



July 16, 2013

FOUNDATION INVESTIGATION AND DESIGN REPORT

HIGHWAY 17 - BIG CACHE CREEK CULVERT AT STATION 10+514
TOWNSHIP OF SPRINGER, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5106-08-00, WP 5013-10-01

Submitted to:
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REPORT





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PART A

**FOUNDATION INVESTIGATION REPORT
HIGHWAY 17 – BIG CACHE CREEK CULVERT AT STATION 10+514
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by MMM Group Limited (MMM), on behalf of the Ministry of Transportation, Ontario (MTO), to provide foundation engineering services for the rehabilitation of the Highway 17 Big Cache Creek culvert at STA 10+514 in Nipissing Township, Ontario. The Key Plan showing the general location of this section of Highway 17 and the location of the investigated area are shown on Drawing 1. The purpose of this investigation is to establish the subsurface conditions at the location of the proposed culvert by borehole drilling, in situ testing and laboratory testing on selected samples.

2.0 SITE DESCRIPTION

The Big Cache Creek culvert is located approximately 9 km west of Sturgeon Falls, Ontario and approximately 0.3 km east of the intersection of Highway 17 and Beaudry Road. In general, the topography in the area of the overall project limits consists of flat terrain utilized as farmland, with moderate tree cover. The existing highway grade is at about Elevation 208 m with the Big Cache Creek located about 9 m below the existing highway grade. The side slopes of the existing embankment are about 1.5 Horizontal to 1 Vertical (1.5H:1V). Rock fill was observed on the embankment side slopes, some pieces in excess of 1 m size. The existing culvert, which is presumed to be an open footing culvert and later a concrete invert slab was poured, is 37 m long with an inside width of 6.1 m. This inside height varies from 1.83 m at the ends to 1.1 m at the centre portion and the north and south inverts are at Elevation 199.6 and 199.3 m, respectively. Photographs 1 and 2 following the text of the report depict the embankment side slopes and culvert ends.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation was carried out between June 18, 2012 and June 27, 2012, during which time a total of six (6) boreholes were advanced at the site: four (4) for the proposed culvert (Boreholes CC-2, CC-3, CC-5 and CC-6) as shown on Section A-A on Drawing 1; and two (2) for the proposed roadway protection (Boreholes CC-1 and CC-4) as shown on Section B-B on Drawing 1. The approximate locations of, and ground surface elevations at, the boreholes are shown on Drawing 1.

Boreholes CC-1 to CC-4, located on the existing highway embankment, were advanced using a truck-mounted CME 55 drill rig outfitted with 108 mm inside diameter continuous flight hollow-stem augers. Boreholes CC-5 and CC-6, located at the south and north toe of slope, respectively, were advanced by wash boring with portable equipment using HQ casing. A Dynamic Cone Penetration Test (DCPT) was advanced from the bottom of Borehole CC-2 from 23.5 m to 31.7 m depth (Elevation 176.5 m) and from the bottom of Borehole CC-5 from 15.8 m to 23.8 m depth (Elevation 175.4 m). The drilling equipment was supplied and operated by Landcore Drilling Inc. of Sudbury, Ontario. Soil samples were obtained at intervals of depths of about 0.75 m and 1.5 m, using a 50 mm outer diameter (O.D.) split-spoon sampler driven by an automatic hammer at Boreholes CC-1 to CC-4 and a manual hammer at Boreholes CC-5 and CC-6, and performed in accordance with Standard Penetration Test (SPT) procedure (ASTM D1586). Selected samples of the cohesive soils were obtained using 76 mm O.D. thin-walled 'Shelby' tubes (ASTM D1587, Standard Practice for Thin-Walled Tube Sampling) for relatively undisturbed samples. Field vane shear tests were conducted in cohesive soils for determination of undrained shear strengths (ASTM D2573, Standard Test Method for Field Vane Strength Shear Test) using



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MTO Standard 'N' size vanes. The groundwater conditions and water levels in the open boreholes were observed during the drilling operations and are described on the Record of Borehole sheets in Appendix A. All boreholes were backfilled with bentonite upon completion of drilling in accordance with Ontario Reg. 903 (as amended).

The fieldwork was supervised throughout by members of our technical staff, who located the boreholes, arranged for the clearance of underground services, observed the drilling, sampling and in situ testing operations, logged the boreholes, and examined and cared for the soil samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Sudbury laboratory where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. Classification testing (water content, Atterberg limits and grain size distribution) was carried out on selected soil samples. In addition, a one-dimensional consolidation (oedometer) test was carried out on one Shelby tube sample of the cohesive soil deposit from Borehole CC-6. The results of the laboratory testing are presented on the Record of Borehole sheets in Appendix A and are also included in Appendix B.

A sample of the creek water was obtained on July 20, 2012, using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters. The results of the analytical testing are summarized in Table B1 in Appendix B, together with the detailed analytical laboratory test results.

The as-drilled borehole locations and ground surface elevations were measured and surveyed by members of our technical staff, referenced to the staked stations and offsets on the highway. The MTM NAD 83 northing and easting coordinates, ground surface elevations referenced to Geodetic datum and borehole depth at each borehole are presented on the Record of Borehole sheets in Appendix A and are summarized below.

Borehole	Borehole Location		Ground Surface Elevation (m)	Borehole/DCPT Depth (m)
	Northing	Easting		
CC-1	5140833.8	263625.8	208.4	15.8
CC-2	5140821.9	263643.2	208.2	23.5/31.7
CC-3	5140832.9	263638.8	208.5	18.9
CC-4	5140820.9	263657.8	208.4	15.8
CC-5	5140808.6	263625.0	199.2	15.8/23.8
CC-6	5140847.8	263655.0	199.9	15.8

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on terrain mapping (Ontario Geological Survey¹), the site is located on a glaciolacustrine plain in an area of, sand, silt and/or clay deposits.

¹ Southern Ontario Engineering Geology Terrain Study, 1980. Ontario Geological Survey.



4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions, as encountered in the boreholes advanced for this investigation, together with the results of the laboratory tests carried out on selected soil core samples, are given on the Record of Borehole sheets in Appendix A. Detailed results of the laboratory testing of the soil samples are provided in Appendix B. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling, observations of drilling progress and the results of SPTs and in situ testing. These boundaries, therefore, represent transitions between soil and rock types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations and on the stratigraphic profile and cross-section shown on Drawing 1.

In general, the subsurface stratigraphy at the site consists of embankment fill underlain by a deposit of clayey silt to clay underlain by a deposit of sandy silt to sand and silt. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Fill

Boreholes CC-1 and CC-2 penetrated an upper and lower layer of asphalt 300 mm and 225 mm thick, respectively, separated by a layer of sand fill up to 100 mm thick. The surface of the asphalt was encountered at Elevation 208.4 m and 208.2 m at Boreholes CC-1 and CC-2, respectively.

Below the asphalt in Boreholes CC-1 and CC-2 and from ground surface in Boreholes CC-3 and CC-4, fill material was encountered consisting of sand and gravel to sand, some silt, with the surface of the deposit between Elevation 208.5 m and 207.6 m and the thickness between 0.8 m and 1.4 m.

Below the sand and gravel to sand fill in each of the four boreholes, a 5.6 m to 7.3 m deposit of sand and silt to clayey silt fill was encountered with the surface between Elevation 207.3 m and 206.4 m. In Borehole CC-2, wood fragments were noted in the bottom sample of fill at a depth of 7.6 m below roadway surface (Elevation 200.6 m). Peat and topsoil pockets were noted in the clayey silt fill sample in Borehole CC-4 at a depth of 4.6 m below ground surface (Elevation 203.8 m). An approximately 1.1 m thick layer of silty clay fill was encountered below the sand and silt to clayey silt fill in Borehole CC-4, at a depth of 5.9 m below ground surface (Elevation 202.5 m).

The augers were noted to be grinding in Borehole CC-4 within the fill at a depth between approximately 6.0 m and 7.0 m below ground surface.

The SPT 'N'-values measured within the sand and gravel to sand fill range between 11 blows and 42 blows per 0.3 m of penetration indicating a compact to dense relative density. The SPT 'N'-values within the sand and silt to clayey silt fill, range between 4 blows and 23 blows per 0.3 m of penetration, indicating a loose to compact relative density (or firm to very stiff consistency). One SPT 'N'-value measured within the silty clay fill in Borehole CC-4 is 4 blows per 0.3 m of penetration suggesting a firm consistency.

Grain size distribution analyses were carried out on the following fill materials:

- one (1) sample of the sand and gravel fill and the results are presented on Figure B1-1 in Appendix B;
- seven (7) samples of the sand and silt to clayey silt fill and the results are presented on Figure B1-2; and



- one (1) sample of the silty clay fill and the results are presented on Figure B1-3.

Atterberg limits testing was carried out on six (6) samples of the sand and silt to clayey silt fill. Measured liquid limits range from 19 per cent to 29 per cent, plastic limits range from 15 per cent to 20 per cent and plasticity indices range from 4 per cent to 9 per cent. The results, which are plotted on a plasticity chart on Figure B1-4 in Appendix B, indicate that the tested samples consist of a silt of slight plasticity to clayey silt of low plasticity. The measured water contents are at, or near, the plastic limit. Further, an Atterberg limits test was carried out on the sample of silty clay fill in Borehole CC-4, and the measured liquid limit is 38 per cent, the plastic limit is 18 per cent and the plastic index is 20 per cent and the water content is near the liquid limit. The results are plotted on Figure B1-5 and indicate that the tested sample is a silty clay of intermediate plasticity.

The measured water content on a sample of the sand and gravel fill is 5 per cent and samples of the sand and silt to silty clay fill are between 17 per cent and 33 per cent. The organic content measured on a sample of the lower portion of the clayey silt fill deposit in Borehole CC-1 is about 2 per cent (slightly organic).

4.2.2 Sandy Silt to Sand

A 0.2 m thick layer of sand was encountered from ground surface (Elevation 199.2 m) in Borehole CC-5 and a 0.8 m thick layer of sandy silt to silty sand was encountered from ground surface (Elevation 199.9 m) in Borehole CC-6.

4.2.3 Clayey Silt to Clay

A deposit of clayey silt to clay was encountered below the embankment fill in Boreholes CC-1 to CC-4 at depths ranging between 7.0 m and 8.7 m below ground surface (Elevation 201.4 m and 199.5 m, respectively), below the sand deposit in Borehole CC-5 at a depth of 0.2 m (Elevation 199.0 m) and below the sandy silt to silty sand in Borehole CC-6 at a depth of 0.8 m (Elevation 199.1 m). In Boreholes CC-2, CC-5 and CC-6, the clayey silt to clay deposit was fully penetrated and is between 10.8 m and 13.2 m thick and was not fully penetrated in Boreholes CC-1, CC-3 and CC-4 after exploring the deposit for a thickness between 7.3 m and 10.4 m. The deposit generally consists of clay in the upper portion, transitioning to a silty clay in the middle of the deposit and a clayey silt in the lower portion. The deposit was noted to be varved, typically with approximately 10 mm to 50 mm thick silt to clayey silt laminae and approximately 10 mm to 25 mm thick clay laminae. Thicker silt seams (0.2 m or greater) were also observed within the deposit. Further, sand seams were noted within the lower clayey silt portion of the deposit, generally encountered below Elevation 193 m.

The SPT 'N'-values measured within the clayey silt to clay deposit range between 0 blows (weight of hammer or rods) to 6 blows per 0.3 m of penetration. In situ field vane testing measured undrained shear strengths ranging from 43 kPa to 81 kPa, with a sensitivity between 2 and 12. The in situ vane test results indicate that the deposit has a firm stiff consistency.

Atterberg limits testing were carried out on fourteen (14) samples of the varved clayey silt to clay and the measured liquid limits range from 22 per cent to 76 per cent, the plastic limits range from 14 per cent to 25 per cent, and plasticity indices range from 8 per cent to 51 per cent. The results, which are plotted on a plasticity chart on Figures B2-1 and B2-2 in Appendix B, indicate that the tested samples of the overall deposit consist of a clayey silt of low plasticity to clay of high plasticity.



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Atterberg limits tests were also carried out on four (4) samples of the deposit separated into the clayey silt laminae and clay laminae and the test results are shown on Figure B2-3. The test results on the three (3) clay laminae samples indicate liquid limits ranging from 54 per cent to 84 per cent, plastic limits ranging from 24 per cent to 33 per cent and plasticity indices ranging from 30 per cent to 51 per cent. For the single clayey silt lamina sample, the liquid limit is 29 per cent, plastic limit is 17 per cent and plasticity index is 13 per cent. The test results confirm that the 'silty' varves are classified as clayey silt of low plasticity and the clayey varves are classified as clay of high plasticity.

The results of grain size distribution testing completed on samples of the clayey silt and clay laminae are shown on Figure B3 in Appendix B and the results of grain size distribution testing completed on a sample of the silty sand seam in Borehole CC-2 is shown on Figure B4.

The natural moisture content measured on the overall varved clayey silt to clay deposit range from 34 per cent to 55 per cent, on samples of the clayey silt laminae range from 30 per cent to 44 per cent and on the clay laminae range from 58 per cent to 71 per cent. The natural moisture content measured on the silty sand seam in Borehole CC-2 is 26 per cent.

One laboratory consolidation (oedometer) test was carried out on a specimen of the clayey silt to clay obtained from Borehole CC-6 and the test results are shown on Figure B5 in Appendix B. The preconsolidation stress was estimated from the Void Ratio versus logarithmic Pressure plot using the Casagrande method as well as from the Total Work versus Pressure plot. The relevant consolidation test results are summarized below:

Borehole/ Sample Number	Elevation (m)	σ_{vo}' (kPa)	σ_p' (kPa)	$\sigma_p' - \sigma_{vo}'$ (kPa)	OCR	e_o	C_r	C_c	c_v^* (cm ² /s)
CC-6/6	195.1	34	270	236	7.9	1.634	0.09	0.90	0.022

Note: *For approximate stress range of $35 \leq \sigma_v' \leq 285$ kPa

where: σ_{vo}' effective overburden stress in kPa

σ_p' preconsolidation stress in kPa

OCR overconsolidation ratio

e_o initial void ratio

C_c compression index (based on void ratio)

C_r recompression index (based on void ratio)

c_v coefficient of consolidation in cm²/s in the normally consolidated range

4.2.4 Sandy Silt to Sand and Silt

A deposit of sandy silt to sand and silt with clay seams was encountered below the clayey silt to clay deposit at a depth between 11.6 m and 20.1 m below ground surface (between Elevation 188.3 m and 185.8 m) in Boreholes CC-2, CC-5 and CC-6. The sampled boreholes did not fully penetrate the deposit after exploring for thicknesses of between approximately 2.4 m and 4.2 m. As discussed in Section 3.0, a DCPT was advanced from the bottom of Borehole CC-2 from a depth of 23.5 m to a depth of 31.7 m and from the bottom of sampled Borehole CC-5 from a depth of 15.8 m to a depth of 23.8 m, potentially not penetrating this deposit based on a review of the results of the DCPT.

The SPT 'N'-values measured within this deposit range between 0 blows (weight of hammer) and 32 blows per 0.3 m of penetration, indicating a very loose to dense relative density.



Grain size analyses were carried out on three (3) samples of this deposit and the results are represented on Figure B6 in Appendix B.

The measured water content on samples of the deposit is between 28 per cent and 33 per cent.

4.2.5 Groundwater Conditions

Unstabilized water levels in Boreholes CC-1 to CC-4 upon completion of drilling ranged from 6.7 m to 12.8 m below roadway level, corresponding to Elevation 201.7 m and 195.6 m. The unstabilized water levels in Boreholes CC-5 and CC-6 upon completion of drilling are at ground surface, corresponding to Elevation 199.2 m and 199.9 m, respectively.

Groundwater levels encountered in the boreholes shortly after drilling may not be representative of static groundwater levels since the groundwater levels in the boreholes may not have stabilized on completion of drilling. Groundwater levels are subject to seasonal fluctuations and to fluctuations after precipitation events and snowmelt.

5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Shane Albert, under the overall direction of Mr. André Bom, P.Eng. This report was prepared by Mr. Nicholas Kicz, Geotechnical Engineering Student and the technical aspects were reviewed by Mr. André Bom, P.Eng. with input by Mr. Fintan J. Heffernan, P.Eng., a specialist consultant with Golder. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and Principal with Golder, conducted an independent quality control review of the report.



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Report Signature Page

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PART B

FOUNDATION DESIGN REPORT

HIGHWAY 17 – BIG CACHE CREEK CULVERT AT STATION 10+514

TOWNSHIP OF NIPISSING, ONTARIO

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6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides an interpretation of the factual geotechnical data obtained during the investigation and conclusions and recommendations on the foundation aspects of design of the proposed works. The recommendations provided are intended for the guidance of the design engineer. Where comments are made on construction, they are provided to highlight aspects of construction that could affect the design of the project. Those requiring information on aspects of construction must make their own interpretation of the subsurface information provided as such interpretation may affect their proposed construction methods, costs, equipment selection, scheduling and the like.

6.1 General

The existing Big Cache Creek concrete box culvert is 37 m long, has an inside width of 6.1 m and an inside height varying from 1.8 m at the ends to 1.1 m at the centre section (7.7 m exterior width and 3.2 m exterior height). The north and south inverts are Elevation 199.6 m and 199.3 m, respectively. Inside the culvert, the top appears to sag near the centre of the culvert. Based on discussion with MMM, the culvert was likely originally constructed as an open bottom culvert and during rehabilitation of the existing culvert (date unknown), a concrete bottom slab was likely installed. Rehabilitation records are not available for the existing culvert. The top of the existing embankment is at Elevation 208 m and the existing side slopes for the 9 m high embankment are about 1.5H:1V. Further, as shown in Photographs 1 and 2, rock fill can be observed on the side slopes, more prominently on the south slope of the embankment and less on the north embankment slope, except at the toe of the north slope, which is generally vegetated. Pieces of rock fill are on the south slope in excess of 1 m size were observed. The rock fill was likely placed during previous highway rehabilitation to improve the embankment slopes against erosion or ravelling.

The subsoils below the culvert alignment generally consist of a 10.8 m to 13.2 m thick deposit of firm to stiff varved clayey silt to clay, underlain by a deposit of very loose to dense sandy silt to sand and silt. Details of the subsurface conditions along the culvert are presented in Section 4.2 and shown in stratigraphic profile and cross-section on Drawing 1. It should be noted that auger grinding was noted during drilling in Borehole CC-4 within the fill material at a depth between approximately 6.0 m and 7.0 m.

As part of the Highway 17 rehabilitation to be carried out in the vicinity of the Big Cache Creek culvert, the embankment slopes at the culvert location will be re-graded to a slope of 2H:1V. The flattening of the existing embankment slopes results in minimal widening at the top of the embankment, a widening of about 2 m near the embankment mid-slope and about 4 m just beyond the existing culvert ends, behind the new wing walls as discussed further below. We understand that a grade raise at the top of the existing embankment will not be required.

It should be noted that present practice by MTO is to include a 2 m wide berm in the embankment slope geometry such that the uninterrupted slope height is not greater than 8 m for an earth slope and 10 m for a rock fill slope, as per OPSD 202.010 (Slope Flattening). Further, the upper portion of the slope should not be configured in such a way that the new fill will act as an active load, but rather the top/upper portion of the slope should be unloaded or the lower portion of the slope flattened.

To accommodate the flatter embankment side slopes, new wing walls will be constructed at the ends of the culvert during rehabilitation, as discussed below.



- A length of 3 m will be removed from each end of the existing culvert. We understand that shoring will be installed near the crest of the embankment to avoid the existing rock fill on the embankment side slope, to facilitate culvert end removal and reconstruction and new wing wall construction. Installation of the temporary shoring through the rock fill observed on the embankment side slopes may not be feasible and may require removal of the rock fill prior to shoring installation.
- Based on discussion with MMM, the new 3 m long culvert ends will consist of a concrete box culvert, rather than a culvert constructed with open bottom footings, due to the presence of the cohesive deposit at the foundation level and the generally low bearing resistances provided by this deposit.
- A new 4.8 m long concrete wing wall will be constructed at each side of the culvert north and south ends for a total of four walls, with the walls cantilevered from the ends of the culvert.

6.2 Culvert Types

The analysis and recommendations presented in this report address the rehabilitation for the Big Cache Creek culvert consisting of a concrete box culvert. Due to the presence of the cohesive deposit of limited strength and the height of the existing embankment, an open bottom concrete culvert for the culvert end replacement is not considered feasible and would not likely be compatible with the existing culvert.

6.3 Stability

Limit equilibrium slope stability analyses were performed for the proposed embankment geometry at the Big Cache Creek culvert using the commercially available program GeoStudio 2007 (Version 7.17), produced by Geo-Slope International Ltd., employing the Morgenstern-Price method of analysis. For all analyses, the Factor of Safety (FoS) of numerous potential failure surfaces was computed in order to establish the minimum FoS. The FoS is defined as the ratio of the forces tending to resist failure to the driving forces tending to cause failure. A target minimum FoS of 1.3 is normally adopted on MTO projects for the design of embankment slopes under static conditions. This FoS is considered adequate for the embankment at this site considering the design requirements and the field data available and is based on deep-seated, global failure surfaces that would affect the operation of the roadways. The stability analyses were performed to check that the target minimum FoS was achieved for the embankment height and geometry at the culvert locations.

The analyses assume that organic soils (if present) beneath the new embankment widening will be removed prior to construction. The existing embankment fill will generally remain in place. The widened portion of the embankment is assumed to be constructed of new granular fill, such as MTO Special Provision (SP) 110S13 (Aggregates) Granular 'B' Type I or Type II, which will need to be keyed into the existing fill as per OPSD 208.010 (Benching of Earth Slopes) and constructed with minimum 2H:1V side slopes.

For the existing cohesionless fill and native cohesionless soils, effective stress parameters were employed in the stability analysis assuming drained conditions and the parameters were estimated from empirical correlations using the results of the in situ SPT 'N'-values. The correlations proposed by NAVFAC (1982) were employed and the results were tempered by engineering judgment based on precedent experience in similar soils.



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For the cohesive layers, total stress parameters were employed in the analysis. The total stress parameters (i.e. undrained shear strength – s_u) for the cohesive soil were assessed based primarily on the results of the in situ field vane tests. Bjerrum's (1973) correction factor as a function of the plasticity index of the soil was employed to estimate the average mobilized undrained shear strength from the results of the in situ field vane tests. Further, a correction (reduction) factor of 25 per cent on the undrained shear strength has been employed due to the silt/clay varves noted within the cohesive deposit to account for the angle of minimum shearing resistance (Milligan and Lo, 1967). The profiles of undrained shear strength versus elevation, together with the selected design lines, based on the field and laboratory data, are presented on Figure 1.

The piezometric surface assumed in the analysis is at Elevation 199.6 m.

The simplified stratigraphy together with the associated strength and unit weight employed for the different native soil types at the culvert location are summarized below.

Soil Type	Unit Weight (kN/m^3)	Undrained Shear Strength (kPa)	Angle of Internal Friction ($^\circ$)
New Granular Fill keyed into existing fill as per OPSD 208.010 (Benching of Earth Slopes) and constructed with 2H:1V side slopes	21	-	35
Existing Embankment Fill (Sand to Sand and Gravel)	20	-	32
Existing Embankment Fill (Sand and Silt to Clayey Silt)	19	-	29
Clayey Silt to Clay	17	45	-
Sandy Silt to Sand and Silt	19	-	28

The stability analysis performed on the proposed embankment at the culvert location indicates that after embankment widening, the embankment will have a FoS of 1.3 or greater for deep-seated, global failure surfaces that would impact the operation of the roadway, as shown on Figure 2.

6.4 Settlement

Based on the consolidation test results on a sample of the clayey silt to clay deposit, together with the field vane undrained shear strength test results, the cohesive deposit is over-consolidated (OCR of about 8) in relation to the present creek bottom or slightly over-consolidated (OCR relative to the adjacent ground surface) beyond the creek. For the currently proposed embankment widening, the total settlement of the cohesive foundation soil under the section of the culvert replacement and the differential settlement between the existing culvert and the replaced culvert ends is estimated to be up to 25 mm. However, if an increase to the existing embankment grade or a greater widening is required than what is currently proposed, the magnitude of settlement will be different than that estimated for the presently proposed construction and measures to mitigate settlement may be required.



It is recommended that consideration be given to the use of SP 110S13 (Aggregates) Granular 'B' Type I or II for embankment reconstruction at the culvert location. Where granular fill will be placed below the water level, Granular 'B' Type II should be used. The material placed below the water level will compress/settle under its self-weight as additional fill is placed over it. The material placed above the water level should be compacted in accordance with OPSS 501 (Compacting). Compression settlement of the fill placed below water and from properly compacted embankment fill above water is expected to occur during construction. It is recommended that the fines content of the Granular 'B' Type II fill used for embankment construction below the water be restricted to a maximum of 5 per cent passing the No. 200 sieve, to reduce the potential for segregation of fines during placement and to reduce the potential post-construction settlement and associated maintenance needs.

6.5 Horizontal Strain

Horizontal strain along the culvert is not expected to occur provided the proposed embankment geometry does not change from the currently proposed geometry. Should the embankment be widened to a greater extent than what is currently proposed or raised compared with the existing geometry, a reassessment of the potential magnitude of horizontal strain will be required.

As a result, culvert end replacement concurrent with embankment widening can be carried out without the need for any foundation mitigation measures or culvert camber provided that the culvert end replacement (and joint to the existing culvert) has been designed to or can tolerate the estimated ant total differential settlement noted above.

6.6 Geotechnical Resistance

For the box culvert end replacement, due to the presence of the up to about 13 m thick clayey silt to clay deposit, we recommend that a factored geotechnical axial resistance at Ultimate Limit States (ULS) of 180 kPa be used for design for an assumed 7.7 m wide box culvert end replacement founded on a properly prepared subgrade overlying the firm to stiff clayey silt to clay soils. It is noted that at this site, the loading on the foundation soils below the culvert end replacement and the associated total settlement at the culvert end replacement will be governed by the widening embankment fills. As such, it is recommended that the structural engineer exercise caution when utilizing the value(s) of the geotechnical axial resistance at Serviceability Limit States (SLS) in the design of the culverts and that consideration be given to the sequence and staging of construction. Based on the above, the geotechnical resistance at SLS (for 25 mm settlement) for a 7.7 m wide box culvert end replacement constructed on the properly prepared granular subgrade overlying the firm to stiff native clayey soils may be taken as 120 kPa.

The geotechnical resistances are given for loads applied perpendicular to the surface of the base of the culvert end replacement. Where loads are not applied perpendicular to the base of the culvert, inclination of the loads should be taken into account in accordance with Section 6.7.4 and Section C6.7.4 of the *Canadian Highway Bridge Code (CHBDC)* and its *Commentary*. For the estimation of the factored ULS value, a minimum culvert embedment depth of 2 m was used (i.e. top of embankment to top of culvert).



6.6.1 Resistance to Lateral Loads/Sliding Resistance

Resistance to lateral forces/sliding resistance between the base of a concrete box culvert and the granular fill/bedding should be calculated in accordance with Section 6.7.5 of the *CHBDC*. The following summarizes the unfactored values of coefficient of friction for the interface materials for a precast and cast-in-place concrete box culvert.

Interface Materials	Coefficient of Friction
Precast Concrete Box on Compacted Granular 'B' Type II	$\tan \delta = 0.45$
Cast-in-Place Concrete on Compacted Granular 'B' Type II	$\tan \Phi' = 0.58$
Granular 'A' Pad – Clay Subgrade – Short-term Loading	Undrained Adhesion = 60 kPa
Granular 'A' Pad – Clay Subgrade – Long-term Loading	Effective Interface Friction Angle = 25°

6.6.2 Frost Protection

The estimated frost penetration depth for the Sturgeon Falls area is 2.0 m, as per OPSD 3090.101 (Foundation Frost Penetration Depths for Southern Ontario).

Box culverts are typically not provided with the standard depth for frost protection as box culverts are tolerant to small magnitudes related to freeze – thaw cycles should these occur. The box culverts should, however, be founded below any existing fill and surficial organic materials. It is recommended that the box culvert segments be placed on a minimum thickness of 300 mm of SP110S13 (Aggregates) Granular 'A' or Granular 'B' Type II granular bedding material. If placed in the wet, Granular "B" Type II material should be used.

6.7 Lateral Earth Pressures – Culverts and Wing Walls

The lateral earth pressures acting on the side walls and wing walls of the culverts will depend on the type and method of placement of backfill materials, the nature of soils/embankment fill behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the walls.

The following recommendations are made concerning the design of the culverts and wing walls. It should be noted that these design recommendations and parameters are applicable to level backfill and ground surface behind the walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope.

- Select, free draining granular fill meeting the requirements of SP110S13 (Aggregates) Granular 'A' or Granular 'B' Type II but with less than 5 percent passing the 200 sieve (0.075 mm) should be used as backfill behind the culverts. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Other aspects of the granular backfill requirements with respect to sub drains and frost taper should be in accordance with OPSD 3121.150 (Walls Retaining, Backfill).
- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the culverts and wing walls, in accordance with *CHBDC* Section 6.9.3 and Figure 6.6.



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Compaction equipment should be used in accordance with OPSS 501 (Compaction). Other surcharge loadings should be accounted for in the design as required.

- Granular fill may be placed either in a zone with the width equal to at least 2.0 m behind the back of the wing walls for a restrained wall (see Figure C6.20(a) of the *Commentary* to the *CHBDC*), or within the wedge shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical (1.5H:1V) extending up and back from the rear face of the base of the wing walls for an unrestrained wall (see Figure C6.20(b) of the *Commentary* to the *CHBDC*).
- For a restrained wall condition, the pressures are based on the proposed embankment fill materials and the existing overburden soils and the following parameters (unfactored) may be used assuming the use of earth fill or rock fill:

	Granular Fill	Rock Fill
Soil unit weight:	21 kN/m ³	19 kN/m ³
Coefficients of static lateral earth pressure:		
Active, K_a	0.31	0.22
At rest, K_o	0.47	0.36

- For an unrestrained wall condition, the pressures are based on the granular fill as placed and the following parameters (unfactored) may be assumed:

	Granular 'A'	Granular 'B' Type II
Soil unit weight:	22 kN/m ³	21 kN/m ³
Coefficients of static lateral earth pressure:		
Active, K_a	0.27	0.27
At rest, K_o	0.43	0.43

If the wing walls and culvert structures allow for lateral yielding, active earth pressures may be used in the geotechnical design of the structures. If the retaining walls and culvert structures do not allow lateral yielding, at-rest earth pressures should be assumed for geotechnical design. The movement to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure, may be taken as presented in Table C6.6 of the *Commentary* to the *CHBDC*.

6.8 Culvert Construction Considerations

6.8.1 Excavations, Subgrade Preparation, Bedding and Backfill Above Base of Culvert

All excavations must be carried out in accordance with Ontario Regulation 213 Ontario Occupational Health and Safety Act for Construction Projects (as amended by Ontario Regulation 443). In addition, provisions for traffic control measures should be included in the Contract Documents to maintain the safe operation of the existing



Highway 17. Temporary excavation support systems should be designed and constructed in accordance with OPSS 539 (Temporary Protection Systems) and is discussed further in Section 6.8.2.

Prior to the placement of any bedding material and fill for new construction, all organic soils where encountered should be stripped from the plan limits of the proposed works. The native subgrade soils may be susceptible to disturbance from construction traffic and/or ponded water. In order to limit this degradation, it is recommended that a concrete working slab be placed on the subgrade if culvert construction is not carried out within four hours after preparation, inspection and approval of the subgrade. A sample Non-Standard Special Provision (NSSP) to address this requirement is included in Appendix C.

The box culvert end replacement will be cast-in-place and groundwater control will be required as discussed in Section 6.8.4. As an alternative to a working slab discussed above, the box culvert could be constructed on a minimum 300 mm thick layer of SP110S13 (Aggregates) Granular 'B' Type II material for bedding purposes and partial frost protection. The Granular 'B' Type II may likely be placed in the wet and when nominally compacted should achieve a density of 90 per cent of the Standard Proctor Maximum Dry Density (SPMDD). The structural design of the culvert should take into consideration the conditions for bedding placement and compaction in accordance with the requirements of Section 7.8.3.6 of the *CHBDC*.

The depth of backfill during placement around the culvert should be maintained equal on both sides of the culvert with one side not exceeding the other by more than 500 mm.

The culvert end replacement should be designed for the full overburden stress and appropriate live loads, assuming a fill unit weight of 22 kN/m³ for Granular 'A' and 21 kN/m³ for Granular 'B' Type II backfill above and surrounding the culvert.

Inspection and field density testing should be carried out by qualified geotechnical personnel during all engineered fill placement operations to ensure that appropriate materials are used, and that adequate levels of compaction have been achieved.

As discussed in Section 6.3, the new granular fill will need to be keyed into the existing fill as per OPSS 208.010 (Benching of Earth Slopes).

6.8.2 Temporary Shoring

Temporary protection systems are required to support the embankment fill during culvert end replacement. The temporary support systems could consist of either driven steel sheet piling where rock fill is not present or soldier piles and lagging where the H-piles would be driven to a suitable depth and horizontal lagging installed as the excavation proceeds. Support to the system could be in the form of struts and walers or rakers and anchors.

Surficial excavation of the rock fill presently on the embankment slopes to install temporary shoring could lead to sloughing of the embankment fill above the excavation.

The temporary excavation support system should be designed and constructed in accordance with OPSS 539 (Temporary Protection Systems). The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS 539. The contractor is responsible for the complete detailed design of the protection system.



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The design of braced soldier pile and lagging walls should be based on a rectangular earth pressure distribution using the design parameters given below. Where the support to the wall is provided by anchors or rakers, the wall design should be based on a triangular earth pressure distribution using the design parameters given below. The raker/anchor support must be designed to accommodate the loads applied from pressures and surcharge pressures from area, line or point loads as well as the impact of sloping ground behind the system. Passive toe restraint to the soldier piles may be determined using a triangular pressure distribution acting over an equivalent width equal to three times the pile socket diameter.

The unfactored triangular earth pressure distribution (p in kN/m^2 ; increasing with depth), can be calculated as follows:

$$\begin{aligned} p &= K_a (\gamma H + q) \\ \text{where } H &= \text{the depth of the excavation at any point (m)} \\ K_a &= \text{active coefficient of earth pressure} \\ \gamma &= \text{soil unit weight (kN/m}^3\text{)} \\ q &= \text{surcharge for traffic and other loading (kN/m}^2\text{)} \end{aligned}$$

For a braced excavation in granular fill and native cohesionless soils, the unfactored rectangular earth pressure distribution (p in kN/m^2 ; constant with depth), can be calculated as follows:

$$\begin{aligned} p &= 0.65 K_a (\gamma H + q) \\ \text{where } H &= \text{the total depth of the excavation (m)} \\ K_a &= \text{active coefficient of earth pressure} \\ \gamma &= \text{soil unit weight (kN/m}^3\text{)} \\ q &= \text{surcharge for traffic and other loading (kN/m}^2\text{)} \end{aligned}$$

For a braced excavation in cohesive soil, the unfactored rectangular earth pressure distribution (p in kN/m^2 ; varying with depth), can be calculated as follows:

$$\begin{aligned} p &= 0 \text{ at ground surface increasing linearly to a depth of } 0.25 H_T \text{ to:} \\ p &= \gamma H_T - 4mS_u \text{ at } 0.25 H_T \text{ and from } 0.25 H_T \text{ to } H_T \text{ below ground surface} \\ \text{where } H_T &= \text{the total depth of the excavation (m)} \\ \gamma &= \text{soil unit weight (kN/m}^3\text{)} \\ q &= \text{surcharge for traffic and other loading (kN/m}^2\text{)} \\ m &= 0.4 \text{ if an extensive soft clay layer underlies the excavation} \\ &= 1.0 \text{ if more resistant layer is present at the excavation base} \\ S_u &= \text{undrained shear strength (kN/m}^2\text{)}. \end{aligned}$$

The support systems may be designed using the following parameters:



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SOIL TYPE	COEFFICIENT OF EARTH PRESSURE			INTERNAL ANGLE OF FRICTION (ϕ , degrees)	UNIT WEIGHT (γ , kN/m ²)	UNDRAINED SHEAR STRENGTH (S_u , kPa)
	Active, K_a	At Rest, K_o	Passive, K_p			
Existing						
Embankment Fill	0.33	0.50	3.0	30	20	-
Clayey Silt to Clay	0.30	0.55	2.7	27	17	45
Sandy Silt to Sand and Silt	0.27	0.43	3.7	28	19	-

The earth pressure coefficients noted above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are present, the coefficients should be adjusted accordingly.

As discussed in Section 6.1, rock fill is present on the existing embankment slopes and during the foundation investigation the augers were noted to be grinding in Borehole CC-4 at depths approximately between 6.0 m and 7.0 m below ground surface. The Contractor should be alerted to these obstructions; an example NSSP (or Notice to Contractor) to be included in the Contract is presented in Appendix C.

6.8.3 Erosion Protection

Provisions should be made for scour and erosion protection (suitable non-woven geotextiles and/or rip-rap) at the culvert location and at the creek bends at either end of the culvert. In order to prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring) or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a concrete cut-off wall or clay seal should be provided at the upstream end of the culvert. If a clay seal is adopted, the clay material should meet the requirements of OPSS 1205 (Clay Seal), and the seal should be a minimum 1 m thick if constructed of natural clay or soil-bentonite mix and extend from a depth of 1 m below the scour level to a minimum horizontal distance of 2 m on either side of the culvert inlet opening, and a minimum vertical height equivalent to the high water level including along the embankment slope. Alternatively, a 0.6 m thick clay blanket (if constructed of natural clay or a soil-bentonite mix) may be constructed, extending upstream three (3) times the culvert height and along the adjacent slopes to a height of two (2) times the culvert height or the high water level, whichever is greater.

The requirements for and design of erosion protection measures for the inlet and outlet of the culvert should be assessed by the hydraulics design engineer. As a minimum, rip-rap treatment for the outlet of the culvert should be consistent with the standard presented in OPSD 810.010 (Rip-Rap Treatment for Sewer and Culvert Outlets). Erosion protection for the inlet of the culverts should follow the standard presented in OPSD 810.010 similar to the outlet but with the rip-rap placed up to the toe of slope level, in combination with the cut-off measures noted above. Similarly, rip-rap should be provided over the full extent of the clay blanket, including the creek side slopes and fill slope over the culvert.



6.8.4 Control of Groundwater and Surface Water

Excavation within the plan limits of the proposed Big Cache Creek end replacement and wing walls will be required to remove organics (where encountered), existing fill, and native soils prior to the placement of bedding material, and construction of the box culvert end replacement and wing walls. The existing culvert flows will need to be diverted/piped during construction. Surficial water seepage into the excavation should be expected and will be heavier during periods of sustained precipitation. Seepage from the granular fills and near surface native fine granular materials should be expected, particularly after precipitation events. It is anticipated that this surficial seepage can be controlled by using properly filtered sumps within a shored/braced excavation.

The culvert end replacement and footings for the wing walls will be cast-in-place and, as such, dewatering will be required for construction in-the-dry. The excavations will be advanced through cohesionless soils above the clay deposit and appropriate unwatering of the water-bearing granular soil deposits will be required to maintain the water level below the founding level during excavation and construction. It is recommended that an NSSP be included in the Contract to address unwatering for the site; a sample NSSP is included in Appendix C.

6.8.5 Analytical Testing for Construction Materials

The analytical test results on a sample of creek water taken adjacent to the culvert site are summarized in Table B1 in Appendix B, together with the detailed analytical laboratory test results. The suite of parameters tested is intended to allow the structural engineer to assess the requirements for the appropriate type of cement to be used in construction and the need for corrosion protection.

7.0 CLOSURE

This report was prepared by Mr. André Bom, P.Eng. with technical input by Mr. Fintan J. Heffernan, P.Eng., a specialist consultant with Golder. Mr. Jorge Costa, Golder's Designated MTO Contact for this project and a Principal with Golder, reviewed the technical aspects of and conducted an independent quality control review of the report.



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Report Signature Page

GOLDER ASSOCIATES LTD.



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Geotechnical Engineer



Jorge M.A. Costa, P.Eng.
Designated MTO Contact, Principal

AB/FJH/JMAC/kp/

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FOUNDATION INVESTIGATION AND DESIGN REPORT HIGHWAY 17 BIG CACHE CREEK CULVERT

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- Canadian Highway Bridge Design Code (CHBDC) and Commentary on CAN/CSA-S6-06. 2006. CSA Special Publication, S6.1-06. Canadian Standard Association.
- Milligan, V. and Lo, K.Y., 1967. Shear Strength Properties of Two Stratified Clays. Journal of the Soil Mechanics and Foundations Division, Proceedings of the American Society of Civil Engineers. January, 1967.
- NAVFAC Design Manual, DM-7.2. Soil Mechanics, Foundation and Earth Structures. U.S. Navy, 1982, Alexandria, Virginia.
- Ontario Geological Survey. 1980. Southern Ontario Engineering Geology Terrain Study.

STANDARDS

ASTM International:

ASTM D1586	Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils
ASTM D1587	Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes
ASTM D2573	Standard Test Method for Field Vane Shear Test in Cohesive Soil

Commercial Software

GeoStudio 2007 (Version 7.17) by Geo-Slope International Ltd.

Ministry of Transportation Ontario Special Provisions

SP 110S13	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material
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Ontario Occupational Health and Safety Act

Ontario Regulation 213/91	Construction Projects
Ontario Regulation 443/09	Amendment to Ontario Regulation 213

Ontario Provincial Standard Drawing

OPSD 208.010	Benching of Earth Slopes
OPSD 810.010	Rip-Rap Treatment for Sewer and Culvert Outlets
OPSD 3090.101	Foundation, Frost Penetration Depths for Southern Ontario
OPSD 3121.150	Walls, Retaining, Backfill, Minimum Granular Requirement
OPSD 202.010	Slope Flattening using Surplus Excavated Material on Earth or Rock Fill Embankment



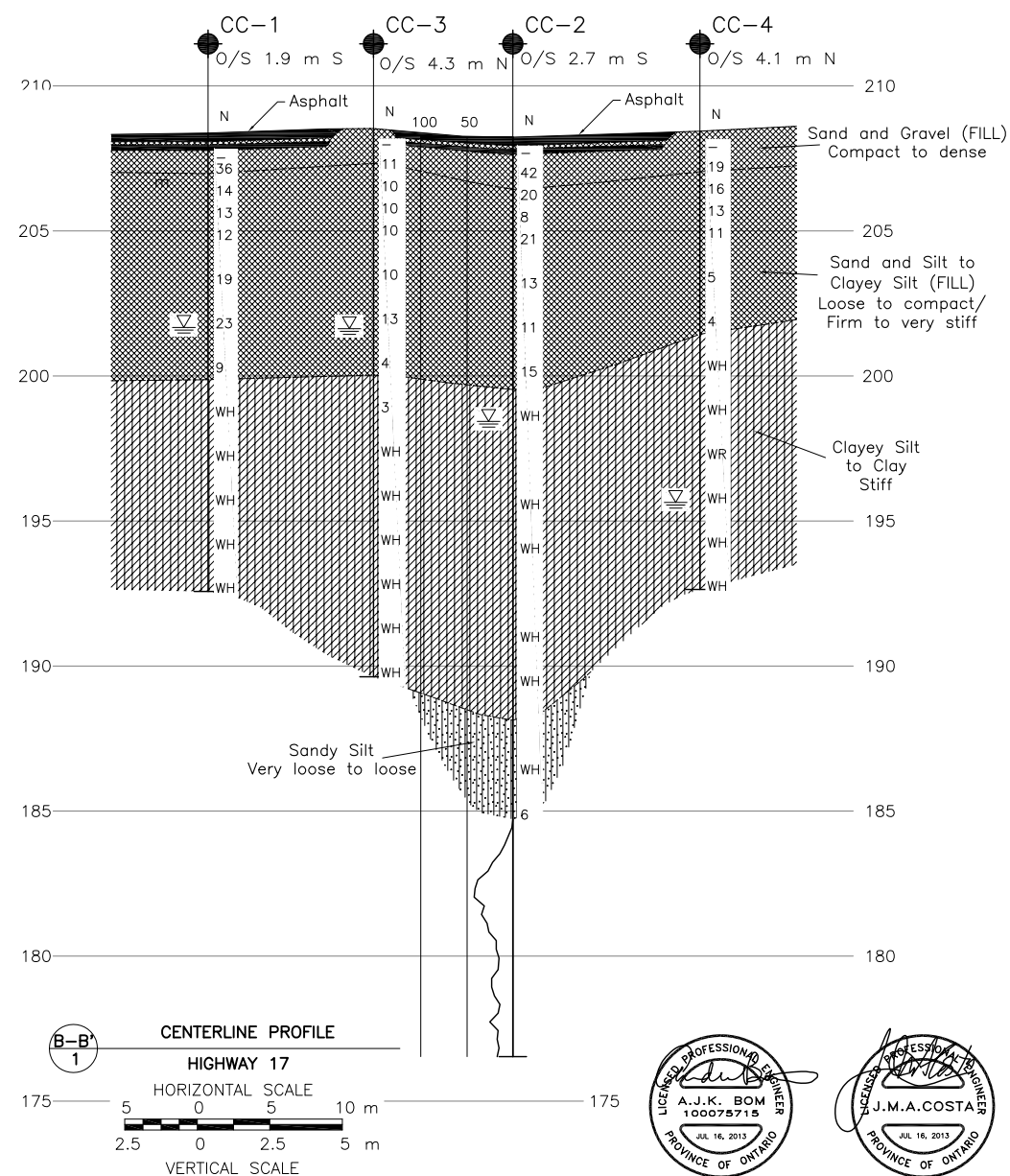
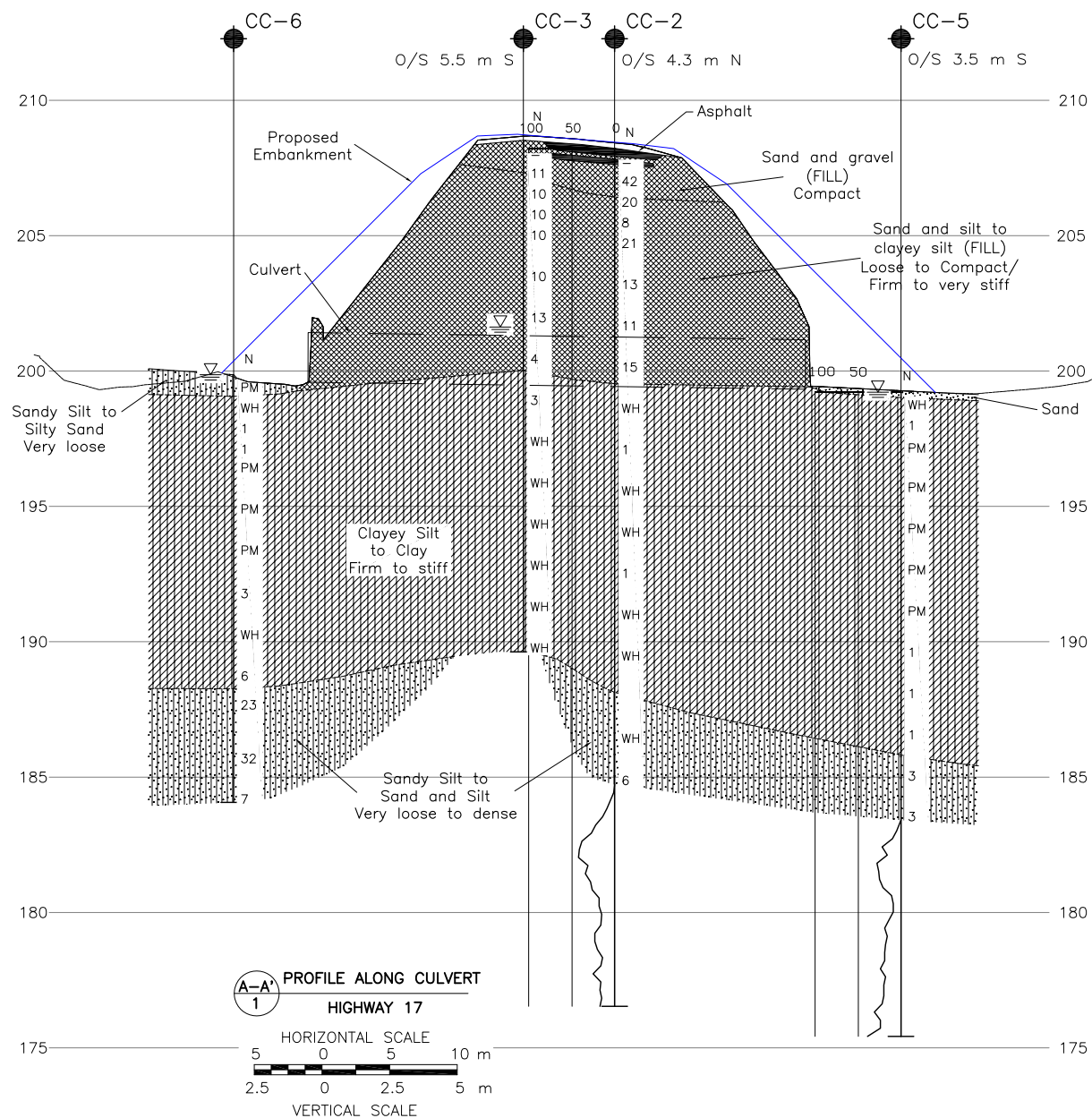
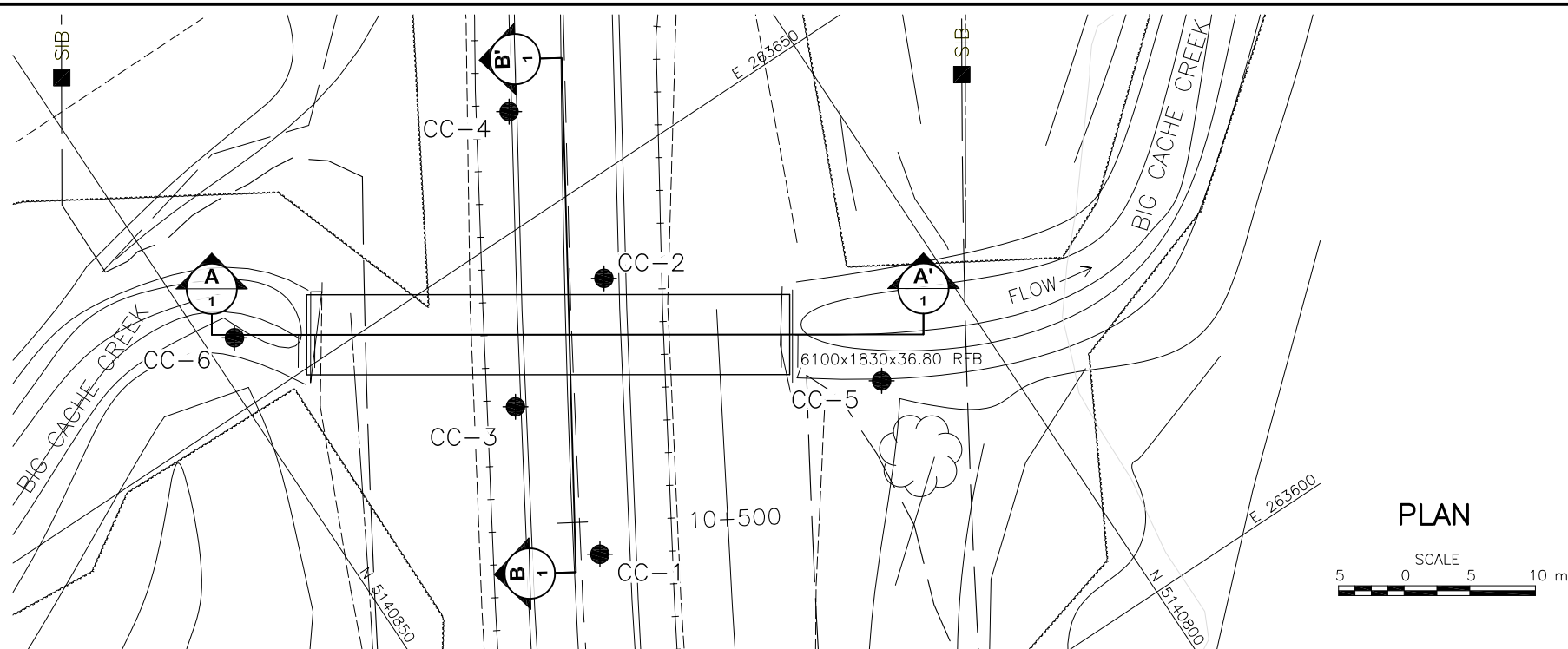
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Ontario Provincial Standard Specification

OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS 501	Construction Specification for Compacting
OPSS 539	Construction Specification for Temporary Protection Systems
OPSS 1205	Clay Seal

Ontario Water Resources Act

Ontario Regulation 372/97	Amendment to Ontario Regulation 903
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METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

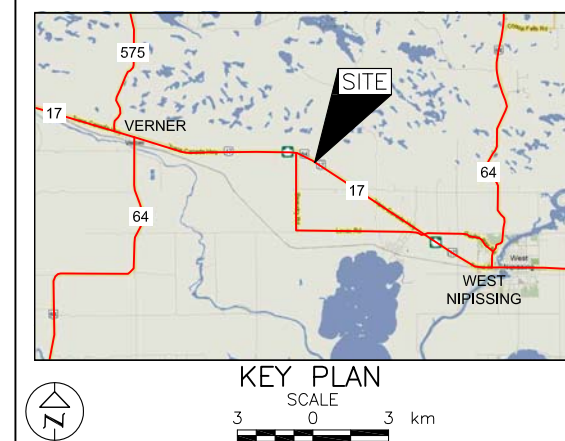
CONT No.
GWP No. 5106-08-00

HIGHWAY 17
BIG CACHE CREEK CULVERT AT STA 10+514
BOREHOLE LOCATIONS
AND SOIL STRATA



SHEET



Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA



LEGEND

- | | |
|---|--|
|  | Borehole |
| N | Standard Penetration Test Value |
| 16 | Blows/0.3m unless otherwise stated
(Std. Pen. Test, 475 j/blow) |
|  | WL upon completion of drilling |

BOREHOLE CO—ORDINATES			
No.	ELEVATION	NORTHING	EASTING
CC-1	208.4	5140833.8	263625.8
CC-2	208.2	5140821.9	263643.2
CC-3	208.5	5140832.9	263638.8
CC-4	208.4	5140820.9	263657.8
CC-5	199.2	5140808.6	263625.0
CC-6	199.9	5140847.8	263655.0

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

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

REFERENCE

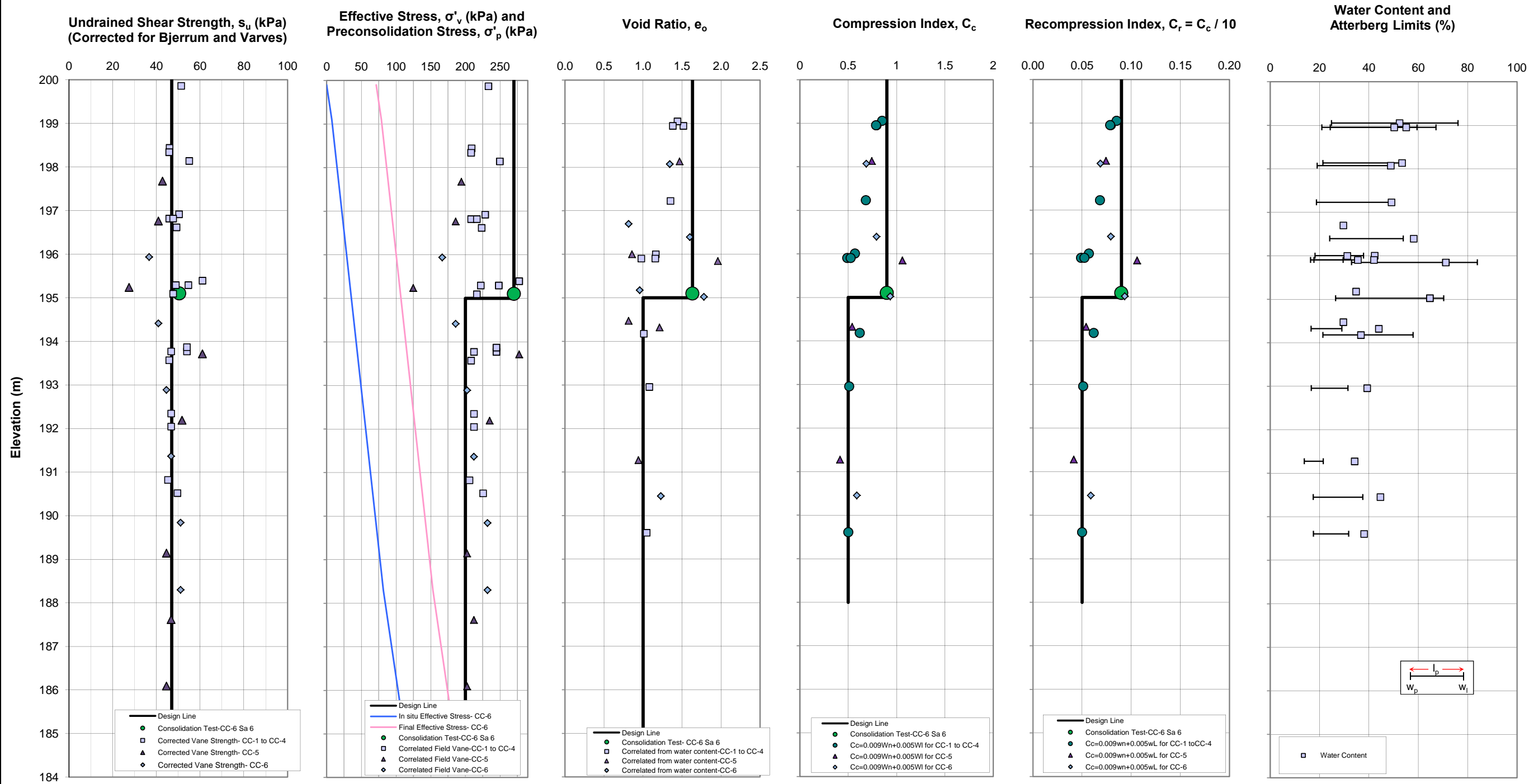
Base plans provided in digital format by MMM, drawing file name "Cont1-Culvert Sections.dwg", received on JULY 16, 2012.
Key plan based on Google Maps.

NO.	DATE	BY	REVISION	
Geocres No. 411-296				
HWY. 17		PROJECT NO. 11-1191-0010		DIST. 43-265
SUBM'D.	CHKD.	DATE: JUL 2013		SITE:
DRAWN: TB	CHKD. AB	APPD. JMAC		DWG. 1

N:\Active\2011\1190 Sudbury\1191\Temp folder for 11-1191-0010 slope-w only\1111910010 Design Parameters - Big Cache.xlsx\Plots - Figure 1

SUMMARY PLOT OF ENGINEERING PARAMETERS FOR
COHESIVE DEPOSIT
Highway 17 Big Cache Creek Culvert

FIGURE 1



Golder Associates

Date: July 2013
Project No: 11-1191-0010

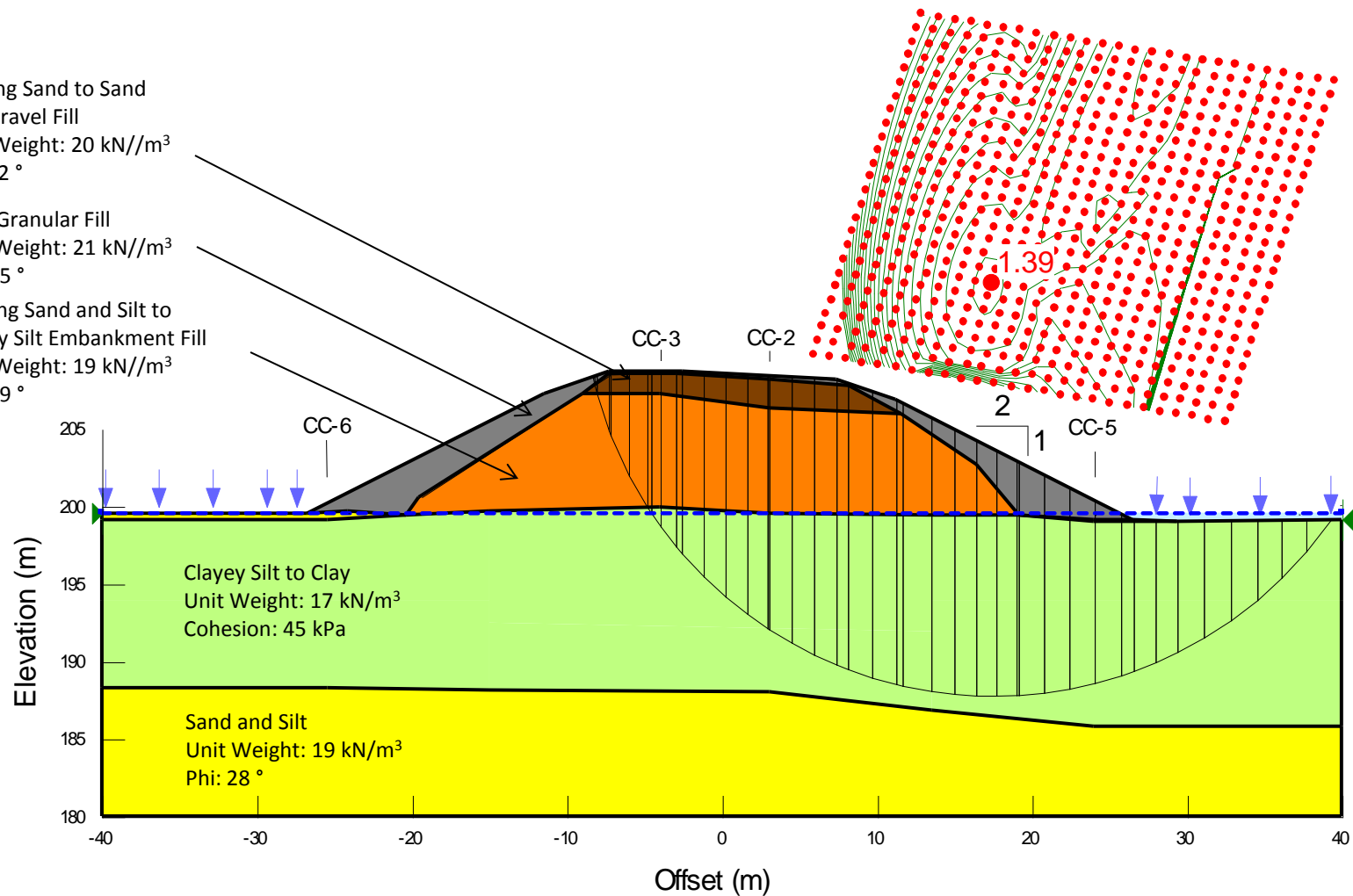
Prepared By: DAM
Checked By: AB



Existing Sand to Sand
and Gravel Fill
Unit Weight: 20 kN//m³
Phi: 32 °

New Granular Fill
Unit Weight: 21 kN//m³
Phi: 35 °

Existing Sand and Silt to
Clayey Silt Embankment Fill
Unit Weight: 19 kN//m³
Phi: 29 °



PROJECT		HIGHWAY 17 BIG CACHE CREEK CULVERT			
TITLE		STABILITY ANALYSIS EMBANKMENT SOUTH SIDE SLOPE			
		PROJECT No. 11-1191-0010		FILE No. ----	
DESIGN	DAM	DEC 2012	SCALE	AS SHOWN	REV.
CADD	--		FIGURE 2		
CHECK	AB	DEC 2012			
REVIEW					





FOUNDATION INVESTIGATION AND DESIGN REPORT HIGHWAY 17 BIG CACHE CREEK CULVERT



Photograph 1: Embankment north slope and culvert inlet (received from MMM December 2012).



Photograph 2: Embankment north slope and culvert outlet (received from MMM December 2012).



APPENDIX A

Record of Boreholes



LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
SS	Split-spoon
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d :

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH:	Sampler advanced by hydraulic pressure
PM:	Sampler advanced by manual pressure
WH:	Sampler advanced by static weight of hammer
WR:	Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Cohesionless Soils

Density Index	N
Relative Density	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils Consistency

	C_u, S_u	
	kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO ₄	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

V. MINOR SOIL CONSTITUENTS

Percent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (cohesionless) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand



LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
$\ln x$,	natural logarithm of x
\log_{10}	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
C_v	coefficient of consolidation (vertical direction)
C_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan \delta$
c'	effective cohesion
C_u, S_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

* Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

Notes: 1
2

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$


PROJECT <u>11-1191-0010</u>		RECORD OF BOREHOLE No CC-1		1 OF 2 METRIC	
W.P. <u>5013-10-01</u>		LOCATION <u>N 5140833.8; E 263625.8</u>		ORIGINATED BY <u>SA</u>	
DIST <u> </u> HWY <u>17</u>		BOREHOLE TYPE <u>108 mm I.D. Continuous Flight Hollow Stem Augers</u>		COMPILED BY <u>TB</u>	
DATUM <u>GEODETIC</u>		DATE <u>June 19, 2012</u>		CHECKED BY <u>AB</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
								20 40 60 80 100	20 40 60 80 100	W _p	W	W _L		
208.4	GROUND SURFACE													
0.0	ASPHALT (300 mm)													
0.6	Sand, some gravel (75 mm) (FILL) ASPHALT (225 mm)		1	AS	-									
	Sand, some gravel, some silt (FILL) Dense Brown Moist		2	SS	36									
207.0														
1.4	Sand and silt to clayey silt (FILL) Compact/Stiff to very stiff Brown to grey Moist		3	SS	14									0 33 47 20
			4	SS	13									
			5	SS	12									
			6	SS	19									0 7 76 17
			7	SS	23									
			8	SS	9									
199.9														
8.5	CLAYEY SILT to CLAY, varved Stiff Grey Wet		9	SS	WH									
			10	SS	WH									
			11	SS	WH									
			12	SS	WH									

Continued Next Page

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

SUD-MTO 001 11-1191-0010.GPJ GAL-MISS.GDT 11/01/13 DATA INPUT:

PROJECT		RECORD OF BOREHOLE				No CC-1		2 OF 2		METRIC								
W.P. 5013-10-01		LOCATION				N 5140833.8; E 263625.8		ORIGINATED BY SA										
DIST _____ HWY 17		BOREHOLE TYPE				108 mm I.D. Continuous Flight Hollow Stem Augers		COMPILED BY TB										
DATUM GEODETIC		DATE				June 19, 2012		CHECKED BY AB										
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa										
	--- CONTINUED FROM PREVIOUS PAGE ---						20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100					WATER CONTENT (%) 20 40 60						
192.6 15.8	CLAYEY SILT to CLAY, varved Stiff Grey Wet Sand seams noted at 15.4 m depth. END OF BOREHOLE Note: 1. Water level at a depth of 6.7 m below ground surface (Elev. 201.7 m) upon completion of drilling.		13	SS	WH		193											

SUD-MTO 001 11-1191-0010.GPJ GAL-MISS.GDT 11/01/13 DATA INPUT:

PROJECT 11-1191-0010			RECORD OF BOREHOLE No CC-2			1 OF 3 METRIC															
W.P. 5013-10-01			LOCATION N 5140821.9; E 263643.2			ORIGINATED BY SA															
DIST _____ HWY 17			BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers			COMPILED BY TB															
DATUM GEODETIC			DATE June 18, 2012			CHECKED BY AB															
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ					
								20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					W _p — W — W _L 20 40 60			kN/m ³			GR SA SI CL		
208.2	GROUND SURFACE																				
0.0	ASPHALT (300 mm)						208														
	Sand, some gravel (100 mm) (FILL)		1	AS	-																
	ASPHALT (225 mm)																				
0.6	Sand, some gravel, some silt (FILL)		2	SS	42		207														
	Dense Brown Moist																				
206.4	Sand and silt to clayey silt (FILL)		3	SS	20		206														
1.8	Compact/Stiff to very stiff Grey to brown Moist		4	SS	8														0 37 51 12		
			5	SS	21		205														
							204														
			6	SS	13		203														
							202												0 5 78 17		
			7	SS	11		201														
	Wood fragments in Sample 8.		8	SS	15		200														
199.5	CLAYEY SILT to CLAY, varved Stiff Grey Wet		9	SS	WH		199														
8.7							198														
			10	SS	1		197														
							196														
			11	SS	WH		195														
							194														
			12	SS	WH																

SUD-MTO 001 11-1191-0010.GPJ GAL-MISS.GDT 11/01/13 DATA INPUT:


Continued Next Page

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



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

CSUD-MTO 001 11-1191-0010.GPJ GAL-MISS.GDT 11/01/13 DATA INPUT:

PROJECT <u>11-1191-0010</u>		RECORD OF BOREHOLE No CC-2				3 OF 3 METRIC										
W.P. <u>5013-10-01</u>		LOCATION <u>N 5140821.9; E 263643.2</u>				ORIGINATED BY <u>SA</u>										
DIST <u> </u> HWY <u>17</u>		BOREHOLE TYPE <u>108 mm I.D. Continuous Flight Hollow Stem Augers</u>				COMPILED BY <u>TB</u>										
DATUM <u>GEODETIC</u>		DATE <u>June 18, 2012</u>				CHECKED BY <u>AB</u>										
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)			
	--- CONTINUED FROM PREVIOUS PAGE ---						<div style="display: flex; justify-content: space-between;"> 20 40 60 80 100 20 40 60 80 100 </div> <div style="display: flex; justify-content: space-between;"> ○ UNCONFINED + FIELD VANE </div> <div style="display: flex; justify-content: space-between;"> ● QUICK TRIAXIAL × REMOULDED </div>					<div style="display: flex; justify-content: space-between;"> W_p W W_L </div>				
176.5	START OF DCPT					178										
31.7	END OF DCPT END OF BOREHOLE					177										
	Note: 1. Water level at a depth of 9.8 m below ground surface (Elev. 198.4 m) upon completion of drilling.															

PROJECT <u>11-1191-0010</u>		RECORD OF BOREHOLE No CC-3		1 OF 2 METRIC	
W.P. <u>5013-10-01</u>	LOCATION <u>N 5140832.9; E 263638.8</u>	ORIGINATED BY <u>SA</u>			
DIST <u> </u> HWY <u>17</u>	BOREHOLE TYPE <u>108 mm I.D. Continuous Flight Hollow Stem Augers</u>	COMPILED BY <u>TB</u>			
DATUM <u>GEODETIC</u>	DATE <u>June 20 and 21, 2012</u>	CHECKED BY <u>AB</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL	
								20	40	60	80	100	20	40	60						
208.5	GROUND SURFACE																				
0.0	Sand and gravel (FILL) Compact Brown Moist		1	AS	-																
207.3			2	SS	11																
1.2	Sand and silt to clayey silt (FILL) Loose to compact/Firm to stiff Brown to grey Moist		3	SS	10																
	Augers grinding at 2.3 m depth.		4	SS	10																
			5	SS	10																
			6	SS	10																
			7	SS	13																
			8	SS	4																
200.0	CLAYEY SILT to CLAY, varved Stiff Grey Wet		9	SS	3																
8.5			10	SS	WH																
			11	SS	WH																
			12	SS	WH																

Continued Next Page

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


SUD-MTO 001 11-1191-0010.GPJ GAL-MISS.GDT 11/01/13 DATA INPUT:

PROJECT <u>11-1191-0010</u>				RECORD OF BOREHOLE No CC-3				2 OF 2 METRIC									
W.P. <u>5013-10-01</u>		LOCATION <u>N 5140832.9; E 263638.8</u>				ORIGINATED BY <u>SA</u>											
DIST <u> </u> HWY <u>17</u>		BOREHOLE TYPE <u>108 mm I.D. Continuous Flight Hollow Stem Augers</u>				COMPILED BY <u>TB</u>											
DATUM <u>GEODETIC</u>		DATE <u>June 20 and 21, 2012</u>				CHECKED BY <u>AB</u>											
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100					
	CLAYEY SILT to CLAY, varved Stiff Grey Wet		13	SS	WH		193										
							192										
			14	SS	WH		191										
							190										
189.6	Sand seams noted at 18.5 m depth.		15	SS	WH												
18.9	END OF BOREHOLE																
	Note: 1. Water level at a depth of 6.9 m below ground surface (Elev. 201.6 m) upon completion of drilling.																

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

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


MSUD-MTO 001 11-1191-0010.GPJ GAL-MISS.GDT 11/01/13 DATA INPUT:

PROJECT <u>11-1191-0010</u>				RECORD OF BOREHOLE No CC-4				2 OF 2 METRIC									
W.P. <u>5013-10-01</u>		LOCATION <u>N 5140820.9; E 263657.8</u>				ORIGINATED BY <u>SA</u>											
DIST <u> </u> HWY <u>17</u>		BOREHOLE TYPE <u>108 mm I.D. Continuous Flight Hollow Stem Augers</u>				COMPILED BY <u>TB</u>											
DATUM <u>GEODETIC</u>		DATE <u>June 19 and 20, 2012</u>				CHECKED BY <u>AB</u>											
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	--- CONTINUED FROM PREVIOUS PAGE ---							20	40	60	80	100					
192.6 15.8	CLAYEY SILT to CLAY, varved Stiff Grey Wet Sand seams noted at 15.4 m depth. END OF BOREHOLE Note: 1. Water level at a depth of 12.8 m below ground surface (Elev. 195.6 m) upon completion of drilling.		13	SS	WH		193										

SUD-MTO 001 11-1191-0010.GPJ GAL-MISS.GDT 11/01/13 DATA INPUT:

SUD-MTO 001 11-1191-0010.GPJ GAL-MISS.GDT 11/01/13 DATA INPUT:

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

PROJECT		RECORD OF BOREHOLE				No CC-5		2 OF 2		METRIC				
W.P. 5013-10-01		LOCATION				N 5140808.6; E 263625.0				ORIGINATED BY SA				
DIST _____ HWY 17		BOREHOLE TYPE				Portable Equipment, HQ Casing, Wash Boring				COMPILED BY TB				
DATUM GEODETIC		DATE				June 24 and 25, 2012				CHECKED BY AB				
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
	--- CONTINUED FROM PREVIOUS PAGE ---							20 40 60 80 100		W _p W W _L				
183.4	SAND and SILT, clay seams Very loose Grey Wet		12	SS	3		184							
15.8	START OF DCPT						183							
							182							
							181							
							180							
							179							
							178							
							177							
							176							
175.4	END OF DCPT END OF BOREHOLE													
23.8	Note: 1. Water level at ground surface (Elev. 199.2 m) upon completion of drilling.													

SUD-MTO 001 11-1191-0010.GPJ GAL-MISS.GDT 11/01/13 DATA INPUT:

PROJECT <u>11-1191-0010</u>		RECORD OF BOREHOLE No CC-6		1 OF 2 METRIC	
W.P. <u>5013-10-01</u>		LOCATION <u>N 5140847.8; E 263655.0</u>		ORIGINATED BY <u>SA</u>	
DIST <u> </u> HWY <u>17</u>		BOREHOLE TYPE <u>Portable Equipment, HQ Casing, Wash Boring</u>		COMPILED BY <u>TB</u>	
DATUM <u>GEODETIC</u>		DATE <u>June 27, 2012</u>		CHECKED BY <u>AB</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _p	W	W _L		
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × REMOULDED					
199.9	GROUND SURFACE													
0.0	Sandy SILT to Silty SAND Very loose Grey Wet		1	SS	PM									
199.1			2	SS	WH		199							
0.8	CLAYEY SILT to CLAY, varved Stiff Grey Wet		3	SS	1		198							
			4	SS	1		197							
	Sample 5: Light grey silt to clayey silt laminae 10 mm to 25 mm thick Dark grey clay laminae 10 mm to 25 mm thick		5	TO	PM		196							0 0 80 20
			6	TO	PM		195							0 1 71 28
	Sample 6: Light grey silt to clayey silt laminae 25 mm to 50 mm thick Dark grey clay laminae 10 mm to 25 mm thick		7	TO	PM		194							
			8	SS	3		193							
	Sand seams noted below 7.9 m depth.		9	SS	WH		192							
			10	SS	6		191							
			11	SS	23		190							
188.3	Sandy SILT, clay seams Loose to dense Grey Wet		12	SS	32		189							
11.6							188							0 29 50 21
							187							
							186							
							185							

Continued Next Page

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

SUD-MTO 001 11-1191-0010.GPJ GAL-MISS.GDT 11/01/13 DATA INPUT:

PROJECT <u>11-1191-0010</u>		RECORD OF BOREHOLE No CC-6				2 OF 2 METRIC											
W.P. <u>5013-10-01</u>		LOCATION <u>N 5140847.8; E 263655.0</u>				ORIGINATED BY <u>SA</u>											
DIST <u> </u> HWY <u>17</u>		BOREHOLE TYPE <u>Portable Equipment, HQ Casing, Wash Boring</u>				COMPILED BY <u>TB</u>											
DATUM <u>GEODETIC</u>		DATE <u>June 27, 2012</u>				CHECKED BY <u>AB</u>											
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)				
	--- CONTINUED FROM PREVIOUS PAGE ---																
184.1	Sandy SILT, clay seams Loose to dense Grey Wet	13	SS	7													
15.8	END OF BOREHOLE Note: 1. Water level at ground surface (Elev. 199.9 m) upon completion of drilling.																

SUD-MTO 001 11-1191-0010.GPJ GAL-MISS.GDT 11/01/13 DATA INPUT:



APPENDIX B

Laboratory Test Results



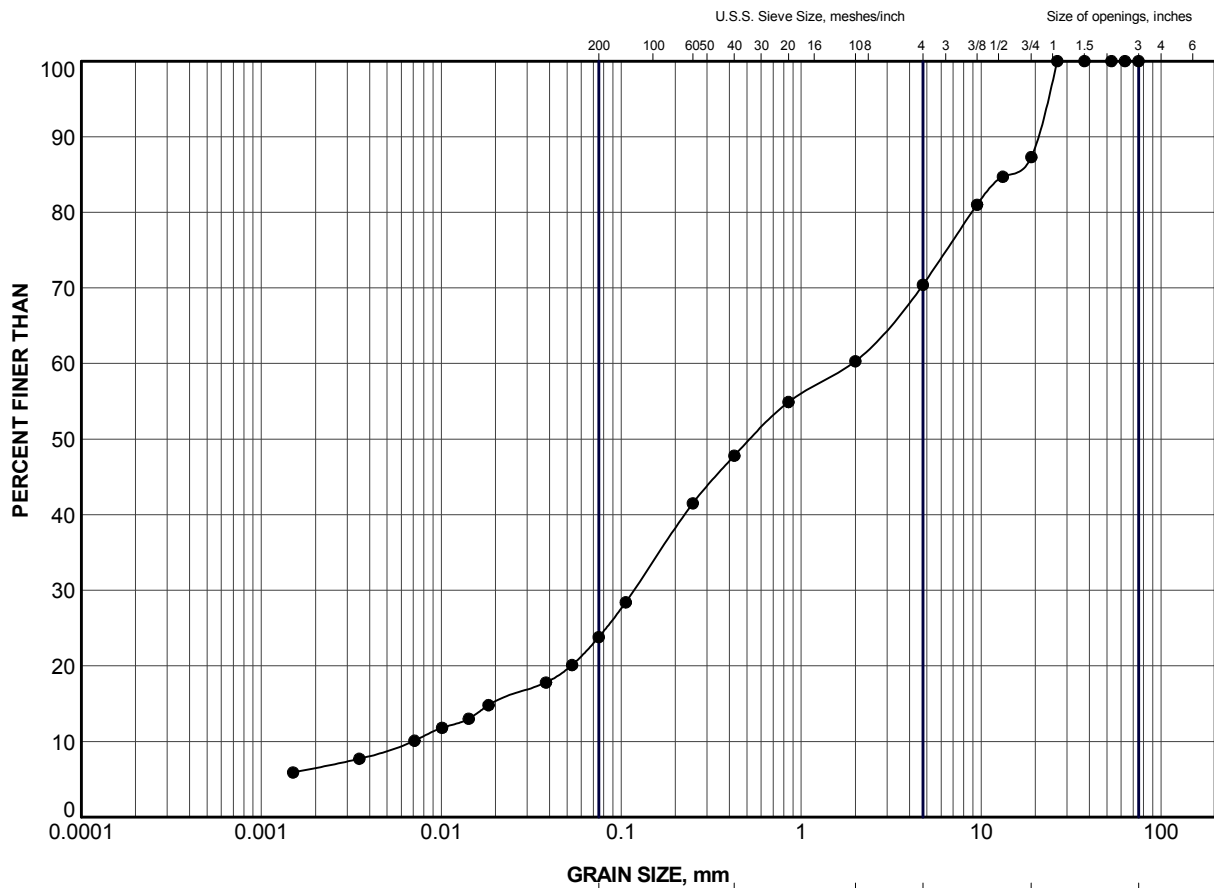
FOUNDATION INVESTIGATION AND DESIGN REPORT HIGHWAY 17 BIG CACHE CREEK CULVERT

Table B1 - Summary of Analytical Testing of Big Cache Creek Water Sample

Parameter	Units	Reportable Detection Limit	Result
Dissolved Chloride	mg/L	1	4
Dissolved Sulphate	mg/L	1	Not Detected
Conductivity	μohm/cm	1	150
Resistivity	ohm-cm	n/a	6900
pH	n/a	n/a	7.82

Checked by: AB


- Notes:
1. Sample obtained on July 20, 2012.
 2. Analytical testing carried out by Maxxam Analytics.

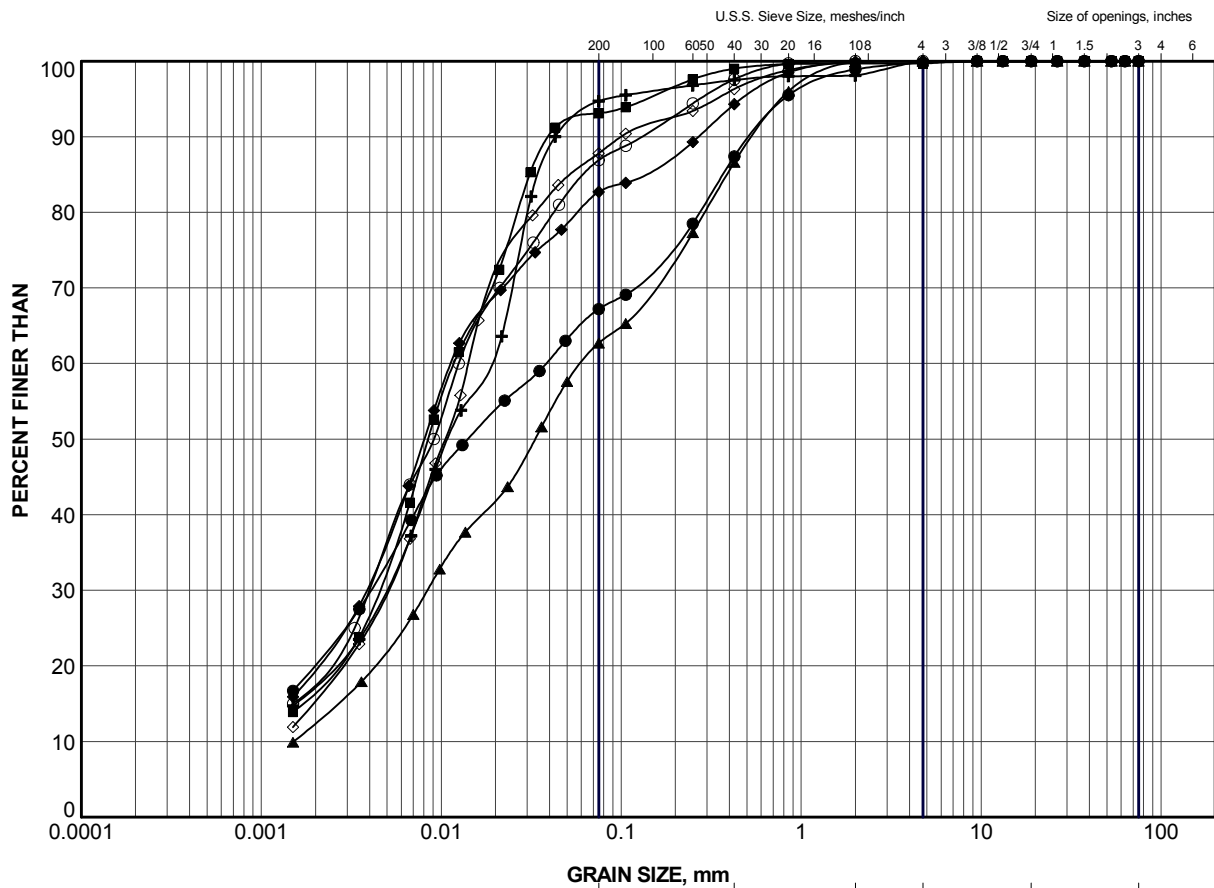


GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CC-4	2	207.3

PROJECT					
HIGHWAY 17 BIG CACHE CREEK CULVERT					
TITLE					
GRAIN SIZE DISTRIBUTION SAND AND GRAVEL (FILL)					
PROJECT No.		11-1191-0010		FILE No. 11-1191-0010.GPJ	
DRAWN	TB	Dec 2012	SCALE	N/A	REV.
CHECK	AB	Dec 2012			
APPR		Dec 2012			
 Golder Associates SUDBURY, ONTARIO			FIGURE B1-1		



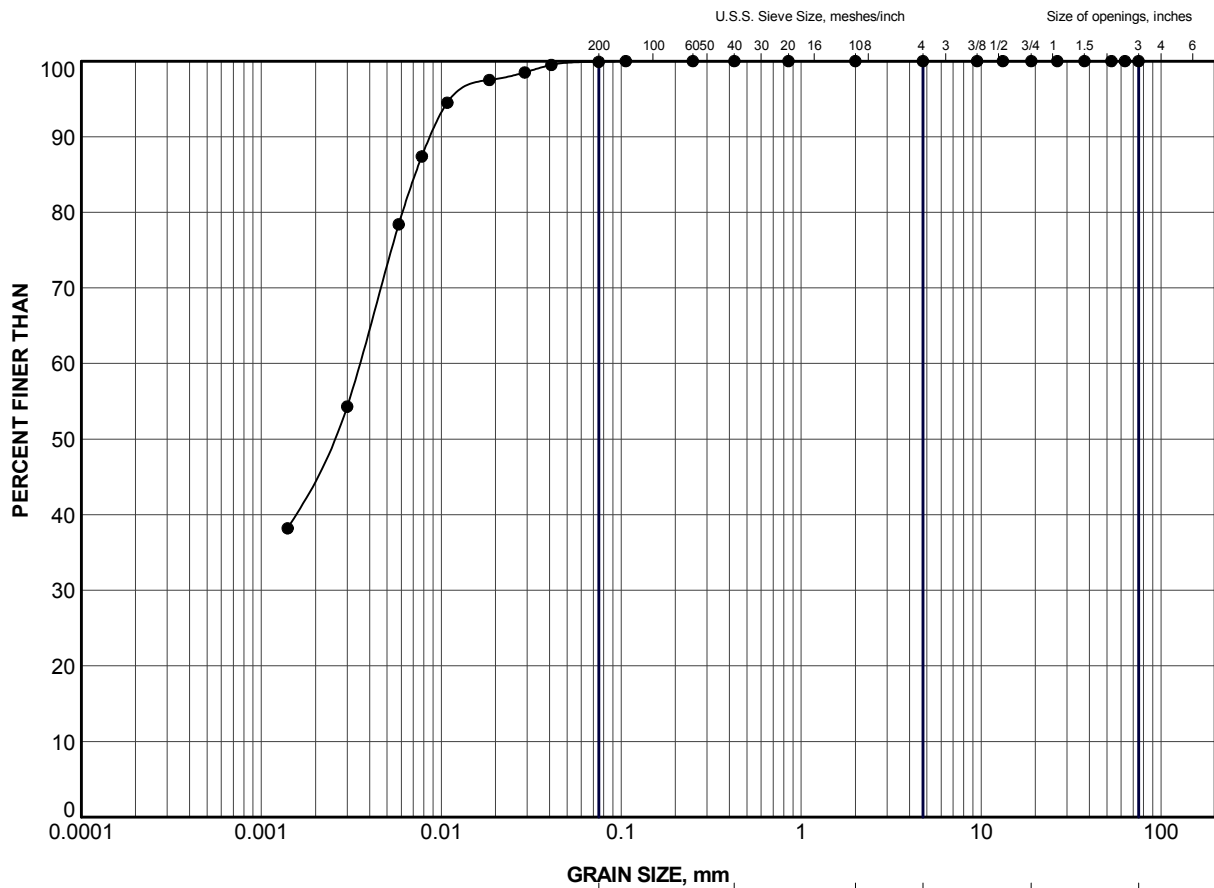
CLAY AND SILT	GRAVEL SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CC-1	3	206.6
■	CC-1	6	203.5
▲	CC-2	4	205.6
+	CC-2	7	201.8
◆	CC-3	4	205.9
◇	CC-3	7	202.1
○	CC-4	5	205.1

PROJECT					
HIGHWAY 17 BIG CACHE CREEK CULVERT					
TITLE					
GRAIN SIZE DISTRIBUTION SAND AND SILT TO CLAYEY SILT (FILL)					
PROJECT No.		11-1191-0010		FILE No. 11-1191-0010.GPJ	
DRAWN	TB	Jan 2013	SCALE	N/A	REV.
CHECK	AB	Jan 2013			
APPR	JMAC	Jan 2013			
			FIGURE B1-2		





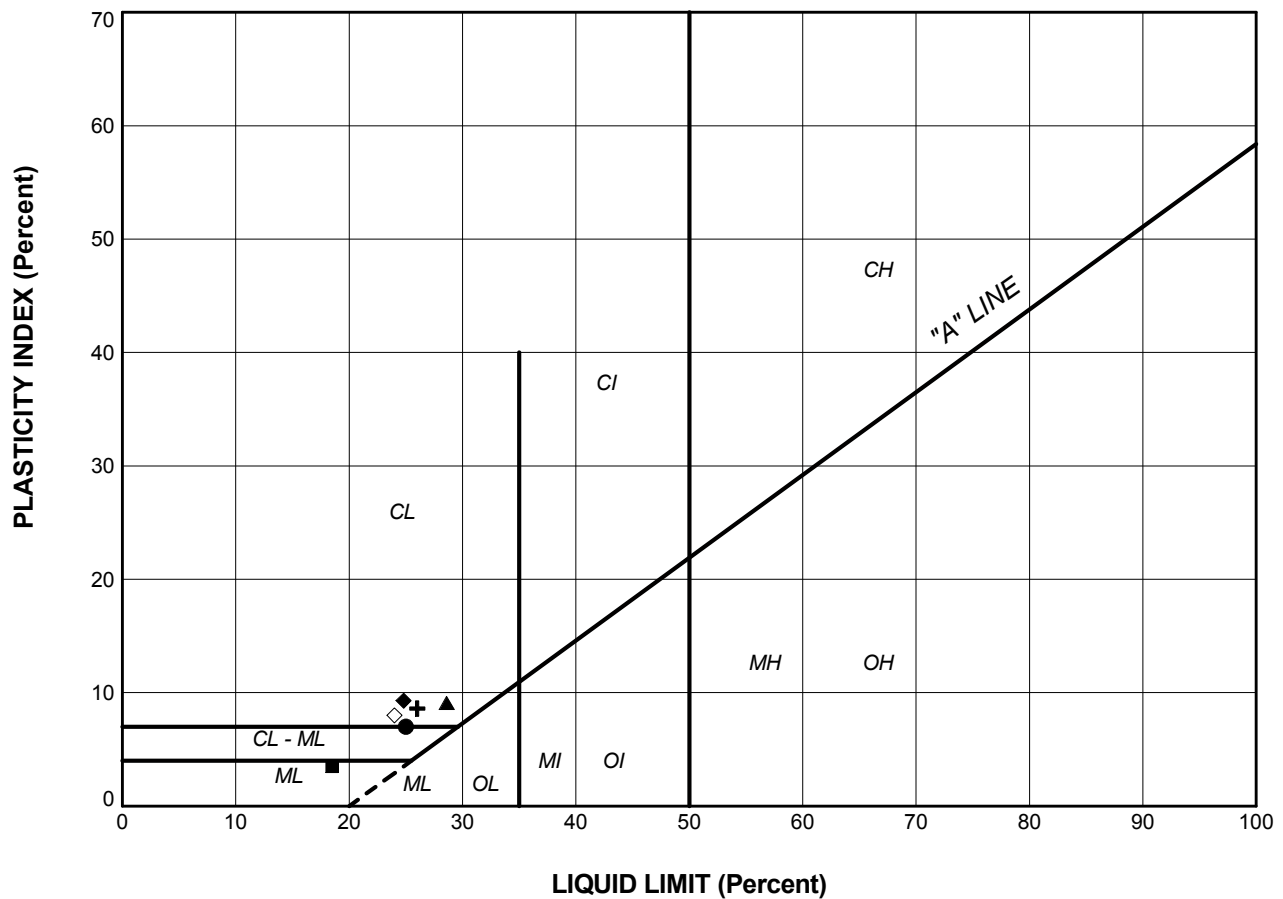
GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CC-4	7	202.0


PROJECT					HIGHWAY 17 BIG CACHE CREEK CULVERT				
TITLE					GRAIN SIZE DISTRIBUTION SILTY CLAY (FILL)				
PROJECT No.		11-1191-0010			FILE No.		11-1191-0010.GPJ		
DRAWN	TB	Dec 2012			SCALE	N/A	REV.		
CHECK	AB	Dec 2012			FIGURE B1-3				
APPR		Dec 2012							

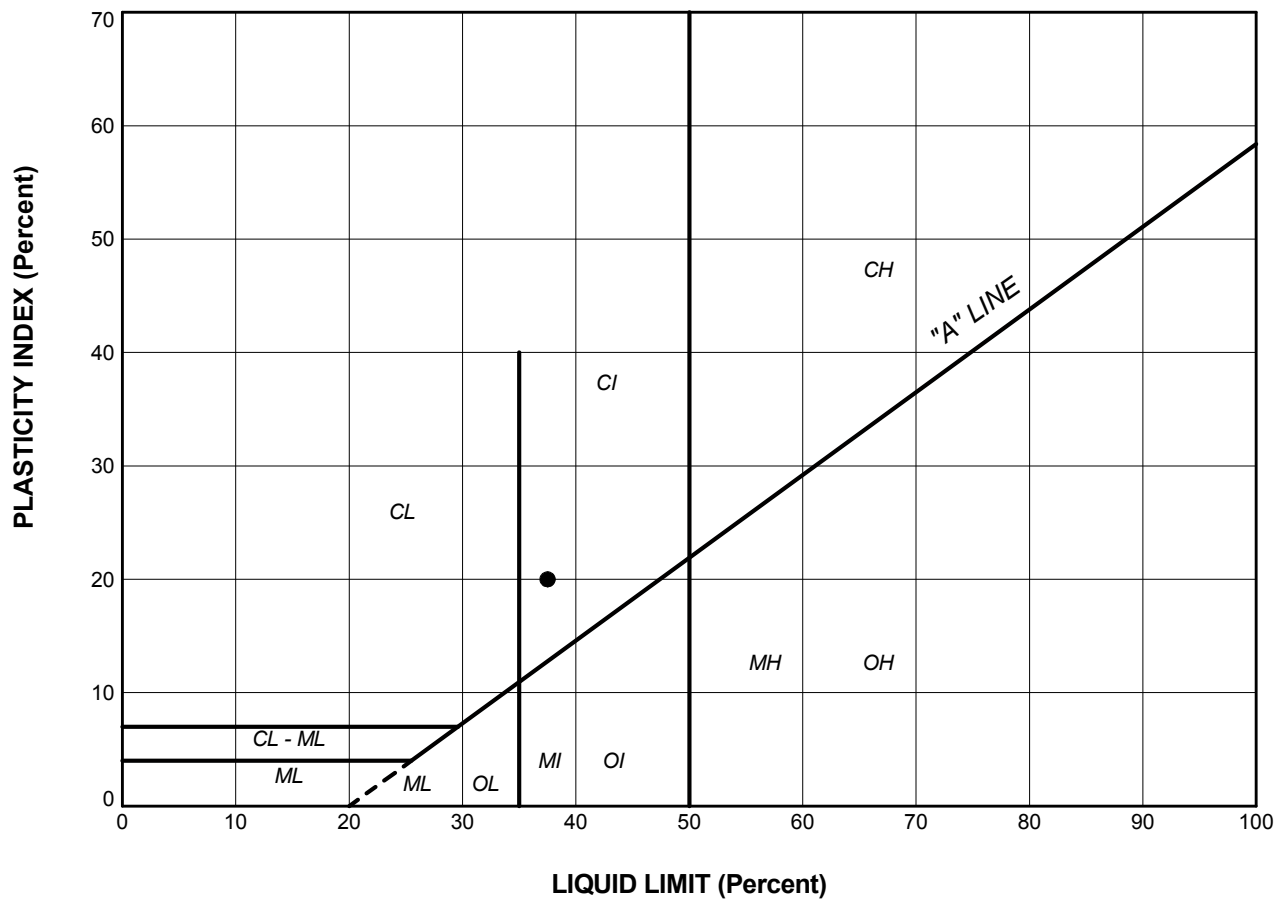




LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	CC-1	6	25	18	7
■	CC-2	4	19	15	4
▲	CC-2	7	29	20	9
+	CC-3	4	26	17	9
◆	CC-3	7	25	16	9
◇	CC-4	5	24	16	8

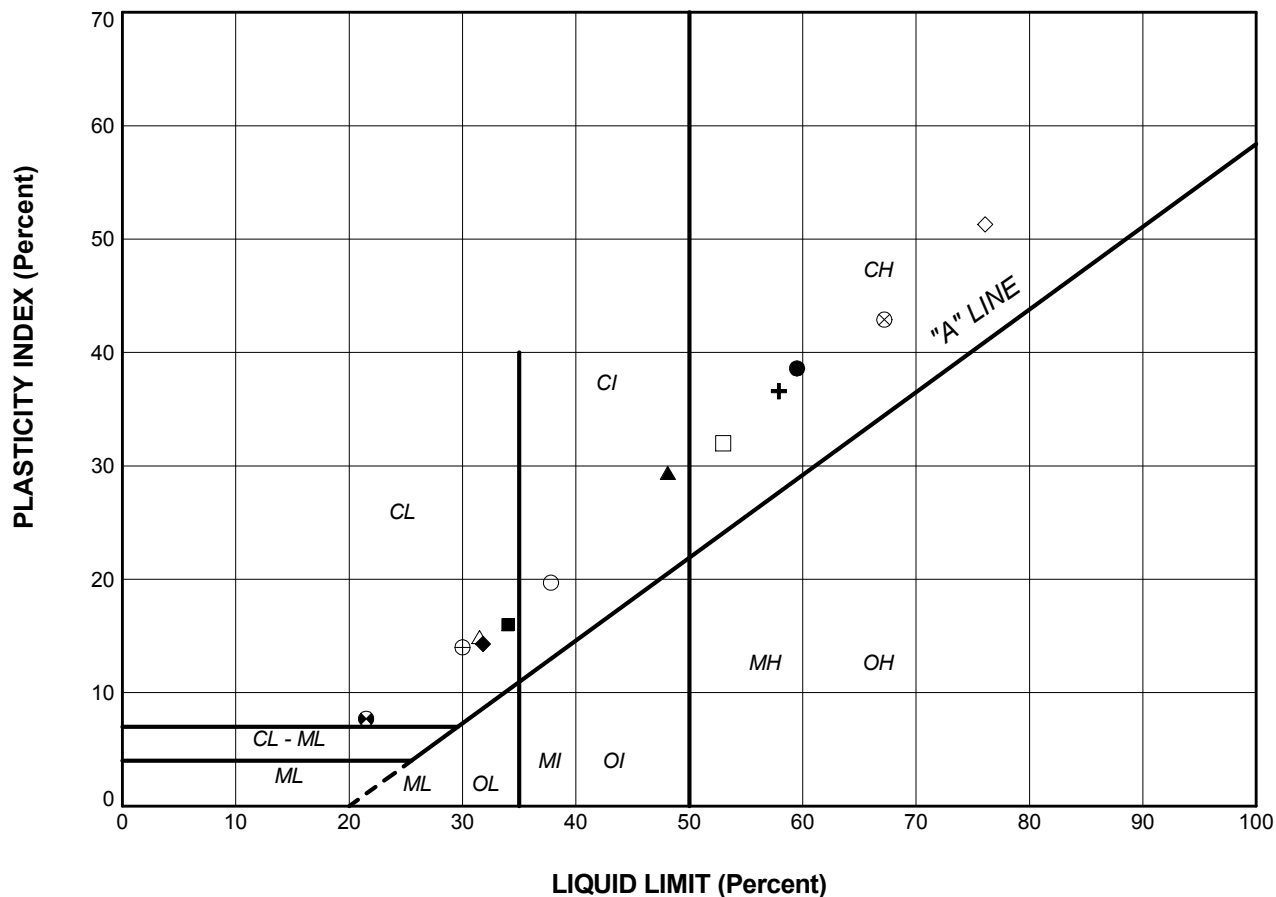
PROJECT					
HIGHWAY 17 BIG CACHE CREEK CULVERT					
TITLE					
PLASTICITY CHART SAND AND SILT TO CLAYEY SILT (FILL)					
PROJECT No.		11-1191-0010		FILE No. 11-1191-0010.GPJ	
DRAWN	TB	Dec 2012	SCALE	N/A	REV.
CHECK	AB	Dec 2012			
APPR		Dec 2012			
 Golder Associates SUDBURY, ONTARIO			FIGURE B1-4		



LEGEND					
SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	CC-4	7	38	18	20


PROJECT					
HIGHWAY 17 BIG CACHE CREEK CULVERT					
TITLE					
PLASTICITY CHART SILTY CLAY (FILL)					
PROJECT No. 11-1191-0010			FILE No. 11-1191-0010.GPJ		
DRAWN	TB	Dec 2012	SCALE	N/A	REV.
CHECK	AB	Dec 2012	FIGURE B1-5		
APPR		Dec 2012			

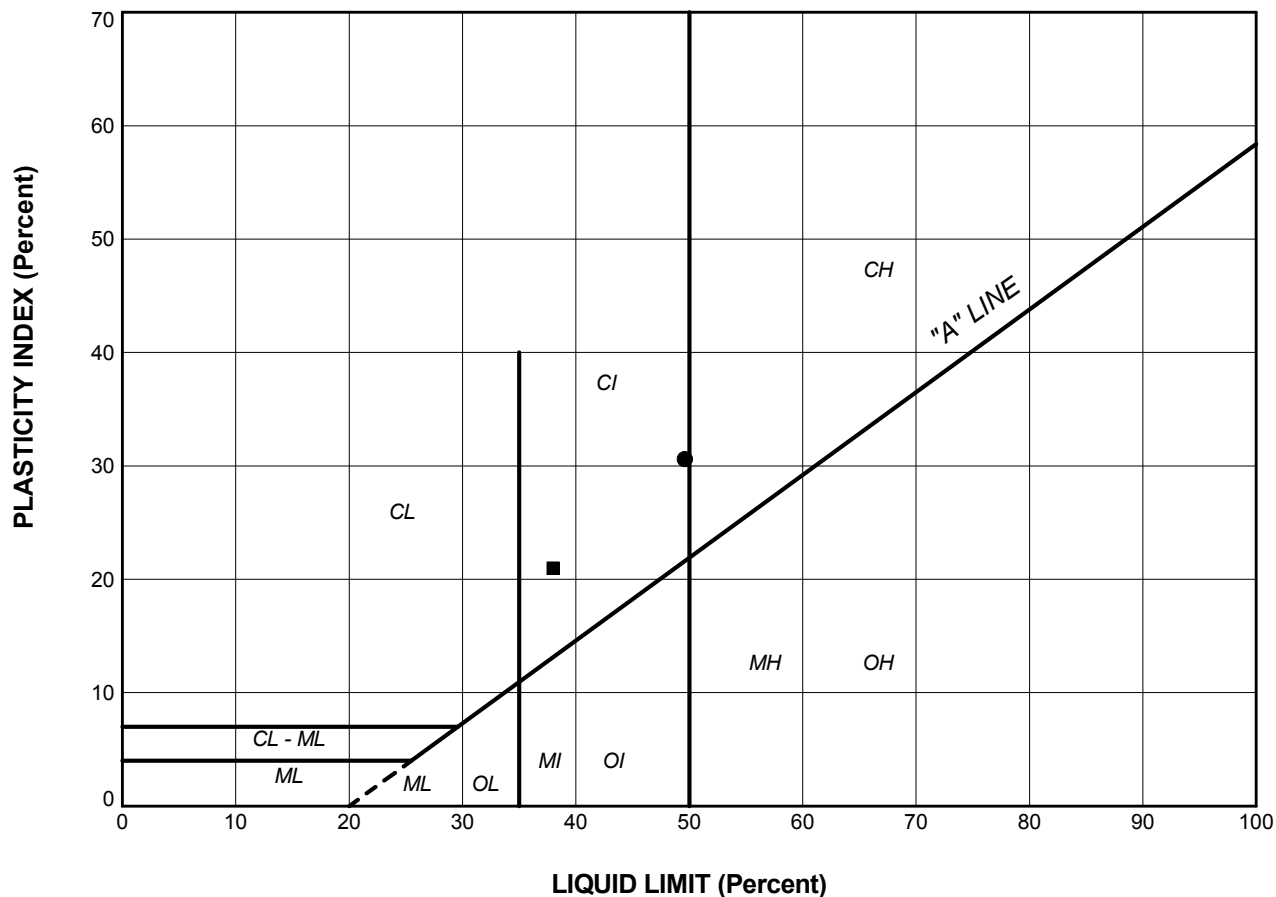




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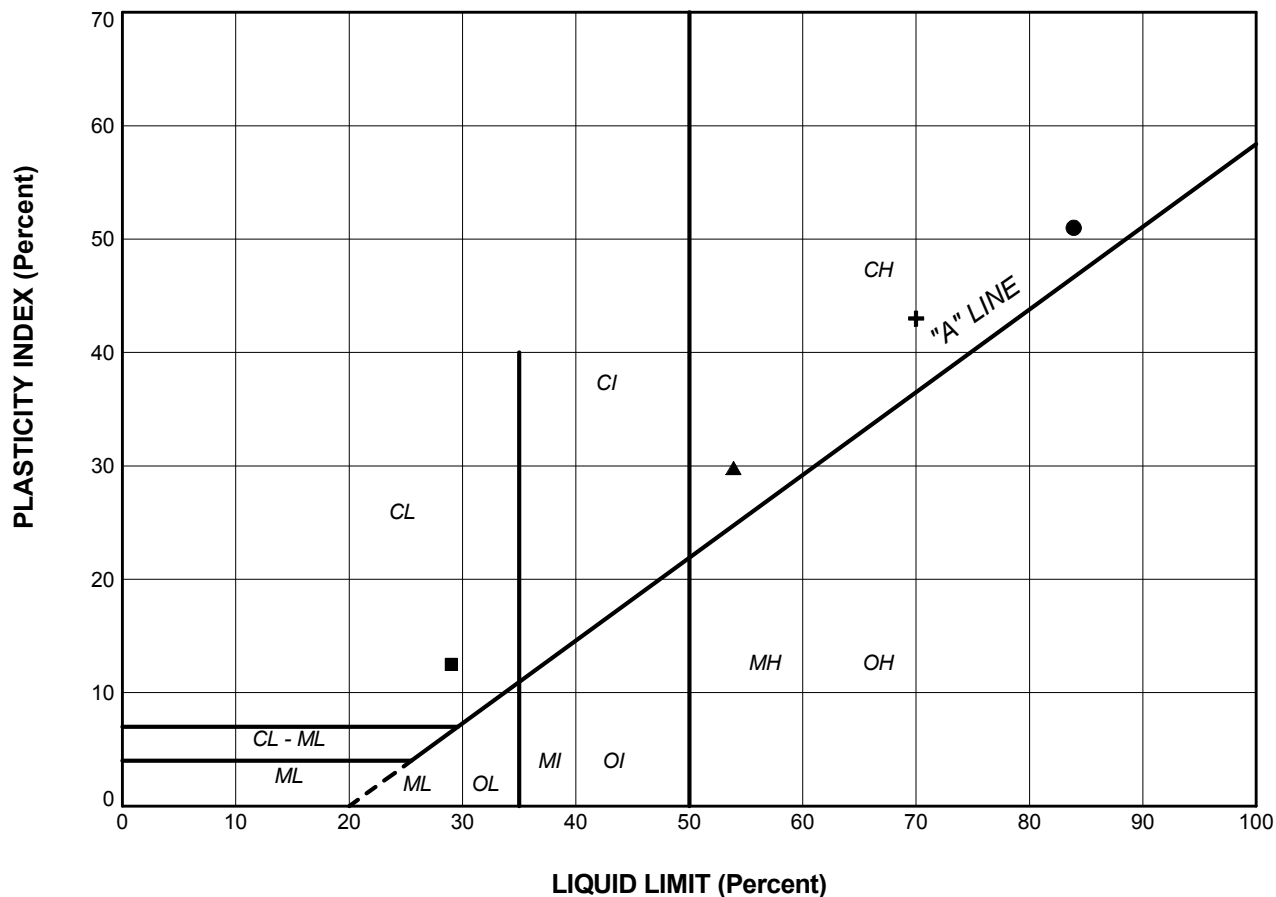
SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	CC-1	9	60	21	39
■	CC-1	11	34	18	16
▲	CC-2	10	48	19	29
+	CC-2	12	58	21	37
◆	CC-2	15	32	18	14
◇	CC-3	9	76	25	51
○	CC-3	11	38	18	20
△	CC-3	13	32	17	15
⊗	CC-4	9	67	24	43
⊕	CC-4	11	30	16	14
□	CC-5	2	53	21	32
⊗	CC-5	7	22	14	8

PROJECT					
HIGHWAY 17 BIG CACHE CREEK CULVERT					
TITLE					
PLASTICITY CHART CLAYEY SILT TO CLAY					
PROJECT No.		11-1191-0010		FILE No.	
DRAWN		TB		Jan 2013	
CHECK		AB		Jan 2013	
APPR		JMAC		Jan 2013	
 Golder Associates SUDBURY, ONTARIO				SCALE N/A REV. FIGURE B2-1	



PROJECT					
HIGHWAY 17 BIG CACHE CREEK CULVERT					
TITLE					
PLASTICITY CHART SILTY CLAY					
PROJECT No. 11-1191-0010			FILE No. 11-1191-0010.GPJ		
DRAWN	TB	Jan 2013	SCALE	N/A	REV.
CHECK	AB	Jan 2013	FIGURE B2-2		
APPR	JMAC	Jan 2013			



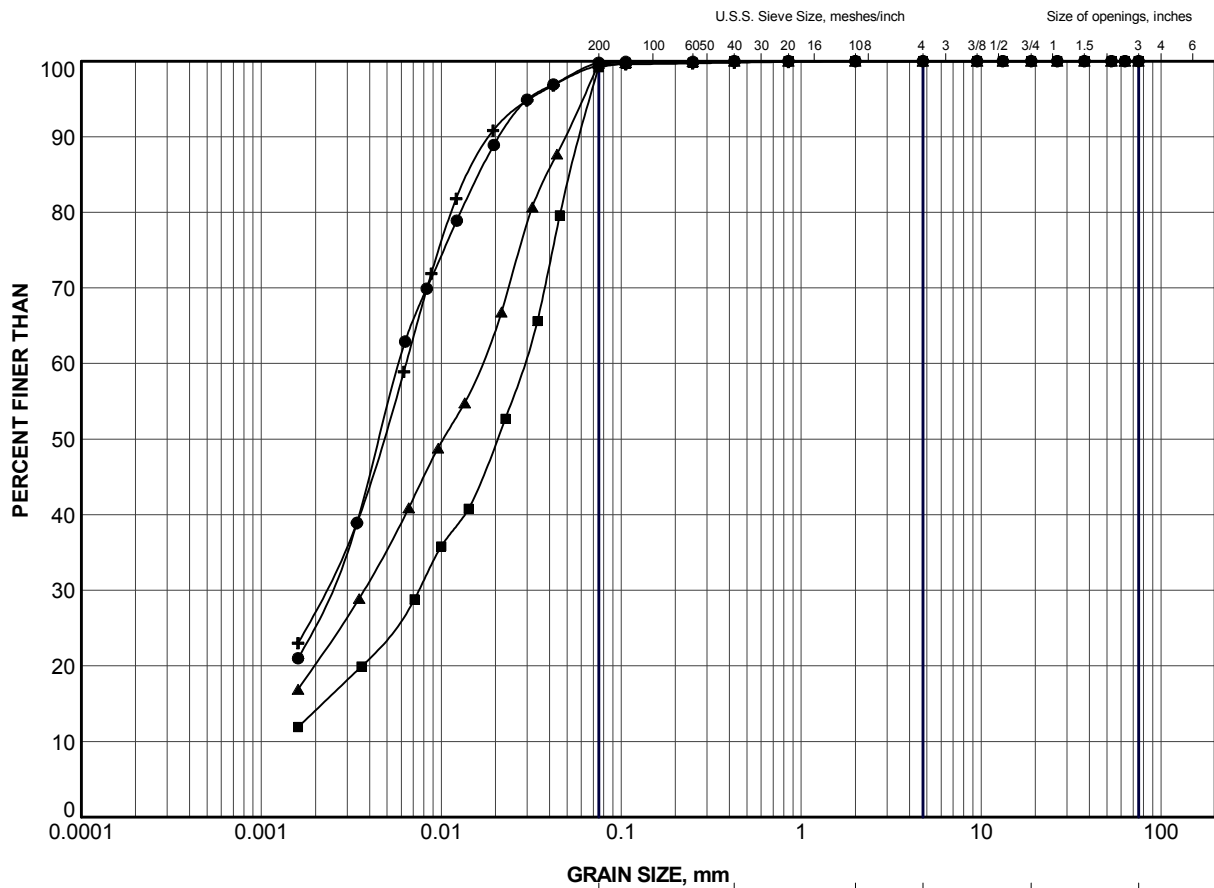


LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	CC-5	4	84	33	51
■	CC-5	5	29	17	13
▲	CC-6	5	54	24	30
+	CC-6	6	70	27	43

PROJECT					
HIGHWAY 17 BIG CACHE CREEK CULVERT					
TITLE					
PLASTICITY CHART CLAYEY SILT AND CLAY LAMINAE					
PROJECT No. 11-1191-0010			FILE No. 11-1191-0010.GPJ		
DRAWN	TB	Jan 2013	SCALE	N/A	REV.
CHECK	AB	Jan 2013	FIGURE B2-3		
APPR	JMAC	Jan 2013			





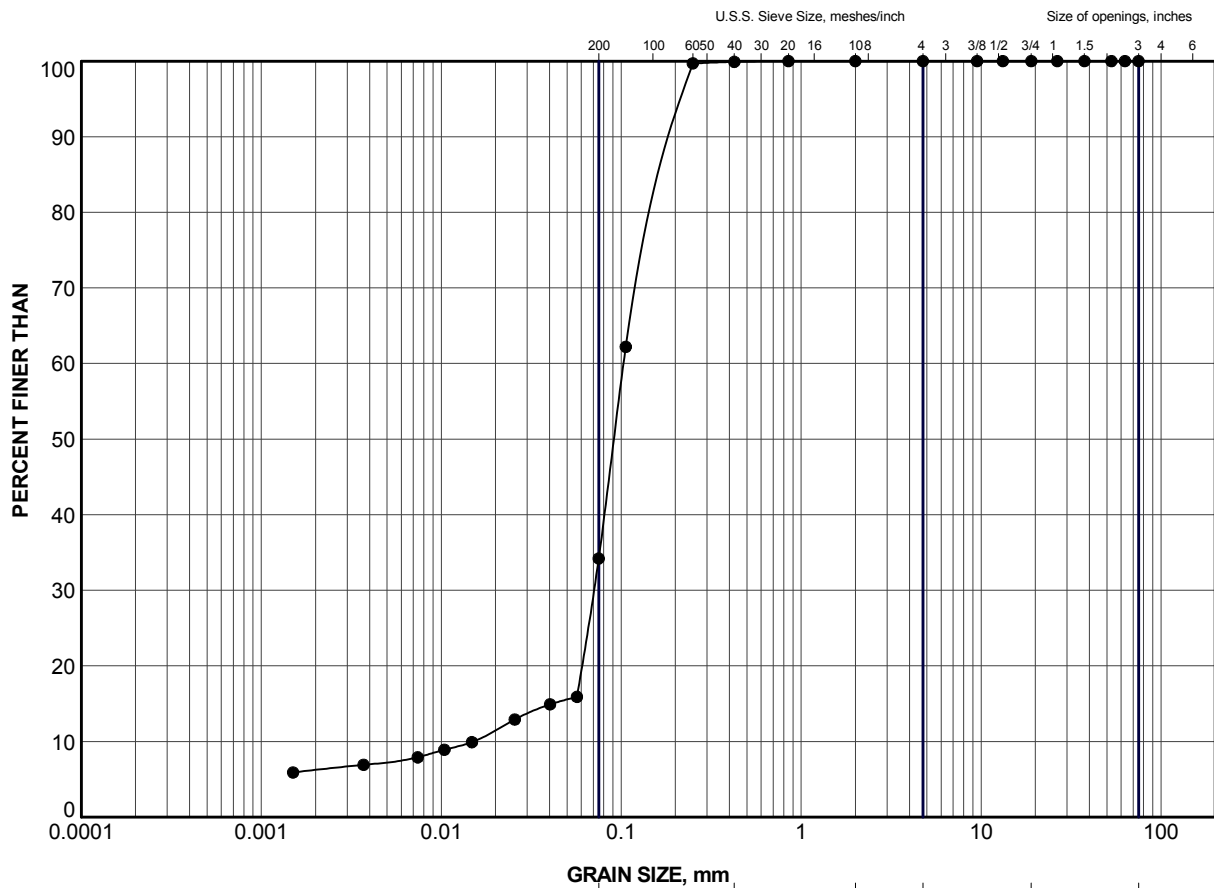
GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CC-5	4	195.8
■	CC-5	5	194.3
▲	CC-6	5	196.6
+	CC-6	6	195.1

PROJECT					HIGHWAY 17 BIG CACHE CREEK CULVERT				
TITLE					GRAIN SIZE DISTRIBUTION SILT TO CLAYEY SILT LAMINAE				
PROJECT No.		11-1191-0010			FILE No.		11-1191-0010.GPJ		
DRAWN	TB	Jan 2013			SCALE	N/A	REV.		
CHECK	AB	Jan 2013			FIGURE B3				
APPR	JMAC	Jan 2013							





CONSOLIDATION TEST SUMMARY**FIGURE B5****Pg. 1 of 4****SAMPLE IDENTIFICATION**

Project Number: 11-1191-0010

Sample Number: 6

Borehole Number: CC-6

Sample Depth, m: 4.6

TEST CONDITIONS

Test Type Standard

Load Duration, hr 24

Oedometer Number 1

Date Started August 14/12

Date Completed August 28/12

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	2.526	Unit Weight, kN/m ³	16.69
Sample Diameter, cm	6.351	Dry Unit Weight, kN/m ³	10.05
Area, cm ²	31.68	Specific Gravity, Assumed	2.70
Volume, cm ³	80.02	Solids Height, cm	0.959
Water Content, %	66.00	Volume of Solids, cm ³	30.39
Wet Mass, g	136.19	Volume of Voids, cm ³	49.64
Dry Mass, g	82.04	Degree of Saturation, %	109.1

TEST COMPUTATIONS

Pressure kPa	Primary Consolidation	Corr. Height cm	Void Ratio	Average Height cm	t ₉₀ sec	cv. cm ² /s	mv m ² /kN	k cm/s	Total Work kJ/m ³
0	0	2.526	1.634	2.526					
9	0.01	2.525	1.632	2.525	29	0.0466	6.21E-05	2.84E-07	0.002
18	0.02	2.523	1.630	2.524	38	0.0355	8.86E-05	3.08E-07	0.013
35	0.05	2.518	1.625	2.520	49	0.0277	1.06E-04	2.87E-07	0.061
69	0.09	2.509	1.615	2.513	60	0.0223	1.09E-04	2.38E-07	0.255
143	0.18	2.491	1.597	2.500	60	0.0221	9.48E-05	2.05E-07	0.998
285	0.26	2.465	1.570	2.478	86	0.0151	7.35E-05	1.19E-07	3.360
570	2.62	2.203	1.297	2.334	4860	0.0002	3.63E-04	8.45E-09	48.791
1140	1.57	2.046	1.133	2.124	3110	0.0003	1.09E-04	3.30E-09	109.849
570	-0.14	2.060	1.148	2.053					
143	-0.54	2.114	1.204	2.087					
35	-0.61	2.175	1.268	2.145					
9	-0.55	2.231	1.326	2.203					

Note:

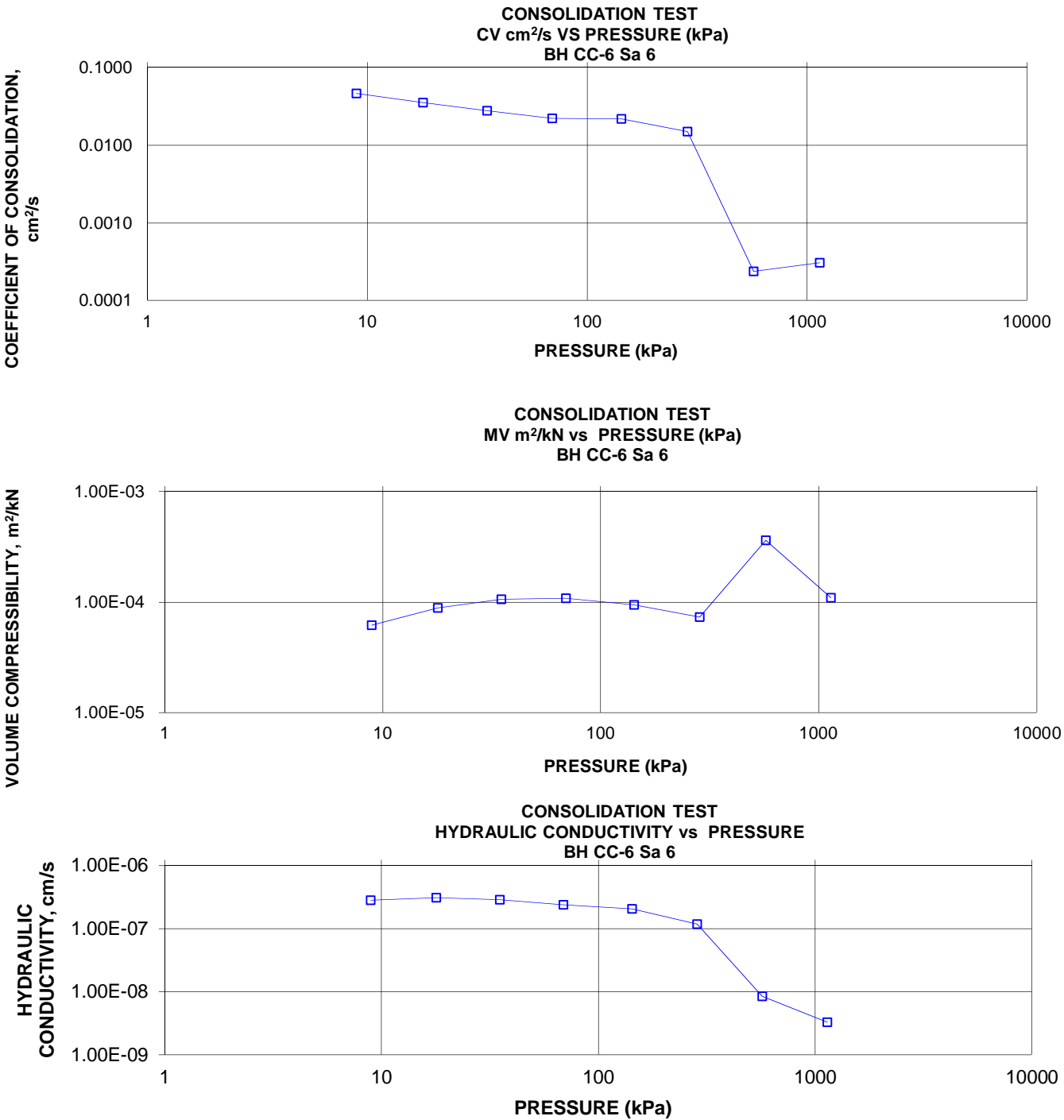
k calculated using α based on t₉₀ values.**SAMPLE DIMENSIONS AND PROPERTIES - FINAL**

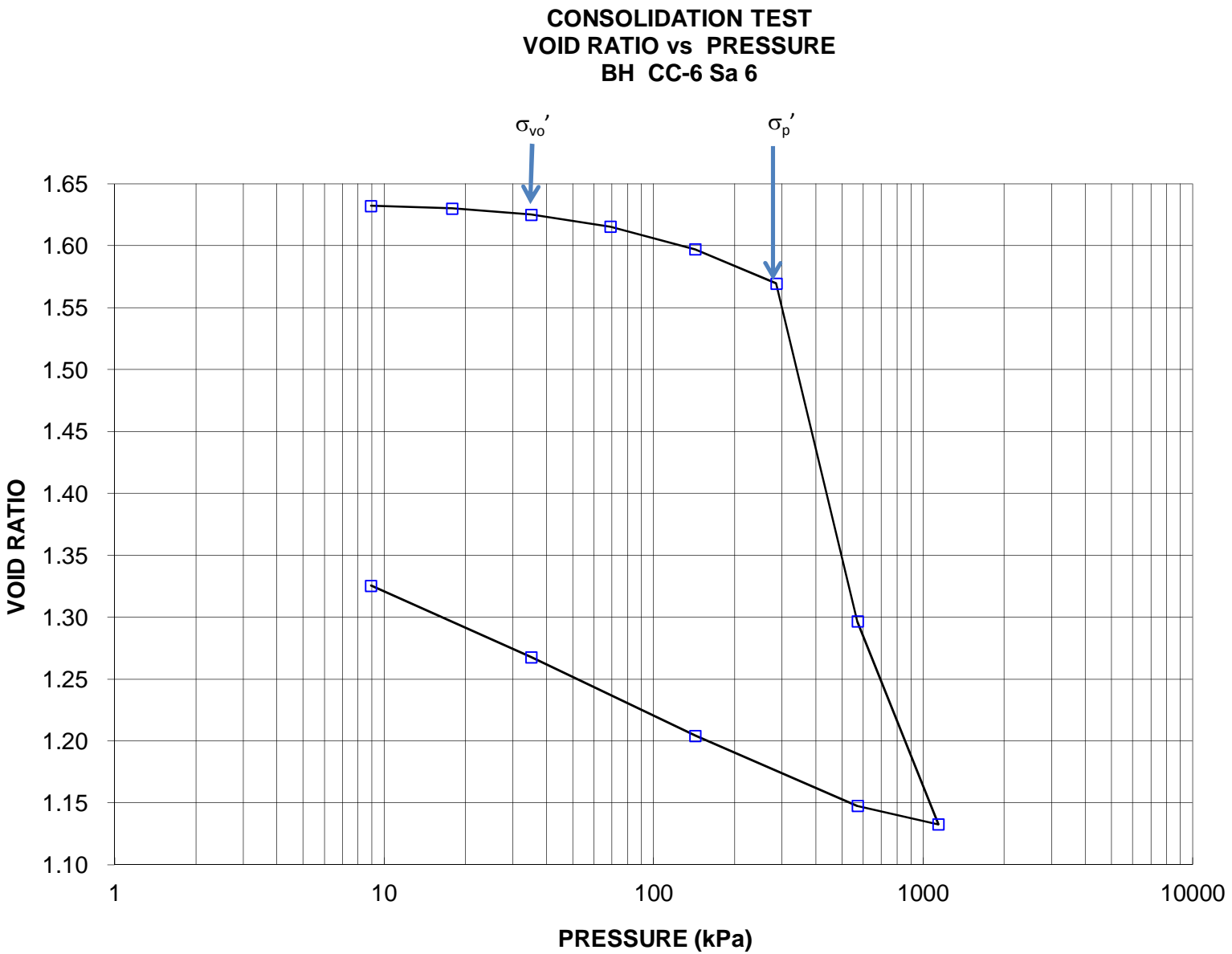
Sample Height, cm	2.231	Unit Weight, kN/m ³	16.93
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m ³	11.39
Area, cm ²	31.68	Specific Gravity, Assumed	2.70
Volume, cm ³	70.66	Solids Height, cm	0.959
Water Content, %	48.72	Volume of Solids, cm ³	30.39
Wet Mass, g	122.01	Volume of Voids, cm ³	40.28
Dry Mass, g	82.04		

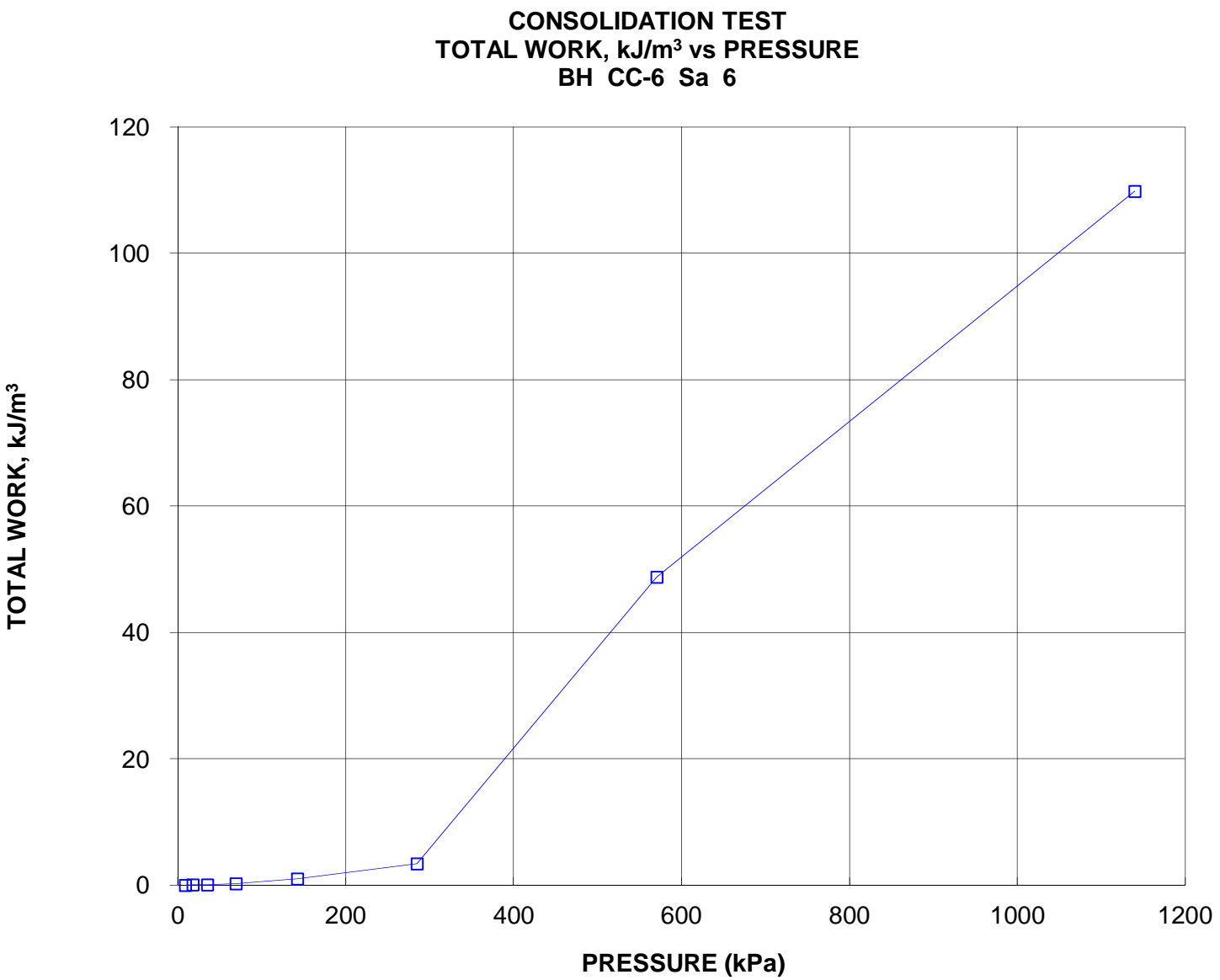
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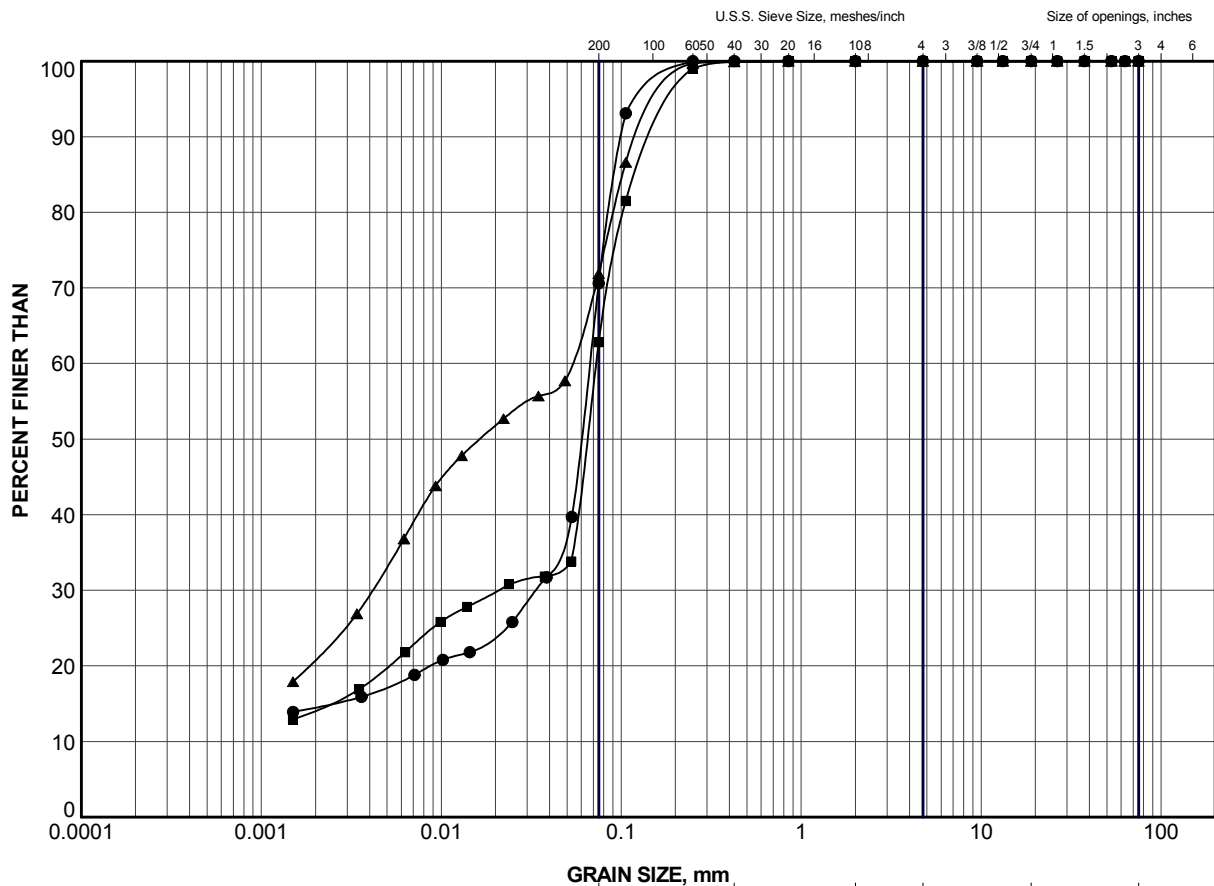
Golder Associates

Checked By: TG










GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CC-2	17	185.0
■	CC-5	11	185.2
▲	CC-6	11	187.9

PROJECT						HIGHWAY 17 BIG CACHE CREEK CULVERT					
TITLE						GRAIN SIZE DISTRIBUTION SANDY SILT TO SAND AND SILT					
PROJECT No.			11-1191-0010			FILE No.			11-1191-0010.GPJ		
DRAWN	TB	Dec 2012	SCALE	N/A	REV.						
CHECK	AB	Dec 2012				FIGURE B6					
APPR		Dec 2012									
 Golder Associates SUDBURY, ONTARIO											



APPENDIX C

Non-Standard Special Provisions

WORKING SLAB, Item No.

Non-Standard Special Provision

Scope

This Special Provision covers the requirements for the supply and placement of a concrete working slab under the structure foundations. The purpose of the working slab is to protect the subgrade from disturbance and loosening due to construction traffic and ponded water and also to provide a level working surface.

Construction

Protection of Founding Soil:

- Following inspection and approval of the prepared subgrade, a working slab with a minimum thickness of 100 mm shall be placed on the foundation subgrade as per the contract drawings and documents. The concrete shall have a minimum 28-day compressive strength of 20 MPa.

Unwatering of the excavation for the footing construction, including the construction of the working slab, may be required and is covered under a separate Tender Item. The unwatering scheme shall be done in such a manner as to prevent any disturbance to the original soil.

Basis of Payment

Payment at the contract price for this Tender Item shall include full compensation for all labour, equipment and material required to do the work.

GROUNDWATER CONTROL - Item No.

Non-Standard Special Provision

Foundations for the Big Cache Creek culvert end replacement and wing walls will require excavations extending below the groundwater level. Cohesionless soils (sandy silt to sand) that are present below the groundwater table will slough, run, boil or cave into the excavation unless appropriate groundwater controls are in place. The Contractor is to design and install an appropriate dewatering system for the culvert site to enable construction in dry conditions, and prevent disturbance to the founding soils.

Basis of Payment

Payment at the lump sum contract price for this Tender Item shall be full compensation for all labour, equipment and materials for completion of the work.

END OF SECTION

OBSTRUCTIONS

Non-Standard Special Provision

As part of the work for the culvert end replacement and wing walls, the Contactor shall be alerted to the presence of rock fill in cobbles and boulder sizes on the embankment slopes.

Further, the Contractor shall be alerted to the grinding of augers during drilling through the embankment fill in Borehole CC-4 at a depth between approximately 6.0 m and 7.0 m below ground surface.

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