



November 27, 2014

FOUNDATION INVESTIGATION AND DESIGN REPORT

**BIQUETTE CREEK CULVERT AT STA 13+350
HIGHWAY 17 REHABILITATION BETWEEN WARREN AND VERNER
FROM HIGHWAY 539 EASTERLY TO 0.2 KM EAST
OF WEST JUNCTION OF HIGHWAY 64
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 300-98-00**

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REPORT





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PART A

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Morrison Hershfield Limited (MH), on behalf of the Ministry of Transportation, Ontario (MTO), to provide foundation engineering services for the replacement of the Highway 17 Biquette Creek culvert at STA 13+350 in the Town of Verner in the Municipality of West Nipissing, 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 culvert by borehole drilling, in situ testing and laboratory testing on selected soil samples.

2.0 SITE DESCRIPTION

The Biquette Creek culvert is located on Highway 17 in the Town of Verner immediately west of the west junction with Highway 64. In general, the topography in the area of the overall project limits consists of flat terrain with commercial and residential properties. The existing highway grade is at about Elevation 210 m with Biquette Creek crossing under the embankment about 10 m below the existing highway grade. The side slopes of the existing embankment are inclined at about 2 Horizontal to 1 Vertical (2H:1V) and the embankment side slopes are vegetated with grass and small trees/shrubs. The existing culvert consists of twin 1.1 m diameter Corrugated Steel Pipes (CSP), 59 m long.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation was carried out between November 27 and December 3, 2013, and between February 12 and 24, 2014, during which time a total of seven boreholes were advanced at the approximate locations shown on Drawing 1:

- four boreholes for the culvert alignment (Boreholes BI-1, BI-2, BI-5/5a and BI-6);
- one borehole for the proposed roadway protection (Borehole BI-3); and
- two boreholes for the proposed cofferdam (Boreholes BI-4 and BI-7).

Boreholes BI-1 to BI-3, located on the existing highway embankment, were advanced to depths between 15.8 m and 21.9 m below ground surface using a truck-mounted CME 55 drill rig outfitted with 108 mm inside diameter continuous flight hollow-stem augers and 'NW' casing with wash boring techniques, supplied and operated by Landcore Drilling Inc. of Sudbury, Ontario. Boreholes BI-4 to BI-7, located at or beyond the existing toe of slope, were advanced to a depth of 14.3 m below ground/ice surface using wash boring methods with portable equipment using NQ casing, supplied and operated by George Downing Estate Drilling Ltd. of Grenville-Sur-La-Rouge, Quebec. Borehole BI-5a was advanced adjacent to Borehole BI-5 to obtain Shelby Tube samples and to complete additional field vane testing. A Dynamic Cone Penetration Test (DCPT) was advanced adjacent to Boreholes BI-2 and BI-4 to BI-6 to depths between 15.2 m and 21.9 m below ground surface.

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 BI-1 to BI-3 and a manual hammer at



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Boreholes BI-4 to BI-7, 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 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. 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 March 10, 2014, 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 marked stations and offsets on the highway or the ends of the culvert, as applicable. 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 Below Ground/Ice Surface (m)
	Northing	Easting		
BI-1	5141606.9	256900.7	210.4	18.9
BI-2	5141600.0	256890.8	210.4	21.9/21.9
BI-3	5141612.0	256878.7	210.5	15.8
BI-4	5141633.4	256911.5	201.4	14.3/15.2
BI-5	5141631.0	256897.4	201.7	14.3/15.2
BI-5a	5141629.9	256897.0	201.7	8.2
BI-6	5141575.9	256881.4	201.3	14.3/15.2
BI-7	5141569.5	256888.3	199.4	14.3*

*includes 0.2 m thick layer of ice and 1.3 m column of water



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 and silt deposits with bedrock knobs/outcrops located to the north and south of the plain.

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. The results of the in situ tests (i.e., SPT “N”-values and undrained shear strengths from the field vanes) as presented on the Record of Borehole sheets and in Section 4 are uncorrected. 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 and on the stratigraphic profile and cross-section shown on Drawing 1 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 types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations.

In general, the subsurface stratigraphy at the site consists of embankment fill (where encountered) or topsoil (where encountered) generally underlain by clayey silt to silty clay, which in turn is underlain by a silt to silt and sand deposit. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Ice/Water

Borehole BI-7 was advanced from the surface of the ice near the outlet to the culvert at Elevation 200.9 m and encountered a 0.2 m thick layer of ice and 1.3 m column of water.

4.2.2 Fill

Boreholes BI-1 to BI-3 penetrated a layer of asphalt 225 mm thick at Elevation 210.4 m and 210.5 m, underlain by a fill deposit comprised of sand and gravel to sand between about 0.5 m and 2.9 m thick, underlain by clayey silt to silt fill between 6.5 m and 7.6 m thick.

The SPT ‘N’-values measured within the sand and gravel to sand fill range between 10 blows and 58 blows per 0.3 m of penetration indicating a compact to very dense relative density; and the ‘N’-values measured within the clayey silt to silt fill range between 5 blows and 24 blows per 0.3 m of penetration suggesting a firm to very stiff consistency.

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



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Grain size analyses were carried out on two samples of the sand and gravel to gravelly sand fill and the results are presented on Figure B1 in Appendix B. Grain size analyses were carried out on two samples of the clayey silt to silt fill and the results are presented on Figure B2.

Atterberg limits tests were carried out on three samples of the cohesive fill and measured liquid limits ranging from about 21 per cent to 34 per cent, plastic limits ranging from about 17 per cent to 19 per cent, and plasticity indices ranging from about 4 per cent to 15 per cent. The results, which are plotted on a plasticity chart on Figures B3 in Appendix B, indicate that the tested samples of the overall deposit consist of clayey silt of low plasticity to silt of slight plasticity.

The natural moisture content measured on samples of the sand and gravel to sand fill is between 2 per cent and 4 per cent and samples of the clayey silt to silt fill is between 24 per cent and 32 per cent.

4.2.3 Topsoil

Borehole BI-4 encountered a 0.7 m thick layer of silty topsoil from ground surface at Elevation 201.4 m.

One SPT 'N'-value measured in the deposit is 3 blows per 0.3 m of penetration, suggesting a very loose consistency.

4.2.4 Sandy Silt to Silty Sand

Below the topsoil in Borehole BI-4 and below the water in Borehole BI-7, a deposit of sandy silt to silty sand was encountered at Elevation 200.7 m and 199.4 m, with a thickness of 1.5 m and 0.6 m, respectively.

Three SPT 'N'-values measured within this deposit are 9 blows and 10 blows per 0.3 m of penetration, indicating a loose to compact relative density.

4.2.5 Clayey Silt to Silty Clay

A deposit of clayey silt to silty clay was encountered below the fill in Boreholes BI-1 to BI-3, from ground surface in Boreholes BI-5 and BI-6 and below the sandy silt to silty sand deposit in Boreholes BI-4 and BI-7. The surface of the deposit was encountered between about Elevations 203.3 m and 198.8 m and the thickness of the deposit is between about 6.6 m and 10.5 m; Borehole BI-3 did not penetrate the deposit after exploring for 8.6 m. Silt laminations were observed within the majority of samples of this deposit. In Borehole BI-6, a 0.3 m layer of silty sand and gravel was encountered at a depth of 2.1 m below ground surface (Elevation 199.2 m).

The SPT 'N'-values measured within the clayey silt to silty clay deposit range between 2 blows and 8 blows per 0.3 m of penetration. In situ field vane testing measured undrained shear strengths ranging from 38 kPa to greater than 100 kPa, with sensitivities between 2 and 6. The in situ vane test results indicate that the deposit has a firm to very stiff consistency.

Atterberg limits tests were carried out on fourteen samples of the cohesive deposit and measured liquid limits ranging from about 21 per cent to 47 per cent, plastic limits ranging from about 14 per cent to 25 per cent and plasticity indices ranging from about 5 per cent to 24 per cent. The results, which are plotted on a plasticity chart



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on Figures B4.1, indicate that the tested samples of the overall deposit consist of clayey silt of low plasticity to silty clay of intermediate plasticity.

Atterberg limits tests were also carried out on one sample of the deposit that was separated into the silt lamina and the clay lamina and the test results are shown on Figure B4.2. The test results on the clay lamina indicate a liquid limit of about 87 per cent, a plastic limit of 27 per cent and a plasticity index of 60 per cent. The silt lamina has a liquid limit of about 23 per cent, a plastic limit of 17 per cent and a plasticity index of 7 per cent. The test results confirm that the 'silty' varves are classified as a silt of slight plasticity and the 'clayey' varves are classified as a clay of high plasticity.

The results of the grain size distribution testing completed on thirteen samples of this deposit, including those on the silt and clay laminae, are shown on Figure B5.

The natural moisture content measured on selected samples of this deposit generally ranges between about 24 per cent and 50 per cent; the moisture content measured on the clay lamina from Borehole BI-5a is 72 per cent.

4.2.6 Silt to Silt and Sand

A deposit of silt to sandy silt to silt and sand, some clay, was encountered below the clayey silt to silty clay deposit in Boreholes BI-1, BI-2 and BI-4 to BI-7. The surface of this deposit was encountered between Elevations 192.6 m and 189.7 m and sampled boreholes did not fully penetrate the deposit after exploring for thicknesses of between approximately 1.1 m and 5.6 m.

The SPT 'N'-values measured within this deposit range between 2 blows and 14 blows per 0.3 m of penetration, indicating a very loose to compact relative density.

Grain size distribution analyses were carried out on nine samples of this deposit and the results are represented on Figure B6.

Atterberg limits tests were carried out on six samples of this deposit: three samples indicate that the material is non-plastic; and three samples measured liquid limits ranging from about 18 per cent to 22 per cent, plastic limits ranging from about 15 per cent to 16 per cent and plasticity indices ranging from about 3 per cent to 6 per cent. The results, which are plotted on a plasticity chart on Figures B7, indicate that the three samples consist of silt of slight plasticity. Atterberg limits testing carried out on the natural moisture content measured on selected samples of this deposit ranges between about 20 per cent and 30 per cent.

4.2.7 Groundwater Conditions

Borehole BI-3 caved at a depth of about 9.8 m below ground surface (Elevation 200.7 m) upon completion of drilling and the borehole was noted to be dry to the cave depth. The unstabilized water level in Boreholes BI-1, BI-2 and BI-4 to BI-6 upon completion of drilling was between Elevation 201.8 m and 200.5 m. The creek ice surface on the south side of the embankment at Borehole BI-7 on February 23, 2014 was Elevation 200.9 m.

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

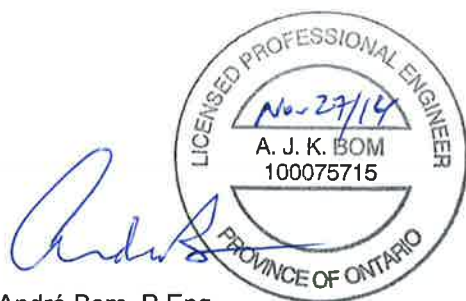
The drilling program was supervised by Mr. Shane Albert and Mr. Mat Riopelle. This report was prepared by Mr. André Bom, P.Eng. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and Principal with Golder, conducted an independent quality control review of the report



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Report Signature Page

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**FOUNDATION REPORT
HIGHWAY 17 BIQUETTE CREEK CULVERT**

PART B

FOUNDATION DESIGN REPORT

BIQUETTE CREEK CULVERT AT STA 13+350

HIGHWAY 17 REHABILITATION BETWEEN WARREN AND VERNER

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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 Biquette Creek culvert consists of a 59 m long, 1.1 m diameter twin CSP. The existing inlet and outlet invert is at Elevation 199.4 m and 199.9 m, respectively. The top of the existing embankment is at about Elevation 210.5 m and the existing side slopes of the 10 m high embankment are inclined at about 2H:1V.

The existing culverts will be replaced with a 2.5 m wide and 1.8 m high box culvert. We understand that during replacement of the culvert traffic will be routed to a detour through the Town of Verner.

As part of the Highway 17 rehabilitation to be carried out in the vicinity of the culvert, a grade raise to the existing embankment of about 150 mm may be required. Further, we understand that there will be no change to the inclination of or additional fill to the embankment side slopes.

6.2 Culvert Types

The analysis and recommendations presented in this report assume that the replacement of the culvert would consist of a concrete box culvert of similar dimensions as the existing culvert. Due to the presence of the cohesive deposit of limited strength and the height of the existing embankment, an open bottom concrete culvert (on strip footings) at this site is not considered feasible.

6.3 Stability

Limit equilibrium slope stability analyses were performed for the proposed embankment geometry, based on the a culvert being replaced, using the commercially available program GeoStudio 2007 (Version 7.23), 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 roadway. The stability analyses were performed to check that the target minimum FoS was achieved for the embankment height and geometry at the culvert location.



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The analyses assume that, for a full culvert replacement, the organic soils (if present) beneath the culvert and immediate area of excavation under the embankment footprint will be removed prior to construction of the new culvert/re-constructed embankment. The analyses assume that the existing embankment fill is reused for embankment construction, provided that the excavated material can be properly compacted consistent with accepted standard for roadway embankment construction, and would be keyed into the existing fill as per OPSP 208.010 (Benching of Earth Slopes) and constructed with 2H:1V side slopes or flatter. Alternatively, new granular fill (sand and gravel, OPSS.Prov1010 Granular 'A' or 'B' Type I or II), could be used for embankment reconstruction.

For the 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.

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 10 per cent on the undrained shear strength has been employed due to the silt laminations noted within the cohesive deposit to account for the angle of minimum shearing resistance (Milligan and Lo, 1967). The profile of undrained shear strength versus elevation, together with the selected design lines, based on the corrected field data, is presented on Figure 1.

The piezometric condition required in the analyses is based on the groundwater level consistent with the creek surface elevation.

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 (°)
New Granular Fill	21	-	35
Existing Embankment Fill (for assessment of staged excavations)	20	-	30
Silty Sand	19	-	30
Clayey Silt to Silty Clay	17	40 to 80 kPa (beyond embankment) 60 to 80 kPa (below embankment) (increasing with depth)	-
Silt to Silt and Sand	19	-	30



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The stability analysis performed on the embankment cross-section for the south slope at the culvert location, based on a water level at Elevation 200.9 m and a ground surface at Elevation 199.4 m at Borehole BI-7, indicates that the embankment will have a FoS greater than 1.3 for deep-seated, global failure surfaces that would impact the operation of the roadway, as shown on Figure 2.

The requirement for incorporating benches in earth embankments 8 m high or greater is discussed in Section 6.8.1. At this site, the uninterrupted height from the top of the embankment to the creek bottom is greater than 8 m and a bench should be incorporated into the embankment side slopes.

During construction of the new culvert, where staged excavations through the existing embankment will be required, we recommend that a restriction be placed in the contract on the side slopes of the excavation, as discussed further in Section 6.8.1.

6.4 Settlement

Based on a proposed grade raise of about 150 mm and the side slope being reconstructed at the same inclination as the existing embankment, the total and differential settlement of the foundation soil below the culvert will be less than 25 mm. However, if a greater increase to the existing embankment grade or a widening is required along the side slopes, 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 OPSS.PROV1010 (Aggregates) Granular 'A' or 'B' Type I or II be used for embankment reconstruction at the culvert location. Alternatively, the existing fill can be used for embankment reconstruction, provided that the excavated material can be properly compacted consistent with accepted standard for roadway embankment construction. Where granular fill will be placed below the water level, Granular 'B' Type II should be used. 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.

6.5 Horizontal Strain

Horizontal strain along the culvert is not expected to occur provided the proposed grade raise and side slope geometry is consistent with the embankment cross-section presented in Section 6.4. 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.

Replacement of the culvert can be carried out concurrent with embankment reconstruction without the need for any foundation mitigation measures or provision of a camber to the culvert designed to tolerate the estimated and total differential settlement noted above.



6.6 Geotechnical Resistance

For the box culvert replacement, we recommend that a factored geotechnical axial resistance at Ultimate Limit States (ULS) of 200 kPa be used for design for a 2.5 m wide box culvert founded on a properly prepared subgrade comprised of compact sandy silt to silty sand and/or the firm to very stiff clayey silt to silt clay deposits.

It is noted that at this site, the additional or new loading on the foundation soils below the culvert replacement would occur if the embankment is widened or raised. As there is no proposed widening and the grade raise of 150 mm is considered minor, the new/additional loading from the fill on the subgrade soil is considered insignificant and the expected additional settlement is much less than 25 mm. As such, it is noted that the structural engineer should exercise prudence when utilizing the value(s) of the geotechnical axial resistance at Serviceability Limit States (SLS) in the design of the new culvert and that consideration be given to the sequence and staging of construction. For design, the geotechnical resistance at SLS (for 25 mm settlement) for a 2.5 m wide box culvert constructed on the properly prepared granular subgrade may be taken as 100 kPa, recognizing that the settlement at the culvert will be much less than the calculated settlement that could occur if an additional embankment loading was applied at the culvert location.

The geotechnical resistances are given for loads applied perpendicular to the surface of the base of the replacement culvert. 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 in this analysis.

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	$\tan \delta = 0.58$

These values represent unfactored values.

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 of movement 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



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culvert segments be placed on a minimum thickness of 300 mm of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II 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 OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II but with less than 5 per cent passing the 200 sieve (0.075 mm) should be used as backfill behind the culverts and wing walls. 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 immediately behind the culvert walls should be in accordance with OPSD 3101.150 (Walls, Abutment, Backfill) and OPSD 3121.150 (Walls Retaining, Backfill). Given the thickness of embankment above the top of the culvert (about 9 m), and the granular composition of the embankment fill over the culvert, frost tapers for pavement structure are not required.
- 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. 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 1.5H: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). The pressures are based on the proposed embankment fill material and the following parameters (unfactored) may be used:

Fill Type	Unit Weight	Coefficients of Static Lateral Earth Pressure	
		At-Rest, K_o	Active, K_a
Granular 'A'	22 kN/m ³	0.43	0.27
Granular 'B' Type II	21 kN/m ³	0.43	0.27

If the culvert structure and wing walls do not allow lateral yielding, at-rest earth pressures should be assumed for geotechnical design. The movement required to allow active pressures to develop within the backfill, and



thereby assume an unrestrained structure for design, should be calculated in accordance with Section C6.9.1 and Table C6.6 of the Commentary to the CHBDC.

6.8 Culvert Construction Considerations

6.8.1 Excavation, Subgrade Preparation, Bedding and Backfill above Base of Culvert

Construction of the pre-cast concrete box culvert with respect to excavation, bedding, backfilling and cover materials, should be carried out in accordance with OPSS 422 (Concrete Box Culverts and Box Sewers in Open Cut).

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.

Based on the results of the stability analysis discussed in Section 6.3, we recommend that the staged excavations through the existing embankment for culvert replacement be restricted such that 1.5H:1V front slopes (parallel to the highway, towards the culvert) and 2H:1V side slopes (perpendicular to the highway) are used at this site. A sample Non-Standard Special Provision (NSSP) to address this requirement is included in Appendix C.

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. To limit degradation of the foundations area, 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 NSSP to address this requirement is included in Appendix C.

For a cast-in-place box culvert replacement, 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 OPSS.PROV 1010 (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 (i.e., with an excavator shovel) should achieve a density of 90 per cent of the Standard Proctor Maximum Dry Density. 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 thickness 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 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.



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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.

The new granular fill placed within the excavation across the embankment should be keyed into the existing fill as per OPSD 208.010 (Benching of Earth Slopes). Fill for reconstruction of the embankment could consist of the material excavated from the embankment except for the material placed against the culvert walls and the initial cover over the culvert roof, provided that the excavated material can be properly compacted consistent with accepted standard for roadway embankment construction.

As the existing embankment is up to 10 m high, and may be raised slightly, present practice by MTO is to include a 2 m wide bench in the embankment slope geometry such that the uninterrupted slope height is not greater than 8 m for an earth embankment (and 10 m high for a rock fill embankment), as per OPSD 202.010 (Slope Flattening). The embankment side slopes should be re-constructed such as to incorporate a bench in the side slopes where the embankment height is greater than 8 m. Further, the upper portion of the slope should be configured in such a way that any new fill for widening of the embankment, if required, will not 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.

6.8.2 Temporary Shoring

Temporary protection systems would be required to support the embankment fill during the culvert replacement if the construction is carried out in stages and the highway continues in operation during the construction period. The temporary support systems could consist of driven steel sheet piling.

Based on foundation investigations at other culverts along Highway 17 in this area, cobbles and/or boulders may be present within the embankment fill and the Contractor should be alerted to the potential presence of these obstructions; an example NSSP (or Notice to Contractor) to be included in the Contract Documents is presented in Appendix C.

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.

The design of the shoring 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:

$$p = K_a (\gamma H + q)$$



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where H = the depth of the excavation at any point (m)
 K_a = active coefficient of earth pressure
 γ = soil unit weight (kN/m^3)
 q = surcharge for traffic and other loading (kN/m^2)

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:

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

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:

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

The support systems may be designed using the following parameters:

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 Silty Clay	0.37	0.55	2.7	27	17	30 at Elev 200 m to 60 kPa at Elev 191 m
Silt, Sand and Silt, Sand	0.36	0.53	2.8	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.



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 and 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 (of natural clay or a soil-bentonite mix) may be constructed extending upstream three times the culvert height and along the adjacent slopes to a height of two 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 culvert replacement and wing walls will require the removal of organics (where encountered), existing fill, and native soils prior to the placement of bedding material, and construction of the box culvert 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.

Dewatering of the excavation for cast-in-place concrete if adopted for culvert replacement, will be required to allow for construction in-the-dry. The excavation 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

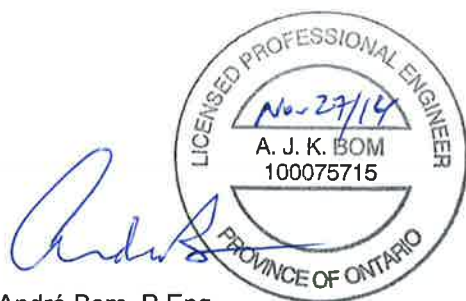
This report was prepared by Mr. André Bom, P.Eng. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and a Principal with Golder, conducted an independent quality control review of the report.



FOUNDATION REPORT HIGHWAY 17 BIQUETTE CREEK CULVERT

Report Signature Page

GOLDER ASSOCIATES LTD.



André Bom, P.Eng
Geotechnical Engineer



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

AB/JMAC/kp

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\\golder.gds\gal\whitby\active\2013\1184 pavement and materials\13-1184-0074 mh hwy 17 warren to verner\1191-foundation\reporting\final\r03 - biquette\13-1184-0074-r3 rpt 14nov27
final fdr biquette creek.docx



FOUNDATION REPORT HIGHWAY 17 BIQUETTE CREEK CULVERT

REFERENCES

- Bjerrum, L., 1973. Problems of Soil Mechanics and Construction of Soft Clays and Structurally Unstable Soils. State of the Art Report, Session 4. Proceedings, 8th International Conference on Soil Mechanics and Foundation Engineering, Moscow, Vol. 3, pp. 111-159.
- 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.
- Unified Facilities Criteria, NAVFAC Design Manual, DM-7.2. Soil Mechanics, Foundation and Earth Structures. U.S. Navy, 1982, Alexandria, Virginia.
- Ontario Geological Survey. Southern Ontario Engineering Geology Terrain Study, 1980.

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 7.23) by Geo-Slope International Ltd.

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 202.010	Slope Flattening Using Surplus Excavated Material on Earth or Rock Fill Embankment
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 3101.150	Walls, Abutment, Backfill
OPSD 3121.150	Walls, Retaining, Backfill, Minimum Granular Requirement

Ontario Provincial Standard Specification

OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
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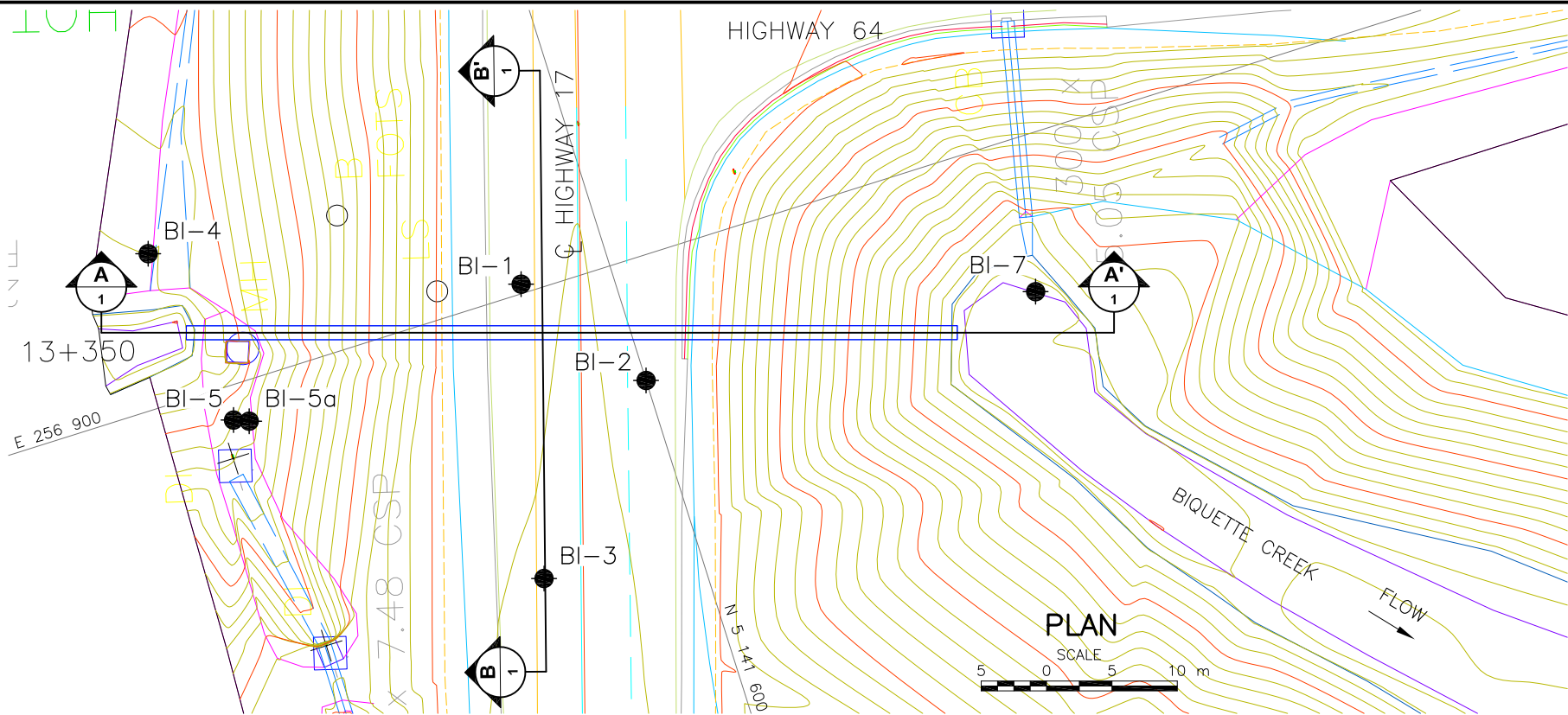


FOUNDATION REPORT HIGHWAY 17 BIQUETTE CREEK CULVERT

OPSS 501	Construction Specification for Compacting
OPSS 539	Construction Specification for Temporary Protection Systems
OPSS.PROV1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material
OPSS 1205	Clay Seal

Ontario Water Resources Act

Ontario Regulation 372/97 Amendment to Ontario Regulation 903



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

CONT No.
GWP No. 300-98-00



HIGHWAY 17
BIQUETTE CREEK CULVERT - STA 13+350
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA



KEY PLAN
SCALE
8 0 8 km

LEGEND

- Borehole - Current Investigation
- 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
BI-1	210.4	5141606.9	256900.7
BI-2	210.4	5141600.0	256890.8
BI-3	210.5	5141612.0	256878.7
BI-4	201.4	5141633.4	256911.5
BI-5	201.7	5141631.0	256897.4
BI-5a	201.7	5141629.9	256897.0
BI-7	200.9	5141569.5	256888.3

NOTES

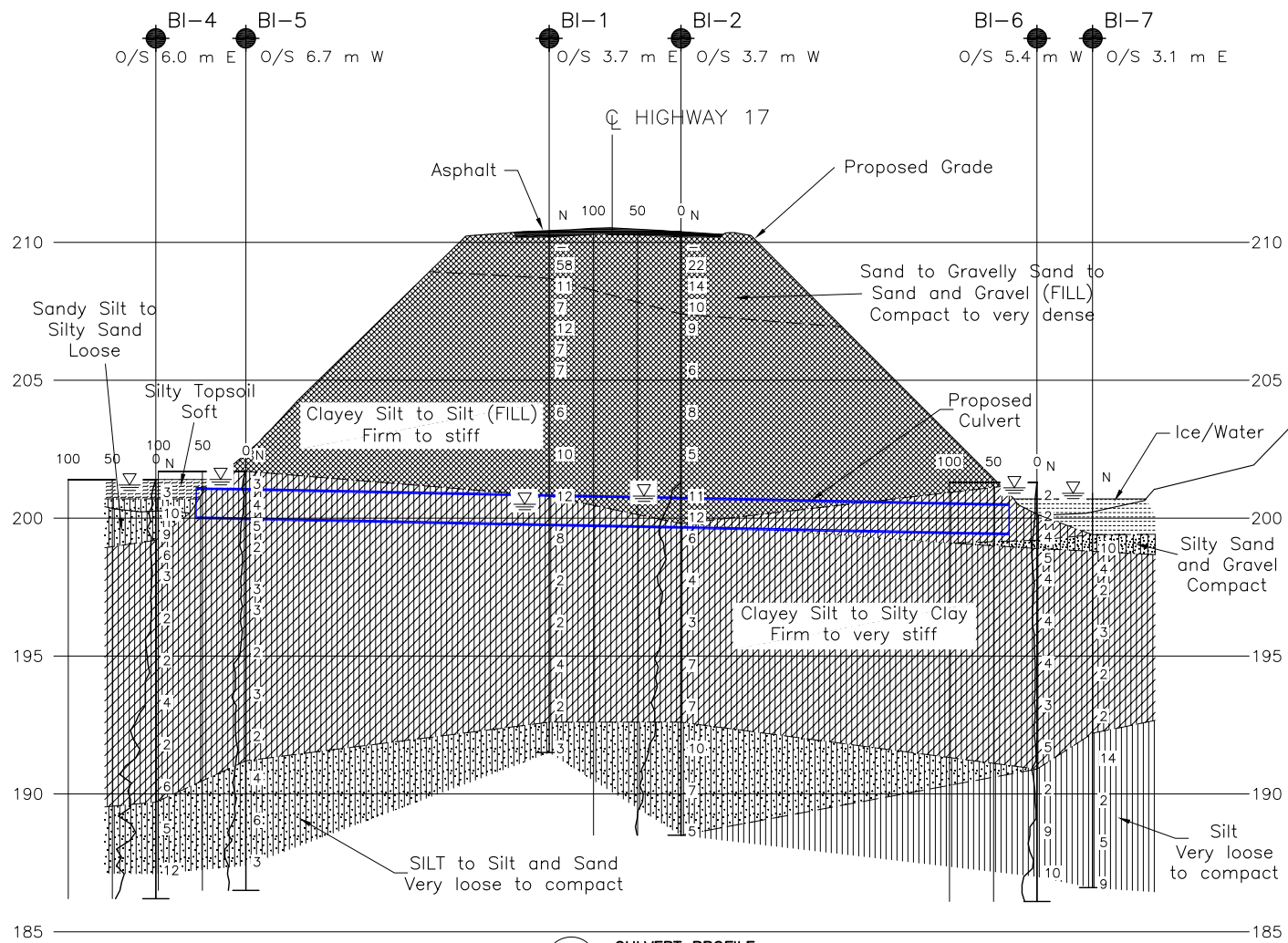
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

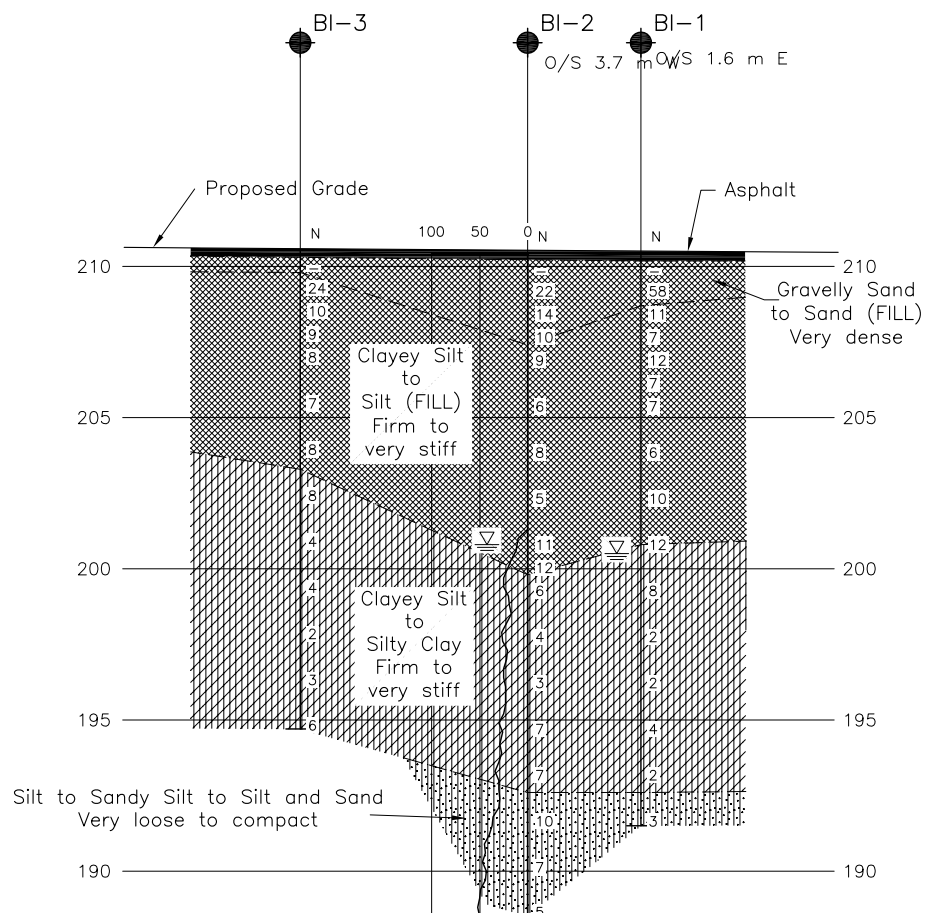
Base plans provided in digital format by Morrison Hershfield, drawing file no. wp3009800a.dwg, received APR 7, 2014 and Biquette Creek Culvert and 11+600 culvert.dwg received on NOV 05, 2014.



A-A'
1
CULVERT PROFILE
HIGHWAY 17
HORIZONTAL SCALE
5 0 5 10 m
2.5 0 2.5 5 m
VERTICAL SCALE



B-B'
1
CROSS-SECTION
HIGHWAY 17
HORIZONTAL SCALE
5 0 5 10 m
2.5 0 2.5 5 m
VERTICAL SCALE

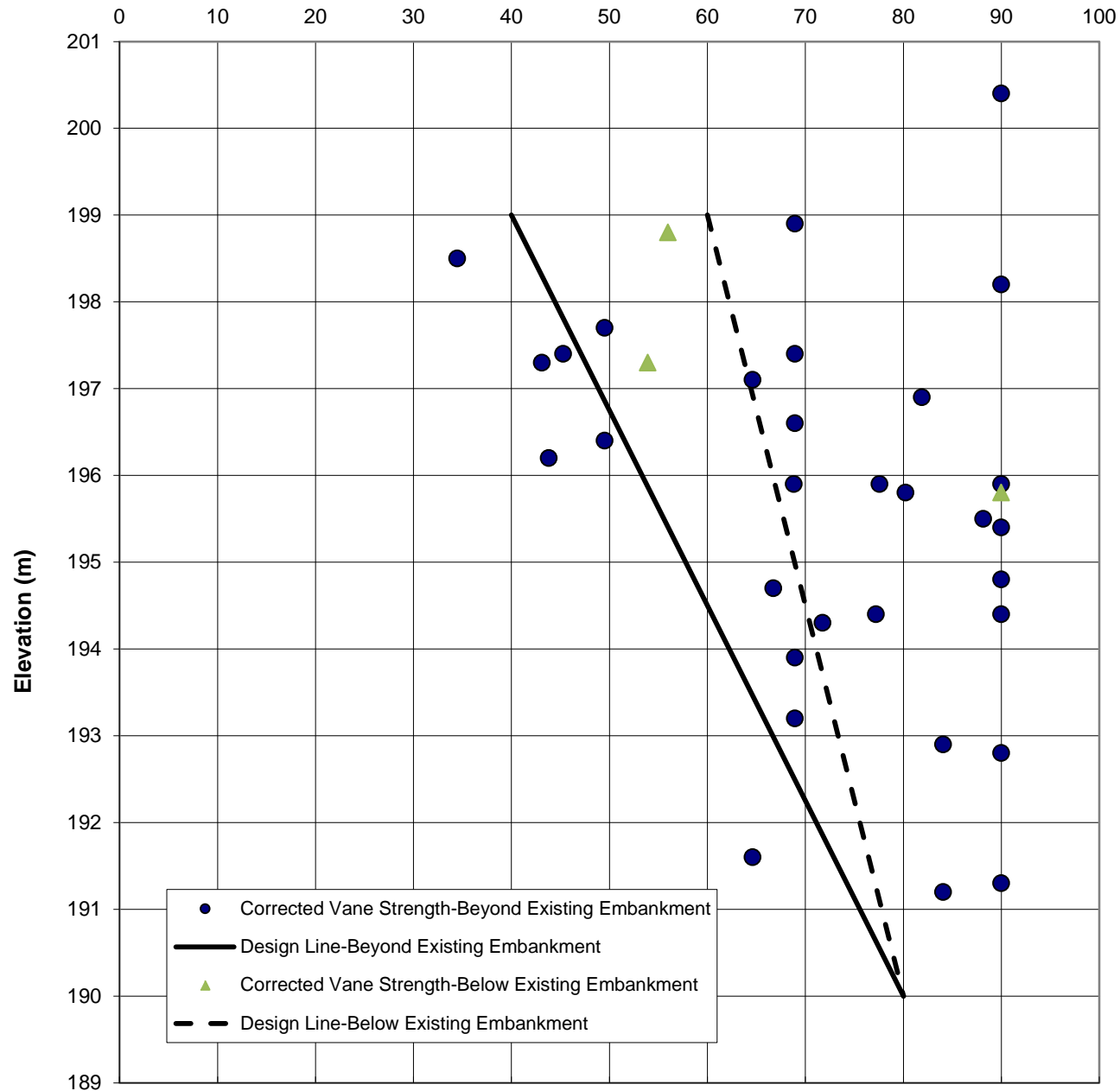


NO.	DATE	BY	REVISION
1	2014-11-05	J.M.A. COSTA	1

Geocres No. 411-316

HWY. 17	PROJECT NO. 13-1184-0074	DIST.
SUBM'D. MT	CHKD. AB	DATE: NOV 2014
DRAWN: TB	CHKD. AB	APPD. JMAC
		SITE: 43-165/C
		DWG. 1

**Undrained Shear Strength (kPa)
(Corrected for Bjerrum and Silt Laminations)**



PROJECT			
HIGHWAY 17 – Biquette Creek Culvert			
TITLE			
SUMMARY PLOT OF UNDRAINED SHEAR STRENGTH			
PROJECT No. 13-1184-0074		FILE No. ----	
DESIGN	--	SCALE	AS SHOWN
CADD	--	REV.	
CHECK	AB	Nov 2014	
REVIEW	JMAC	Nov 2014	
Golder Associates			FIGURE 1

New Granular FillUnit Weight: 21 kN/m³

Phi: 35 °

Clayey Silt to Silty Clay (Beyond Embankment)Unit Weight: 17 kN/m³

Cohesion: 40 kPa to 80 kPa

Rate of Change: 4.4 kPa/m

Silt to Silt and SandUnit Weight: 19 kN/m³

Phi: 30 °

Silty SandUnit Weight: 19 kN/m³

Phi: 28 °

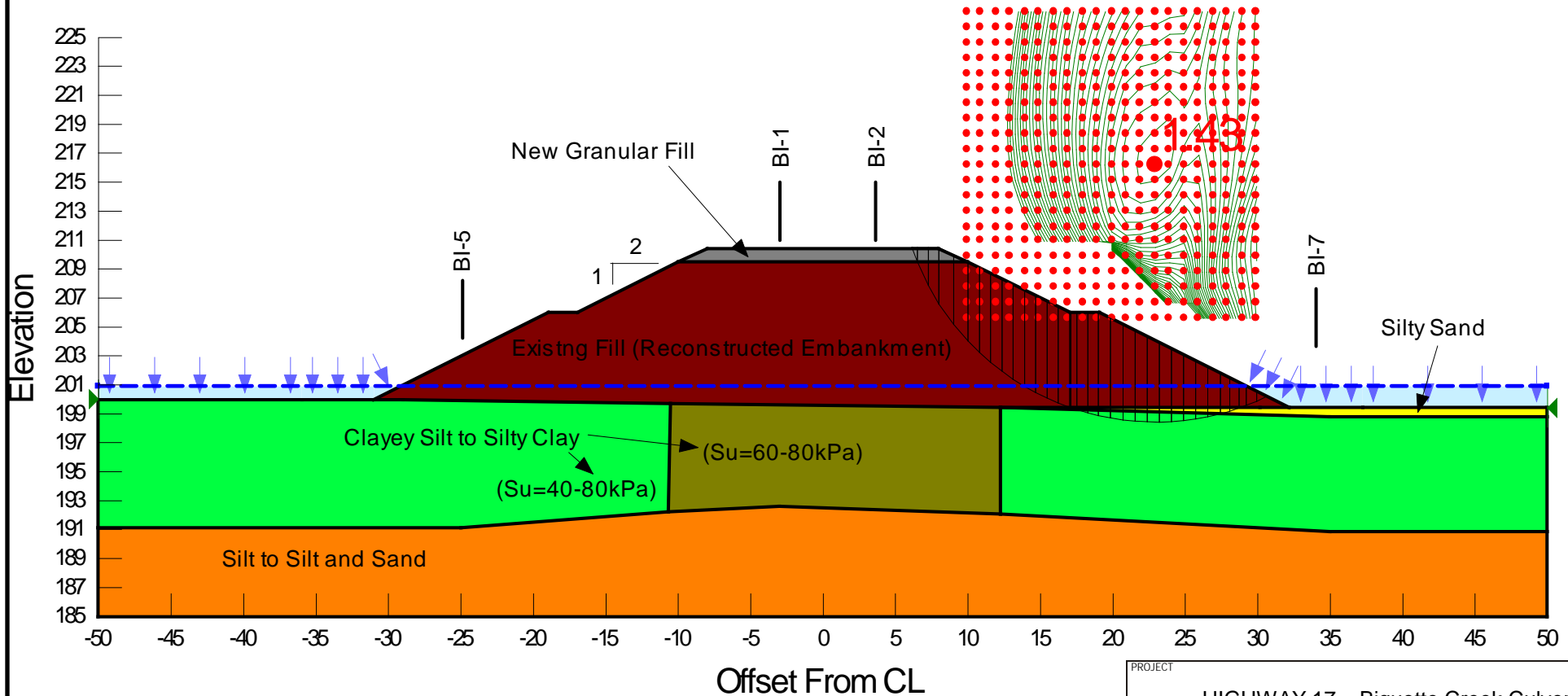
Existing Fill (Reconstructed Embankment)Unit Weight: 20 kN/m³

Phi: 30 °

Clayey Silt to Silty Clay (Below Embankment)Unit Weight: 17 kN/m³

Cohesion: 60 kPa to 80 kPa

Rate of Change: 8.9 kPa/m



PROJECT

HIGHWAY 17 – Biquette Creek Culvert

TITLE

**STABILITY ANALYSIS
EMBANKMENT SOUTH SIDE SLOPE**



PROJECT No. 13-1184-0074		FILE No. ----	
DESIGN	--	SCALE	AS SHOWN
CADD	--	REV.	
CHECK	AB	Nov 2014	
REVIEW	JMAC	Nov 2014	

FIGURE 2



FOUNDATION REPORT HIGHWAY 17 BIQUETTE CREEK CULVERT

APPENDIX A

Record of Boreholes



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
FoS	factor of safety

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

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

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



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
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
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) Non-Cohesive (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


Per cent 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 (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand

PROJECT 13-1184-0074				RECORD OF BOREHOLE No BI-1				1 OF 2 METRIC						
G.W.P. 300-98-00				LOCATION N 5141606.9; E 256900.7				ORIGINATED BY SA						
DIST _____ HWY 17				BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers				COMPILED BY MT						
DATUM GEODETIC				DATE November 27, 2013				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						
210.4	GROUND SURFACE													
0.0	ASPHALT (225 mm)													
0.2	Gravelly sand to sand, trace silt (FILL) Very dense Brown Moist		1	AS	-		210							
			2	SS	58		209							
208.7			3a	SS	11									
1.7	Clayey silt to silt, occasional organic pockets (FILL) Firm to stiff Brown to grey Moist		3b				208							
			4	SS	7									
			5	SS	12		207							
			6	SS	7		206							
			7	SS	7		205							
			8	SS	6		204							
			9	SS	10		203							
			10	SS	12		202							
200.8							201							
9.6	CLAYEY SILT to SILTY CLAY, silt laminations Firm to stiff Grey Wet		11	SS	8		200							
			12	SS	2		199							
			13	SS	2		198							
							197							
							196							

Continued Next Page

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

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 19/11/14 DATA INPUT:

PROJECT <u>13-1184-0074</u>		RECORD OF BOREHOLE No BI-1				2 OF 2 METRIC													
G.W.P. <u>300-98-00</u>		LOCATION <u>N 5141606.9; E 256900.7</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>MT</u>													
DATUM <u>GEODETIC</u>		DATE <u>November 27, 2013</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							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%)						
								20	40	60	80	100	20	40	60				
192.6	CLAYEY SILT to SILTY CLAY, silt laminations Firm to stiff Grey Wet		14	SS	4		195												
							194												
			15	SS	2		193												
17.8	SILT and SAND, some clay Very loose Grey Wet						192												
191.5			16	SS	3											NP	0 38 49 13		
18.9	END OF BOREHOLE Note: 1. Water level at a depth of 9.9 m below ground surface (Elev. 200.5 m) upon completion of drilling.																		

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

PROJECT 13-1184-0074		RECORD OF BOREHOLE No BI-2				2 OF 2 METRIC							
G.W.P. 300-98-00		LOCATION N 5141600.0; E 256890.8				ORIGINATED BY SA							
DIST _____ HWY 17		BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers				COMPILED BY MT							
DATUM GEODETIC		DATE November 28 and 29, 2013				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 WATER CONTENT (%)					
192.6	CLAYEY SILT, trace to some sand, silt laminations Stiff to very stiff Grey Wet		14	SS	7								1 10 64 25
			15	SS	7								
17.8	SILT to SAND, trace to some clay Loose to compact Grey Wet		16	SS	10								0 60 32 8
			17	SS	7								
			18	SS	5								0 5 79 16
188.5	END OF BOREHOLE												
21.9	Note: 1. Water level at a depth of 9.6 m below ground surface (Elev. 200.8 m) upon completion of drilling. 2. Pre-drilled hole to 9.2 m depth immediately adjacent to Borehole BI-2 and advanced DCPT from 9.2 m to 21.9 m.												

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 19/11/14 DATA INPUT:

PROJECT 13-1184-0074				RECORD OF BOREHOLE No BI-3				1 OF 2 METRIC						
G.W.P. 300-98-00				LOCATION N 5141612.0; E 256878.7				ORIGINATED BY SA						
DIST _____ HWY 17				BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers				COMPILED BY MT						
DATUM GEODETIC				DATE December 3, 2013				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	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
210.5	GROUND SURFACE							20 40 60 80 100	20 40 60					
0.0	ASPHALT (225 mm)													
0.2	Gravelly sand, some silt (FILL)		1	AS	-		210							23 59 (18)
209.8	Brown Moist													
0.7	Clayey silt to silt, trace sand (FILL)		2	SS	24		209							
	Firm to very stiff													
	Grey Moist		3	SS	10		208							
			4	SS	9		207							
			5	SS	8		206							
			6	SS	7		205							
			7	SS	8		204							
203.3	CLAYEY SILT, some sand, silt laminations		8	SS	8		203							
7.2	Stiff to very stiff													
	Grey Wet		9	SS	4		202							
			10	SS	4		201							
							200							
			11	SS	2		199							
							198							
			12	SS	3		197							
							196							

Continued Next Page

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

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 19/11/14 DATA INPUT:



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

SSUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 19/11/14 DATA INPUT:

PROJECT 13-1184-0074			RECORD OF BOREHOLE No BI-4			1 OF 2 METRIC											
G.W.P. 300-98-00			LOCATION N 5141633.4; E 256911.5			ORIGINATED BY MR											
DIST _____ HWY 17			BOREHOLE TYPE NW Casing, Wash Boring			COMPILED BY MT											
DATUM GEODETIC			DATE February 20, 2014			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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED			WATER CONTENT (%) W _p W W _L			γ	GR SA SI CL		
201.4	GROUND SURFACE							20 40 60 80 100									
0.0	Silty TOPSOIL Very loose Brown Wet		1	SS	3		201										
200.7	Sandy SILT to Silty SAND, trace to some clay Loose Brown to grey Wet		2	SS	10		200										
			3	SS	9		199										
199.2	Sandy CLAYEY SILT to SILTY CLAY, silt laminations Firm to very stiff Grey Wet		4	SS	6		198										
			5	SS	3		197										
			6	SS	2		196										
			7	SS	2		195										0 1 42 57
			8	SS	4		194										
			9	SS	2		193										
			10	SS	6		192										
			11	SS	5		191										0 22 60 18
189.7	SILT and SAND, trace to some clay Loose to compact Grey Wet		12	SS	12		190										
187.1	END OF BOREHOLE						189										
14.3							188										
							187										0 38 52 10

Continued Next Page

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

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 19/11/14 DATA INPUT:



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

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 19/11/14 DATA INPUT:

PROJECT 13-1184-0074			RECORD OF BOREHOLE No BI-5			1 OF 2 METRIC											
G.W.P. 300-98-00			LOCATION N 5141631.0; E 256897.4			ORIGINATED BY MR											
DIST HWY 17			BOREHOLE TYPE NW Casing, Wash Boring			COMPILED BY MT											
DATUM GEODETIC			DATE February 12 and 13, 2014			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	20 40 60 80 100	20 40 60 80 100	W _p	W	W _L	γ	GR	SA	SI	CL
201.7	GROUND SURFACE																
0.0	CLAYEY SILT to SILTY CLAY Firm to very stiff Grey to brown Wet		1	SS	3		201										
			2	SS	4		200										0 5 71 24
			3	SS	5		199										
	Silt laminations below 2.3 m depth.		4	SS	2		198										
			5	SS	3		197										
			6	SS	3		196										
			7	SS	2		195										0 2 50 48
			8	SS	3		194										
			9	SS	2		193										
			10	SS	4		192										
191.2	SILT to SILT and SAND, some clay Very loose to loose Grey Wet		11	SS	6		189										0 13 72 15
10.5			12	SS	3		188										
187.4	END OF BOREHOLE						187										

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 19/11/14 DATA INPUT:

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



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

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 19/11/14 DATA INPUT:

PROJECT 13-1184-0074			RECORD OF BOREHOLE No BI-5a			1 OF 1 METRIC											
G.W.P. 300-98-00			LOCATION N 5141629.9; E 256897.0			ORIGINATED BY MR											
DIST _____ HWY 17			BOREHOLE TYPE NW Casing, Wash Boring			COMPILED BY MT											
DATUM GEODETIC			DATE February 12 and 13, 2014			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 kN/m ³	GR SA SI CL
							20 40 60 80 100	20 40 60 80 100	W _p	W	W _L	20 40 60					
201.7 0.0	GROUND SURFACE CLAYEY SILT to SILTY CLAY Firm to very stiff Grey to brown Wet						201										
							200										
							199										
	Silt laminations about 2 mm to 5 mm thick, spaced 5 mm to 20 mm apart in Samples 1 and 2.		1	TO	PH		198									0 3 63 34	
							197										
			2 (s) 2 (c)	TO	PH		196										
							195										
	No recovery in Sample 3.		3	TO	PH		194										
	No recovery in Sample 4.		4	TO	PH												
193.5 8.2	END OF BOREHOLE Note: 1. Borehole advanced 1.2 m south of Borehole BI-5.																

PROJECT 13-1184-0074			RECORD OF BOREHOLE No BI-6			1 OF 2 METRIC											
G.W.P. 300-98-00			LOCATION N 5141575.9; E 256881.4			ORIGINATED BY MR											
DIST _____ HWY 17			BOREHOLE TYPE NW Casing, Wash Boring			COMPILED BY MT											
DATUM GEODETIC			DATE February 24, 2014			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	20 40 60 80 100	20 40 60	W _p W W _L	γ	GR SA SI CL					
201.3	GROUND SURFACE																
0.0	Sandy SILTY CLAY, trace organics Soft Grey Wet		1	SS	2		201										
			2	SS	2		200				OC=3.5%	0 22 62 16					
199.2			3	SS	4												
198.9	Silty SAND and GRAVEL Grey Wet		4	SS	5		199										
2.4	SILTY CLAY, trace sand, silt laminations Firm to very stiff Grey Wet		5	SS	4		198										
							197	2									
			6	SS	4		196										
							195	3									
			7	SS	4		194										
							193	3									
			8	SS	3		192										
							191	4									
			9	SS	5		190										
190.9	SILT, some clay, some sand Very loose to compact Grey Wet		10	SS	2		189										
10.4	Silty clay laminations encountered below 10.4 m depth.						188										
			11	SS	9		187										
187.0	END OF BOREHOLE		12	SS	10												
14.3																	

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 19/11/14 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

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 19/11/14 DATA INPUT:

PROJECT 13-1184-0074			RECORD OF BOREHOLE No BI-7			1 OF 1 METRIC														
G.W.P. 300-98-00			LOCATION N 5141569.5; E 256888.3			ORIGINATED BY MR														
DIST _____ HWY 17			BOREHOLE TYPE NW Casing, Wash Boring			COMPILED BY MT														
DATUM GEODETIC			DATE February 23, 2014			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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%) W _p — W — W _L			γ	GR	SA	SI	CL
200.9	ICE SURFACE							20	40	60	80	100	20	40	60					
0.0	ICE																			
0.2	WATER																			
199.4							200													
1.5	Silty SAND, trace gravel Compact Grey Wet		1	SS	10		199													
198.8																				
2.1	CLAYEY SILT to SILTY CLAY, trace sand Stiff to very stiff Grey Wet		2	SS	4		198													
			3	SS	2		197													
	Silt laminations encountered below 4.6 m depth.		4	SS	3		196													
			5	SS	2		195													
							194													
			6	SS	2		193													
192.2							192													
8.7	SILT, some clay, trace to some sand Very loose to compact Grey Wet		7	SS	14		191													
			8	SS	2		190													
			9	SS	5		189													
							188													
			10	SS	9		187													
186.6																				
14.3	END OF BOREHOLE																			

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 19/11/14 DATA INPUT:

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



APPENDIX B

Laboratory Test Results



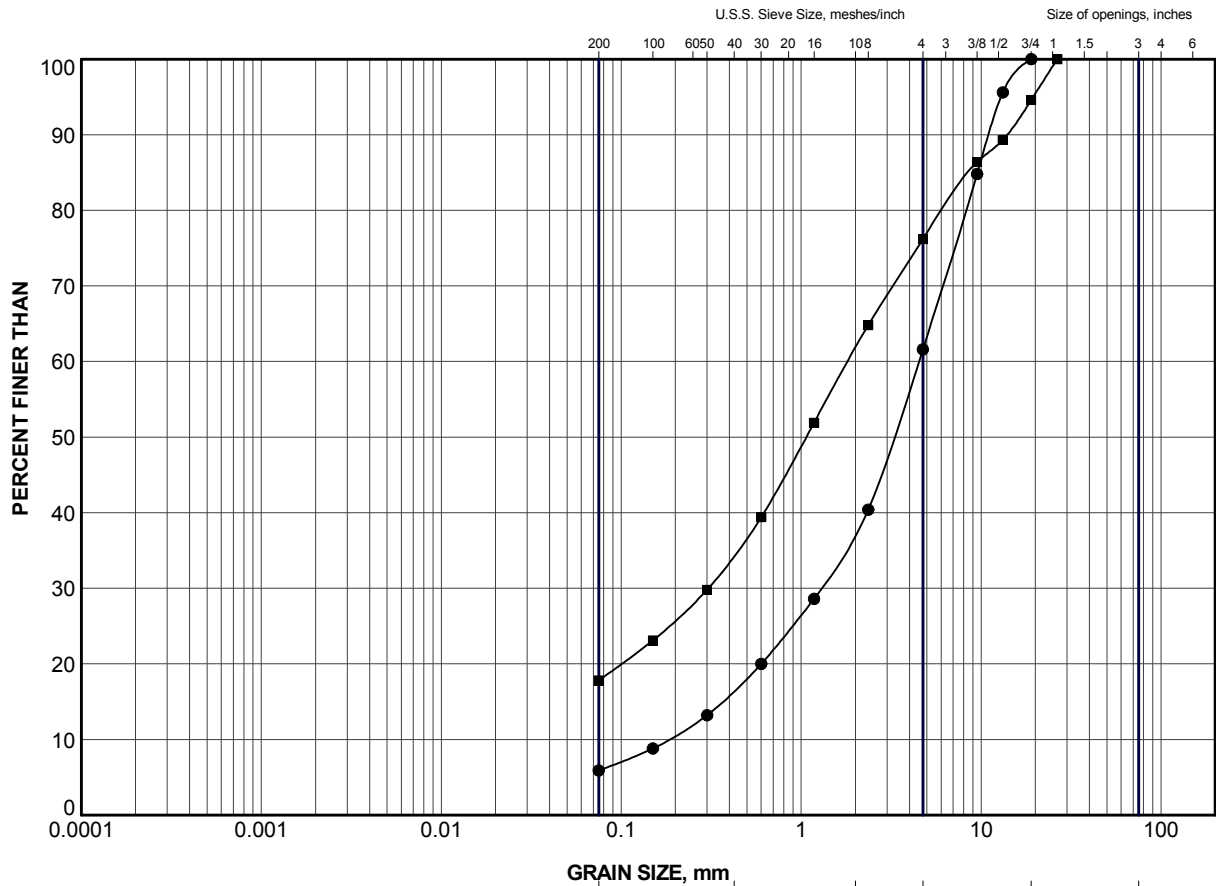
FOUNDATION INVESTIGATION AND DESIGN REPORT HIGHWAY 17 BIQUETTE CREEK CULVERT

Table B1 - Summary of Analytical Testing of Biquette Creek Water Sample

Parameter	Units	Reportable Detection Limit	Result
Dissolved Chloride	mg/L	1	5
Dissolved Sulphate	mg/L	1	Not Detected
Conductivity	µohm/cm	1	71
Resistivity	ohm-cm	n/a	14,000
pH	n/a	n/a	6.97

- Notes:
1. Sample obtained on March 10, 2014.
 2. Analytical testing carried out by Maxxam Analytics.


Checked by: AB

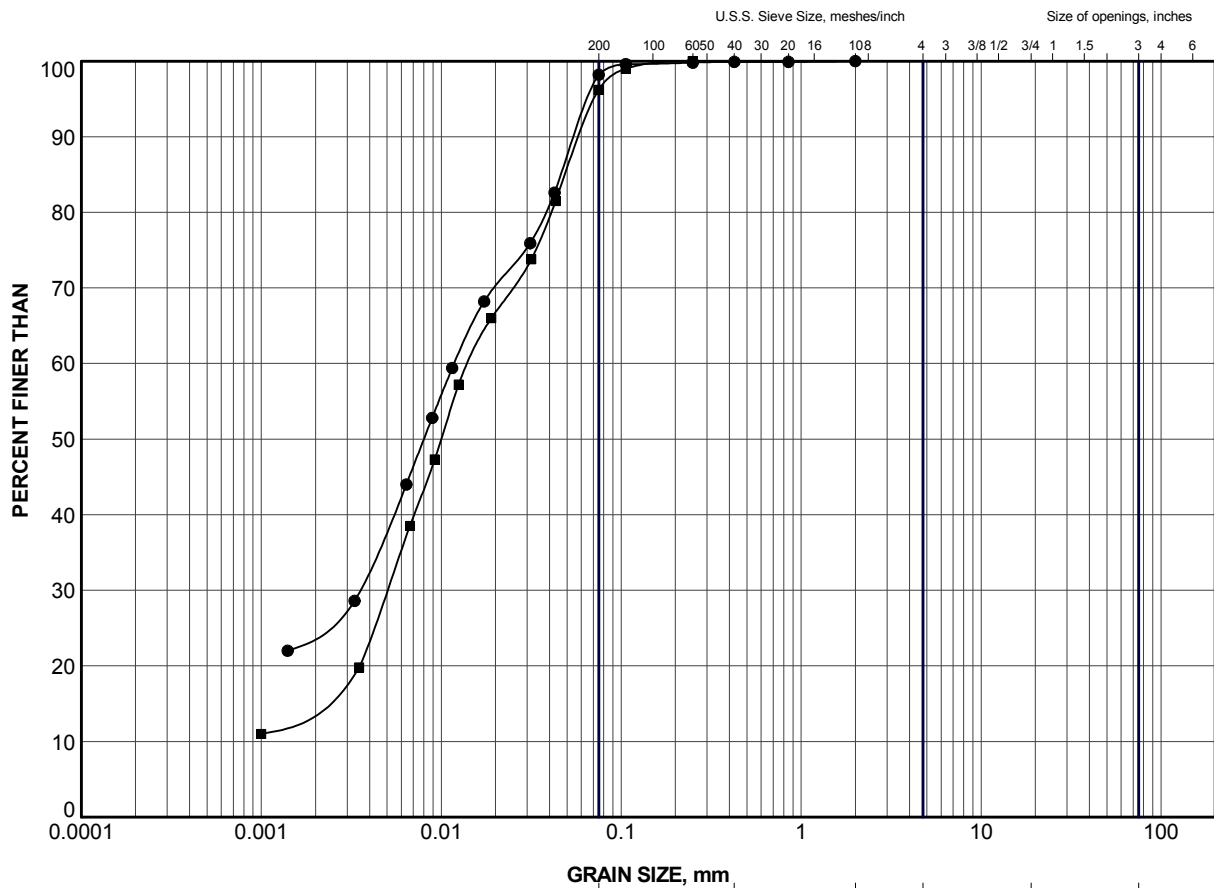


CLAY AND SILT	GRAIN SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BI-2	3	208.6
■	BI-3	1	210.1

PROJECT					HIGHWAY 17 BIQUETTE CREEK CULVERT - STA 13+350				
TITLE					GRAIN SIZE DISTRIBUTION SAND and GRAVEL to GRAVELLY SAND (FILL)				
PROJECT No.		13-1184-0074			FILE No.		13-1184-0074.GPJ		
DRAWN	TB	Jun 2014			SCALE	N/A	REV.		
CHECK	AB	Jun 2014			FIGURE B1				
APPR	JMAC	Jun 2014							
 Golder Associates SUDBURY, ONTARIO									



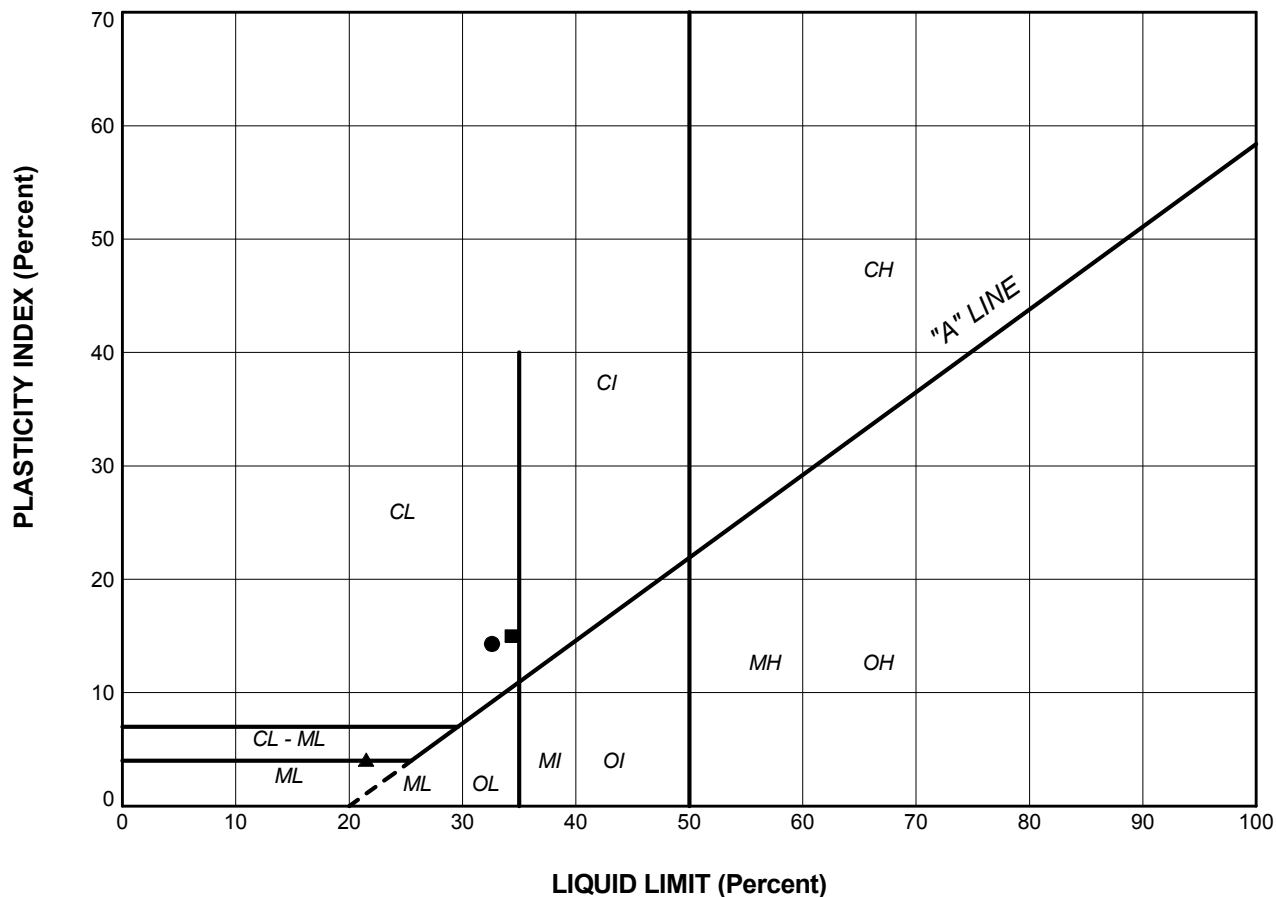
GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BI-1	4	207.8
■	BI-3	6	205.6


PROJECT					
HIGHWAY 17 BIQUETTE CREEK CULVERT - STA 13+350					
TITLE					
GRAIN SIZE DISTRIBUTION SILT to CLAYEY SILT (FILL)					
PROJECT No.		13-1184-0074		FILE No. 13-1184-0074.GPJ	
DRAWN	TB	Jun 2014	SCALE	N/A	REV.
CHECK	AB	Jun 2014	FIGURE B2		
APPR	JMAC	Jun 2014			

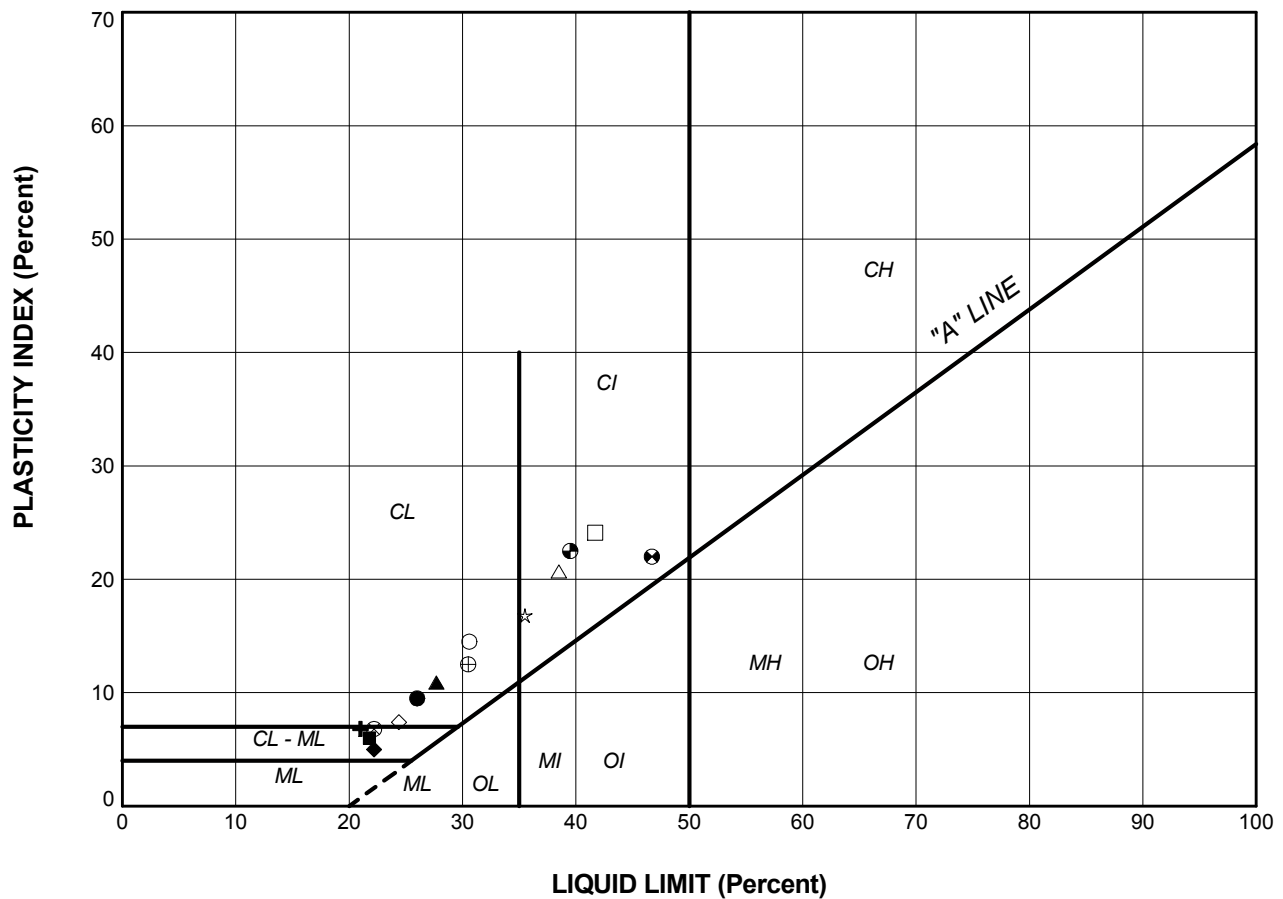




LEGEND


SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	BI-1	4	32.6	18.3	14.3
■	BI-2	8	34.3	19.3	15.0
▲	BI-3	6	21.5	17.4	4.1

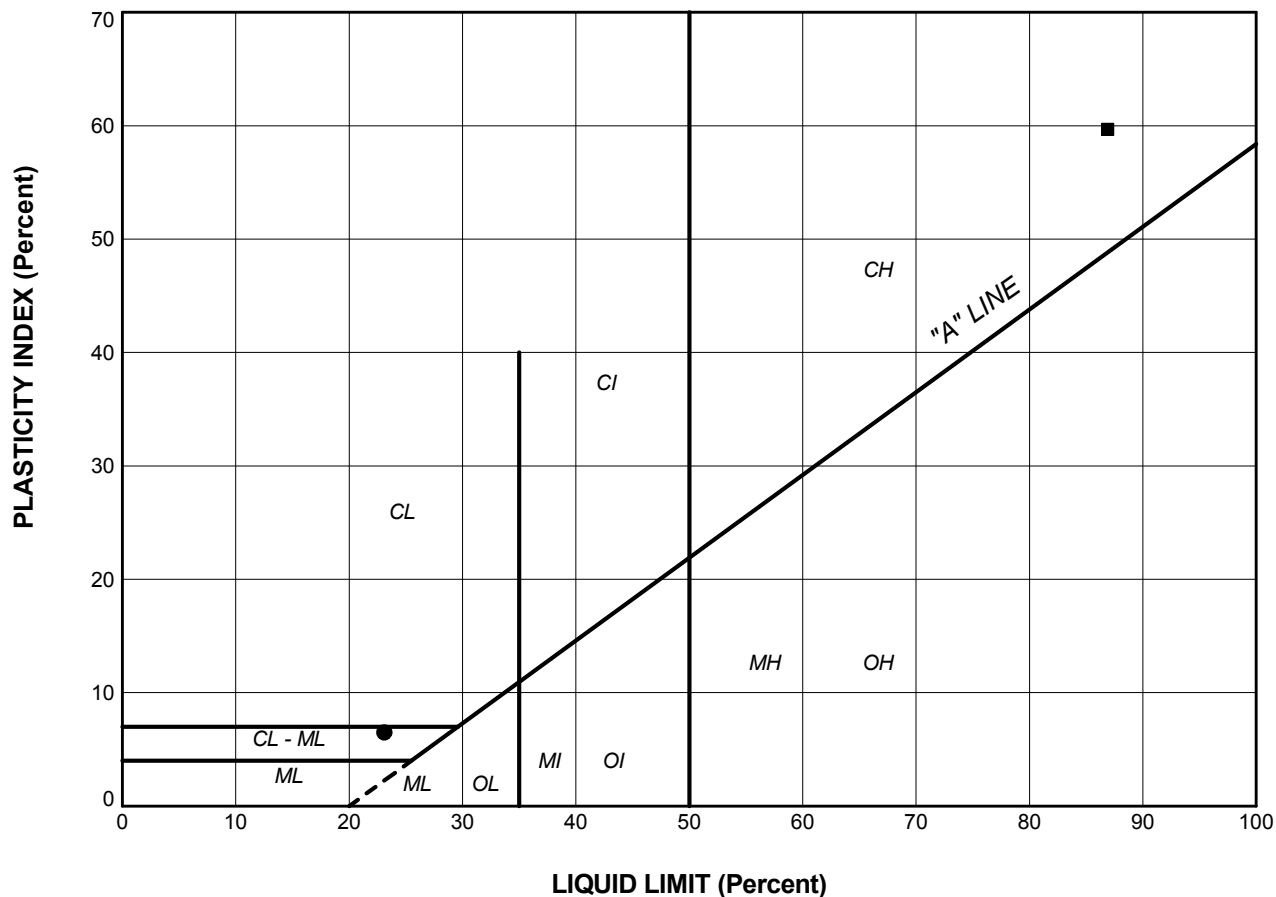
PROJECT					
HIGHWAY 17 BIQUETTE CREEK CULVERT - STA 13+350					
TITLE					
PLASTICITY CHART SILT to CLAYEY SILT (FILL)					
PROJECT No.		13-1184-0074		FILE No.	
DRAWN		TB		Jun 2014	
CHECK		AB		Jun 2014	
APPR		JMAC		Jun 2014	
 Golder Associates SUDBURY, ONTARIO				SCALE N/A REV.	
FIGURE B3					



LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	BI-1	12	26.0	16.5	9.5
■	BI-2	11	21.8	15.8	6.0
▲	BI-2	13	27.7	16.8	10.9
+	BI-2	14	21.0	14.2	6.8
◆	BI-3	9	22.2	17.2	5.0
◇	BI-3	10	24.4	17.0	7.4
○	BI-3	12	30.6	16.1	14.5
△	BI-4	7	38.5	17.8	20.7
⊗	BI-4	10	22.2	15.4	6.8
⊕	BI-5	2	30.5	18.0	12.5
□	BI-5	7	41.7	17.6	24.1
⊗	BI-6	2	46.7	24.7	22.0
⊕	BI-6	7	39.5	17.0	22.5
☆	BI-7	4	35.5	18.7	16.8

PROJECT					
HIGHWAY 17 BIQUETTE CREEK CULVERT - STA 13+350					
TITLE					
PLASTICITY CHART CLAYEY SILT to SILTY CLAY					
PROJECT No.		13-1184-0074		FILE No.	
DRAWN		TB		Jun 2014	
CHECK		AB		Jun 2014	
APPR		JMAC		Jun 2014	
 Golder Associates SUDBURY, ONTARIO				SCALE N/A REV.	
FIGURE B4.1					



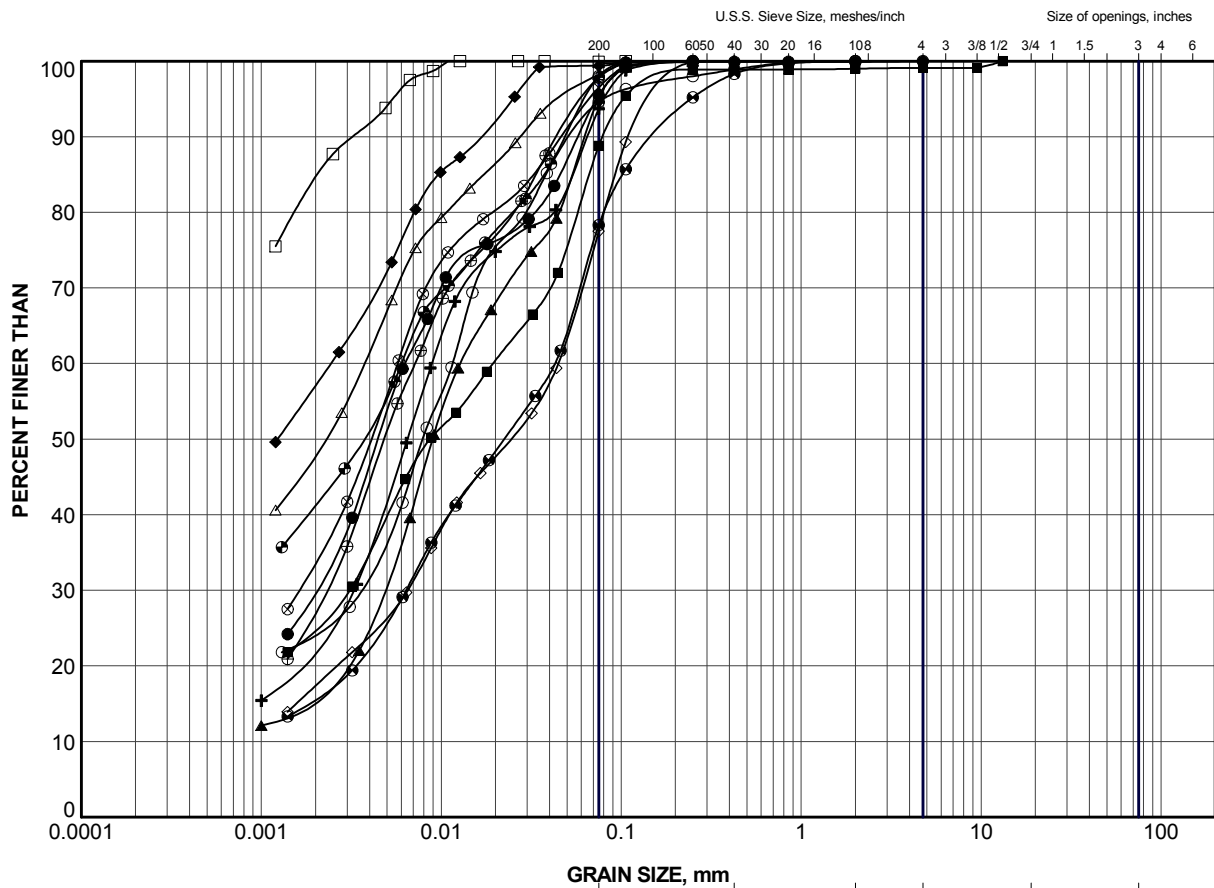
LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	BI-5a	2 (s)	23.1	16.6	6.5
■	BI-5a	2 (c)	86.9	27.2	59.7

Note:
 (s) silt lamina
 (c) clay lamina

PROJECT					
HIGHWAY 17 BIQUETTE CREEK CULVERT - STA 13+350					
TITLE					
PLASTICITY CHART SILT and CLAY LAMINAE					
PROJECT No.		13-1184-0074		FILE No.	
DRAWN		TB		Jun 2014	
CHECK		AB		Jun 2014	
APPR		JMAC		Jun 2014	
SCALE		N/A		REV.	
FIGURE B4.2					





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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BI-1	12	197.9
■	BI-2	14	194.9
▲	BI-3	9	201.1
+	BI-3	10	199.5
◆	BI-4	7	195.0
◇	BI-4	10	190.4
○	BI-5	2	200.6
△	BI-5	7	195.3
⊗	BI-5a	1	198.4
⊕	BI-5a	2 (s)	197.0
□	BI-5a	2 (c)	196.9
⊙	BI-6	2	200.2
⊖	BI-6	7	194.9

PROJECT

HIGHWAY 17
BIQUETTE CREEK CULVERT - STA 13+350

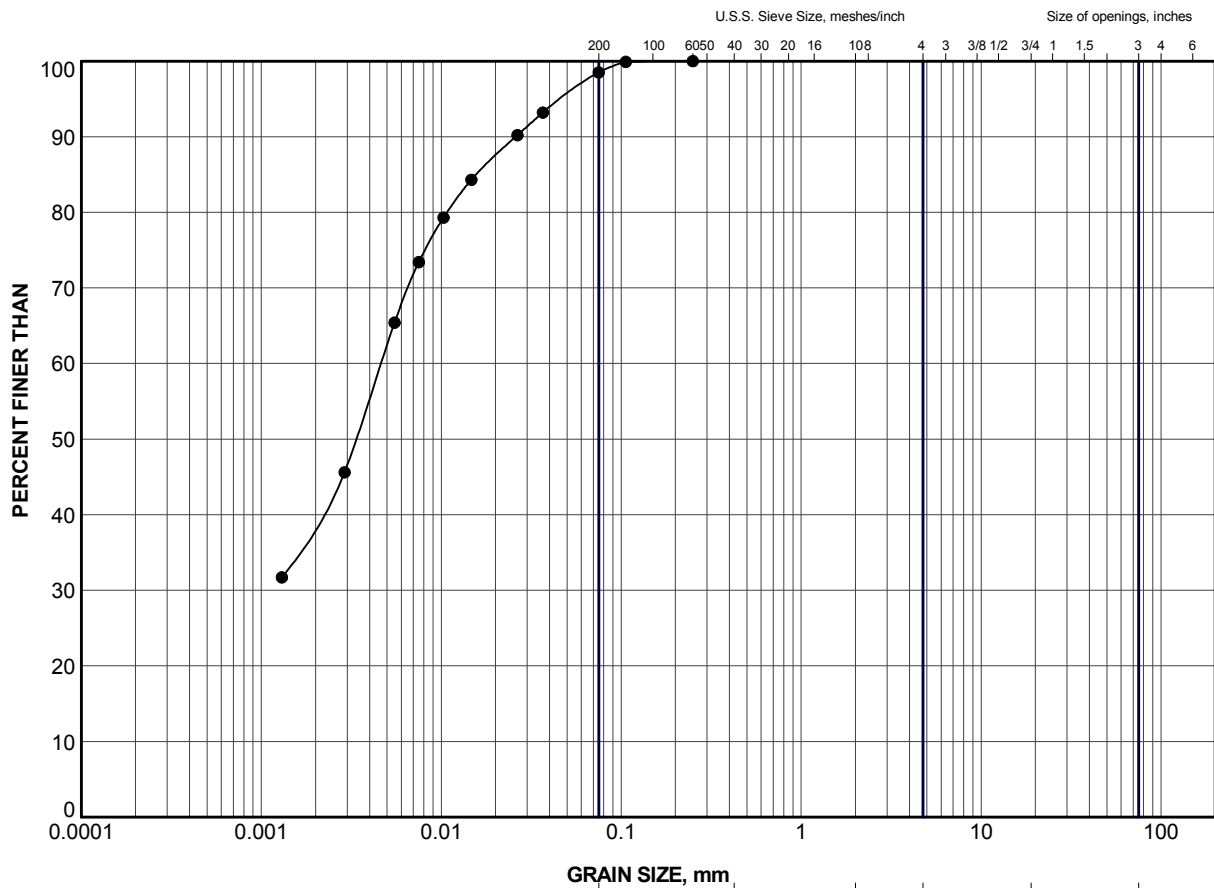
TITLE

GRAIN SIZE DISTRIBUTION

CLAYEY SILT to SILTY CLAY



PROJECT No. 13-1184-0074			FILE No. 13-1184-0074.GPJ		
DRAWN	TB	Jun 2014	SCALE	N/A	REV.
CHECK	AB	Jun 2014	FIGURE B5.1		
APPR	JMAC	Jun 2014			



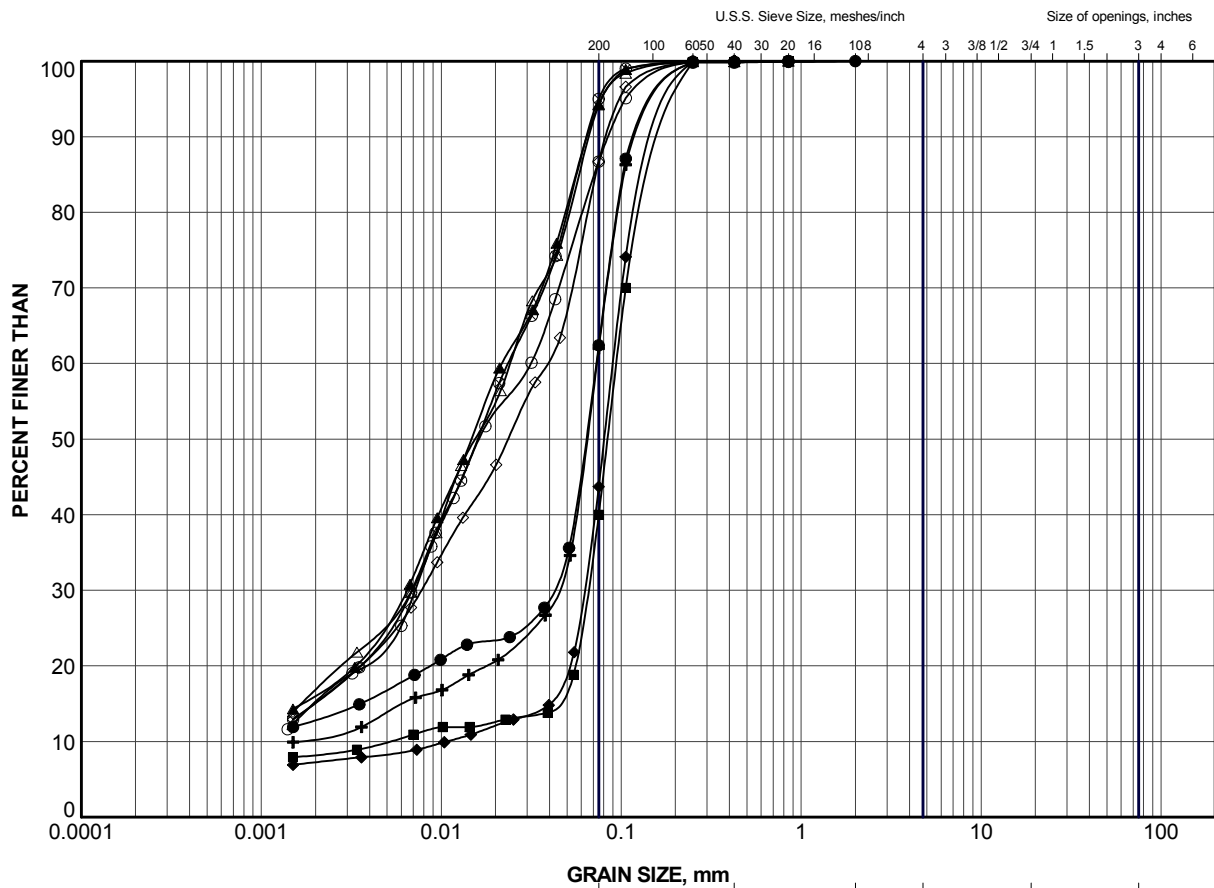
GRAIN SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BI-7	4	196.0

PROJECT					HIGHWAY 17 BIQUETTE CREEK CULVERT - STA 13+350				
TITLE					GRAIN SIZE DISTRIBUTION CLAYEY SILT to SILTY CLAY				
PROJECT No.		13-1184-0074			FILE No.		13-1184-0074.GPJ		
DRAWN	TB	Jun 2014			SCALE	N/A	REV.		
CHECK	AB	Jun 2014			FIGURE B5.2				
APPR	JMAC	Jun 2014							





LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BI-1	16	191.8
■	BI-2	16	191.8
▲	BI-2	18	188.8
+	BI-4	12	187.4
◆	BI-5	10	190.7
◇	BI-5	11	189.2
○	BI-6	11	188.8
△	BI-7	7	191.5
⊗	BI-7	9	188.4

PROJECT

HIGHWAY 17
BIQUETTE CREEK CULVERT - STA 13+350

TITLE

GRAIN SIZE DISTRIBUTION

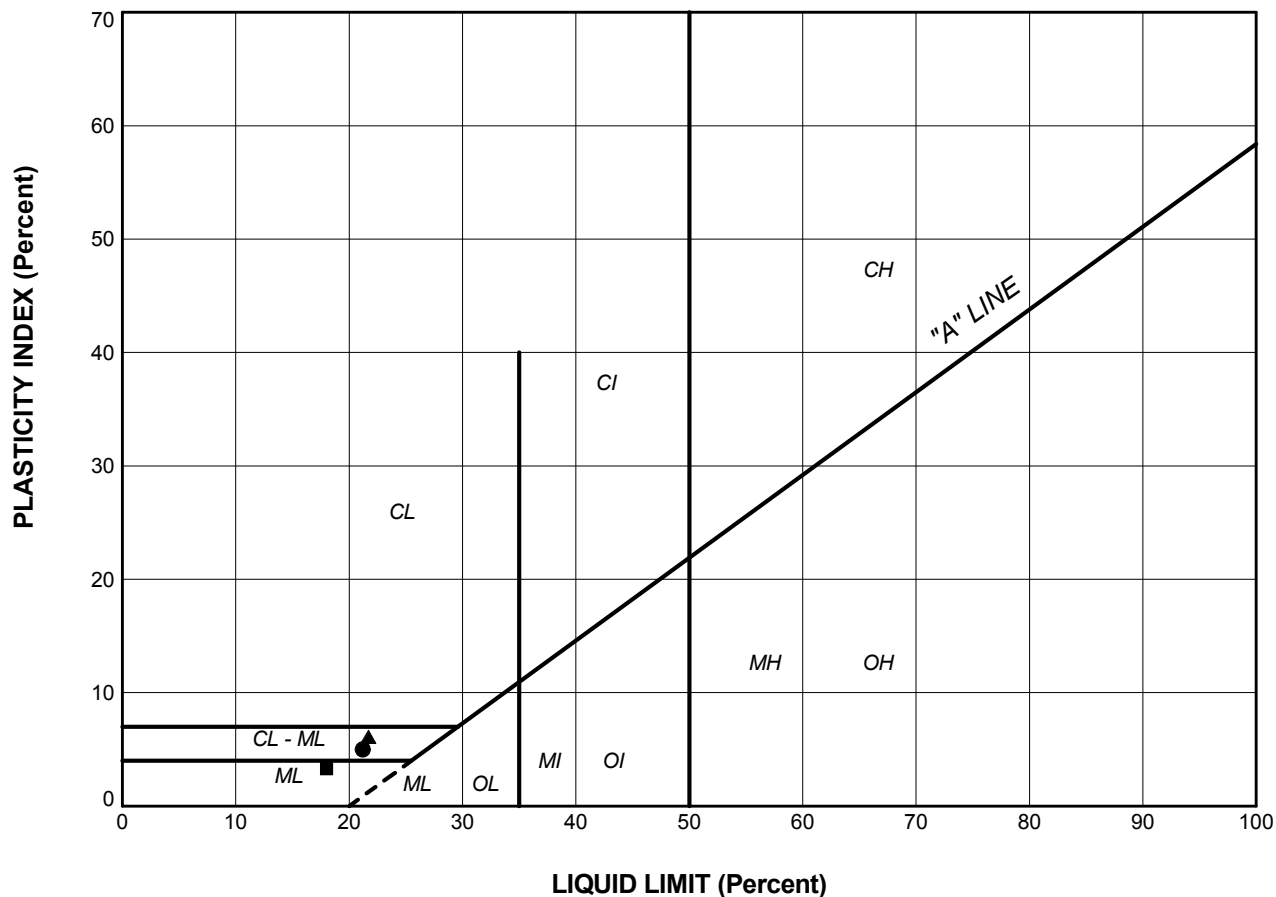
SILT to SILT and SAND




**Golder
Associates**
SUDBURY, ONTARIO

PROJECT No.	13-1184-0074	FILE No.	13-1184-0074.GPJ
DRAWN	TB	Jun 2014	SCALE N/A
CHECK	AB	Jun 2014	REV.
APPR	JMAC	Jun 2014	

FIGURE B6



PROJECT					
HIGHWAY 17 BIQUETTE CREEK CULVERT - STA 13+350					
TITLE					
PLASTICITY CHART SILT to SILT and SAND					
PROJECT No.		13-1184-0074		FILE No.	
DRAWN		TB		Jun 2014	
CHECK		AB		Jun 2014	
APPR		JMAC		Jun 2014	
 Golder Associates SUDBURY, ONTARIO				SCALE N/A REV.	
FIGURE B7					



APPENDIX C

Non-Standard Special Provisions

EMBANKMENT SLOPES – Item No.

Non-Standard Special Provision

Scope of Work

At the Biquette Creek Culvert site, excavation side slopes within the existing embankment during construction should be no steeper than 1.5 Horizontal to 1 Vertical (1.5H:1V) for the front slopes towards the culvert (parallel to the highway) and 2H:1V for the side slopes (perpendicular to the highway).

Basis of Payment

Payment at the lump sum contract price for the above tender item includes full compensation for all labour, equipment and material for completion of the work.

END OF SECTION

WORKING SLAB – Item No.

Non-Standard Special Provision

Scope of Work

The subgrade soils for the box culvert foundations may be susceptible to disturbance and loosening from construction traffic and ponded water.

Where precast box culverts are used, if all of the box segments are not placed on the prepared subgrade within four hours of its inspection and approval, a concrete working slab of 20 MPa compressive strength at 28 days with minimum thickness of 100 mm, shall be placed on the foundation subgrade. A minimum 75 mm thick uncompacted levelling pad consisting of Granular 'A' material (OPPS.PROV 1010) or concrete fine aggregate (meeting the grading requirements specified in OPSS.PROV 1002) shall be provided on top of the concrete working slab.

Basis of Payment

Payment at the lump sum contract price for the above tender item includes full compensation for all labour, equipment and material for completion of the work.

END OF SECTION

UNWATERING OF STRUCTURE EXCAVATION - Item No.

Non-Standard Special Provision

Construction of the culvert will require excavations to extend below the groundwater level. The cohesionless soils 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 excavation protection and unwatering system to enable construction in dry conditions, to 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

The Contactor shall be alerted to the presence of cobbles and boulders that may be present within the embankment fill. Considerations of the presence of these obstructions must be made in the selection of appropriate equipment and procedures for sub-excavation and installation of the temporary shoring and roadway protection system, if required.

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

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

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