level in the water course.

4.2 Culvert Replacement at Station 28+430 (New Highway 26) – Site 30-680C

A new culvert will be constructed on the new alignment of Highway 26 at Station 28+430. Boreholes C1, C2 and C3 were put down at the site of the proposed new culvert, in addition to Golders Boreholes 3 and 4. The ground surface elevations range from 190.0 to 190.4 m at the borehole locations.

Boreholes C1, C2 and C3 encountered a 0.2 to 0.3 m thick topsoil at the surface. Below the topsoil, a 6.1 to 8.3 m thick major sandy silt till deposit was encountered, followed by a silty sand to sand deposit, further underlain by silt in Borehole C3. Based on groundwater observations in the open boreholes and the standpipe piezometer installed in Borehole C1, the groundwater table at the time of our investigation was between depth/elevation 7.2 m/ 183.1 m and 6.7 m/183.3 m, but would be subject to seasonal fluctuations.

Details of the subsurface conditions encountered in the boreholes are presented on the Record of Borehole Sheets in Appendix A2. Inferred stratigraphic section at the culvert location is also presented on Drawing No. A2-2. The following description of the individual soil strata is to assist the designers of the project with an understanding of the anticipated subsurface conditions underlying the site. It should be noted that the soil and groundwater conditions may vary in between and beyond the borehole locations.

4.2.1 Topsoil

Boreholes were advanced from the existing grade of proposed alignment of Highway 26 (i.e. o.g. level) and encountered a 0.2 to 0.3 m thick silty topsoil at ground surface.

4.2.2 Sandy Silt Till

Beneath the topsoil, the boreholes encountered a 6.1 to 8.3 m thick sandy silt till deposit which extends to elevations 183.0 m (Borehole C1), 181.8 m (Borehole C2) and 183.7 m (Borehole C3).

The glacial deposit consists of a heterogeneous, unsorted mixture of sandy silt with traces to some gravel and clay size particles. The presence of cobbles was also inferred while drilling and also due to broken cobble pieces in the samples recovered.

Four grain size analyses were carried out on representative samples of the sandy silt till. The results are presented on the Record of Borehole sheets in Appendix A2, and the grain size curves are presented in Figure B2-1 in Appendix B2. This indicates the following grain-size distribution.

Gravel:	2-24%
Sand:	27-38%
Silt & Clay:	43-71%

This is a basically granular (non-cohesive) soil, although in some zones, where their percentage is high, the clay particles impart some slight cohesion to the deposit.

Standard Penetration tests performed below 0.7 m depth in this granular deposit yielded N-values of 17 to in excess of 50 blows/0.3 m. These results indicate that the relative density of this glacial deposit can be described as compact to very dense. It is believed however that some of the recorded high N-values are somewhat higher than actual due to the presence of cobbles.

Within the upper 0.7 m, N-values of 12, 3 and 36 blows/0.3 m recorded in Boreholes C1, C2 and C3, respectively, showing a variable relative density of very loose to dense.

Due to their mode of deposition, the presence of cobbles and boulders should always be anticipated in the glacial till deposits. In fact, in Borehole C2 refusal to augering was encountered at a depth of 2.3 m (believed to be due to the presence of a boulder) which necessitated the relocation and redrilling of the borehole.

4.2.3 Sand/Silty Sand

Underlying the glacial deposit, the boreholes encountered a sand to silty sand deposit at depths of 6.3 m (El. 183.7 m) to 8.6 m (El. 181.8 m). Boreholes C1 and C2 were terminated within this deposit at depths of 12.7 and 11.1 m (El. 177.6 and 179.3 m), after penetrating the deposit for a vertical distance of 5.4 and 2.5 m, respectively. In Borehole C3, a silt deposit was contacted at 10.9 m depth or at El. 179.1 m, underlying the sand deposit.

The grain-size distribution of the deposit ranges from silty fine sand to fine to medium sand with some silt and clay size particles.

The grain-size distribution of two samples of the silty sand from Borehole C1 was determined in the laboratory and the resulting curve is given in Figure B2-2 in Appendix B2. The following grain-size distribution is indicated.

Gravel:	0-1%
Sand:	54-70%
Silt & Clay:	29-46%

Grain size analysis tests performed on two samples on the somewhat coarser sand with some silt from Boreholes C2 and C3 yielded the following grain-size distribution, as shown in Figure B2-3 in Appendix B2.

Gravel:	0%
Sand:	76 to 83%
Silt and Clay:	17 and 24%

This is a granular (non-cohesive) material. Standard Penetration tests, performed in this granular deposit, yielded N-values of 6 to 71 blows/0.3 m, indicating loose to very dense condition.

4.2.4 Silt

Beneath the sand, Borehole C3 contacted a silt deposit at a depth of 10.9 m (El. 179.1 m). The borehole was terminated within this unit at a depth of 11.1 m (El. 178.9 m).

A sample from this deposit was determined in the laboratory and the resulting curve is given in Figure B-4 in Appendix B2. The following grain-size distribution is indicated.

Gravel:	0%
Sand:	11%
Silt:	82%
Clay:	7%

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

An N-value 24 blows/0.3 m was recorded, which indicates a compact relative density.

4.2.5 Groundwater Conditions

Groundwater levels in the open boreholes were observed during the drilling and at the completion of each borehole. In addition, a piezometer was installed in Borehole C1 to allow groundwater monitoring over a prolonged period of time, without interference from surface water. The observations and recorded values are shown on the individual Record of Borehole sheets.

The observed water levels in the open boreholes on completion ranged from 6.7 to 7.3 m below grade, or elevation 183.1 to 183.3 m. In the piezometer, installed within the silty sand deposit in Borehole C1, a measured water level of 7.2 m (Elevation 183.1 m) was obtained about five weeks after installation, which is likely the stabilized water level.

Based on the above observations, at the time of our investigation the groundwater table was between elevations 183.1 and 183.3 m. However, based on the change of the colour of the soil from brown to grey, it may be at higher elevations at different times of the year, as it would be subject to seasonal fluctuations as well as fluctuations due to weather events.

For and on behalf of Coffey Geotechnics Inc.

Gwangha Roh, Ph.D.

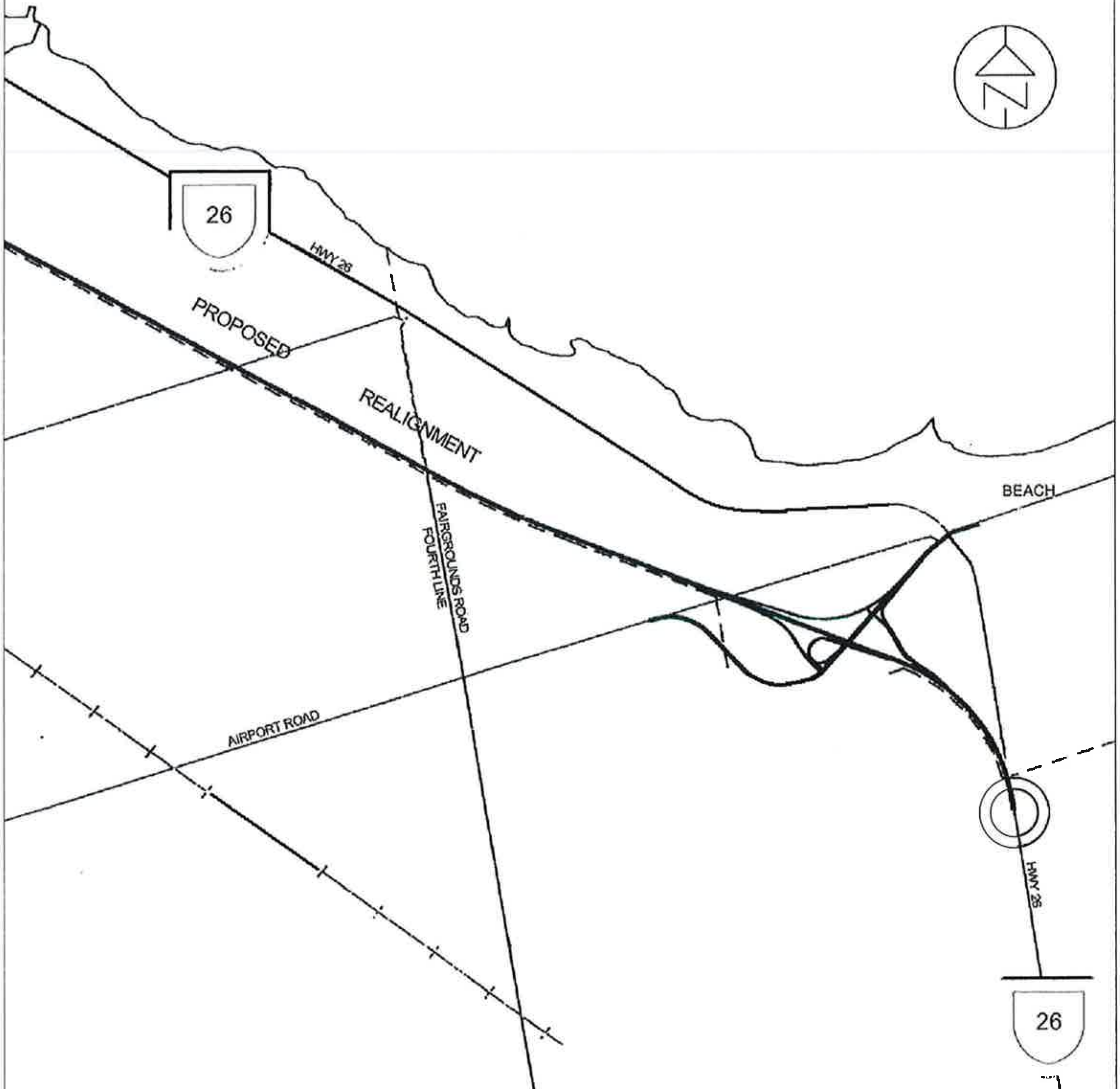
LICENSED PROFESSIONAL ENGINEER
RAMON MIRANDA
PROVINCE OF ONTARIO

Ramon Miranda, P. Eng.

Zuhtu Ozden, P. Eng.

Z. S. OZDEN

Drawing



drawn:	PHK	coffey geotechnics SPECIALISTS MANAGING THE EARTH	G.W.P. 630-91-00	
checked:	RM		project: HIGHWAY 26 REALIGNMENT PROPOSED CULVERTS	
approved:	ZO			
date:	Feb. 26, 2010		title: SITE LOCATION PLAN	
scale:	NTS		project no: TRANETOB01232AA	drawing no: 1

Appendix A1

Drawings & Record of Borehole Sheets for Culvert at Station 9+845

NOTES:

FOR DETAILED SUBSURFACE CONDITIONS REFER TO RECORD OF BOREHOLE SHEETS.

METRIC

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

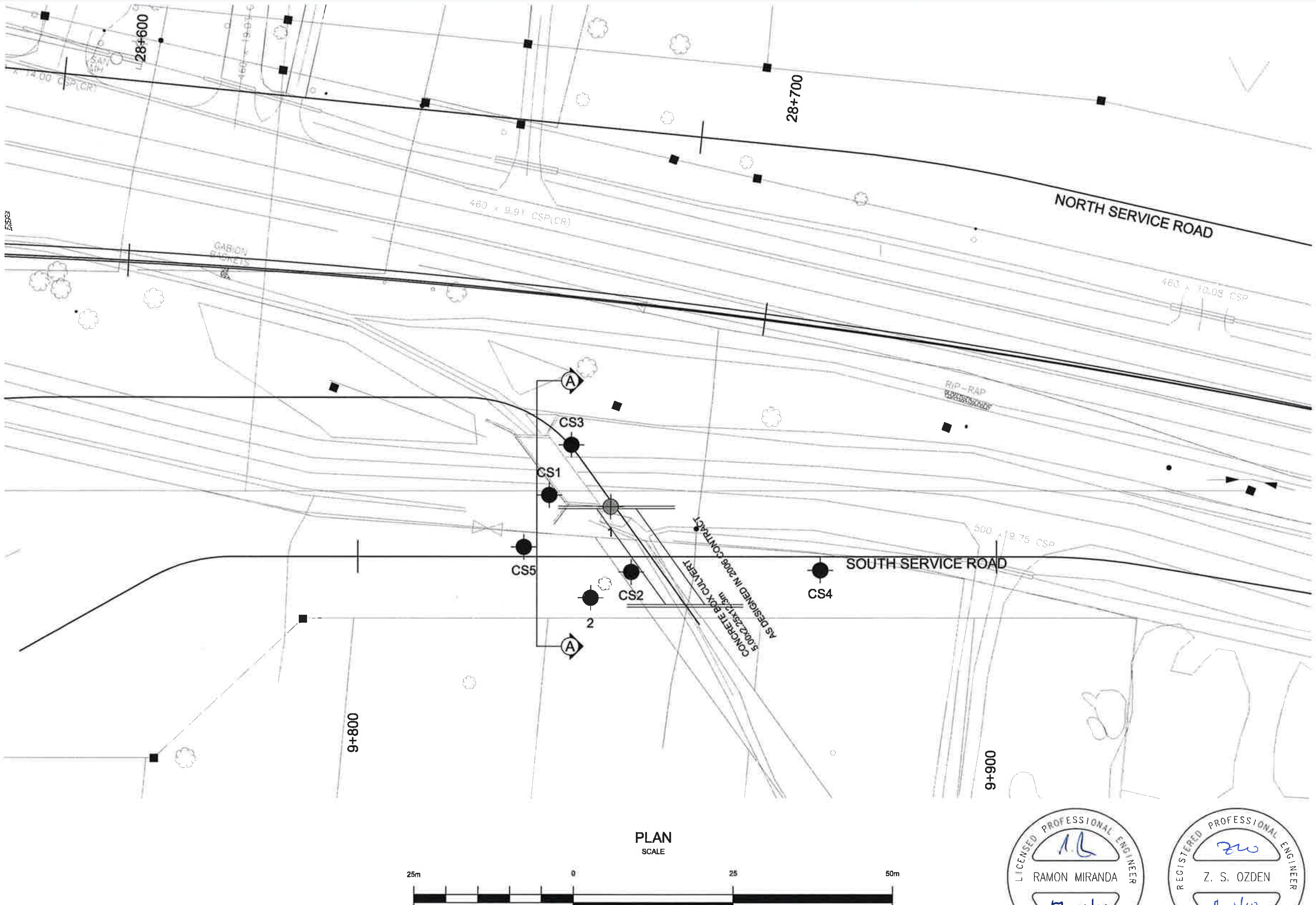
CONT No.

GWP: 630-91-00

SHEET

HIGHWAY 26 REALIGNMENT
PROPOSED CULVERT @ STATION 9+845
BOREHOLE LOCATION PLAN

coffey geotechnics
SPECIALISTS MANAGING THE EARTH



KEY PLAN
N.T.S.

LEGEND

- Borehole (Coffey)
- Borehole (Golder)

No.	ELEVATION	NORTHING	EASTING
CS1	194.1	4924151.04	256684.87
CS2	192.6	4924134.75	256678.18
CS3	194.2	4924150.60	256693.47
CS4	194.2	4924107.13	256689.03
CS5	194.2	4924151.85	256675.82
1	194.3	4924141.40	256686.60
2	193.8	4924139.20	256672.10

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

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

LICENSED PROFESSIONAL ENGINEER
RAMON MIRANDA
Mar 1/10
PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER
Z. S. OZDEN
Mar 1/10
PROVINCE OF ONTARIO

REVISIONS	DATE	BY	DESCRIPTION

Geocres No. 41A-211

TRANETOB01232AA			DIST
SUBM'D	CHECKED	DATE Feb. 26, 2010	SITE 30-682C
DRAWN PHK	CHECKED RM	APPROVED ZO	DWG A1-1

NOTES:

FOR DETAILED SUBSURFACE CONDITIONS REFER TO RECORD OF BOREHOLE SHEETS.

METRIC

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

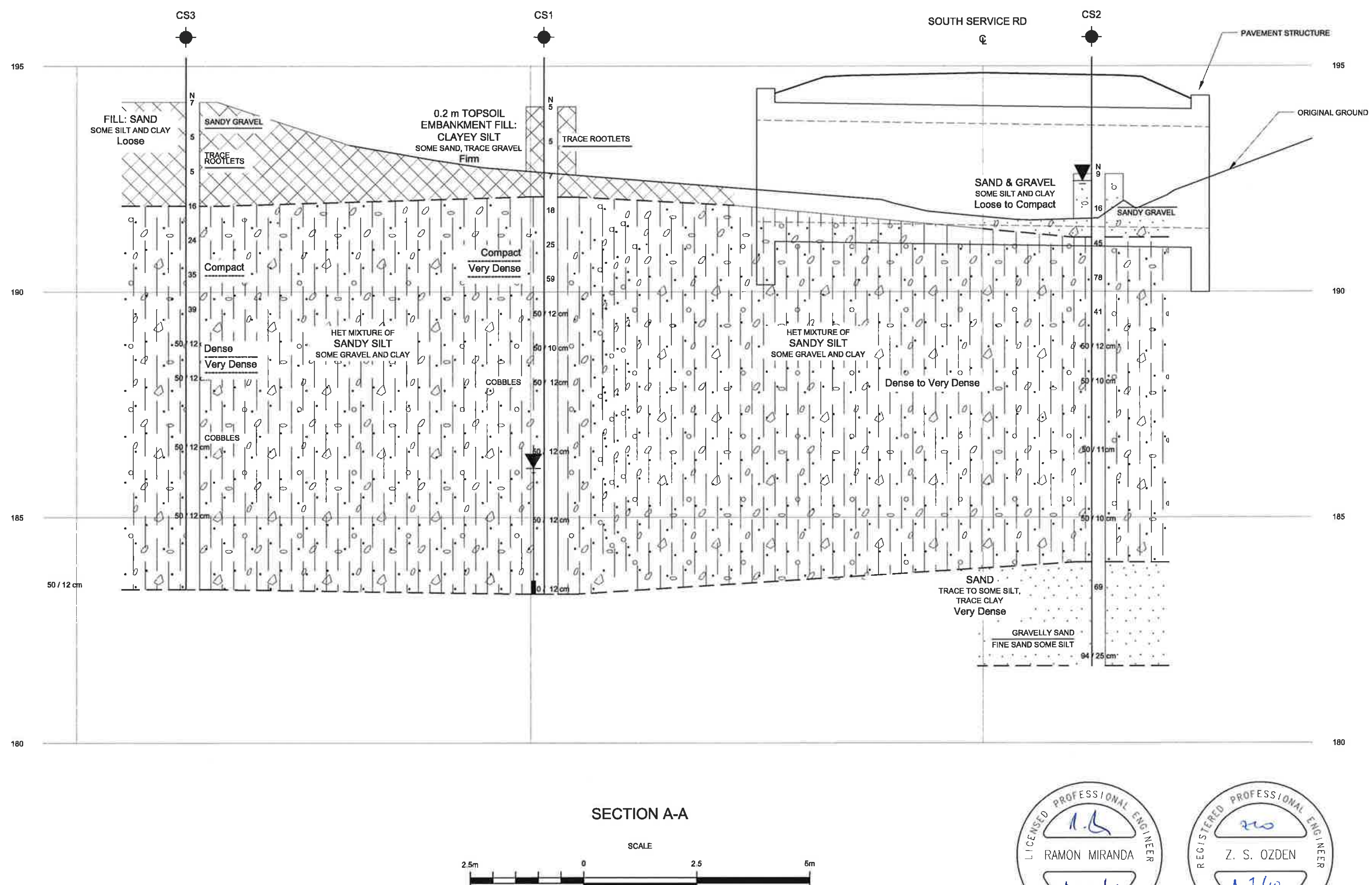
CONT No.

GWP: 630-91-00

HIGHWAY 26 REALIGNMENT
PROPOSED CULVERT @ STATION 9+845
SOIL STRATA

SHEET

coffey geotechnics SPECIALISTS MANAGING THE EARTH



KEY PLAN
N.T.S.

LEGEND

Borehole (Coffey)

N Blows/0.3m (Std. Pen. Test, 475 J/blow)

Water Level at Time of Investigation (W. L. NOT STABILIZED)

Water Level in Piezometer

Piezometer

No.	ELEVATION	NORTHING	EASTING
CS1	194.1	4924151.04	256684.87
CS2	192.6	4924134.75	256678.18
CS3	194.2	4924150.60	256693.47

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

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

LICENSED PROFESSIONAL ENGINEER RAMON MIRANDA PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER Z. S. OZDEN PROVINCE OF ONTARIO

REVISIONS	DATE	BY	DESCRIPTION

Geocres No. 41A-211

	TRANETOB01232AA		DIST	
SUBM'D	CHECKED	DATE Feb. 26, 2010	SITE	30-682C
DRAWN PHK	CHECKED RM	APPROVED ZO	DWG	A1-2

RECORD OF BOREHOLE No CS1

METRIC

GWP 630-91-00	LOCATION Station : 9+831, 8.3 m Lt C/L of South Service Road	ORIGINATED BY RK
DIST HWY 26	BOREHOLE TYPE Solid Stem Auger	COMPILED BY RK
DATUM Geodetic	DATE 11/10/2008	CHECKED BY RM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
194.1	GROUND SURFACE					
0.0	0.2 m **TOPSOIL**	1	SS	5	194	
	EMBANKMENT FILL: Clayey Silt, some sand, tr. gravel, brown, firm, moist; tr. rootlets	2	SS	5	193	
192.1		3	SS	7	192	2 25 47 26
2.0	**SANDY SILT TILL** (heterogeneous mixture of sandy silt with some gravel and clay) grey, damp to moist	4	SS	18		
	compact	5	SS	25	191	7 39 37 17
	v. dense	6	SS	59	190	
		7	SS	50 / 12 cm	189	auger grinding
		8	SS	50 / 10 cm		auger grinding
	cobbles	9	SS	50 / 12 cm	188	5 41 40 14
		10	SS	50 / 12 cm	187 / 186	
		11	SS	50 / 12 cm	185 / 184	
183.3 / 10.8		12	SS	50 / 12 cm		

End of borehole
Borehole dry (not stabilized) and open upon completion
Piezometer installed to 10.8 m

Piezometer reading
Dec12, 2008 - 8.0 m (El. 186.1 m)

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH (kPa): ○ UNCONFINED, + FIELD VANE, ● POCKET PENETR., × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³

+³, ×³: Numbers refer to Sensitivity   15-⊕-5 (20/10) (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No CS2

METRIC

GWP 630-91-00 LOCATION Station : 9+843, 2.4 m Rt C/L of South Service Road ORIGINATED BY RK

DIST HWY 26 BOREHOLE TYPE Solid Stem Auger & NW Casing COMPILED BY RK

DATUM Geodetic DATE 11/11/2008 CHECKED BY RM

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%) (approx.)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
192.6	GROUND SURFACE							
0.0	**SAND & GRAVEL** some silt and clay brown, wet, loose to compact	1	SS	9	▼*	192	~14	spoon wet
	sandy gravel	2	SS	16			~6	spoon wet
191.2 / 1.4	**SANDY SILT TILL** (heterogeneous mixture of sandy silt with some gravel and clay) grey, dense to v. dense	3	SS	45		191	~7	5 34 43 18
		4	SS	78		190	~6	
		5	SS	41		189	~6	wash boring (NW casing) started at 3.0 m depth (El. 189.5)
		6	SS	50 / 12 cm		188	~7	
		7	SS	50 / 10 cm		187	~8	
	moist / wet	8	SS	50 / 11cm		186	~8	9 34 42 15
		9	SS	50 / 10 cm		185	~9	
184.0 / 8.6	**SAND** tr. to some silt, tr. clay grey, wet, v. dense	10	SS	69		184, 183	~6	22 59 (19)
	gravelly sand / fine sand some silt	11	SS	94 / 25 cm		182	~15	
181.7 / 10.9	End of borehole. Water level at 0.2 m depth upon completion(not stabilized)* Borehole caved in at 3.7 m upon completion.							

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE 20 40 60 80 100

PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³

$+^3, \times^3$: Numbers refer to Sensitivity; 15-⊕-5 (20/10) (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No CS3

METRIC

GWP 630-91-00 | LOCATION Station : 9+833, 20.4 m Lt C/L of South Service Road | ORIGINATED BY RK

DIST ______ HWY 26 | BOREHOLE TYPE Solid Stem Auger | COMPILED BY RK

DATUM Geodetic | DATE 11/10/2008 | CHECKED BY RM

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
194.2	GROUND SURFACE							
0.0	EMBANKMENT FILL: Sand, some silt and clay, brown, loose, moist; sandy gravel	1	SS	7				
	tr. rootlets	2	SS	5				
		3	SS	5	0	78	(22)	
191.9 / 2.3	SANDY SILT TILL (heterogeneous mixture of sandy silt with some gravel and clay) grey, damp to moist	4	SS	16				
	compact	5	SS	24	7	35	41	17
		6	SS	35				
	dense	7	SS	39				
	v. dense	8	SS	50 / 12 cm				
		9	SS	50 / 12 cm				
	cobbles							
		10	SS	50 / 12 cm	5	33	45	17
		11	SS	50 / 12 cm				
183.4		12	SS	50 / 12 cm				
10.8	End of borehole. Borehole is dry (not stabilized) and open upon completion.							

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (194 to 184); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH (kPa): ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE (20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (10 20 30); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

+ ³, × ³: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

Foundation Design

TRANETOB01234AA: HWY26

RECORD OF BOREHOLE No CS4

METRIC

GWP 630-91-00 LOCATION Station : 9+872, 2.1 m Rt C/L of South Service Road ORIGINATED BY RK
DIST HWY 26 BOREHOLE TYPE Solid Stem Auger COMPILED BY RK
DATUM Geodetic DATE 11/10/2008 CHECKED BY RM

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
194.2	GROUND SURFACE						
0.0	0.4 m **TOPSOIL** dark brown, tr. rootlets	1	SS	5			
	CLAYEY SILT tr. gravel, some sand firm to v. stiff, damp to moist	2	SS	16			
	brown / grey	3	SS	12			
		4	SS	21			4 29 40 27
190.9 / 3.3	**SANDY SILT TILL** (heterogeneous mixture of sandy silt with some gravel and clay) grey, damp to moist; compact / v. dense	5	SS	30			
		6	SS	51			
		7	SS	50			5 41 42 12
		8	SS	50 / 12 cm			
		9	SS	50 / 12 cm			
							auger grinding
		10	SS	50 / 12 cm			
							auger grinding
		11	SS	50 / 10 cm			
					▼*		
184.2 / 10.0	**SAND** fine to medium sand, tr. to some silt grey, v. dense, wet						spoon wet
183.3 / 10.9		12	SS	85 / 25 cm			6 79 (15)

End of borehole
Water level @ 9.8 m depth (not stabilized)* upon completion
Borehole is open upon completion

Elevation scale: 194, 193, 192, 191, 190, 189, 188, 187, 186, 185, 184

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH (kPa): ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE: 20 40 60 80 100
PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%): 10 20 30
UNIT WEIGHT γ kN/m³

+ ³, × ³: Numbers refer to Sensitivity; 20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No CS5

METRIC

GWP 630-91-00	LOCATION Station : 9+828, 3.0 m Lt C/L of South Service Road		ORIGINATED BY RK
DIST	HWY 26	BOREHOLE TYPE Solid Stem Auger	COMPILED BY RK
DATUM Geodetic	DATE 11/10/2008		CHECKED BY RM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
194.2	GROUND SURFACE					
0.0	0.4 m **TOPSOIL**	1	SS	1	194	
	CLAYEY SILT tr. to some sand, tr. gravel brown, v. soft to v. stiff	2	SS	10	193	
		3	SS	17		0 7 32 61
192.1 / 2.1	**SANDY SILT TILL** (heterogeneous mixture of sandy silt with some gravel and clay) grey, compact to v. dense, moist	4	SS	39	192	
		5	SS	20	191	5 39 43 13
		6	SS	39	190	
	silty sand layer	7	SS	67		8 44 38 10
		8	SS	50 / 12 cm	189	
		9	SS	50 / 12 cm	188	
	cobbles				187	
		10	SS	50 / 12 cm	186	
		11	SS	50 / 10 cm	185	
					184	
183.1 / 11.1		12	SS	40		
	End of borehole. Borehole is dry (not stabilized) and open upon completion .					

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE (20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L, WATER CONTENT (%) (10 20 30); UNIT WEIGHT γ kN/m³.

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

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

Golder Associates
London, Ontario

PROJECT 001-3232-4-4 **RECORD OF BOREHOLE No 1** 1 OF 1 **METRIC**

G.W.P. 630-91-00 LOCATION N 4924141.4 ;E 256686.6 ORIGINATED BY DJM

DIST 30 HWY 26 BOREHOLE TYPE POWER AUGER (HOLLOW STEM) COMPILED BY WDF

DATUM GEODETIC DATE 21 August 2002 CHECKED BY AMH

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
194.31						
0.00	(FILL), sand and gravel, Brown				194	
0.21	SAND, fine, some silt, Loose, Brown	1	SS	6		
193.40 / 0.91	CLAYEY SILT, trace sand, trace gravel, Firm, Brown				193	
192.94 / 1.37	CLAYEY SILT, trace sand, trace gravel and organic material, Stiff, Black	2	SS	10		
192.63 / 1.68	CLAYEY SILT, trace sand, trace gravel (TILL), Stiff, Brown					
192.33 / 1.98	SANDY SILT, trace to some clay, trace gravel, with cobbles and boulders (TILL), Compact to very dense, Brown to Grey below 3.6m	3	SS	71	192	7 41 39 13
		4	SS	38	191	
		5	SS	28	190	
		6	SS	42		
		7	SS	85	189	
		8	SS	72	188	
					187	
		9	SS	106	186	
185.01 / 9.30	END OF BOREHOLE	10	SS	106		

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, X LAB VANE; 20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³.

Borehole dry during drilling
Aug. 21, 2002

Installation dry to elev. 185.47m
Aug. 22, 2002

Groundwater measured at elev. 189.86m
Aug. 27, 2002

Groundwater measured at elev. 190.41m
Aug. 20, 2003

ON_MTO 001-3232-4-4.GPJ ON_MOT.GDT 26/11/03 DATA INPUT:

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

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 2

1 OF 1 **METRIC**

PROJECT 001-3232-4-4
G.W.P. 630-91-00
DIST 30 HWY 26
DATUM GEODETIC

LOCATION N 4924139.2 ;E 256672.1
BOREHOLE TYPE POWER AUGER (HOLLOW STEM)
DATE 21 August 2002

ORIGINATED BY DJM
COMPILED BY WDF
CHECKED BY AMH

Column headings: SOIL PROFILE (ELEV / DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20, 40, 60, 80, 100); PLASTIC LIMIT W_p, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) (GR, SA, SI, CL)

ELEV / DEPTH	DESCRIPTION
193.77 / 0.00	TOPSOIL, silty, Brown
0.24	SILTY SAND, trace organic material, Compact, Brown
192.55 / 1.22	SANDY SILT, trace to some clay, trace gravel, with cobbles and boulders (TILL), Compact to very dense, Brown to Grey below 2.7m
184.32 / 9.45	END OF BOREHOLE Borehole dry during drilling Aug. 21, 2002

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1	SS	12	0	52	41	7
2	SS	31				
3	SS	29				
4	SS	38	8	43	36	13
5	SS	47				
6	SS	70				
7	SS	100/250mm				
8	SS	60				
9	SS	91				

Elevation scale: 193, 192, 191, 190, 189, 188, 187, 186, 185

ON_MTO 001-3232-4-4.GPJ ON_MOT.GDT 25/11/03 DATA INPUT:

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

Appendix A2

Drawings & Record of Borehole Sheets for Culvert at Station 28+430

NOTES:

FOR DETAILED SUBSURFACE CONDITIONS REFER TO RECORD OF BOREHOLE SHEETS.

METRIC

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

CONT No.

GWP: 630-91-00

SHEET

HIGHWAY 26 REALIGNMENT
PROPOSED CULVERT @ STATION 28+430
BOREHOLE LOCATION PLAN

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

PLAN

SCALE

25m 0 25 50m

KEY PLAN
N.T.S.

LEGEND

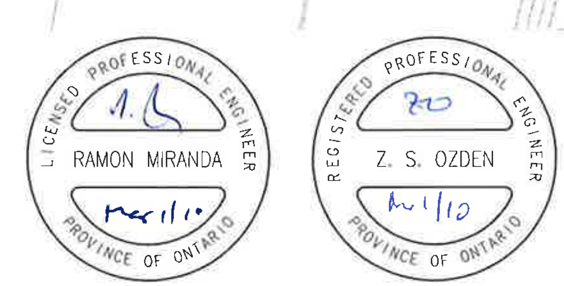
Borehole (Coffey)

Borehole (Golder)

No.	ELEVATION	NORTHING	EASTING
C1	190.3	4924384.79	256628.99
C2	190.4	4924360.24	256631.28
C3	190.0	4924408.32	256612.31
3	190.4	4924402.90	256644.00
4	190.4	4924363.20	256618.00

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

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



REVISIONS		
DATE	BY	DESCRIPTION

Geocres No. 41A-211

TRANETOB01232AA			DIST
SUBM'D	CHECKED	DATE Feb. 26, 2010	SITE 30-680C
DRAWN PHK	CHECKED RM	APPROVED ZO	DWG A2-1

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.

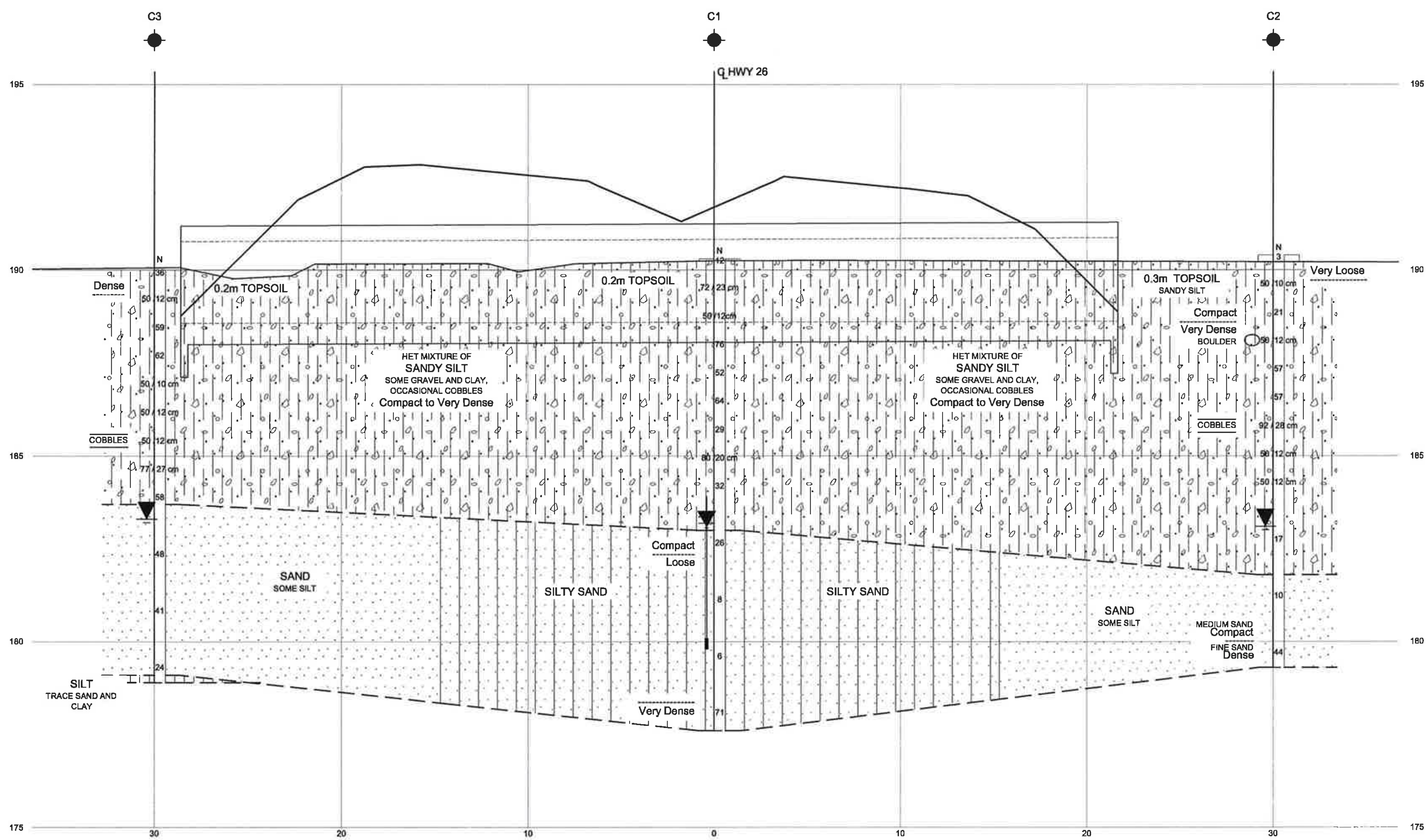
CONT No.

GWP: 630-91-00

SHEET

HIGHWAY 26 REALIGNMENT
PROPOSED CULVERT @ STATION 28+430
SOIL STRATA

coffey geotechnics
SPECIALISTS MANAGING THE EARTH



SECTION A-A

SCALE

10m 0 10 20m

KEY PLAN
N.T.S.

LEGEND

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

No.	ELEVATION	NORTHING	EASTING
C1	190.4	4924384.79	256631.28
C2	190.4	4924360.24	256612.31
C3	190.1	4924402.32	256654.17

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

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

REVISIONS	DATE	BY	DESCRIPTION

Geocres No. 41A-211

	TRANETOB01232AA			DIST	
SUBM'D	CHECKED		DATE Feb. 26, 2010	SITE	30-680C
DRAWN PHK	CHECKED RM		APPROVED ZO	DWG	A2-2

Ministry of Transportation Ontario

TRANETOB01234AA: HWY26

RECORD OF BOREHOLE No C1

METRIC

GWP 630-91-00 LOCATION Station : 28+418, at C/L of New Hwy 26 ORIGINATED BY RK

DIST HWY 26 BOREHOLE TYPE Solid Stem Auger COMPILED BY RK

DATUM Geodetic DATE 11/7/2008 CHECKED BY RM

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
190.3	GROUND SURFACE					
0.0	0.2m **TOPSOIL**	1	SS	12	190	
	SANDY SILT TILL (heterogeneous mixture of sandy silt with some gravel and clay) occ. cobbles, compact to v. dense damp to moist	2	SS	72 / 23 c		
		3	SS	50 /12c	189	
	brown					
	grey	4	SS	76	188	24 33 (43)
		5	SS	52	187	
		6	SS	64	186	
		7	SS	29		
		8	SS	80 /20 c	185	
		9	SS	32	184	
183.0 7.3	**SILTY SAND** grey, wet				183	
	compact	10	SS	26		1 70 (29) spoon wet
	loose				182	
		11	SS	8	181	spoon wet
					180	
		12	SS	6	179	0 54 38 8
	v. dense	13	SS	71	178	spoon wet
177.6 12.7	End of Borehole. Water level @ 7.2 m depth (not stabilized) upon completion. Borehole caved-in @ 10.8 m upon completion. Piezometer installed to 10.7 m. Piezometer reading: Dec.12,2008 / water level @ 7.2 m depth/ El.183.1 m					

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH (kPa): ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE — 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m^3

+^{3}, ×^{3}: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No C2

METRIC

GWP 630-91-00 LOCATION Station : 28+440, 30.0 m Rt C/L of New Hwy 26 ORIGINATED BY RK

DIST HWY 26 BOREHOLE TYPE Solid Stem Auger COMPILED BY RK

DATUM Geodetic DATE 11/7/2008 CHECKED BY RM

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
190.4	GROUND SURFACE							
0.0	0.3 m **TOPSOIL** dark brown, sandy silt; v. loose	1	SS	3		190		
		2	SS	50 /10 cm				
						189		spoon wet
	brown, compact	3	SS	21				auger refusal
	grey, v. dense; boulder	4	SS	50 /12 cm		188		borehole moved 1 m south
	SANDY SILT TILL (heterogeneous mixture of sandy silt with some gravel and clay) occ. cobbles, compact to v. dense damp to moist	5	SS	57		187		2 38 41 19
		6	SS	57		186		
	cobbles	7	SS	92 / 28 cm				
		8	SS	50 /12 cm		185		
		9	SS	50 /12 cm		184		
					▼*	183		
	wet	10	SS	17				spoon wet; 2 27 67 4
181.8 / 8.6	**SAND** grey, some silt, wet					182		
		11	SS	10		181		0 83 (17)
	medium sand, compact; fine sand, dense					180		
179.3		12	SS	44				
11.1	End of borehole. Water level @ 7.3 m (not stabilized)* upon completion Borehole caved in @ 7.8 m upon completion							

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³

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

RECORD OF BOREHOLE No C3

1 OF 1

METRIC

GWP 630-91-00 LOCATION Station : 28+400, 30.0 m Lt C/L of New Hwy 26 ORIGINATED BY RK

DIST HWY 26 BOREHOLE TYPE Solid Stem Auger COMPILED BY RK

DATUM Geodetic DATE 11/6/2008 CHECKED BY RM

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
190.0	GROUND SURFACE					190	
0.0	0.2 m **TOPSOIL**	1	SS	36			
	dense						
		2	SS	50/12 cm		189	
	SANDY SILT TILL (heterogeneous mixture of sandy silt with some gravel and clay) occ. cobbles grey, damp to moist, v. dense	3	SS	59		188	
		4	SS	62			
		5	SS	50 / 10 cm		187	4 31 46 19
		6	SS	50 / 12 cm		186	
	cobbles	7	SS	50/12 cm		185	
		8	SS	77 / 27 cm		184	
183.7 6.3	**SAND** some silt grey, fine to medium sand; moist / wet	9	SS	58	▼*	183	
		10	SS	48		182	spoon wet
		11	SS	41		181 / 180	spoon wet 0 76 (24)
179.1 10.9	**SILT** grey, tr. sand and clay, wet	12	SS	24		179	0 11 82 7
178.9 11.1	End of borehole Water level at 6.7 m (not stabilized)* upon completion Borehole caved in at 7.60 m upon completion						

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH (kPa): ○ UNCONFINED + FIELD VANE ● POCKET PENETR. × LAB VANE — 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³

+ ³, × ³ : Numbers refer to Sensitivity

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

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 3

METRIC

PROJECT 001-3232-4-4
G.W.P. 630-91-00
DIST 30 HWY 26
DATUM GEODETIC

LOCATION N 4924402.9 ;E 256644.0
BOREHOLE TYPE POWER AUGER (HOLLOW STEM)
DATE 21 August 2002

ORIGINATED BY PJM
COMPILED BY WDF
CHECKED BY AMH

ELEV / DEPTH	DESCRIPTION
190.37 / 0.00	TOPSOIL, silty Brown
190.07 / 0.30	SANDY SILT, trace clay, trace gravel, with cobbles and boulders (TILL) Dense to very dense Brown to Grey below 2.1m
186.33 / 4.04	CLAYEY SILT, trace sand, trace gravel, Hard Grey
185.95 / 4.42	SANDY SILT, trace to some clay, trace gravel, with cobbles and boulders (TILL) Dense Brown to Grey below 2.7m
183.36 / 7.01	SAND, fine to medium, trace silt, trace gravel Compact to dense Grey
180.77 / 9.60	END OF BOREHOLE

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	38	
2	SS	100	
3	SS	82	12 42 38 8
4	SS	75	
5	SS	70	
6	SS	42	
7	SS	43	
8	SS	40	1 83 16 0
9	SS	15	

Groundwater encountered at elev. 183.36m during drilling Aug. 21, 2002

Groundwater measured at elev. 182.69m Aug. 22, 2002

Installation dry to elev. 182.45m Aug. 27, 2002

Installation blocked at elev. 190.07m Aug. 20, 2003

Column headings: STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (190–181); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, X LAB VANE, 20 40 60 80 100; PLASTIC LIMIT W_p, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³

+3, X3: Numbers refer to Sensitivity O 3% STRAIN AT FAILURE

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 4

METRIC

PROJECT 001-3232-4-4
G.W.P. 630-91-00 LOCATION N 4924363.2 ;E 256618.0 ORIGINATED BY DJM
DIST 30 HWY 26 BOREHOLE TYPE POWER AUGER (HOLLOW STEM) COMPILED BY WDF
DATUM GEODETIC DATE 21 August 2002 CHECKED BY AMH

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
190.38					
0.00 / 0.12	TOPSOIL, silty / Brown				
	SANDY SILT, trace clay, trace to some gravel, with cobbles and boulders (TILL) Dense to very dense Grey	1	SS	100/250mm	
		2	SS	100/225mm	
		3	SS	101/250mm	
		4	SS	76	25 35 33 7
		5	SS	48	
		6	SS	55	
		7	SS	78	
183.06 / 7.32	SANDY SILT, trace clay, trace gravel Compact Grey	8	SS	14	
181.85 / 8.53	SANDY SILT, layered Dense Grey				
181.08 / 9.30 / 9.45	SAND, fine, some silt, layered Dense Grey	9	SS	32	

END OF BOREHOLE

Groundwater encountered at elev. 181.85m during drilling Aug. 21, 2002

Groundwater measured at elev. 182.91m Aug. 22, 2002

Groundwater measured at elev. 182.88m Aug. 27, 2002

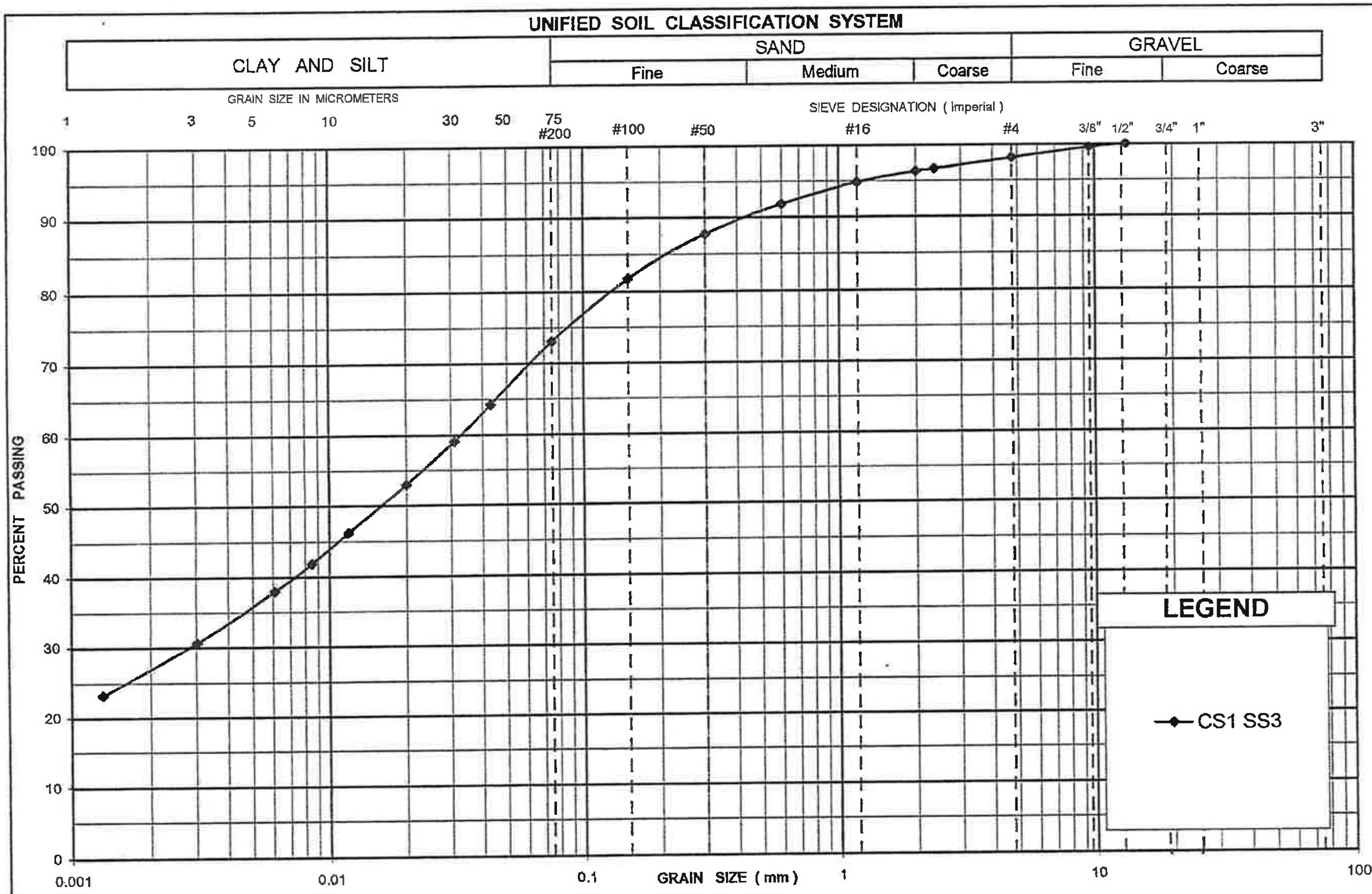
Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (190 to 181); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, X LAB VANE (20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³.

+3, X3: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

ON_MTO 001-3232-4-4.GPJ ON_MOT.GDT 28/11/03 DATA INPUT:

Appendix B1

Laboratory Test Results for Culvert at Station 9+845



coffey geotechnics
SPECIALISTS MANAGING THE EARTH

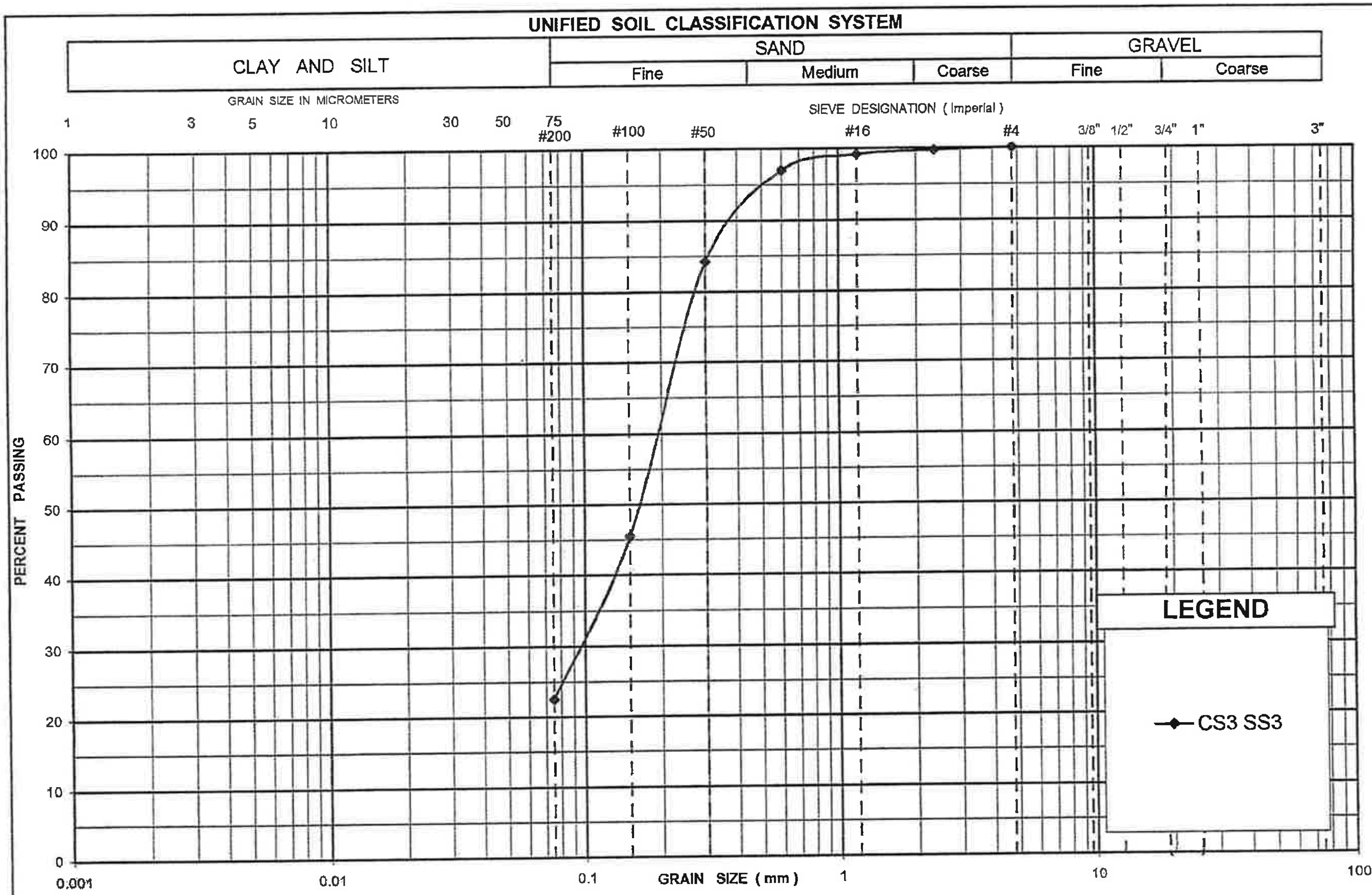
GRAIN SIZE DISTRIBUTION

EMBANKMENT FILL: Clayey Silt, some sand

FIGURE NO.: B1-1

PROJECT NO:TRANETOB01232AB

DATE: June 10, 2009

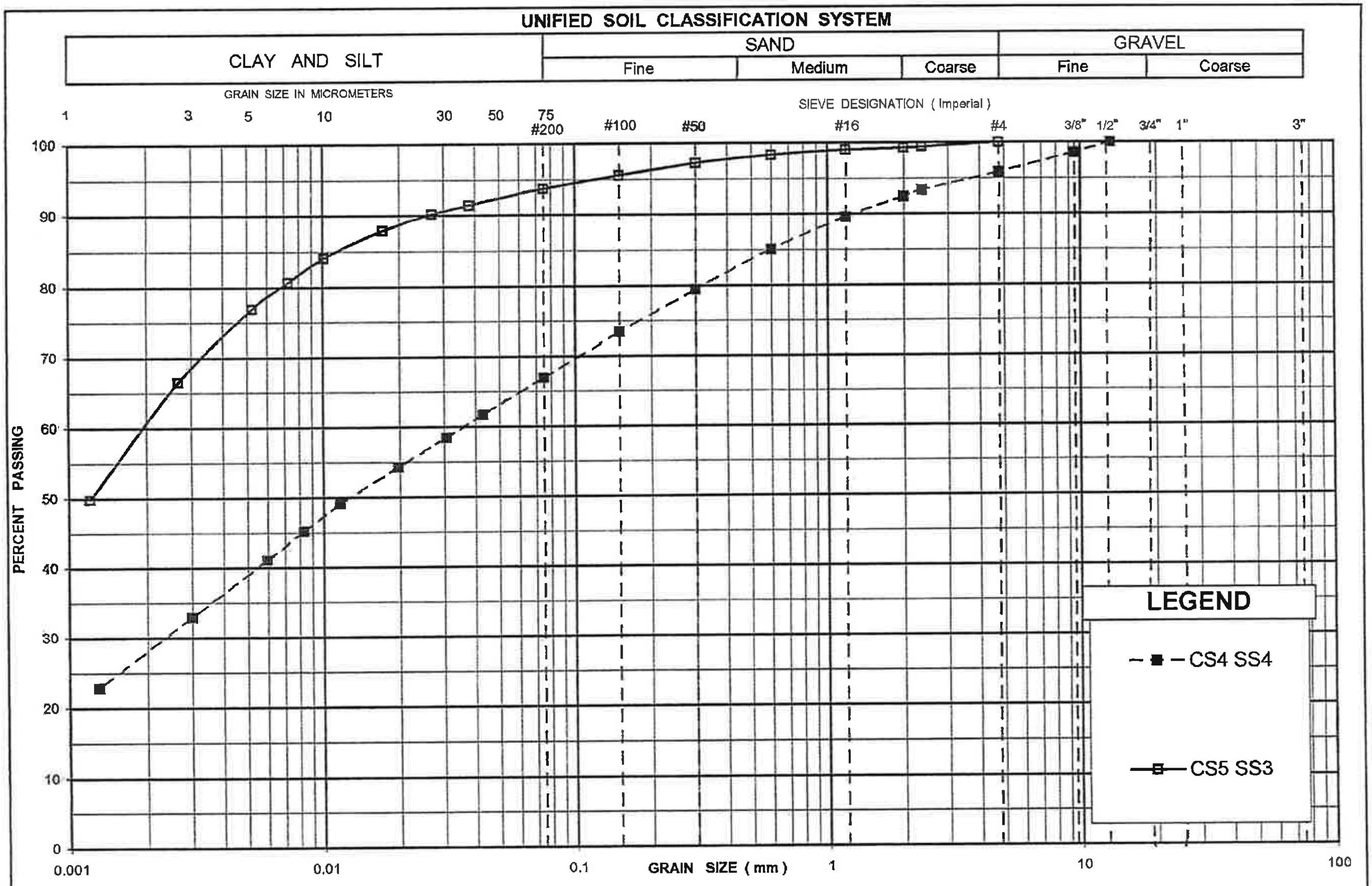


coffey geotechnics
SPECIALISTS MANAGING THE EARTH

GRAIN SIZE DISTRIBUTION

EMBANKMENT FILL: Sand, some silt

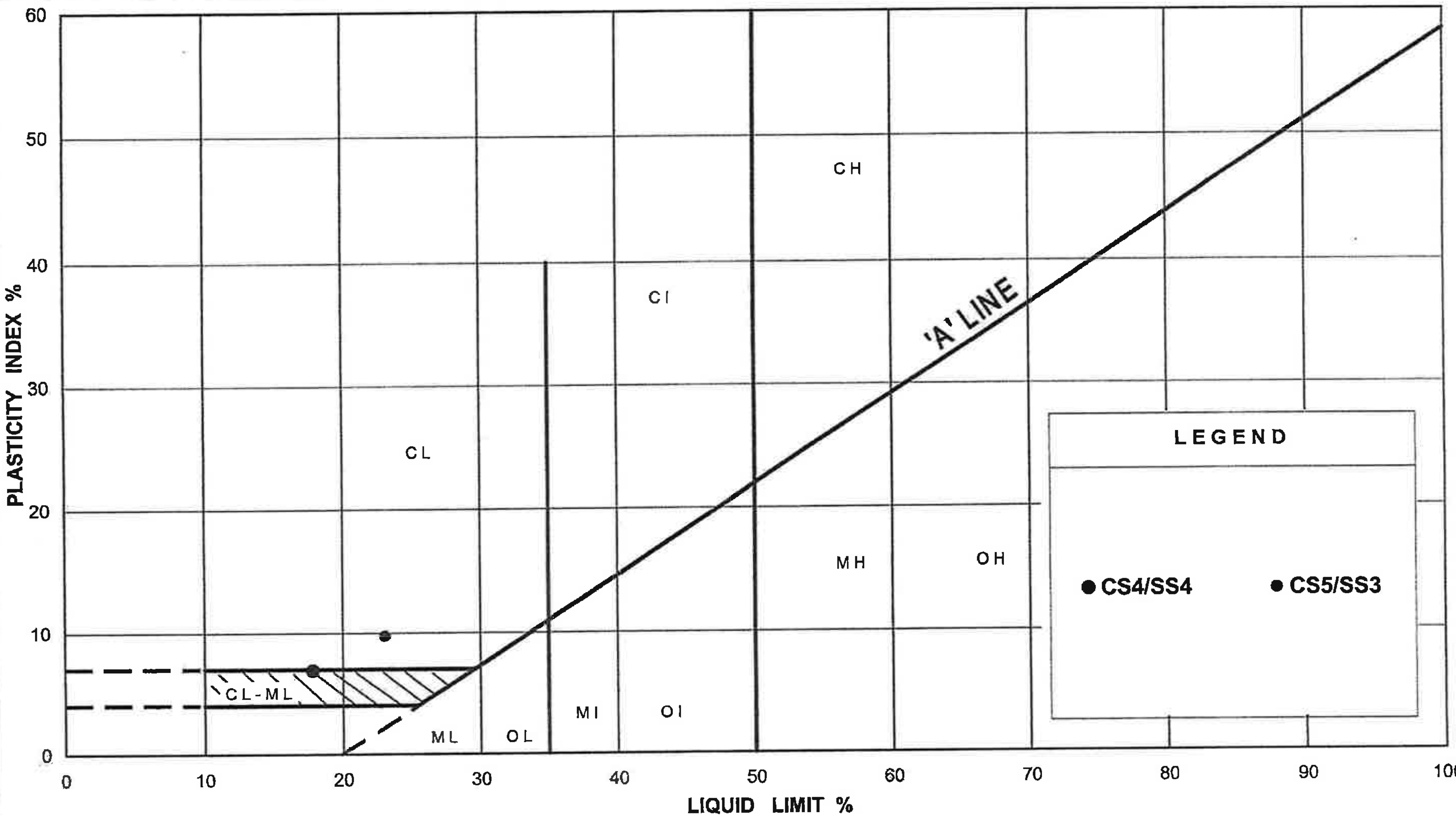
FIGURE NO.:	B1-2
PROJECT NO:	TRANETOB01232AB
DATE:	June 10, 2009



coffey geotechnics
SPECIALISTS MANAGING THE EARTH

GRAIN SIZE DISTRIBUTION
CLAYEY SILT (Possible Till)

FIGURE NO.:	B1-3
PROJECT NO:TRANETOB01232AB	
DATE:	June 10, 2009

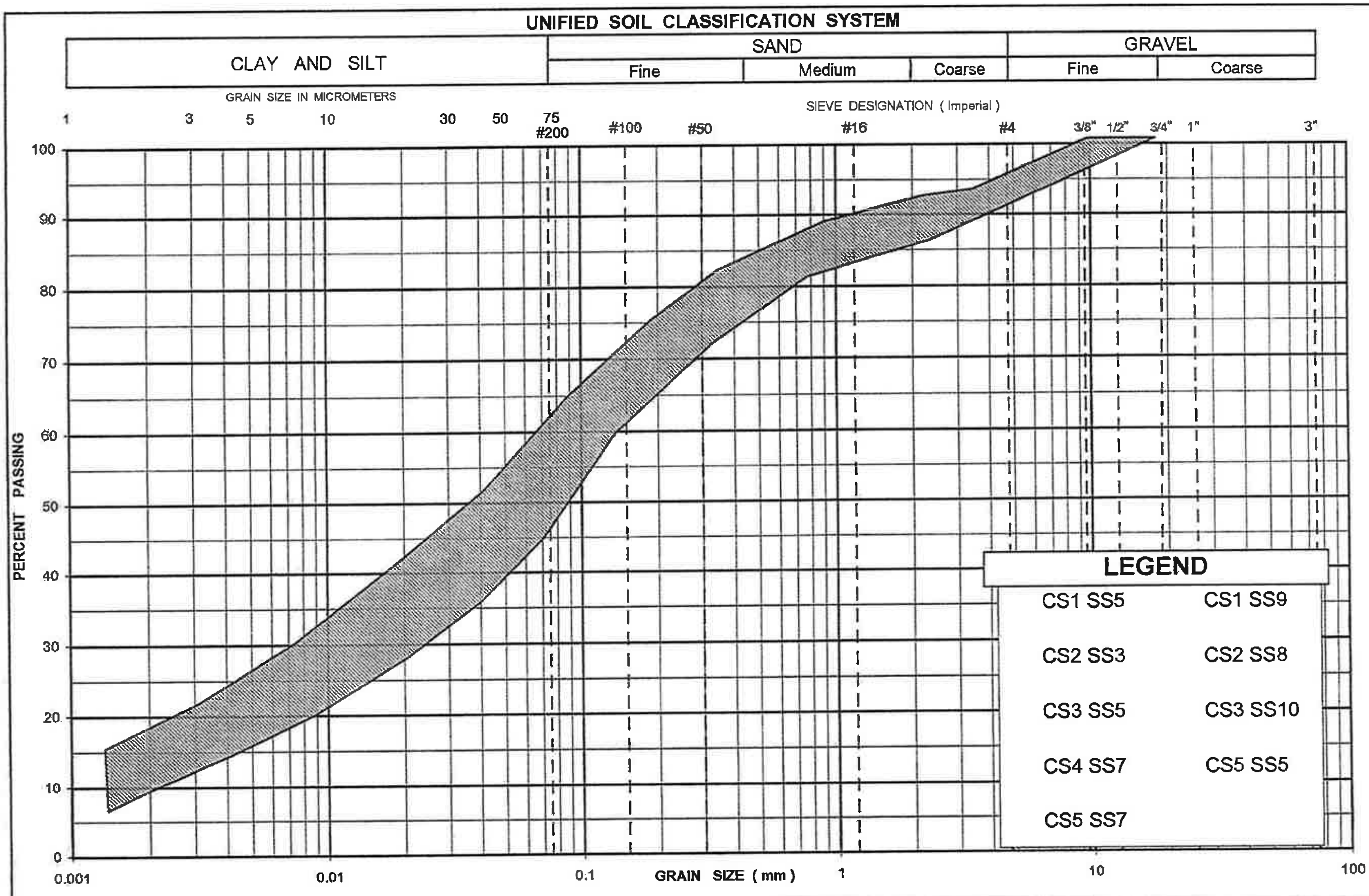


coffey geotechnics
SPECIALISTS MANAGING THE EARTH

PLASTICITY CHART

CLAYEY SILT

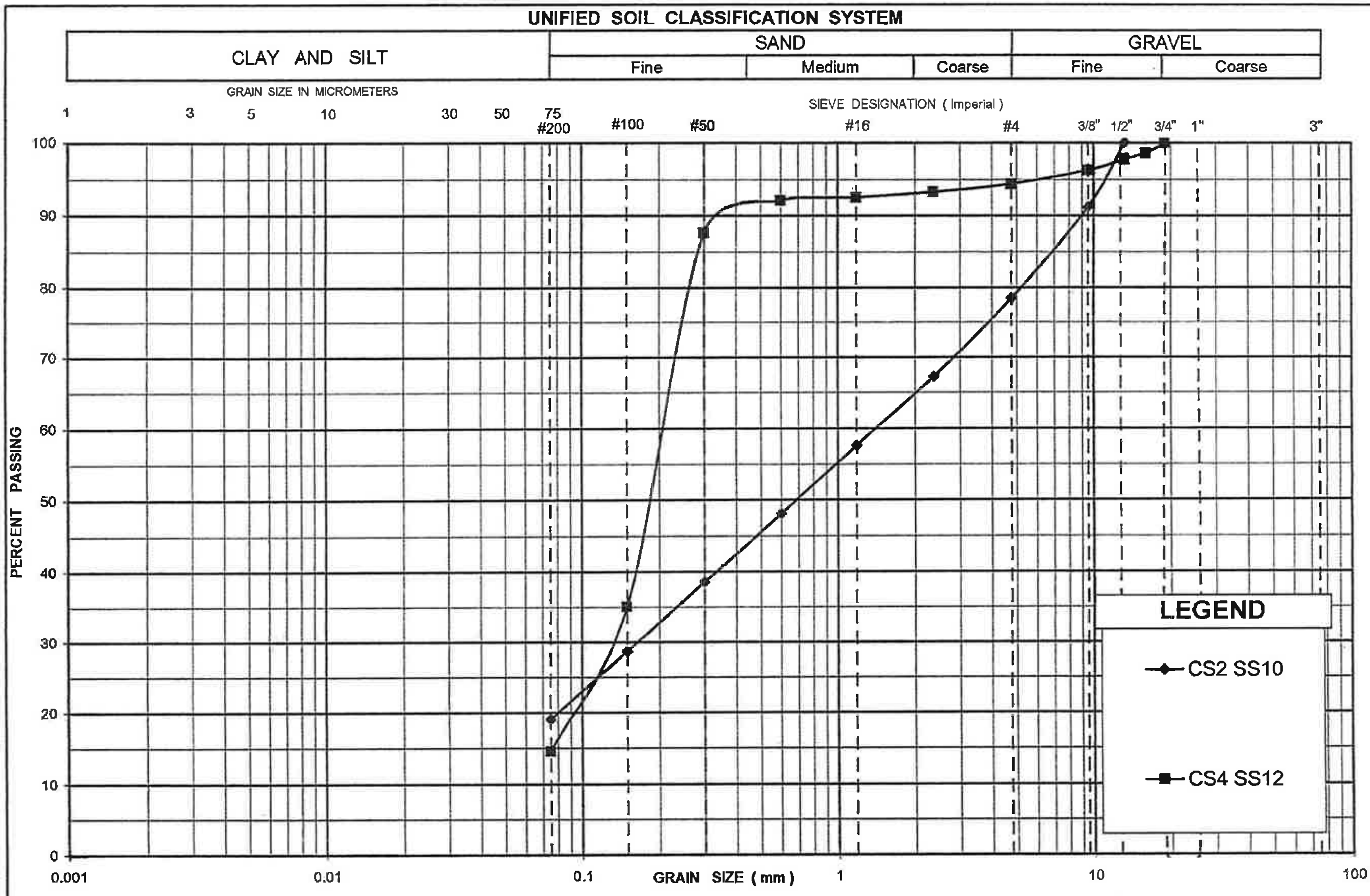
FIGURE No.	B1-4
REF. No.	TRANETOB01232AB
DATE	June 2009



coffey geotechnics
SPECIALISTS MANAGING THE EARTH

GRAIN SIZE DISTRIBUTION
SANDY SILT TILL

FIGURE NO.: B1-5
PROJECT NO: TRANETOB01232AB
DATE: June 10, 2009



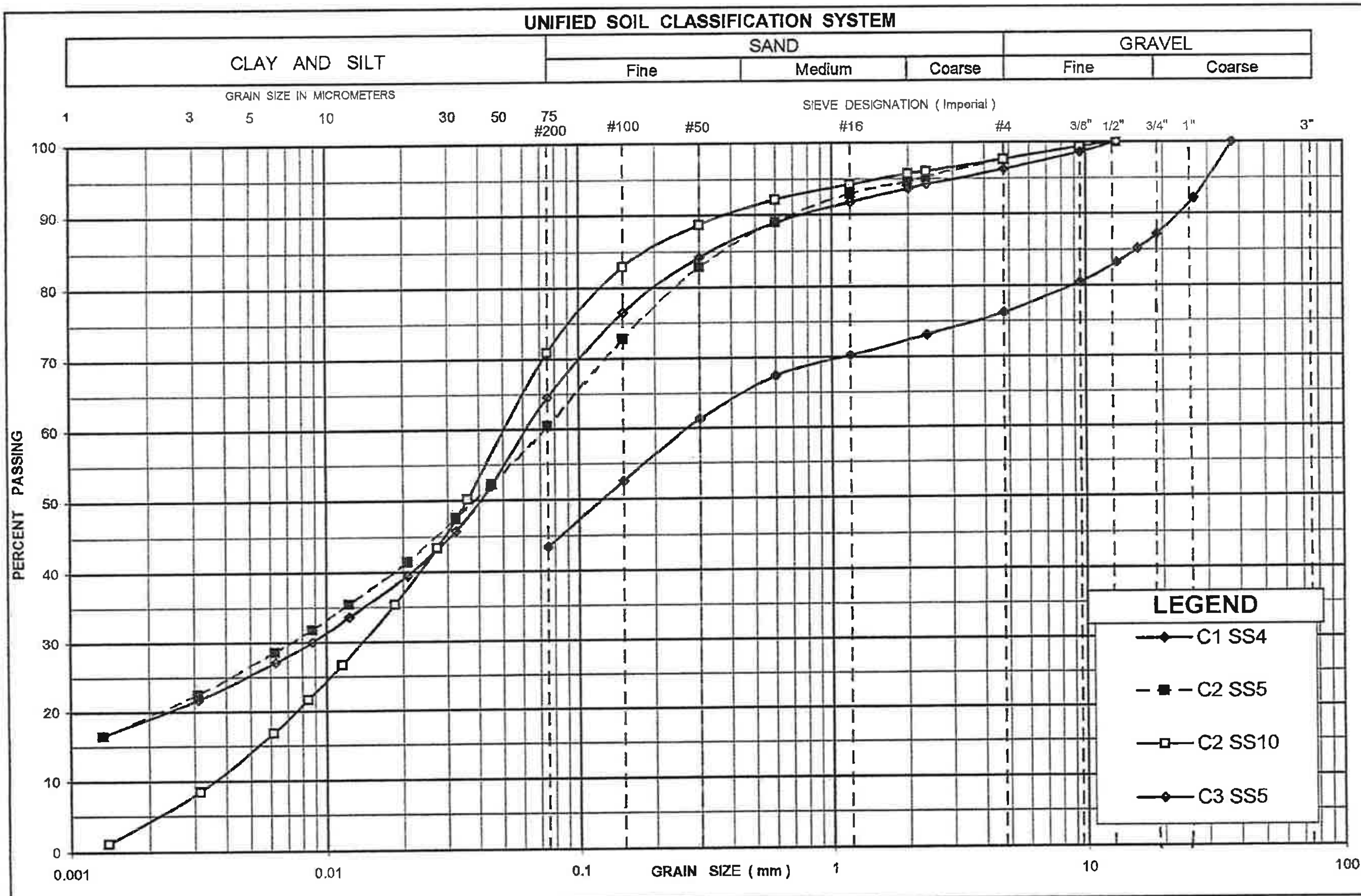
coffey geotechnics
SPECIALISTS MANAGING THE EARTH

GRAIN SIZE DISTRIBUTION
LOWER SAND

FIGURE NO.: B1-6
PROJECT NO:TRANETOB01232AB
DATE: June 10, 2009

Appendix B2

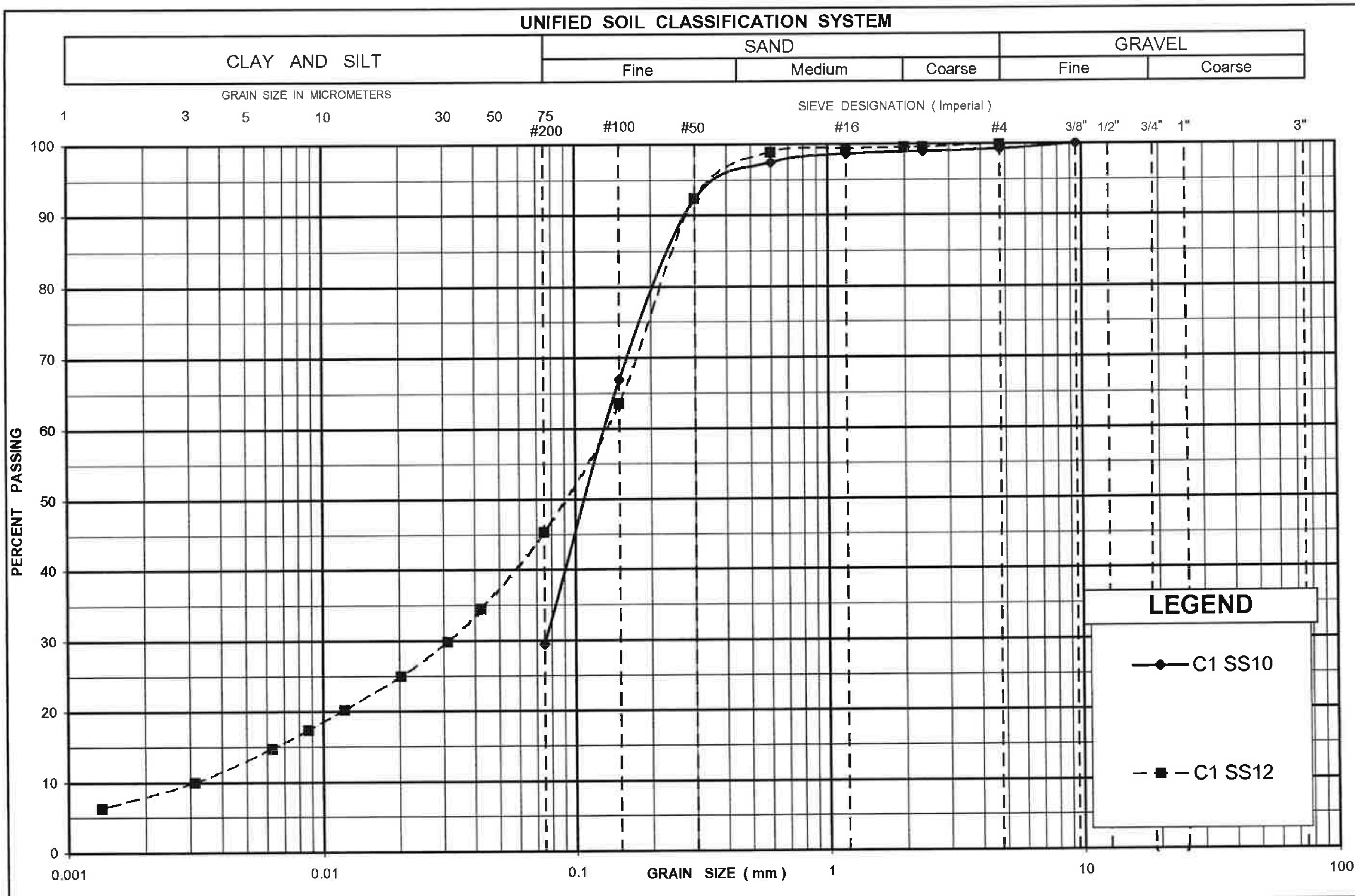
Laboratory Test Results for Culvert at Station 28+430



coffey geotechnics
SPECIALISTS MANAGING THE EARTH

GRAIN SIZE DISTRIBUTION
SANDY SILT TILL

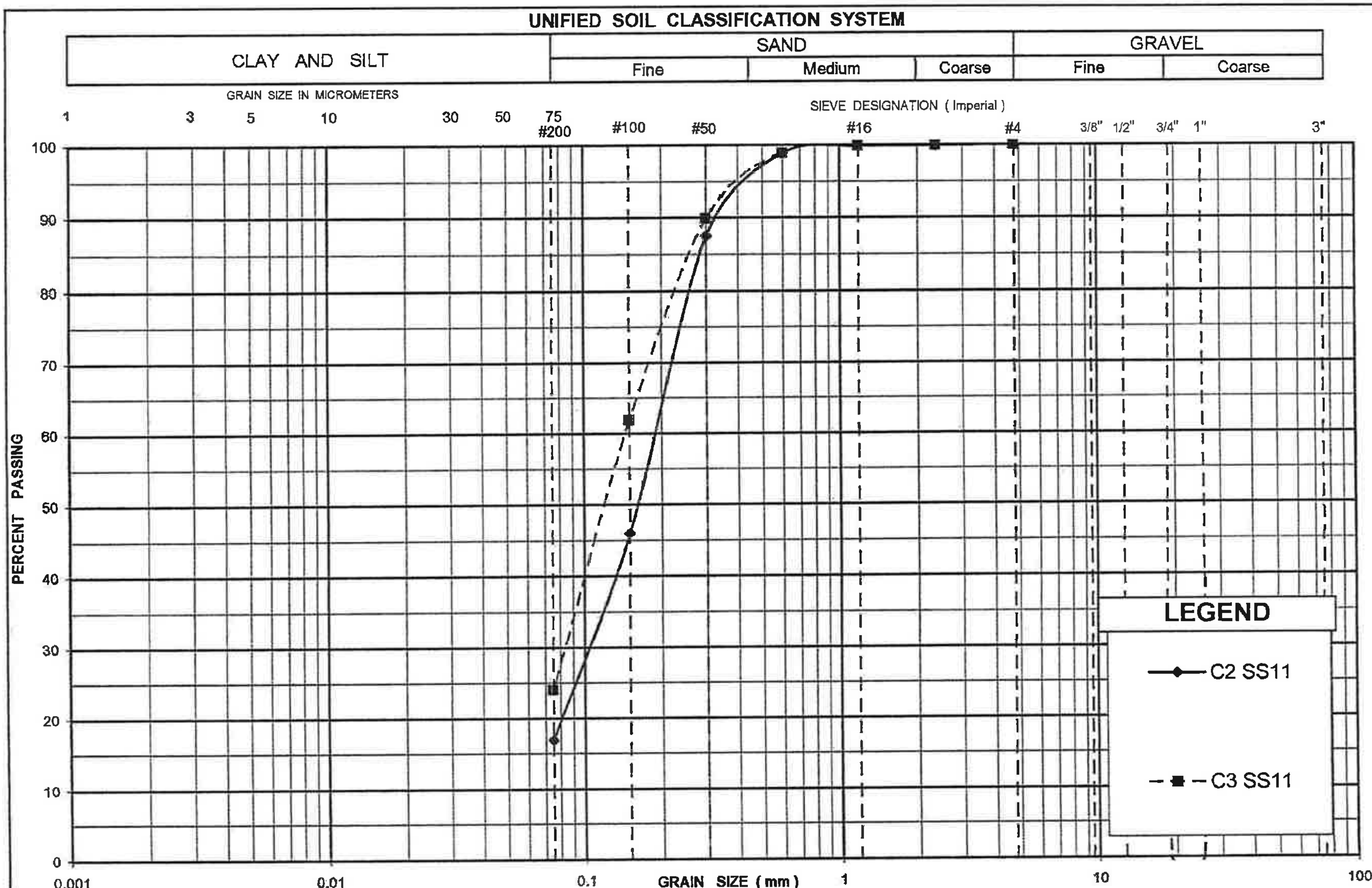
FIGURE NO.:	B2-1
PROJECT NO:	TRANETOB01232AB
DATE:	June 10, 2009



coffey geotechnics
SPECIALISTS MANAGING THE EARTH

GRAIN SIZE DISTRIBUTION
SILTY SAND

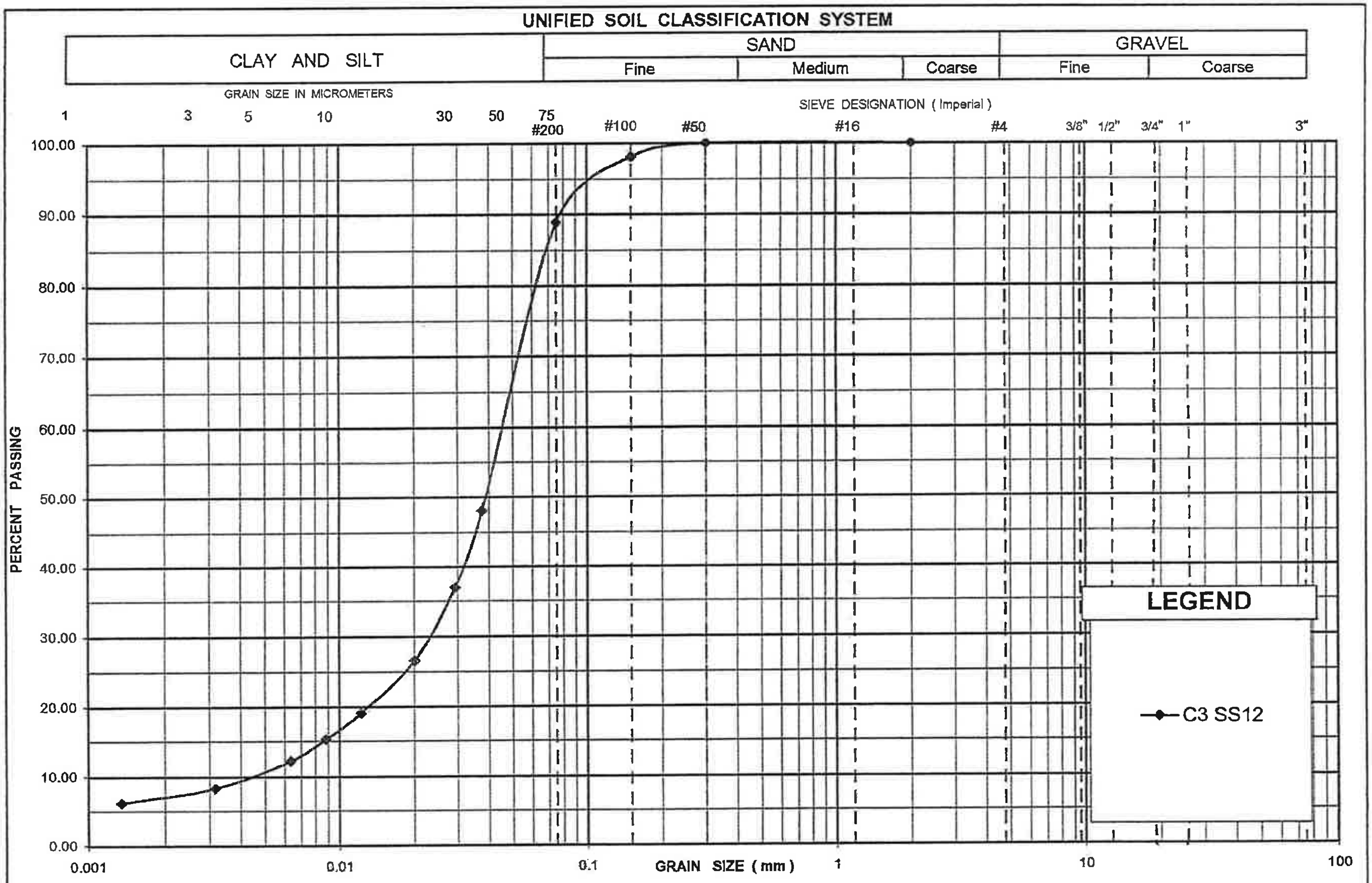
FIGURE NO.: B2-2
PROJECT NO: TRANETOB01232AB
DATE: June 10, 2009



coffey geotechnics
SPECIALISTS MANAGING THE EARTH

GRAIN SIZE DISTRIBUTION
SAND, some silt

FIGURE NO.:	B2-3
PROJECT NO:	TRANETOB01232AB
DATE:	June 10, 2009



coffey geotechnics SPECIALISTS MANAGING THE EARTH

GRAIN SIZE DISTRIBUTION
SILT

FIGURE NO.:	B2-4
PROJECT NO:	TRANETOB01232AB
DATE:	June 10, 2009

Appendix C

Site Photographs

Photograph C-1 South service Road Culvert, Looking towards West

Photograph C-2 South Service Road Culvert, Looking towards South

Photograph C-3 South Service Road Culvert, Looking towards East

Photograph C-4 South Service Road Culvert, Looking towards Southwest

Photograph C-5 Culvert Station 28+420, Looking towards Southwest

Photograph C-6 Culvert Station 28+420, Looking towards Northwest

Appendix D

Previous Investigation Report (by Golder Associates)

4.0 SUBSURFACE CONDITIONS

4.1 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes, together with the results of the laboratory tests carried out on selected soil samples, are given on the attached Record of Borehole sheets following the text of this report and in Appendix A. The stratigraphic boundaries shown on the borehole sheets are inferred from non-continuous sampling and, therefore, may represent transitions between soil types rather than exact planes of geological change. Subsoil conditions will vary between and beyond the borehole locations.

In summary, boreholes 1 and 2, drilled at the Service Road culvert site, encountered the existing granular base or surficial topsoil underlain by thin surficial layers of sand, clayey silt and clayey silt till over compact to very dense sandy silt till. Boreholes 3 and 4, drilled at the culvert site at Station 28+420, encountered a layer of topsoil at ground surface underlain by about 7 metres of dense to very dense sandy silt till over deposits of compact sandy silt and compact to dense sand. At the culvert site at Station 28+050, boreholes 5 and 6 encountered a layer of topsoil at ground surface underlain by about 3.5 metres of very dense sandy silt till which was underlain by dense to very dense sand deposits. Boreholes 7 and 8, drilled near the south end of the existing Mosley Street culvert encountered the existing pavement structures and/or topsoil and fill underlain by about 4 metres of compact to very dense sandy silt till over dense to very dense sand and silt deposits.

The locations and elevations of the borings, together with the interpreted stratigraphic profile at each of the culvert sites, are shown on the attached Drawings 1 to 3. A detailed description of the subsurface conditions encountered in the boreholes at each of the culvert sites for this investigation is provided on the Record of Borehole sheets and is summarized in the following sections.

4.1.1 Service Road Culvert

Roadbase

Borehole 1 was drilled on the existing Service Road and encountered 210 millimetres of sand and gravel roadbase at ground surface.

Topsoil

Borehole 2, drilled on the west side of the proposed Service Road realignment, encountered 240 millimetres of silty topsoil at ground surface.

Sand and Silty Sand

Under the road base, borehole 1 encountered a sand layer some 0.7 metres thick. This 0.7 metre thick deposit of loose sand was encountered at elevation 194.1 metres and extended to elevation 193.4 metres. The sand deposit had a standard penetration test N value of 5 blows per 300 millimetres penetration and the water content of the sand sample collected from the borehole was about 17 per cent.

Under the topsoil, borehole 2 encountered a one metre thick layer of compact silty sand. This deposit was encountered at elevation 193.5 metres and extended to elevation 192.6 metres. The silty sand deposit had a standard penetration test N value of 12 blows per 300 millimetres penetration and a water content of about 13 per cent.

Figure A-2 in Appendix A shows a gradation curve for a sample of the silty sand deposit in borehole 2. The deposit consists mainly of sand with silt and a trace of clay.

Clayey Silt

Layers of firm to stiff clayey silt materials were encountered beneath the sand in borehole 1. The layers were about 0.8 metres in total thickness and contained varying amounts of sand, gravel and organic material. The clayey silt deposit had standard penetration test N values of 5 and 10 blows per 300 millimetres penetration and water contents of about 20 per cent.

Clayey Silt Till

A 0.3 metre thick deposit of stiff clayey silt till with a trace of gravel was encountered at elevation 192.6 metres beneath the clayey silt layers. The clayey silt till had a single standard penetration test N value of 10 blows per 300 millimetres penetration and a water content of about 19 per cent.

Sandy Silt Till

Beneath the clayey silt till in borehole 1 and the silty sand in borehole 2 a compact to very dense sandy silt till deposit was encountered. The surface of the till was 1.2 to 2.0 metres below ground surface or at elevation 192.3 to 192.5 metres. The boreholes were terminated in the till at depths of 9.3 and 9.5 metres, or at elevations 184.3 and 185.0 metres. The till had standard penetration test N values between 28 blows per 300 millimetres penetration and 100 blows per 250 millimetres penetration, with an average N value of about 65 blows per 300 millimetres penetration. The water contents of the till samples collected from the boreholes were between about 5 and 15 per cent, with an average of about 8 per cent. The average plastic and liquid limits for the till, based two samples tested, are 10 and 15 per cent, respectively, with an average plasticity index of 5 per cent. The limit data are plotted on the plasticity chart, Figure A-1 in Appendix A, and show the deposit to be a silt of low plasticity.

Figure A-3 in Appendix A shows gradation curves for two samples recovered from the sandy silt till deposit in boreholes 1 and 2. The deposit consists mainly of sand and silt size material with some clay and a trace of gravel. Cobbles and boulders should be expected in the till.

4.1.2 Culvert at Station 28+420

Topsoil

Boreholes 3 and 4 were drilled near the two ends of the new culvert proposed at Station 28+420. The boreholes encountered 120 to 300 millimetres of silty topsoil at ground surface.

Sandy Silt Till

Beneath the topsoil, boreholes 3 and 4 encountered a dense to very dense sandy silt till deposit at elevation 190.1 to 190.3 metres. The till deposit was about 6.7 to 7.2 metres thick and extended to about elevation 183 metres. A pocket of clayey silt material was encountered within the till in borehole 3. The till had standard penetration test N values between 36 blows per 300 millimetres penetration and 100 blows per 225 millimetres penetration. The water contents of the till samples collected from the boreholes were between about 4 and 9 per cent, with an average of about 6 per cent. The average plastic and liquid limits for the till, based on two samples tested, are 10 and 12 per cent, respectively, with an average plasticity index of 2 per cent. The limit data are plotted on the plasticity chart, Figure A-1 in Appendix A, and show the deposit to be a silt of low plasticity.

Figure A-3 in Appendix A shows gradation curves for samples recovered from the sandy silt till deposit in boreholes 3 and 4. The deposit consists mainly of sand and silt size material with some gravel and a trace of clay. Cobbles and boulders should be expected in the till.

Clayey Silt

A 0.4 metre thick pocket of clayey silt was encountered within the till deposit in borehole 3 at elevation 186.3. The clayey silt pocket had a standard penetration test N value of 70 blows per 300 millimetres penetration and a water content of about 9 per cent.

Sandy Silt

Beneath the till, borehole 4 encountered compact to dense sandy silt layers totalling 2.0 metres in thickness at elevation 183.1 metres. The sandy silt layers had standard penetration test N values of 14 and 32 blows per 300 millimetres penetration and water contents of about 10 and 17 per cent.

Sand

Under the till in borehole 3 and the sandy silt in borehole 4, a deposit of compact to dense sand was encountered at elevations between 181.1 and 183.4 metres. The boreholes were terminated in the sand deposit at depths of 9.5 to 9.6 metres below ground surface, or at elevations of 180.9 and 180.8 metres. The sand deposit had standard penetration test N values of 15 to 40 blows per 300 millimetres penetration and water contents of about 14 to 18 per cent.

Figure A-4 in Appendix A shows a gradation curve for a sample recovered from the sand deposit in borehole 3. The deposit consists mainly of fine sand with a trace to some silt.

Appendix E

Explanation of Terms Used in Report

EXPLANATION OF TERMS USED IN REPORT

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

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

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

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

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

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

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

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

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

JOINT AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

STRESS AND STRAIN

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

MECHANICALL PROPERTIES OF SOIL

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

PHYSICAL PROPERTIES OF SOIL

P_s	kg/m^3	DENSITY OF SOLID PARTICLES	e	1,%	VOID RATIO	e_{min}	1,%	VOID RATIO IN DENSEST STATE
i_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
i_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
i	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
i_d	kN/m^3	UNIT WEIGHT OF DRY SOIL	I_P	%	PLASTICITY INDEX = $(W_L – W_L)$	v	m/s	DISCHARGE VELOCITY
P_{sat}	kg/m^3	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $(W – W_P)/ I_P$	i	1	HYDAULIC GRADIENT
i_{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
i'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL						

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

FOUNDATION DESIGN REPORT PROPOSED NEW CULVERTS (STATIONS 9+845 SOUTH SERVICE ROAD-SITE 30-682C AND 28+430 NEW HIGHWAY 26 - SITE 30+680C) TOWNSHIP OF CLEARVIEW, ONTARIO, G.W.P. 630-91-00, GEOCRES NO. 41A-211

Delcan Corporation

Project TRANETOB01232AA-AB
March 01, 2010

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

CONTENTS

FOUNDATION DESIGN REPORT
PROPOSED NEW CULVERTS
(STATIONS 9+845 SOUTH SERVICE ROAD AND 28+430 NEW HIGHWAY 26)
TOWNSHIP OF CLEARVIEW, ONTARIO
G.W.P. 630-91-00

5 DISCUSSION AND RECOMMENDATIONS

We understand that two new culverts will be constructed along the new alignment of Highway 26 and the South Service Road in the Township of Clearview. The culvert details including invert elevations, dimensions and type of culverts are based on information and drawings provided to us by Delcan Corporation (Delcan) and these are summarized in Table 5.1.

Table 5.1 Proposed Culvert Summary

Location of Culvert	Type of Culvert	Proposed Culvert Section Dimensions and Length (m)	Ground Surface Elevation (m)	Proposed Invert Elevation (m)
Sta. 9+845 South Service Road	Rigid Concrete Box	Width x Rise 5.00 x 2.25 (18.5 m long)	194.2	191.6 (inlet) 191.4 (outlet)
Sta. 28+430 New Highway 26	Rigid Concrete Box	Width x Rise 5.00 x 2.25 (60.0 m long)	190.4	188.4 (inlet) 188.3 (outlet)

The proposed new culverts can be installed using an open cut construction as the proposed culverts are off the existing highway/road.

Deep foundations are neither suitable nor recommended for this project.

5.1 Culvert at Station 9+845 (South Service Road)

5.1.1 Proposed Culvert

The proposed culvert at South Service Road (at Station 9+845) will be installed adjacent to the existing culvert at a skew angle of about 55° to the centreline of the proposed Highway 26.

Boreholes CS1 and CS3 were drilled from near the shoulder of the existing service road and encountered 2.0 and 2.3 m of embankment fill, respectively. Boreholes CS4 and CS5 encountered a 0.4 m thick topsoil at the ground surface, underlain by a clayey silt deposit to depths of 2.1 to 3.3 m. Borehole CS2 contacted a 1.4 m thick surficial granular soil which consists of sand and gravel. Below these surficial deposits, all boreholes encountered a sandy silt till deposit. Boreholes CS1, CS3 and CS5 were terminated in this sandy silt till at a depth of about 11 m below the ground surface or at El. 183.1 to 183.4 m, while in Boreholes CS2 and CS4, a sand deposit was found underlying the sandy silt till at depths/elevations of 8.6/184.0 and 10.0/184.2 m, respectively. Based on the recorded N-values, the sandy silt till is typically compact to dense near the surface, becoming very dense with increasing depth. At the time of our investigation, the groundwater table was encountered at about 8 m below grade or at about El. 186 m. It could however fluctuate and can be higher, as evidenced by the change of colour of the soil from brown to grey at significantly higher elevations.

Drawings prepared by Delcan indicate that a rigid frame concrete box culvert will be constructed at the site. The invert of the culvert will be at about El. 191.6 m at the inlet and El. 191.4 m at the outlet. The wall thickness of the concrete box will be about 0.4 m and thus the bottom of the culvert can be expected to be at about El. 191.0 m. A low embankment is proposed (i.e. a relatively thin cover above the culvert).

At elevation 191.0 m, all of the five boreholes advanced by Coffey (except for Borehole CS4 which contacted sandy silt till at elevation 190.9 m) and the two boreholes put down by Golder show the presence of a compact to dense sandy silt till deposit and the groundwater table at the time of the investigations was below the anticipated excavation level, although a perched water level could occur. These conditions are favourable for the construction of the culvert from a geotechnical foundation engineering point of view. As such, both flexible type of culvert (e.g. CSP) or rigid culvert (e.g. concrete box culvert) would be suitable, as discussed in the following sections of this report. The following table presents the advantages and disadvantages of various culvert types.

Table 5.1.1.1 - Summary of Foundation Options

Culvert Type	Advantages/Disadvantages	Risks/Consequences/Relative Cost
Corrugated Steel Pipe (CSP) type culvert	• Flexible and as such can withstand relatively high settlement without significant damage. • Can be placed very rapidly. • Not very resistant to corrosion, especially in case of aggressive environment (i.e. soft water) in the watercourse. • Needs adequate cover.	Least expensive but not preferred by MTO due to shorter life span. Soil conditions at the present site do not require the use of a flexible structure (i.e. relatively competent soils). Adequate cover may not be available.
Precast Concrete Box Culvert	More flexible than a rigid concrete box or a rigid concrete open bottom culvert but less flexible than a CSP type culvert. Typically used when subsurface conditions warrant the use of a flexible culvert but a CSP is unsuitable due to environmental reasons.	Used when a CSP type culvert is not feasible and subsurface condition require the use of a relatively flexible structure. High cost

Culvert Type	Advantages/Disadvantages	Risks/Consequences/Relative Cost
Rigid Frame Concrete Box Culvert	Requires relatively competent soil conditions. Requires considerable construction time and as such is not frequently used under existing highway embankments. In this case, however, this is not the case as the construction will proceed along the new alignment.	Cannot withstand high differential settlements, but for the present site this is not an issue. Somewhat more expensive than an open bottom rigid box culvert but avoids scour issue. Recommended option if the use of a concrete culvert is required.
Rigid Frame Open Bottom Concrete Culvert	Similar to rigid frame concrete box culvert	Similar to rigid frame concrete box culvert but the compact sandy silt till may be susceptible to scour (i.e. less suitable than a closed bottom culvert).

5.1.2 Corrugated Steel Pipe (CSP) Type Culvert

The native compact to very dense sandy silt till, in its undisturbed state, is suitable to support a CSP type culvert.

A minimum bedding of 200 mm is recommended to be placed underneath the culvert. After excavating the site (to the underside of the proposed bedding elevation), the exposed subgrade should be carefully inspected and approved. If organic or other unsuitable soils, such as fill or loose materials, are found they should be removed to the surface of the inorganic, suitable soil and replaced with suitable granular fill. After stripping, evaluation and approval, the exposed subgrade should be compacted from the surface (i.e. proof-rolled).

The following geotechnical resistances can be used for design purposes at or below about El. 191.3 m, for undisturbed subgrade soils.

Factored Geotechnical Resistance at U.L.S = 350 kPa

Geotechnical Resistance at S.L.S = 250 kPa

Provided that the founding natural subgrade is undisturbed during the construction, the settlements should not exceed 25 mm. It is therefore our opinion that cambering is not required at this site.

CSP type culverts require adequate side support to maintain their structural integrity. The removal of unsuitable soils should therefore extend to a suitable distance beyond the foot-print of the culvert and adequate compaction should be applied to the surrounding fills.

5.1.3 Cast-in-Place or Precast Concrete Box Culvert

The natural compact to very dense sandy silt till, in its undisturbed state, is suitable to support a concrete box culvert.

It is our understanding that the proposed new culvert will be 3080 mm high x 5800 mm wide (outside dimensions) x 18.5 m long. The anticipated elevation for the invert is 191.6 m at the inlet and 191.4 m at the outlet (i.e. on average of 191.5 m). Allowing 0.4 m for the concrete thickness, the underside elevation for the box culvert will be at about El. 191.1 m. We recommend a minimum 150 mm of bedding and thus the average stripping elevation will be about 190.9 m. At this elevation, the boreholes show the presence of compact to very dense sandy silt till.

The following resistances are available at or below this elevation (i.e. at or below 190.9 m).

Factored Geotechnical Resistance at U.L.S = 400 kPa

Geotechnical Resistance at S.L.S = 250 kPa

The following procedures should be followed.

After excavating the site to the required subgrade level, the exposed subgrade should be carefully inspected, evaluated and approved by the Geotechnical Engineer appointed by the QVE. If organic or otherwise unsuitable soils, such as fill, loose soils, etc, are encountered they should be removed to the surface of the suitable, natural compact to very dense sandy silt till. After this, the subgrade should be proof-rolled using a suitable compactor under the direction of the Geotechnical Engineer. The grade should then be raised using well compacted granular fill.

Provided that the founding natural subgrade is undisturbed during the construction, the settlements should not exceed 25 mm and therefore cambering is not necessary.

5.1.4 Rigid Frame Open Bottom Concrete Culvert

Conditions, as revealed by the boreholes are considered suitable for an open bottom concrete culvert, using the following geotechnical resistances, at or below El. 190.5 m.

Factored Geotechnical Resistance at U.L.S = 400 kPa

Geotechnical Resistance at S.L.S = 250 kPa

When recommending these figures a minimum 2.0 m wide footing was assumed.

After the excavation, the exposed subgrade should be inspected, evaluated and approved. It is recommended that an allowance be made to pour, as directed by the Geotechnical Engineer appointed by the QVE, a 75 to 100 mm thick layer of lean concrete (mud mat) on foundation bearing surfaces, as soon as possible after the excavation and the approval because the founding soils at the site are sensitive to disturbance and loosening due to water seepage and/or ponding.

Frost and scour should be taken into consideration when choosing the footing depths.

From the above discussion it is evident that all four types of culvert can be used at the site (i.e. CSP, Precast Concrete Box, Rigid Frame Concrete Box or Rigid Frame Open Bottom Concrete culvert) but a rigid frame open bottom concrete culvert is the least suitable because of scour considerations as well as possible potential problems due to groundwater (i.e. dewatering requirements).

The choice between a rigid concrete box culvert and a more flexible concrete precast box culvert is mainly a matter of economics. Normally, a precast structure would likely be more costly and is thus not used when constructing a new road, unless settlements are considered to present problems.

A CSP type culvert is the most economical choice, including the ease and duration of installation. Frequently, however, MTO policy is to use concrete culverts, considering their longevity.

5.2 Culvert at Station 28+430 (New Highway 26)

Based on the information provided to us by Delcan, the proposed culvert at Station 28+430 will be a 5.0 m span, 2.25 m rise and 61.0 m long concrete box culvert, with an invert elevation of 188.4 m at the inlet and 188.3 m at the outlet. The new culvert will be constructed at a skew angle of about 61° to the centre line of the new proposed Highway 26.

Boreholes C1, C2 and C3, drilled at the site, show at the proposed invert elevations, the presence of compact to very dense but generally very dense sandy silt till. The groundwater table at the time of our investigation was found at about Elevation 183 m, that is about 5 m below the proposed invert elevations. It would however be subject to seasonal fluctuations and fluctuations in response to weather events; as well, a perched water table may occur.

These conditions are essentially very similar to those encountered at the proposed culvert site at Station 9+845 (South Service Road) and as such the discussion regarding the suitability of the type of culvert, including Table 5.1.1.1 would apply and will not be repeated here for the sake of brevity.

5.2.1 Corrugated Steel Pipe (CSP) Type Culvert

In its undisturbed state the compact to very dense sandy silt till is suitable to support a CSP type culvert.

A granular bedding of not less than 200 mm is recommended to be placed underneath the culvert. After excavation to the underside elevation of the bedding material, the exposed subgrade should be inspected and approved by the Geotechnical Engineer appointed by the QVE. If organic, loose or otherwise unsuitable soils such as fills are encountered they should be removed to the surface of the competent sandy silt till. After its approval the exposed subgrade should be proof-rolled from the surface under the direction of the geotechnical engineer, using a suitable compactor for the prevailing site conditions at the time of the construction. The grade should then be raised using well compacted granular soils to the underside of the structure.

Based on the borehole data the following geotechnical resistances are available for the undisturbed, natural compact to very dense till, at or below El. 188.2 m.

Factored Geotechnical Resistance at U.L.S. = 450 kPa

Geotechnical Resistance at S.L.S. = 300 kPa

Provided that the founding natural subgrade is undisturbed during the installation of the culvert, total settlements should not exceed 25 mm and therefore cambering is in our opinion is not necessary.

CSP type culverts need adequate side support for structural integrity and therefore the removal of unsuitable soils should extend a sufficient distance beyond the culvert foot-print and the fill surrounding the pipe should receive adequate compaction.

5.2.2 Cast-in-Place or Precast Concrete Box Culvert

The compact to very dense, native sandy silt till is suitable to support a concrete box culvert.

According to information supplied by Delcan at present it is planned to construct a cast-in-place concrete box culvert which will be a 5.0 m wide, 2.25 m high (inside dimensions) and 61.0 m long rectangular structure. At the inlet and outlet the proposed invert elevations are 188.4 m and 188.3 m, respectively. Assuming a combined concrete base and a granular bedding thickness of 0.6 m, the excavation can be expected to extend to about El. 187.8 m. At this elevation the boreholes show the presence of very dense sandy silt till. Based on this, the following geotechnical resistances would be available at or below about Elevation 188.0 m.

Factored Geotechnical Resistance at U.L.S. = 500 kPa

Geotechnical Resistance at S.L.S. = 300 kPa

Higher resistances would be available but are not required for this project.

We recommend a minimum 150 mm thick granular bedding material to be placed beneath the concrete culvert.

After excavating to the required subgrade level (i.e. underneath the bedding material), the exposed subgrade should be carefully inspected, evaluated and approved by Geotechnical Engineer appointed by QVE. If any unsuitable soils such as organic or fill materials or not sufficiently dense materials are encountered they should be removed to the surface of the natural, dense to very dense sandy silt till. After the approval, if necessary, the approved subgrade should be proof-rolled from the surface, under the direction of the Geotechnical Engineer. The grade should then be raised using well compacted granular fill.

Provided that the subgrade is undisturbed during the construction, the settlements should be less than 25 mm and therefore cambering is not considered to be necessary at this site.

5.2.3 Rigid Frame Open Bottom Concrete Culvert

The borehole data show that foundation conditions are suitable for the use of a rigid frame open bottom concrete culvert at the site. The following geotechnical resistances are recommended for a footing with a minimum width of 2.0 m, at or below El. 188.0 m.

Factored Geotechnical Resistance at U.L.S. = 500 kPa

Geotechnical Resistance at S.L.S. = 300 kPa

Higher resistances would be available but are considered to be unnecessary for this project.

The following procedures should be followed. After the excavation to the proposed subgrade level, the exposed materials should be inspected, evaluated and approved by the Geotechnical Engineer appointed by the QVE. It is recommended that allowance be made to place a 75 to 100 mm thick layer of lean concrete (mud mat) on foundation bearing surfaces, as soon as possible after the excavation and the approval, as directed by the Geotechnical Engineer.

Frost and scour depths should be taken into consideration when deciding on the foundation depths.

While all four culvert types (i.e. CSP, Precast Concrete Box, Cast-in-Place Concrete Box or Open Bottom Concrete), the Open Bottom Concrete type culvert is relatively less desirable than others with due consideration for possible scour and possible dewatering requirements (i.e. deeper excavations for footings increase the chances of encountering groundwater).

As was mentioned in the previous sections, a CSP type culvert is generally more economical but in many instances because of their vulnerability to corrosion, their use is discouraged, especially when ease of construction and timing are not significant issues, such as this project (as the construction will proceed along the new alignment and not under the existing highway where traffic needs to be maintained). The choice between a cast-in-place (rigid frame) box culvert and a more flexible precast concrete box culvert is primarily a matter of cost, as soil conditions are equally suitable for both (i.e. there is not a requirement for accommodating differential settlements, as the subsoils below the proposed invert elevations are quite competent).

5.3 Bedding

For a CSP type culvert, we recommend that a minimum 200 mm thick bedding material be placed beneath the pipe to provide a uniform support underneath the culvert structure. For a concrete box culvert this thickness can be decreased to 150 mm.

The bedding should consist of a well-graded granular material such as a Granular ‘A’ or a Granular ‘B’ Type II. For ease of construction, consideration may also be given to the use of 20 mm clear stone or preferably an HL4 type material. In this case (i.e. if a well-graded bedding material is not used) however, the bedding should be protected against the migration of the fine particles from subgrade by placing a suitable geotextile against the subgrade soil. The geotextile (OPSS 1860) should be a Class II non woven type of filter cloth with Filtering Opening Size (F.O.S.) not larger than 115 micron (such as Terraxfix 400R, or approved equivalent). We also recommend that the compatibility of the geotextile with the exposed silty subgrade be reviewed and approved during the construction.

The unfactored horizontal resistance against sliding between approved subgrade (granular till) and the bedding can be calculated using a friction angle of 28°. The same value can be used if a geotextile is utilized in conjunction with the bedding (i.e. if a poorly grade material is used as a bedding material). It is, however, believed that sliding will not present a problem.

The bedding material should be placed as soon as practicable after the preparation of the subgrade, its inspection and approval, as was discussed in the previous sections of this report. The bedding material should be in accordance with appropriate standard (e.g. OPSD-802.010 and 802.014 for flexible pipes and OPSD 802.030, 802.031, 802.032 and 802.034 for rigid pipes whichever is applicable).

The bedding material should be compacted to MTO standards (OPSS 501 or SP 105S10 whichever is applicable).

5.4 Backfilling

The bedding and embedment material should be extended along the sides and the top to cover the pipe. The selection and placing of the backfill should be in accordance with OPSD-802.010 and 802.014 for flexible pipes, OPSD 802.030, 802.031, 802.032 and 802.034 for rigid pipes and OPSD-803.010 for concrete culverts. The backfill should consist of free-draining, non-frost susceptible granular materials such as Granular ‘A’ or ‘B’ (OPSS-1010). All granular backfill materials should be placed in thin lifts (i.e. not exceeding 300 mm before compaction) and each lift should be compacted to at least 96% of the material’s SPMDD (Standard Proctor Maximum Dry Density). The Granular ‘A’ base and Granular ‘B’ sub-base courses should be compacted to 100% of the material’s SPMDD.

We would like to point out that the performance of flexible pipe culverts (especially arch types) and to a certain extent, concrete box culverts is largely dependent on the side support provided by the backfill and the adjacent soils. The use of proper backfill material and especially good compaction are, therefore, necessary for proper side support. For the same reason, the organic soils should be removed within a suitable distance from the footprint of the culvert. The use of heavy compaction equipment should be avoided immediately adjacent and above the culvert, as per MTO practice. During backfill placement, the height of the backfill should be maintained at approximately same level on both sides of the structure, to avoid lateral displacement of the structure.

For fills immediately below any roadway, it is recommended that Granular ‘A’ or ‘B’ aggregates be used. Where necessary, proper tapering as per standards should be provided. Below a depth of about 1.5 m from any finished road grade, approved compactable fill, such as select subgrade materials (SSM) can be used.

Proper frost treatment is required in accordance with OPSD-803.030 or 803.031, whichever is applicable.

Backfilling behind any retaining (wing) walls, if any, should consist of granular materials in accordance with the MTO standards. Free draining backfill materials, weepholes, etc. should be provided in order to prevent hydrostatic pressure build-up.

Computation of earth pressures acting against rigid culvert walls and any wing walls should be in accordance with the Canadian Highway Bridge Design Code, (CHBDC) 2006. For design purposes, the following properties can be assumed for backfill.

Compacted Granular ‘A’ or Granular ‘B’ Type II

Angle of Internal Friction ϕ=35° (unfactored)

Unit weight = 22 kN/m^3

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 ϕ=30° (unfactored)

Unit Weight = 21 kN/m^3

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

Where K_b is the 'intermediate' earth pressure coefficient for a partially restrained structure. This case occurs when some movement (yield) of the retaining structure occurs but not in a sufficient magnitude to fully mobilize an active condition (as such an intermediate condition between K_o and K_a occurs).

K* is the earth pressure coefficient for a soil loading a fully-restrained structure, including compaction surcharge 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 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 as per SP 599S22 and SP 599S23, in which case the designer will have to include the geometric, performance and appearance requirements (i.e: medium performance and medium appearance).

5.5 Retaining Walls

Typically, in Ontario wing walls consists of reinforced concrete retaining walls supported on normal strip footing foundations placed on undisturbed competent natural soils.

Reinforced Soil System (RSS) is also frequently used. Gabion type walls (or similar crib-type gravity walls) or geoweb type walls are also occasionally used.

We understand that the present design incorporates reinforced concrete wing walls at Station 9+845 (South Service Road).

Conventional reinforced concrete type retaining walls are supported on normal strip footing foundations, placed on undisturbed competent natural soils. From the information provided to us the founding elevation for the proposed walls is 190.0 m. Boreholes CS1 through CS5, drilled at the site, show the presence of compact to very dense sandy silt till at or below the elevation and therefore the following geotechnical resistances can be used for footings at least 2.0 m wide.

Factored Geotechnical Resistance at U.L.S. = 400 kPa

Geotechnical Resistance at S.L.S. = 250 kPa

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

The structure should be checked against overturning and sliding, with an appropriate factor of safety. The unfactored horizontal resistance against sliding between poured concrete and approved sandy silt till subgrade surface can be calculated using a friction angle of 28 degrees. Additional resistance can be provided by keying into the founding soil, if necessary.

The lateral earth pressures acting on retaining walls will depend on the type and the method of placement of the backfill materials and on the subsequent lateral movements of the structure. The backfill properties given in Section 5.4 can be used for design purposes. In addition, traffic loads may need to be taken into consideration.

As mentioned in Section 5.1.4 of this report, after excavating to the proposed footing level, the exposed subgrade should be inspected, evaluated and approved by the Geotechnical Engineer appointed by the QVE. It is recommended that an allowance be made to place a 75 to 100 mm thick layer of skim coat of lean concrete on the foundation bearing surface, as rapidly as possible after the excavation and the approval.

Frost and scour should be taken into consideration when choosing the founding depths.

If any retaining type walls are required at the proposed culvert location at Station 28+430 (Highway 26), reference can be made to Section 5.2.3 of this report.

RSS type walls at both culvert locations can be utilized after the removal of any underlying fill, weak or otherwise unsuitable natural soils and their replacement with properly compacted, acceptable engineered fills. Scour will need to be considered.

If feasible (i.e. depending on the site conditions at the time of construction) for RSS construction, the exposed surface should be rolled from the surface. The grade can then be raised using engineered fill placed in thin layers (i.e. not exceeding 0.3 m when loosely placement) and each layer should be properly compacted to at least 98% of its Standard Proctor Maximum dry density. The fill should consist of a clean, compactable soil, which is free of organics, boulders, frozen soils and other deleterious materials. The first 0.6 m (i.e. immediately above the exposed acceptable subgrade) of the fill may need to consist of granular material such as Granular ‘A’ or ‘B’ Type II materials, to provide a suitable base upon which the required degree of compaction can be attained with other soil types.

While no major problems are anticipated, the RSS is typically a patented method and the provider of the system normally guarantees its stability. This aspect should be looked into after the details are known.

Gabion type walls (or similar crib-type gravity walls) or geoweb would be suitable after the removal of all unsuitable soils. These type of walls may undergo vertical or horizontal movements and are seldom used for primary highways. Scour will need to be considered in this case, as well.

5.6 Construction

The excavation should be carried out in accordance with the Safety Regulation of the Province (i.e. Occupational Health and Safety Act O. Reg 213/91), as well as the following specifications:

SP105 S19 – Protection Systems

SP902 S01 – Excavation and Backfilling to Structures

The boreholes show that the excavations for the construction of the culvert can be expected to extend through topsoil, granular embankment fill (Boreholes CS1 and CS3), clayey silt (Boreholes CS4 and CS5), sand and gravel (Borehole CS2) and sandy silt till. These soils can be classified as follows:

Embankment Fill	Type 3 soil
Clayey Silt	Type 2 soil
Sand and Gravel	Type 3 above water level
	Type 4 below water level
Sandy Silt Till	Type 2 above water level
	Type 4 below water level

At the time of our investigation the groundwater table was contacted at a depth of about 7 to 8 m below the ground surface, at both culvert sites. There is however evidence that the groundwater table may be closer to ground surface at different times of the year, as well as the presence of a perched water table. Depending on the site conditions at the time of construction, therefore, dewatering may be required to stabilize the soil and to prevent its disturbance. It is our opinion that the groundwater level can be lowered by up to about 0.6 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 0.6 to 0.8 m water lowering, vacuum 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.

We understand that at the site of the culvert at Station 9+845 (South Service Road), a temporary pipe culvert will be placed to maintain the flow of water in the creek so that the construction can be carried out in sufficiently dry conditions. We also understand that the Contractor will be assigned with the design of providing proper diversion of the creek water flow and the dewatering of the foundation excavations. We recommend that the Contractor be ‘red-flagged’ the potentially dilatent nature of the sandy silt till and requirements for dewatering to facilitate the construction and to prevent the dilation of the sandy silt till. The Contractor should also be warned of the possible presence of boulders in the glacial till deposit.

It is our understanding that temporary shoring will only be required for the construction of the new culvert at the south service road location. The following recommendations would be applicable to this particular location, as well as the culvert at Station 28+430, if shoring is required. 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 5.7.1 can be used for the design of the temporary shoring system.

Table 5.7.1 Recommended Unfactored Parameters for Temporary Shoring Design

Soil Type	K_a	K_o	K_p	Unit Weight (kN/m^3)
Sandy Embankment Fill	0.35	0.52	2.9	20.0
Clayey Embankment Fill	0.39	0.56	2.6	19.0
Topsoil	0.41	0.58	2.4	15.0
Clayey Silt	0.38	0.55	2.7	18.0
Clayey Silt Till	0.36	0.52	2.8	19.5
Sand & gravel	0.28	0.44	3.6	21.0
Sandy Silt till	0.29	0.45	3.5	21.5

5.7 Erosion Protection

Erosion/scour protection should be provided at the culvert inlet and outlet (including the side slopes). The erosion/scour protection should be designed by a specialist River Engineer/Scientist (as erosion and scour largely depend on the velocity of water in the watercourse and its regime), who is familiar with the findings of this report. The following are some general suggestions, considering that the boreholes indicate that below some surficial deposits, the main soil type consists of sandy silt till.

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

In addition to cut-off and head walls, consideration may be given to erosion/scour protection at the inlet and the outlet.

At the inlet, consideration may also be given, as an alternative to concrete head walls, to the use of a clay seal. The purpose of the clay seal is to ensure that water flow is channeled through the culvert and does not seep through the backfill around the structure and from beneath the structure. The clay seal should therefore be continuous and at least 0.6 m thick. It should comply with the material specifications given in OPSS 1205. It should be extended around the culvert from at least 0.3 m above the high water level in the watercourse down to the channel bed and up the other side in a continuous manner. It should be ensured that it extends to cover all the granular backfill materials to prevent any seepage through them. The clay seal should be protected by laying a 0.6 m thick rock protection over it. The clay seal should be extended at least 6 m beyond the inlet.

At the outlet as well as at the inlet (if clay seal is not used), in addition to the concrete cut-off and head walls or in conjunction with, a 0.6 m thick rock protection consisting of 300 mm size rock can be considered, overlying a 200 mm thick layer of granular filter material. This should extend at least 6 m along the channel and the sides (to at least 0.3 m above the high water level). The granular filter material underlying the rock protection should consist of a suitable granular material such as Granular ‘A”. Alternatively, a suitable geotextile can be used underneath the rock fill, in lieu of the granular filter material.

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

5.8 Frost Protection

Design frost protection for the general area is 1.5 m. Therefore, a permanent soil cover of 1.5 m or its thermal equivalent of artificial insulation is required for frost protection of foundations. In case of riprap (rock fill), only one-half of the rock fill thickness should be assumed to be effective in providing frost protection.

6 CLOSURE

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

For and on behalf Coffey Geotechnics Inc.

Gwangha Roh, Ph.D.

Ramon Miranda, P. Eng.

Zuhtu Ozden, P. Eng.

Appendix F

OPSD

List of Standard Specifications

OPSD

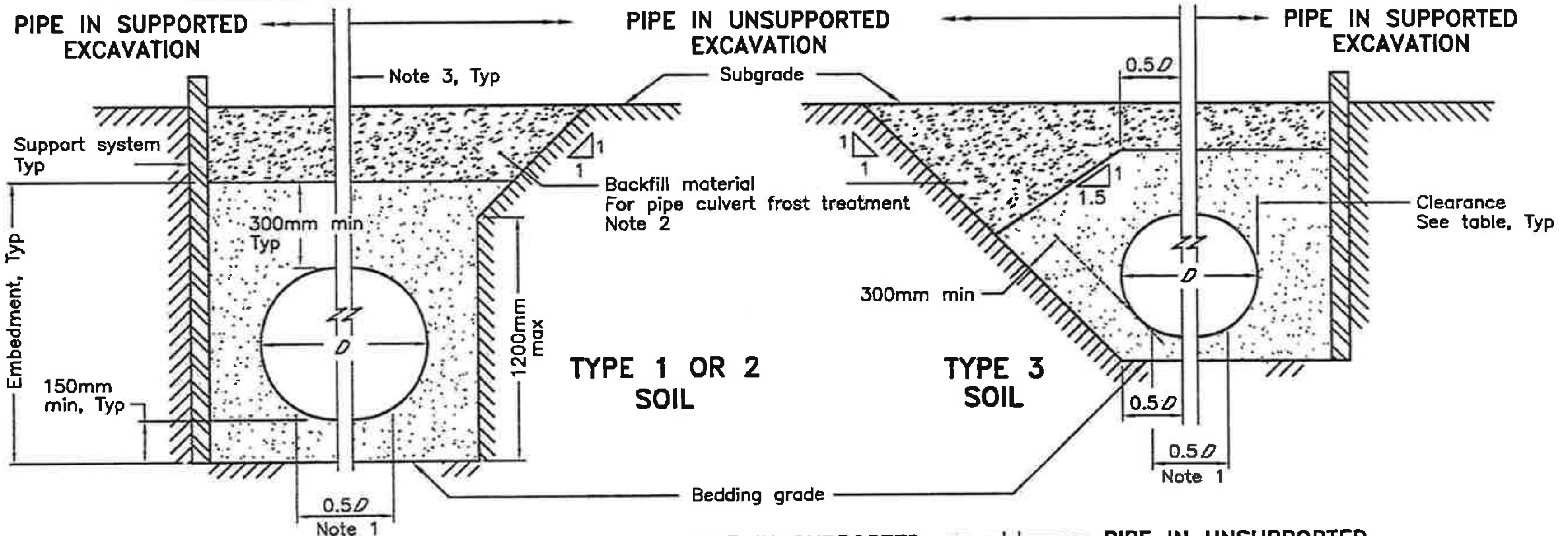
- 802.010 Flexible Pipe Embedment and Backfill Earth Excavation
- 802.014 Flexible Pipe Embedment in embankment Original Ground: Earth or Rock
- 802.030 Rigid Pipe Bedding, Cover, and Backfill Type 1 or 2 Soil – Earth Excavation
- 802.031 Rigid Pipe Bedding, Cover, and Backfill Type 3 Soil – Earth Excavation
- 802.032 Rigid Pipe Bedding, Cover, Backfill Type 4 Soil – Earth Excavation
- 802.034 Rigid Pipe Bedding and Cover in Embankment Original Ground: Earth or Rock
- 803.010 Backfill and Cover for Concrete Culverts
- 803.030 Frost Treatment – Pipe Culverts Frost Penetration Line Below Bedding Grade
- 803.031 Frost Treatment – Pipe Culverts Frost Penetration Line Between Top of Pip and Bedding Grade
- 810.010 Riprap Treatment for Sewer and Culvert Outlets

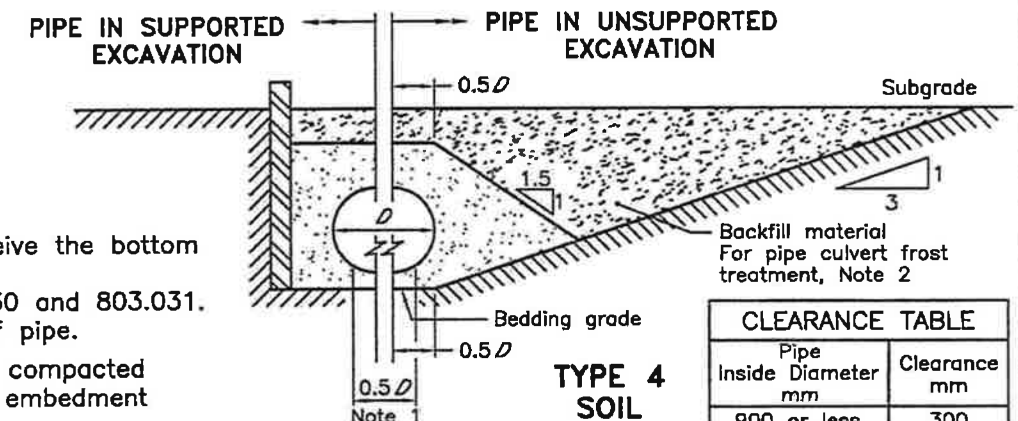
OPSS

- 501 Construction Specification for Compacting
- 1010 Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material
- 1205 Material Specification for Clay Seal
- 1860 Material Specification for Geotextiles

SP

- 105S10 Amendment to OPSS 501, February 1996
- 105S19 Amendment to OPSS 539, November 2003
- 599S22 Retained Soil System
- 599S23 Retained Soil System
- 902S01 Excavation and Backfilling - Structures





LEGEND:

D — Inside diameter

NOTES:

1 The pipe bed shall be compacted and shaped to receive the bottom of the pipe.
2 Pipe culvert frost treatment according to OPSD–803.030 and 803.031.
3 Condition of trench is symmetrical about centreline of pipe.

A Granular material placed in the haunch area shall be compacted prior to placing and compacting the remainder of the embedment material.
B Soil types as defined in the Occupational Health and Safety Act and Regulations for Construction Projects.
C All dimensions are in metres unless otherwise shown.

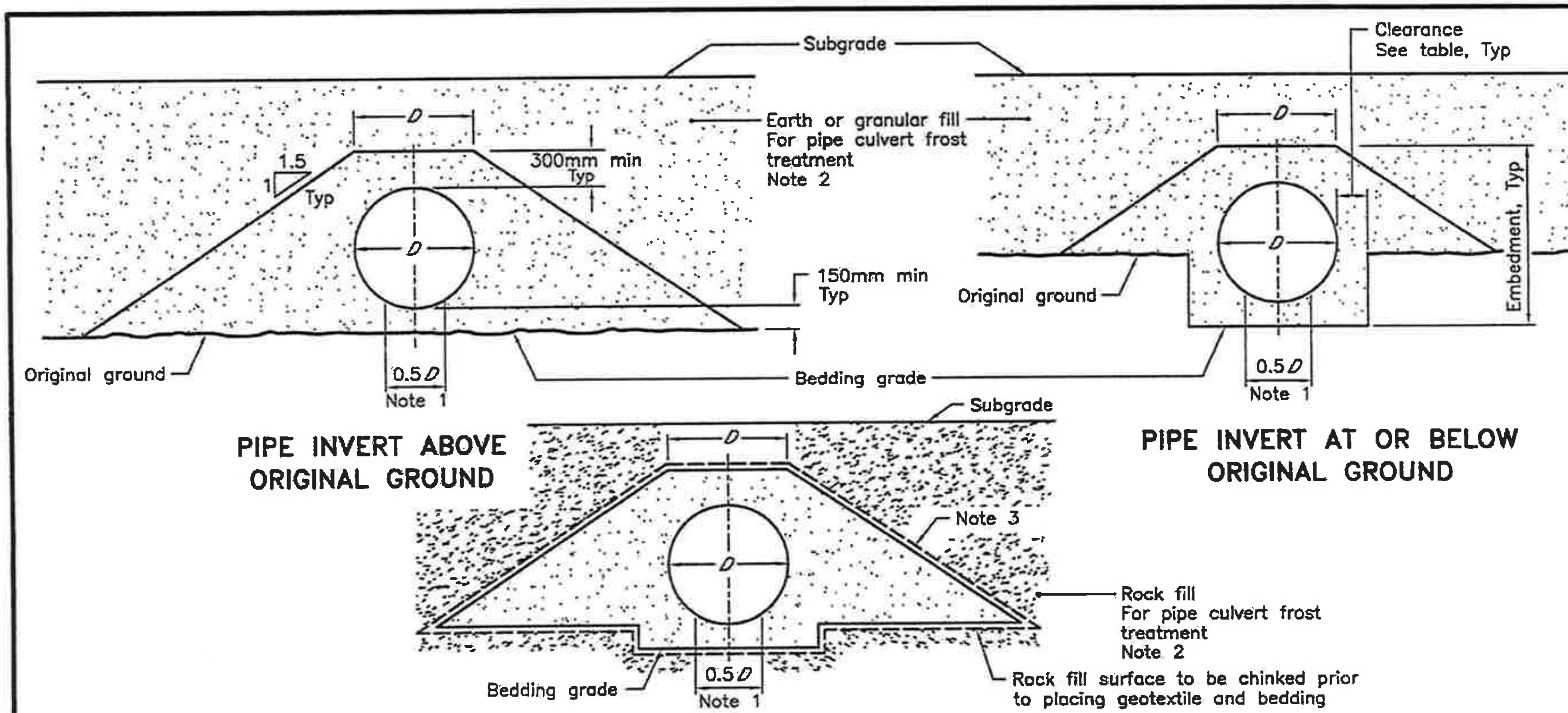
CLEARANCE TABLE

Pipe Inside Diameter mm	Clearance mm
900 or less	300
Over 900	500

ONTARIO PROVINCIAL STANDARD DRAWING | Nov 2005 | Rev 1

FLEXIBLE PIPE EMBEDMENT AND BACKFILL EARTH EXCAVATION

OPSD – 802.010



LEGEND:

D – Inside diameter

NOTES:

1 The pipe bed shall be compacted and shaped to receive the bottom of the pipe.
2 Pipe culvert frost treatment according to OPSD–803.030 and 803.031.
3 Embedment material to be wrapped in non–woven geotextile when specified.

A Granular material placed in the haunch area shall be compacted prior to placing and compacting the remainder of the embedment material.
B All dimensions are in metres unless otherwise shown.

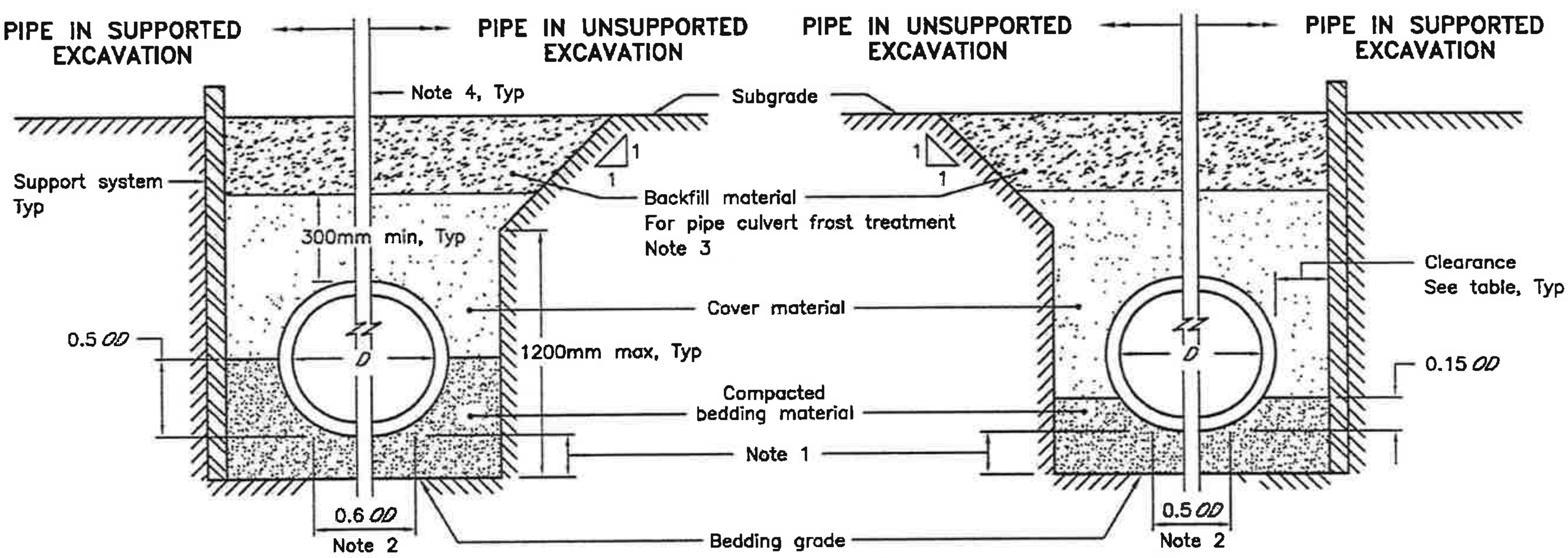
CLEARANCE TABLE	
Pipe Inside Diameter mm	Clearance mm
900 or less	300
Over 900	500

ONTARIO PROVINCIAL STANDARD DRAWING

Nov 2005 Rev 1

FLEXIBLE PIPE EMBEDMENT IN EMBANKMENT ORIGINAL GROUND: EARTH OR ROCK

OPSD – 802.014



CLASS B BEDDING

CLASS C BEDDING

NOTES:

1 The minimum bedding depth below the pipe shall be 0.15*D*. In no case shall this dimension be less than 150mm or greater than 300mm.

2 The pipe bed shall be compacted and shaped to receive the bottom of the pipe.

3 Pipe culvert frost treatment according to OPSD–803.030 and 803.031.

4 Condition of trench is symmetrical about centreline of pipe.

A Soil types as defined in the Occupational Health and Safety Act and Regulations for Construction Projects.

B All dimensions are in metres unless otherwise shown.

LEGEND:

D – Inside diameter

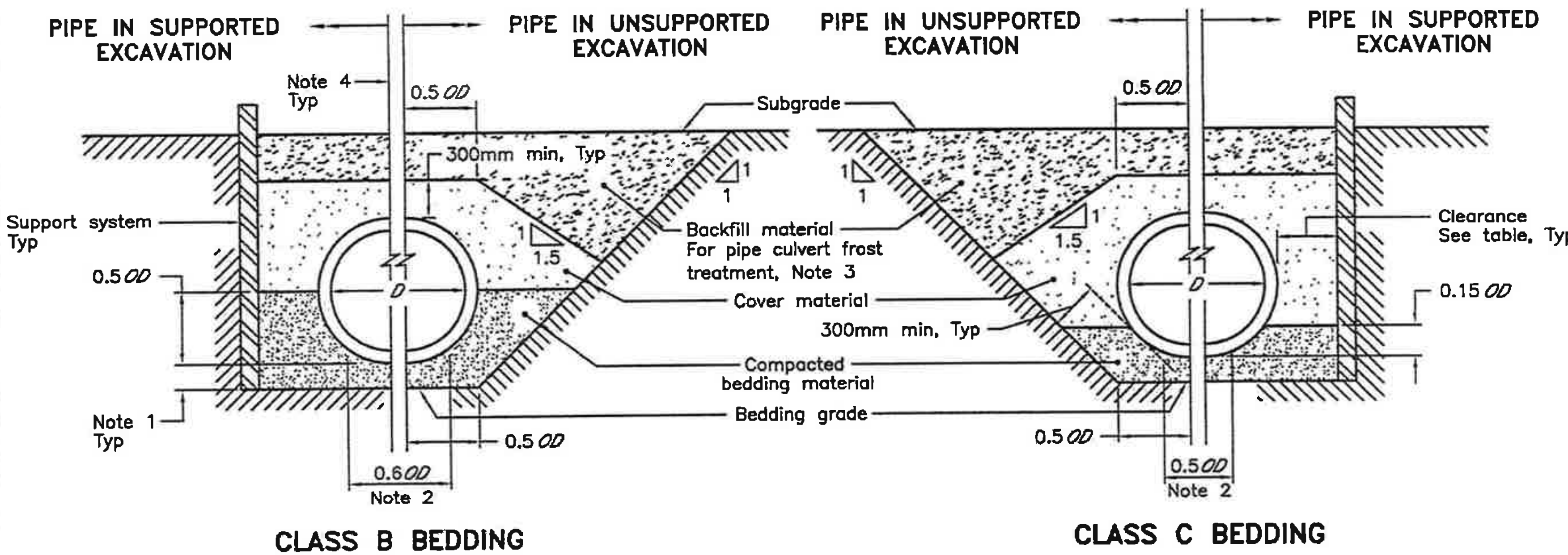
OD – Outside diameter

CLEARANCE TABLE	
Pipe Inside Diameter mm	Clearance mm
900 or less	300
Over 900	500

ONTARIO PROVINCIAL STANDARD DRAWING | Nov 2005 | Rev 1

RIGID PIPE BEDDING, COVER, AND BACKFILL TYPE 1 OR 2 SOIL – EARTH EXCAVATION

OPSD – 802.030



NOTES:

1 The minimum bedding depth below the pipe shall be 0.15*D*. In no case shall this dimension be less than 150mm or greater than 300mm.
2 The pipe bed shall be compacted and shaped to receive the bottom of the pipe.
3 Pipe culvert frost treatment according to OPSD–803.030 and 803.031.
4 Condition of trench is symmetrical about centreline of pipe.
A Soil types as defined in the Occupational Health and Safety Act and Regulations for Construction Projects.
B All dimensions are in metres unless otherwise shown.

LEGEND:

D – Inside diameter
OD – Outside diameter

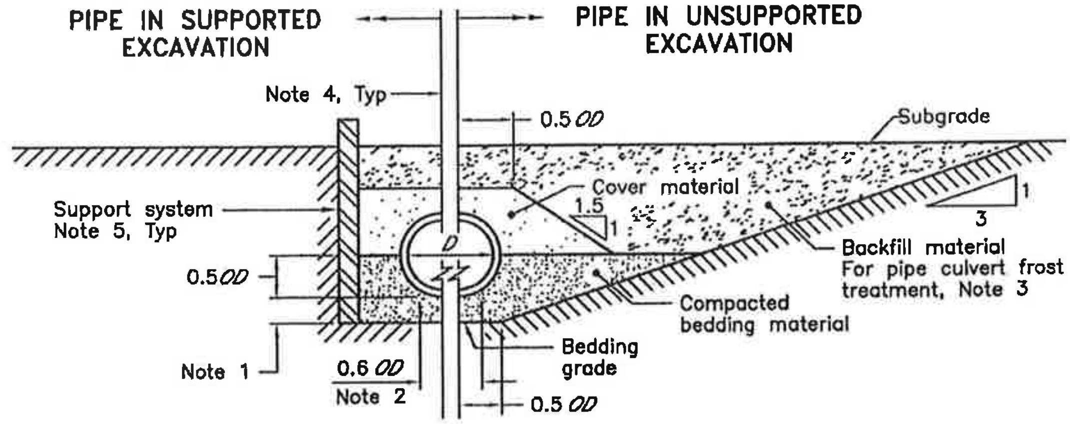
CLEARANCE TABLE

Pipe Inside Diameter mm	Clearance mm
900 or less	300
Over 900	500

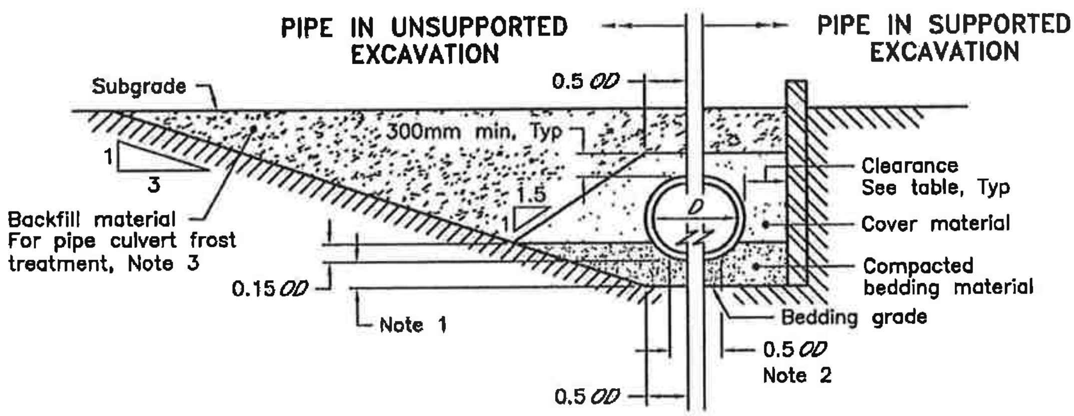
ONTARIO PROVINCIAL STANDARD DRAWING | Nov 2005 | Rev 1

RIGID PIPE BEDDING, COVER, AND BACKFILL
TYPE 3 SOIL – EARTH EXCAVATION

OPSD – 802.031



CLASS B BEDDING



CLASS C BEDDING

CLEARANCE TABLE	
Pipe Inside Diameter mm	Clearance mm
900 or less	300
Over 900	500

LEGEND:

D – Inside diameter

OD – Outside diameter

NOTES:

1 The minimum bedding depth below the pipe shall be 0.15*D*. In no case shall this dimension be less than 150mm or greater than 300mm.

2 The pipe bed shall be compacted and shaped to receive the bottom of the pipe.

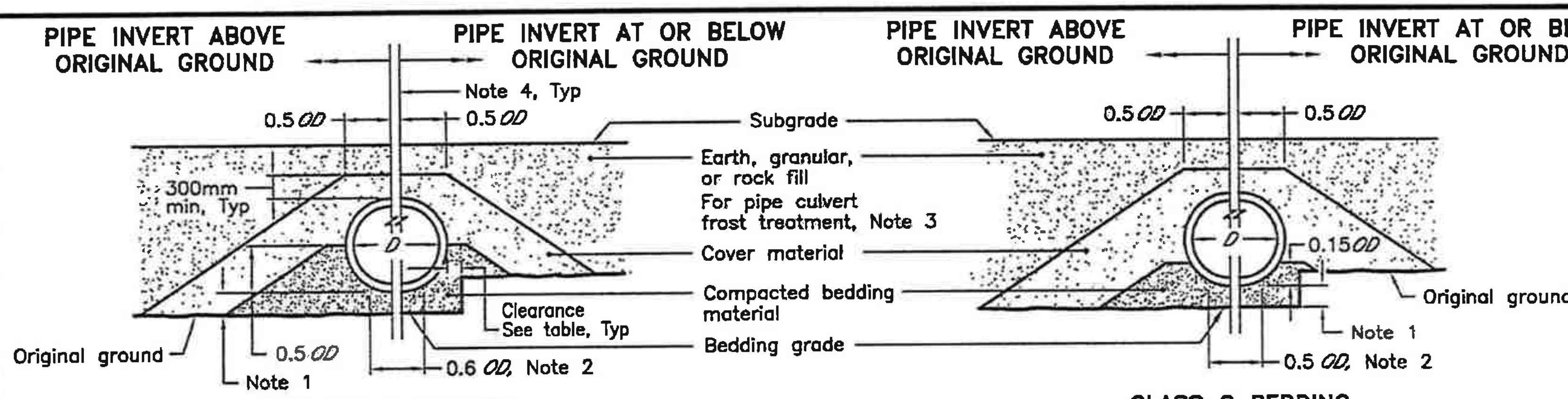
3 Pipe culvert frost treatment according to OPSD–803.030 and 803.031.

4 Condition of trench is symmetrical about centreline of pipe.

A Soil types as defined in the Occupational Health and Safety Act and Regulations for Construction Projects.

B All dimensions are in metres unless otherwise shown.

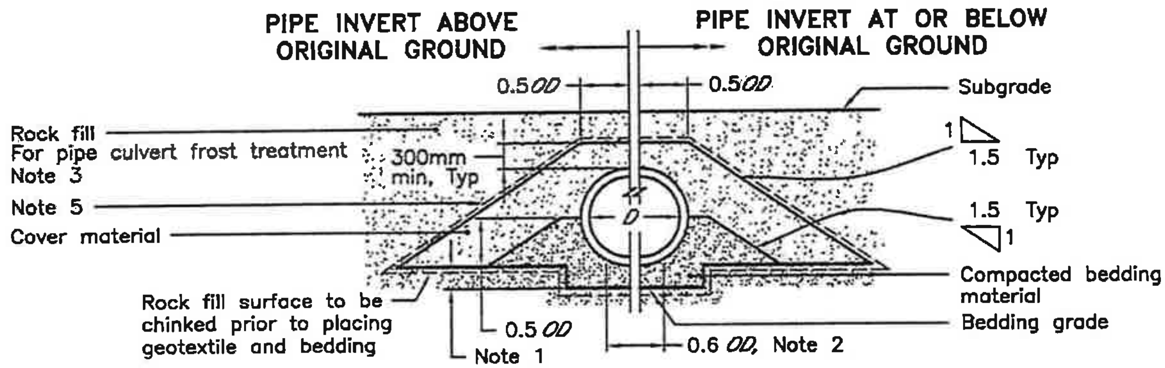
ONTARIO PROVINCIAL STANDARD DRAWING	Nov 2005	Rev 1
RIGID PIPE BEDDING, COVER, AND BACKFILL TYPE 4 SOIL – EARTH EXCAVATION	OPSD – 802.032	



CLASS B BEDDING

CLASS C BEDDING

EARTH AND ROCK EXCAVATION



PIPE BEDDING AND COVER
WITH ROCK FILL UNDER AND OVER THE PIPE

CLEARANCE TABLE	
Pipe Inside Diameter mm	Clearance mm
900 or less	300
Over 900	500

NOTES:

1 The minimum bedding depth below the pipe shall be 0.15*D*, except on a rock foundation where the minimum bedding depth shall be 0.25*D*. In no case shall the minimum dimension be less than 150mm or the maximum dimension exceed 300mm.
2 The pipe bed shall be compacted and shaped to receive the bottom of the pipe.
3 Pipe culvert frost treatment according to OPSD-803.030 and 803.031.
4 Condition of trench is symmetrical about centreline of pipe.
5 Bedding and cover material to be wrapped in non-woven geotextile when specified.

A All dimensions are in metres unless otherwise shown.

LEGEND:

D – Inside diameter
OD – Outside diameter

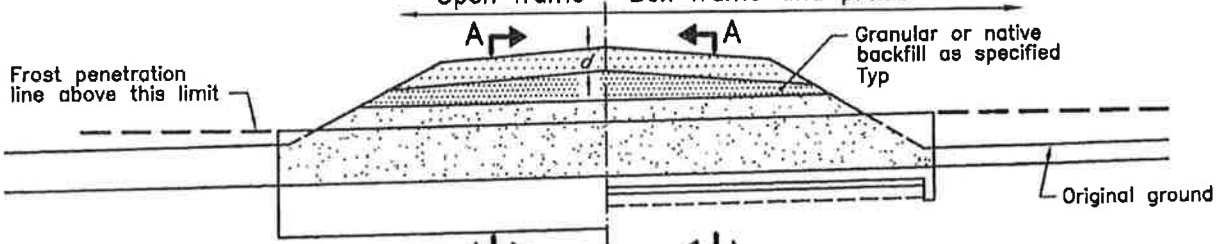
ONTARIO PROVINCIAL STANDARD DRAWING

Nov 2005 | Rev 1

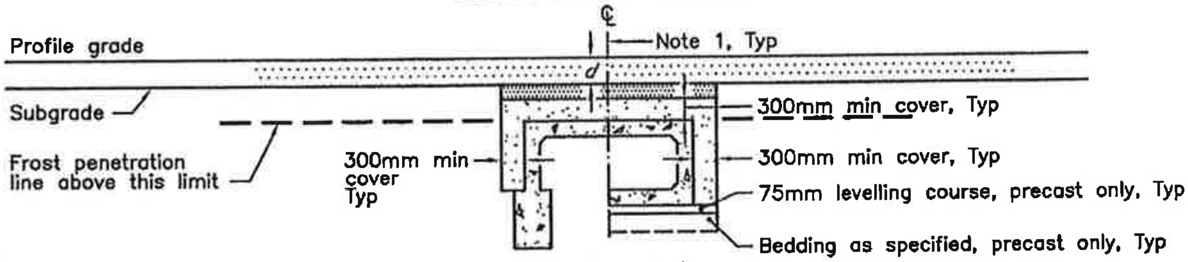
RIGID PIPE BEDDING AND COVER IN EMBANKMENT ORIGINAL GROUND: EARTH OR ROCK

OPSD – 802.034

FROST PENETRATION LINE AT OR ABOVE TOP OF CULVERT

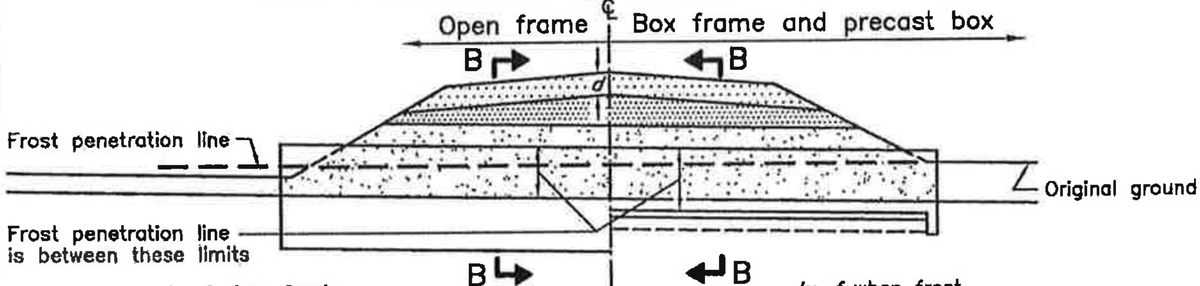


LONGITUDINAL SECTION

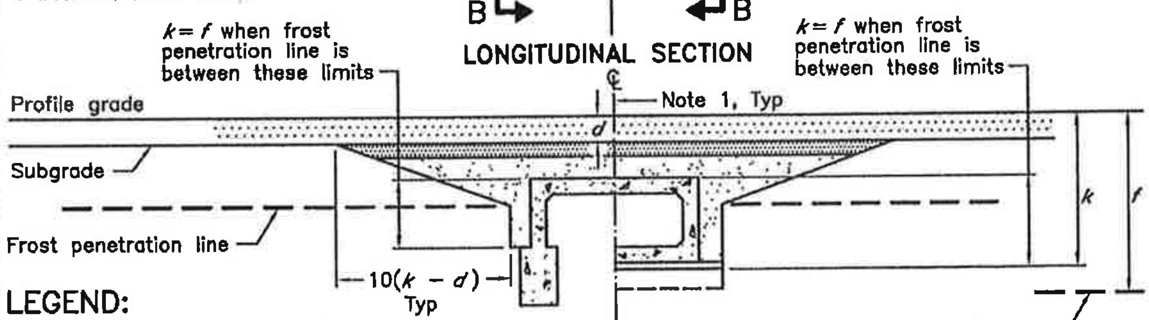


SECTION A–A

FROST PENETRATION LINE BELOW TOP OF CULVERT



LONGITUDINAL SECTION



LEGEND:

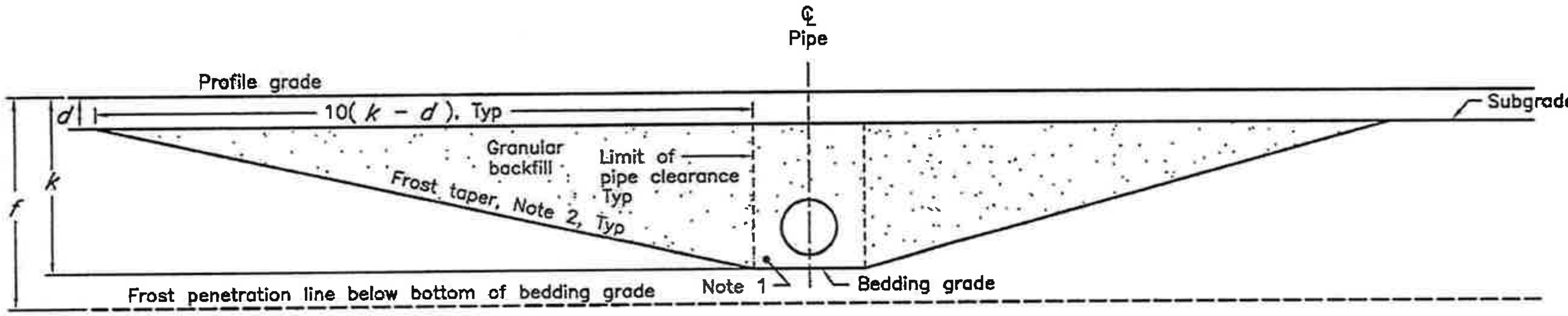
d = depth of roadbed granular
k = depth of frost treatment
f = depth of frost penetration

SECTION B–B

NOTES:

1 Condition of frost treatment symmetrical about centreline of culvert.
A Bedding, levelling, and cover material to be granular as specified.
B This standard applies to cast-in-place and precast concrete culverts with spans less than or equal to 3.0m.
C The depth of roadbed granular to be 600mm minimum.
D The maximum depth of frost treatment to be bottom of box frame or top of footing.
E All dimensions are in millimetres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING	Nov 2006	Rev 1
BACKFILL AND COVER FOR CONCRETE CULVERTS	OPSD 803.010	



FROST TREATMENT − RIGID AND FLEXIBLE PIPE

NOTES:

1 Pipe embedment or bedding, cover, and backfill according to:
   a) Flexible − OPSD−802.010, 802.013, 802.014, 802.020, 802.023, and 802.024
   b) Rigid − OPSD−802.030, 802.031, 802.032, 802.033, 802.034, 802.050, 802.051, 802.052, 802.053, and 802.054.

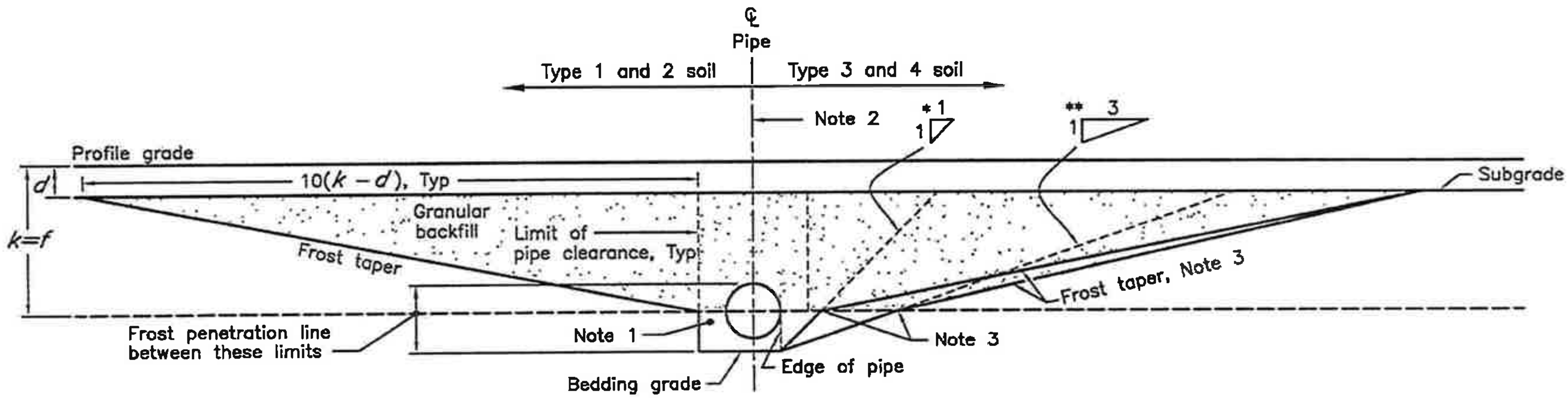
2 Frost tapers start at bedding grade.

A Frost tapers are not required in rock embankment.

LEGEND:

d −depth of roadbed granular
k −depth of frost treatment
f −depth of frost penetration

ONTARIO PROVINCIAL STANDARD DRAWING	Nov 2005	Rev 1
FROST TREATMENT − PIPE CULVERTS FROST PENETRATION LINE BELOW BEDDING GRADE		
	OPSD − 803.030	



FROST TREATMENT – RIGID AND FLEXIBLE PIPE

NOTES:

1 Pipe embedment or bedding, cover, and backfill according to:
  a) Flexible – OPSD–802.010, 802.013, 802.014, 802.020, 802.023 and 802.024
  b) Rigid – OPSD–802.030, 802.031, 802.032, 802.033, 802.034, 802.050, 802.051, 802.052, 802.053, and 802.054

2 Condition of frost treatment symmetrical about centreline of pipe.

3 Frost tapers start at the intersection of the 1H:1V or 3H:1V slope and the frost penetration line.

A Frost tapers are not required in rock embankment.

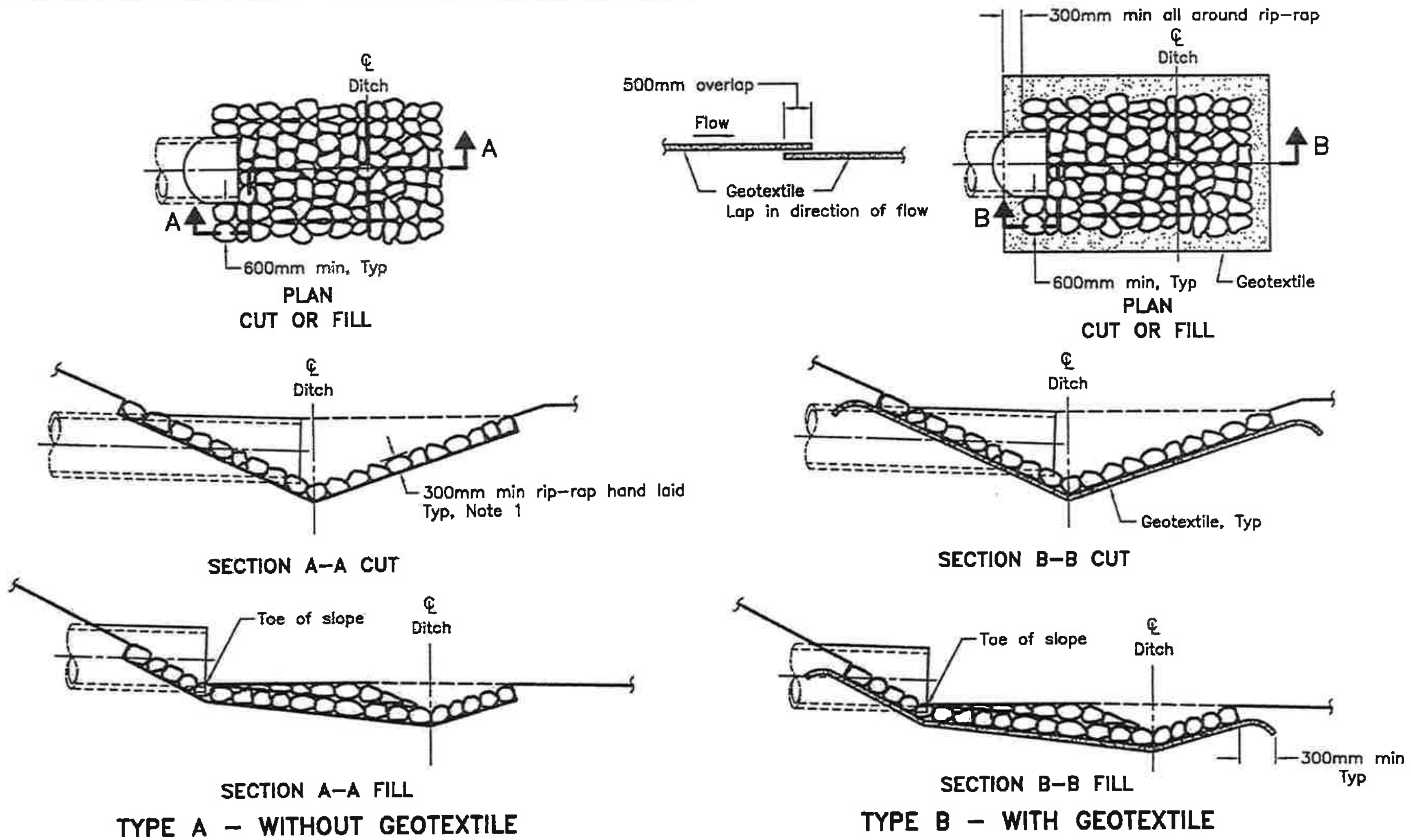
B Frost tapers not required when frost line is above the top of pipe.

C Soil types as defined in the Occupational Health and Safety Act and Regulations for Construction Projects.

LEGEND:

d – depth of roadbed granular
k – depth of frost treatment
f – depth of frost penetration
* – Type 3 soil
** – Type 4 soil

ONTARIO PROVINCIAL STANDARD DRAWING	Nov 2005	Rev 2
FROST TREATMENT – PIPE CULVERTS FROST PENETRATION LINE BETWEEN TOP OF PIPE AND BEDDING GRADE	OPSD – 803.031	



NOTES:

1 The thickness of the rip-rap layer shall be at least 1.5 times the rip-rap mean diameter.

A All dimensions are in millimetres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING	Nov 2007	Rev 1
RIP-RAP TREATMENT FOR SEWER AND CULVERT OUTLETS	OPSD 810.010	

Appendix G

Limitations of Reports

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 Coffey Geotechnics Inc. (Coffey) at the time of preparation. Unless otherwise agreed in writing by Coffey, 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. Coffey accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.