November 27, 2014

FOUNDATION INVESTIGATION AND DESIGN REPORT

CENTRELINE CULVERT AT STA 11+600, CALDWELL TOWNSHIP
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

FOUNDATION INVESTIGATION REPORT

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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 rehabilitation of the Highway 17 Centreline Culvert at STA 11+600 in Caldwell Township 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 centreline culvert is located across Highway 17 east of the Town of Warren approximately 1.0 km west of the junction with Highway 575. In general, the topography in the area of the overall project limits consists of flat terrain primarily utilized as farmland. The existing highway grade is at about Elevation 217 m and the creek bed is about 8 m below the existing highway grade. The side slopes of the existing embankment are inclined at about 1.2 Horizontal to 1 Vertical (1.2H:1V) on the south side of the embankment and 1.6H: 1V on the north side of the embankment. The existing culvert is 35 m long, 2.3 m wide and 1.7 m high Corrugated Steel Pipe Arch (CSPA).

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation was carried out between December 3 and 6, 2013 and between March 18 and 24, 2014, during which time a total of four boreholes (CE-1 to CE-4) were advanced at the approximate locations shown on Drawing 1.

Boreholes CE-1 and CE-2, 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, supplied and operated by Landcore Drilling Inc. of Sudbury, Ontario. Boreholes CE-3 and CE-4, located near the culvert ends, were advanced by wash boring methods with portable equipment using NQ casing provided by George Downing Estate Drilling Ltd. of Grenville-Sur-La-Rouge, Quebec. A Dynamic Cone Penetration Test (DCPT) was advanced adjacent to Boreholes CE-1, CE-3 and CE-4.

Soil samples were obtained at intervals of depths of about 0.75 m and 1.5 m, using a 50 mm outer diameter split-spoon sampler driven by an automatic hammer at Boreholes CE-1 and CE-2 and a manual hammer at Boreholes CE-3 and CE-4, and performed in accordance with Standard Penetration Test (SPT) procedure (ASTM D1586). A field vane shear test was conducted in the cohesive stratum in Borehole CE-2 to determine undrained shear strength (ASTM D2573, Standard Test Method for Field Vane Strength Shear Test) of this stratum using an MTO Standard 'N' size vane. 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 21, 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. 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 Surface (m)
	Northing	Easting		
CE-1	5142115.8	255218.8	216.8	17.0 / 15.2
CE-2	5142105.5	255233.6	216.7	12.8
CE-3	5142128.2	255231.4	210.0	3.9 / 3.7
CE-4	5142097.7	255209.4	209.5	8.2 / 11.4

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on NOEGTS[1] mapping, the topography in the vicinity of the centreline culvert is generally characterized as a glaciolacustrine plain comprised of mainly silty and sandy soils with undulating and rolling bedrock knobs within approximately 200 m north of the site.

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

[1] Northern Ontario Engineering Geology Terrain Study, Ontario Geological Survey Digital Map 41ISE.

undrained shear strength from the field vane) 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.

4.2.1 Fill

Boreholes CE-1 and CE-2 penetrated a layer of asphalt 250 mm thick at Elevation 216.8 m and 216.7 m, respectively, underlain by fill comprised of sand, some gravel transitioning to silty sand, some gravel in Borehole CE-1 and silty clay to silt in Borehole CE-2. The thickness of the overall fill deposit is about 8.7 m and 3.7 m at the respective boreholes. From ground surface in Boreholes CE-3 and CE-4, an approximately 0.8 m thick deposit of fill consisting of sand, some silt, trace gravel, trace organic was encountered.

The SPT ‘N’-values measured within the fill range between 2 blows and 45 blows per 0.3 m of penetration indicating a very loose to dense relative density. The SPT ‘N’-values measured within the silty clay to silt portion of the fill range from 9 blows to 18 blows per 0.3 m of penetration suggesting a stiff to very stiff consistency.

Grain size analyses were carried out on three samples of the fill deposit (two of the silty sand portion and one of the silty clay portion) and the results are represented on Figure B1 in Appendix B.

An Atterberg limits test carried out on a sample of the cohesive fill measured a liquid limit of about 36 per cent, a plastic limit of about 21 per cent and a plasticity index of about 14 per cent. The result, which is plotted on a plasticity chart on Figure B2 in Appendix B, indicates that the tested sample consist of silty clay of intermediate plasticity.

The natural moisture content measured on selected samples of the sand to silty sand portion of the fill range from about 3 per cent to 30 per cent. The natural moisture content measured on two samples of the silty clay to silt fill are about 20 per cent to 23 per cent.

4.2.2 Silt

Underlying the fill in Borehole CE-2, a 1.9 m thick deposit of silt, trace to some clay was encountered at Elevation 213.0 m.

The SPT ‘N’-values measured within this deposit are 13 blows and 15 blows per 0.3 m of penetration, indicating a compact relative density.

A grain size analyses was carried out on a sample of this deposit and the result is represented on Figure B3 in Appendix B.

An Atterberg limits test was carried out on a sample of the silt and indicates that the material is non-plastic.

The natural moisture content measured on selected samples of the silt are about 22 per cent and 23 per cent.

4.2.3 Clayey Silt

A deposit of clayey silt was encountered below the silt in Borehole CE-2 at a depth of 5.6 m (Elevation 211.1 m) and below the fill in Borehole CE-4 at a depth of 0.8 m (Elevation 208.7 m), with a thickness of 4.8 m and 3.7 m, respectively. A 0.1 m thick organic layer was noted in Borehole CE-4 at a depth of 2.0 m (Elevation 207.5 m). Sand and/or silt laminations/layers were generally observed in the lower portion of the deposit.

The SPT 'N'-values measured within the clayey silt deposit range between 4 blows (weight of hammer) and 8 blows per 0.3 m of penetration and two 'N'-values in the sand and/or silt laminations/layers are 22 blows and 33 blows per 0.3 m of penetration. One in situ field vane test measured an undrained shear strength of about 72 kPa, with a sensitivity of 2. The in situ vane test result indicates that the deposit generally has a stiff consistency.

Grain size analyses were carried out on two samples of this deposit and the results are represented on Figure B4 in Appendix B.

Atterberg limits testing were carried out on four samples of the cohesive deposit and measured liquid limits ranging from about 27 per cent to 33 per cent, plastic limits ranging from about 16 per cent to 20 per cent, and plasticity indices ranging from about 11 per cent to 16 per cent. The results, which are plotted on a plasticity chart on Figure B5 in Appendix B, indicate that the tested samples of the overall deposit consist of clayey silt of low plasticity.

A grain size analysis was carried out on a sample of the silt and sand lamination/layer in Borehole CE-2 and the result is presented on Figure B6 in Appendix B.

The natural moisture content measured on selected samples of the clayey silt deposit ranges between about 26 per cent and 48 per cent; whereas, the natural moisture content measured on the sample of the sand and/or silt interlayer is about 26 per cent.

4.2.4 Gravelly Silty Sand to Sand

A deposit of sand or gravely silty sand was encountered below the fill in Boreholes CE-1 and CE-3 and a deposit of silty sand to sand was encountered beneath the clayey silt in Boreholes CE-2 and CE-4. The surface of the deposit was encountered between Elevations 209.2 m and 205.0 m. The deposit was explored for a depth of about 2.4 m in Borehole CE-2 and the thickness of the deposit in Boreholes CE-1, CE-3 and CE-4 is between about 3.1 m and 8.3 m as inferred from split-spoon, auger, casing and/or DCPT refusal. A silt to clayey silt layer was encountered in Borehole CE-1 at a depth of 15.5 m below ground surface (Elevation 201.3 m). Heaving of sands into the casing occurred in Boreholes CE-1 and CE-2 as the boreholes were advanced below a depth of 10.7 m.

The SPT 'N'-values measured within this deposit range between 4 blows and 40 blows per 0.3 m of penetration, indicating a loose to dense relative density, however the majority of the 'N'-values are in the compact range. Two SPT 'N' values near/at the bottom of Borehole CE-1 are 79 blows per 0.2 m of penetration indicating a very dense relative density and 97 blows per 0.5 m of penetration on inferred refusal.

Grain size analyses were carried out on four samples of this deposit and the results are represented on Figure B7 in Appendix B. A grain size analysis was carried out on a sample of the silt to clayey silt layer in Borehole CE-1 and the result is presented on Figure B8 in Appendix B.

The natural moisture content measured on selected samples of this deposit ranges between about 11 per cent and 23 per cent. The natural moisture content measured on the layer of silt to clayey silt in Borehole CE-2 is about 17 per cent.

4.2.5 Refusal

Refusal to further split-spoon, casing and/or auger advancement was encountered in the following boreholes and corresponding DCPTs.

Borehole	Borehole Refusal Depth/Elevation (m)	DCPT Refusal Depth/Elevation (m)
CE-1	17.0/199.8	15.2/201.6
CE-3	3.9/206.1	3.7/206.3
CE-4	8.2/201.3	11.4/198.1

4.2.6 Groundwater Conditions

The unstabilized water levels in Boreholes CE-1 to CE-4 upon completion of drilling range between ground surface to 7.8 m below ground surface, between Elevations 210.1 m and 209.0 m. The creek water level surface was surveyed by MH at Elevation 209.4 m in December 2013.

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. Mat Riopelle and Mr. Shane Albert. This report was prepared by Mr. Adam Core, E.I.T. and reviewed 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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PART B

FOUNDATION DESIGN REPORT

CENTRELINE CULVERT AT STA 11+600, CALDWELL TOWNSHIP

HIGHWAY 17 REHABILITATION BETWEEN WARREN AND VERNER

FROM HIGHWAY 539 EASTERLY TO 0.2 KM EAST

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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 centreline culvert consists of a 35 m long, 2.3 m wide by 1.7 m high CSPA. The top of the existing embankment is at about Elevation 217 m and the existing side slopes of the approximately 8 m high earth fill embankment are inclined at about 1.2H:1V on the south side and 1.6H:1V on the north side.

We understand that the culvert will be lined, however, foundation engineering design recommendations are provided herein in the event a replacement with a CSP culvert is required. In this case we have assumed that a circular culvert of similar open area to the existing would be used.

As part of the Highway 17 rehabilitation to be carried out in the vicinity of the centreline 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, except that the sideslopes immediately adjacent to the culvert replacement would be re-constructed at a recommended a inclination of 2H:1V, as discussed in Section 6.2.

6.2 Stability

Limit equilibrium slope stability analyses were performed for the proposed embankment geometry, immediately adjacent to the location of the culvert replacement at the south side of the embankment, 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 roadways. The stability analyses were performed to check that the target minimum FoS was achieved for the embankment height and geometry at the culvert location.

The analyses assume that, for a full culvert replacement, the organic soils (if present) beneath the footprint of the culvert and immediate area of the adjacent embankment will be removed prior to construction of the new culvert/re-constructed embankment. The analyses assume that new granular fill (sand and gravel, Granular ‘A’ or 'B' Type I or II), is used for embankment reconstruction, and would be keyed into the existing fill as per OPSD 208.010 (Benching of Earth Slopes) and constructed locally with 2H:1V side slopes or flatter.

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 result of the in situ field vane tests and SPT 'N'-values as well as on laboratory test data. 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 result of the in situ field vane test.

The piezometric condition required in the analyses is based on the groundwater level consistent with the creek surface Elevation 209.4 m measured by MH.

The simplified stratigraphy together with the associated strength and unit weight employed for the fill and 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 (^{o})**
Existing Fill	20	-	30
New Granular Fill	21	-	35
Clayey Silt	17	60	-
Gravelly Silty Sand to Sand/ Silty Sand to Sand	19	-	30

The stability analysis performed on the south embankment cross-section at the tie-in of the existing embankment to the new backfill immediately to the culvert location indicates that 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 for a slope inclined at 2H:1V. Although the existing earth embankment slopes are presently inclined at about 1.2H:1V on the south side and 1.6H:1V on the north side of the embankment, and there does not appear to be any visual evidence of slope distress, the calculated FoS for such slope inclination is less than or approximates 1.0 for surficial failure surfaces. Therefore, following culvert lining or replacement, we recommend that the embankment side slopes be regraded to an inclination of 2H:1V, as shown on Figure 1. Should the culvert lining operations damage the vegetated cover on the existing side slopes or further steepen any sections of the slopes locally, then surficial failures could occur and the failure surfaces could retrogress towards the roadway. Therefore, locally, the side slopes should be graded into the 2H:1V reconstructed slopes over the adjacent slopes. The new granular fill should be keyed into the existing side slope fill as further discussed in Section 6.5.1.

6.3 Settlement

Based on a proposed grade raise of about 150 mm and maintaining the side slope at the same inclination as the existing embankment, or the embankment is reconstructed locally with side slopes at 2H:1V over the culvert if the culvert is replaced, 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. 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.

6.4 Horizontal Strain

If the culvert is replaced, 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 Sections 6.2 and 6.3. 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, replacement of the culver can be carried out concurrent with embankment reconstruction without the need for any foundation mitigation measures.

6.5 Culvert Construction Considerations

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

The bedding, levelling pad and backfill for a circular concrete pipe or CSP culvert should be in accordance with OPSD 802.034 (Rigid Pipe Bedding and Cover in Embankment) or OPSD 802.010 (Flexible Pipe Embedment and Backfill – Earth Excavation), respectively, and culvert construction should be in accordance with OPSS 421 (Pipe Culvert Installation in Open Cut). It is important that the backfill at the haunches be well compacted. The circular culvert should be constructed on an at least 150 mm thick layer of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II material for bedding purposes in the case of a flexible pipe or a 300 mm thick bedding layer in the case of a rigid pipe.

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 as discussed in Section 6.5.2.

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 culvert should be designed for the full overburden stress and appropriate live loads, assuming a fill unit weight of 22 kN/m^3 for Granular ‘A’ and 21 kN/m^3 for Granular ‘B’ Type II backfill above and surrounding the culvert.

Fill for culvert bedding/cover and embankment reconstruction should be compacted in accordance with OPSS 501 (Compacting). 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 6.2, the new granular fill used to reconstruct the embankment, including the culvert surround, will need to 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.

6.5.2 Temporary Shoring

A temporary protection system is required to support the embankment fill during the culvert replacement. The temporary support system could consist of driven steel sheet piling or a soldier pile and lagging components.

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 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:

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

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 Active, K_a	At Rest, K_o	Passive, K_p	INTERNAL ANGLE OF FRICTION (ϕ, degrees)	UNIT WEIGHT (γ, kN/m^2)	UNDRAINED SHEAR STRENGTH (S_u, kPa)
Existing Embankment Fill	0.33	0.50	3.0	30	20	-
Clayey Silt	0.37	0.55	2.7	27	17	60 kPa
Silt	0.36	0.53	2.8	28	18	-
Gravelly Silty Sand/ Sand	0.33	0.50	3.0	30	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.

6.5.3 Erosion Protection

Provisions should be made for scour and erosion protection (suitable non-woven geotextiles and 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 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.

6.5.4 Control of Groundwater and Surface Water

Creek flows via the culvert and any local ditch flows at the time of culvert lining or replacement will need to be diverted/piped away from the excavation areas during the construction period. Surface water should be directed away from the excavation areas to prevent ponding of water that could result in disturbance and weakening of the foundation subgrade.

6.5.5 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.

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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\r05 - centreline\13-1184-0074-r05 rpt 14nov27 final fidr centerline culvert.docx

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.

Unified Facilities Criteria, NAVFAC Design Manual, DM-7.2. Soil Mechanics, Foundation and Earth Structures. U.S. Navy, 1982, Alexandria, Virginia.

Ontario Geological Survey. Northern 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 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	Construction Projects (as amended)

Ontario Provincial Standard Drawing

OPSD 208.010	Benching of Earth Slopes
OPSD 802.010	Flexible Pipe Embedment and Backfill, Earth Excavation
OPSD 802.034	Rigid Pipe Bedding and Cover in Embankment, Original Ground: Earth or Rock
OPSD 810.010	Rip-Rap Treatment for Sewer and Culvert Outlets

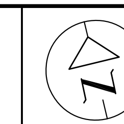
Ontario Provincial Standard Specification

OPSS 421	Construction Specification for Pipe Culvert Installation in Open Cut
OPSS 501	Construction Specification for Compacting
OPSS 539	Construction Specification for Temporary Protection Systems
OPSS 1205	Clay Seal
OPSS.PROV1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

Ontario Water Resources Act

Regulation 903	Wells (as amended)

CONT No.
GWP No. 300–98–00



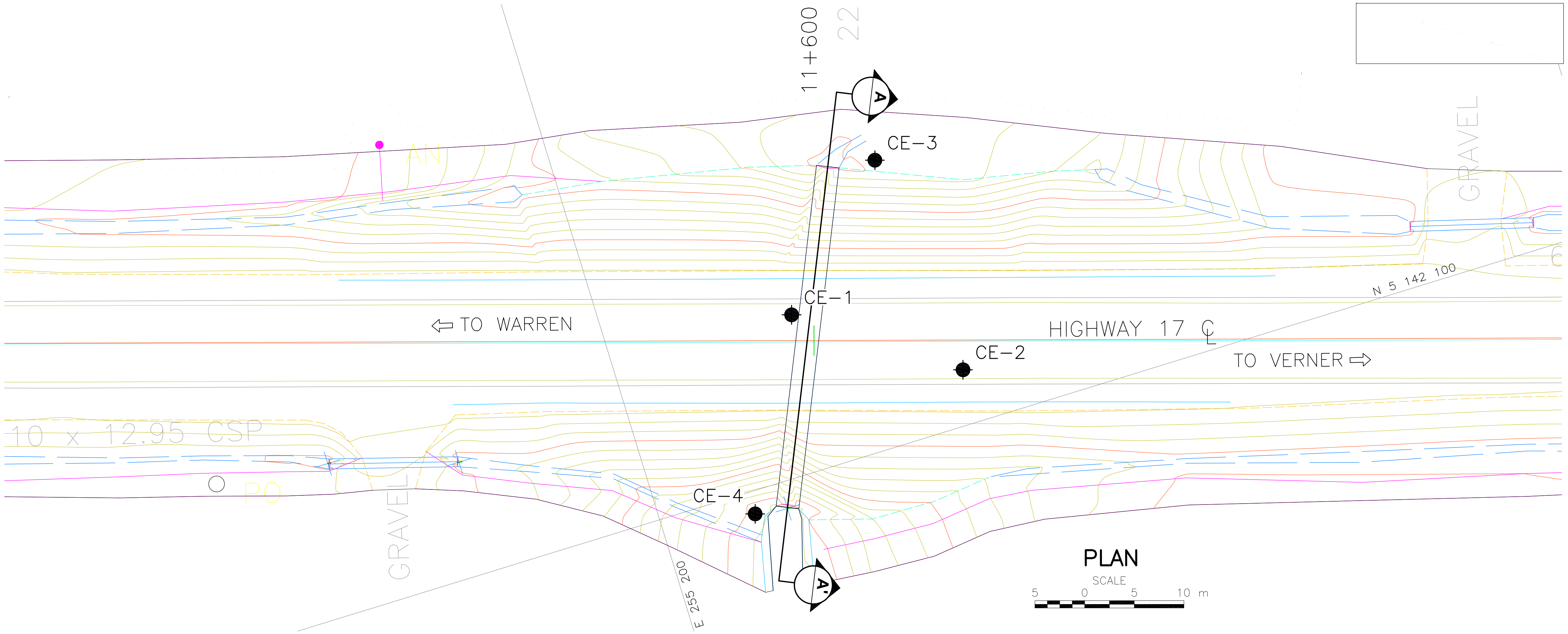
SHEET

HIGHWAY 17

CENTRELINE CULVERT – STA 11+600

BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA



PLAN

SCALE 5 0 5 10 m

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)
R	Refusal
▽	WL upon completion of drilling

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
CE–1	216.8	5142115.8	255218.8
CE–2	216.7	5142105.5	255233.6
CE–3	210.0	5142128.2	255231.4
CE–4	209.5	5142097.7	255209.4

NOTES

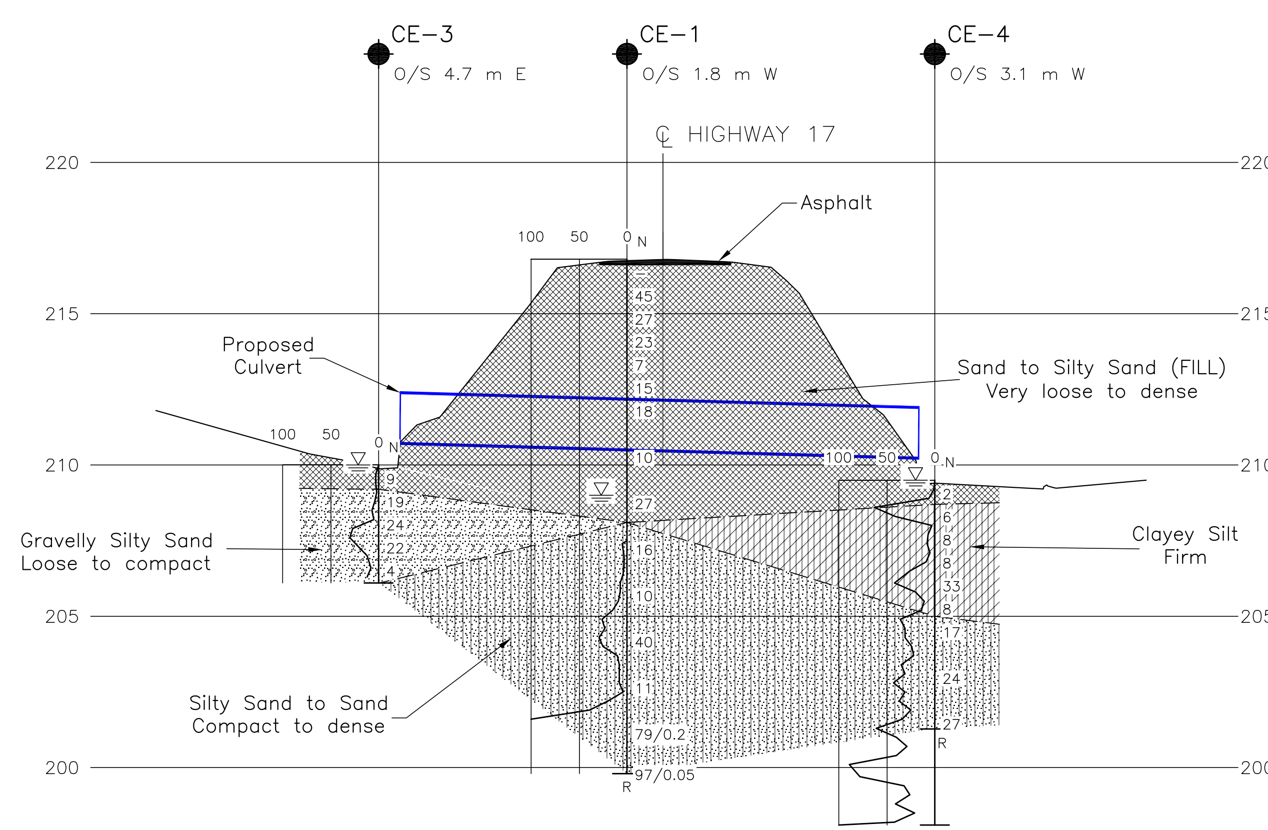
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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. 43–165C_01.dwg, received on APR 7, 2014. Proposed grade profile drawing file no. Biquette Creek Culvert and 11+600 culvert.dwg, received on NOV 05, 2014.

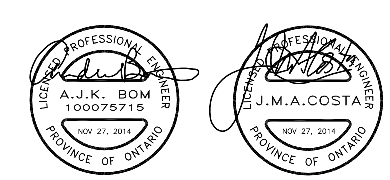


A–A' PROFILE

HIGHWAY 17

HORIZONTAL SCALE 5 0 5 10 m

2.5 0 2.5 5 m VERTICAL SCALE



NO.	DATE	BY	REVISION

Geocres No. 41I–320

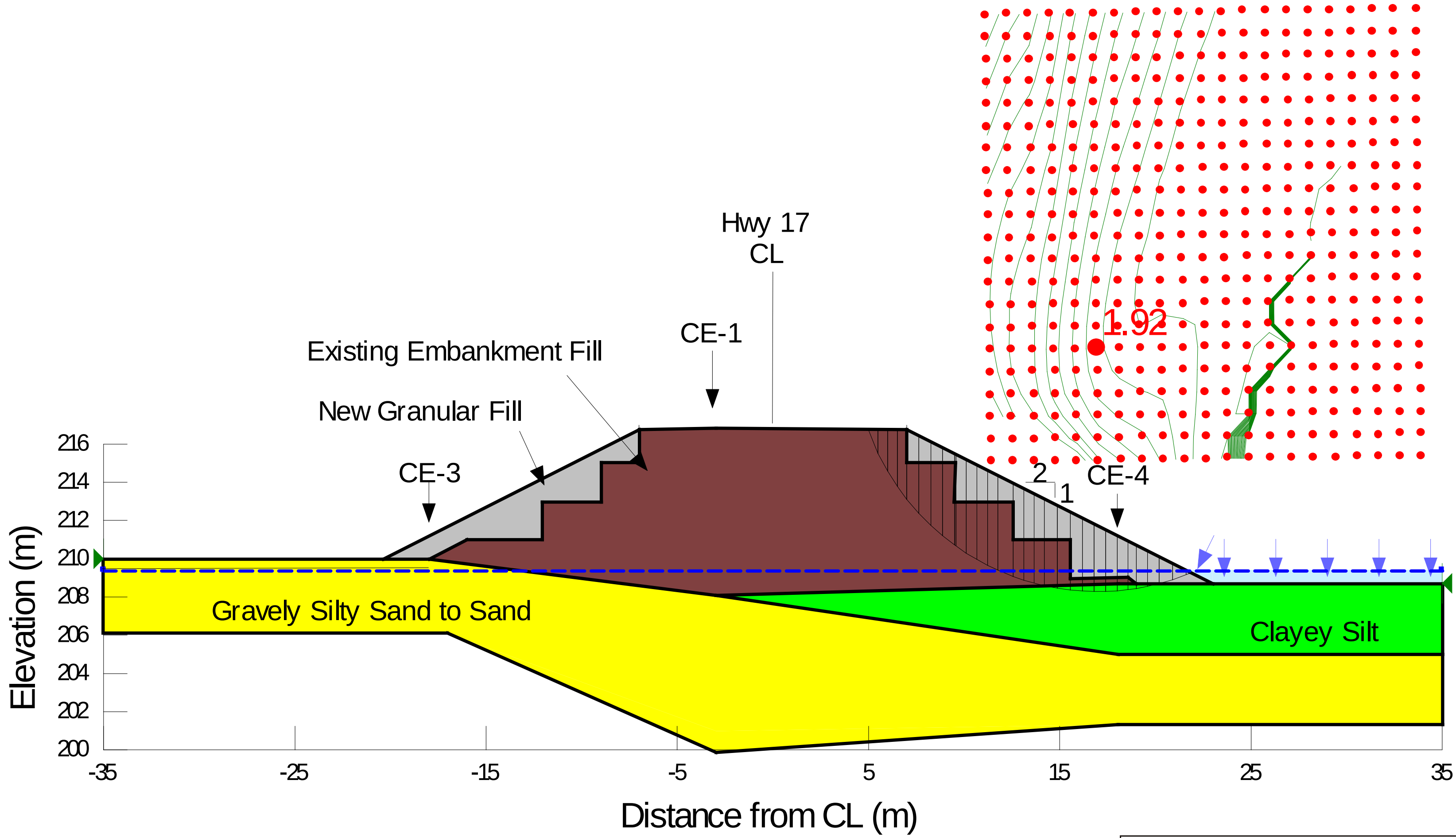
HWY. 17		PROJECT NO. 13–1184–0074	DIST.
SUBM'D. MT	CHKD.	DATE: NOV 2014	SITE:
DRAWN: TB	CHKD. AB	APPD. JMAC	DWG. 1

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

Existing Embankment Fill
Unit Weight: 20 kN/m³
Phi: 30 °

Gravely Silty Sand to Sand
Unit Weight: 19 kN/m³
Phi: 30 °

Clayey Silt
Unit Weight: 17 kN/m³
Cohesion: 60 kPa



PROJECT
HIGHWAY 17 – Centreline Culvert at STA 11+600

TITLE
STABILITY ANALYSIS
EMBANKMENT SOUTH SIDE SLOPE

Golder Associates

PROJECT No. 13-1184-0074			FILE No. ----	
DESIGN			SCALE AS SHOWN	REV.
CADD	--		**FIGURE 1**	
CHECK	AB	Sept 2014		
REVIEW	JMAC	Sept 2014		

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
υ	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

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

(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 $= \sigma'_p / \sigma'_{vo}$

(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 δ
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

Notes:
1. $\tau = c' + \sigma' \tan \phi'$
2. shear strength = (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, 60º 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 cm^2 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 / **Relative Density**	**N** / **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	c_u, s_u 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	Sand and Gravel
	With (cohesive)	Silty Clay with sand / Clayey Silt with sand

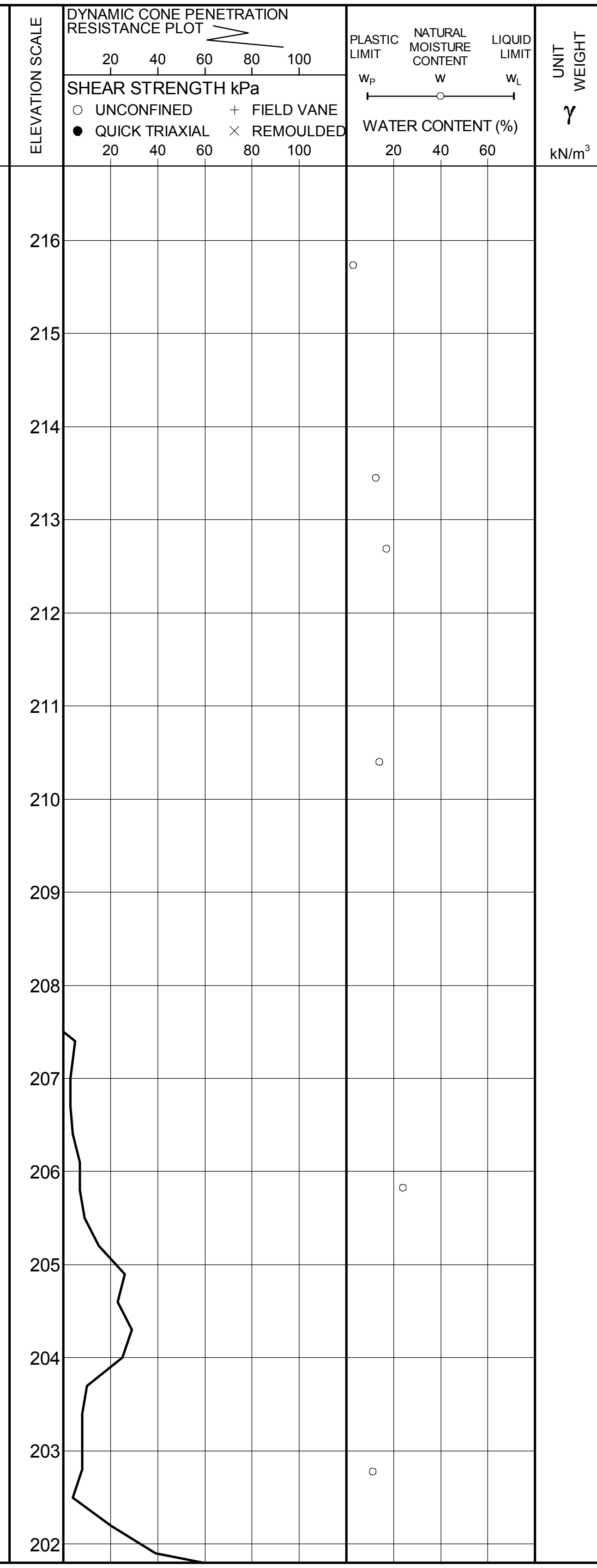
Golder Associates

RECORD OF BOREHOLE No CE-1

 METRIC

PROJECT 13-1184-0074			
G.W.P. 300-98-00	LOCATION N 5142115.8; E 255218.8		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 and 5, 2013	CHECKED BY DAM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
216.8	GROUND SURFACE					
0.0	ASPHALT (250 mm)					
0.2	Sand, some gravel, trace to some silt (FILL) Compact to dense Brown Moist	1	AS	-		
		2	SS	45		
		3	SS	27		
		4	SS	23		
213.8 / 3.0	Silty sand, some gravel, some clay (FILL) Loose to compact Brown Moist	5	SS	7		16 43 29 12
		6	SS	15		
		7	SS	18		
		8	SS	10		25 41 25 9
		9	SS	27	▽	
208.1 / 8.7	SAND, trace to some gravel, trace to some silt, trace clay Compact to dense Brown Wet	10	SS	16		
	Heaving of sand into casing below 10.7 m depth.	11	SS	10		8 82 8 2
		12	SS	40		
		13	SS	11		10 78 (12)



Continued Next Page

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

RECORD OF BOREHOLE No CE-1

 METRIC

PROJECT 13-1184-0074			
G.W.P. 300-98-00	LOCATION N 5142115.8; E 255218.8	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 and 5, 2013	CHECKED BY DAM	

ELEV DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	SAND, trace to some gravel, trace to some silt, trace clay Compact to dense Brown Wet SILT to clayey silt layer at 15.5 m depth.		14	SS	79/0.2		201		○		1 15 62 22
199.8 17.0			15	SS	97/0.05		200				
	END OF BOREHOLE AUGER AND SPLIT-SPOON REFUSAL Note: 1. Water level at a depth of 7.8 m below ground surface (Elev. 209.0 m) upon completion of drilling. 2. DCPT advanced 1 m west of Borehole CE-1. Preaugered to 9.1 m depth and refusal at 15.2 m depth.										

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No CE-2

 METRIC

PROJECT 13-1184-0074

G.W.P. 300-98-00

LOCATION N 5142105.5; E 255233.6

ORIGINATED BY SA

DIST ______ HWY 17

BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers

COMPILED BY MT

DATUM GEODETIC

DATE December 6, 2013

CHECKED BY DAM

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ (kN/m³)	GR	SA	SI	CL
216.7	GROUND SURFACE									
0.0	ASPHALT (250 mm)									
0.2	Sand, some gravel, trace to some silt (FILL) Compact Brown Moist	1	AS	-						
215.6 / 1.1	Silty clay to silt, trace sand (FILL) Stiff to very stiff Grey to brown Moist	2A / 2B	SS	10						
		3	SS	12			0	5	68	27
		4	SS	18						
		5	SS	9						
213.0 / 3.7	SILT, trace to some clay, trace sand Compact Grey to brown Wet	6	SS	13		NP	0	1	89	10
		7	SS	15						
211.1 / 5.6	CLAYEY SILT, trace sand Stiff Grey to brown Wet	8	SS	7	▽ (Elev. 210.1)		0	1	64	35
	Approximately 0.6 m thick silt and sand layer encountered at 7.6 m depth.	9	SS	22			0	38	52	10
		10	SS	4			0	3	65	32
206.3 / 10.4	Silty SAND, trace gravel, trace clay Compact Grey Wet. Approximately 0.3 m of heave encountered at 10.7 m depth.	11	SS	10						
		12	SS	21						
203.9 / 12.8	END OF BOREHOLE									

Note:

1. Water level at a depth of 6.6 m below ground surface (Elev. 210.1 m) upon completion of drilling.

Chart legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (20, 40, 60). Elevation scale 216 to 204. Field vane value at approx. elev. 206.6 with sensitivity 2.

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

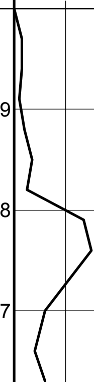
Golder Associates

RECORD OF BOREHOLE No CE-3

 METRIC

PROJECT 13-1184-0074
G.W.P. 300-98-00
DIST ______ HWY 17
DATUM GEODETIC
LOCATION N 5142128.2; E 255231.4
BOREHOLE TYPE NW Casing, Wash Boring
DATE March 21 and 24, 2014
ORIGINATED BY MR
COMPILED BY MT
CHECKED BY DAM

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
210.0	GROUND SURFACE					▽					
0.0	Sand, some silt, trace gravel, trace organics (FILL) Loose Brown Wet		1	SS	9				○		
209.2 / 0.8	Gravelly Silty SAND to Gravelly SAND, some silt, trace clay Loose to compact Grey Wet		2	SS	19		209				
			3	SS	24		208		○		27 49 21 3
			4	SS	22		207				
	Coarse gravel (up to 75 mm) recovered in casing barrel below 3.7 m depth.		5	SS	4				○		
206.1 / 3.9	END OF BOREHOLE REFUSAL TO FURTHER CASING ADVANCEMENT										



Notes:

1. Water level at ground surface (Elev. 210.0 m) upon completion of drilling.

2. DCPT andvanced 0.5 m west of Borehole CE-1 and refusal at 3.7 m depth.

SUD-MTO 001 13-1184-0074.GPJ GAL-MISS.GDT 29/10/14 DATA INPUT:

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

Golder Associates

RECORD OF BOREHOLE No CE-4

 METRIC

PROJECT 13-1184-0074

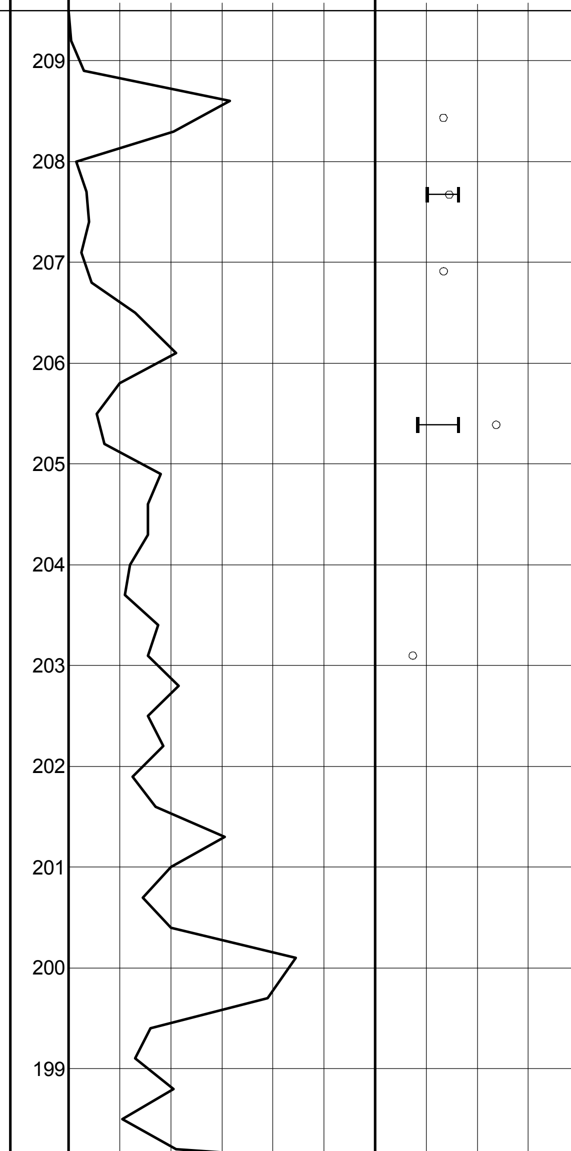
G.W.P. 300-98-00 LOCATION N 5142097.7; E 255209.4 ORIGINATED BY MR

DIST HWY 17 BOREHOLE TYPE NW Casing, Wash Boring COMPILED BY MT

DATUM GEODETIC DATE March 18, 2014 CHECKED BY DAM

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
209.5	GROUND SURFACE				
0.0	Sand, some silt, trace gravel, trace organics (FILL) Very loose Brown Wet	1	SS	2	
208.7 0.8	CLAYEY SILT, trace sand Firm Grey Wet	2	SS	6	
		3	SS	8	
	Approximately 0.1 m thick organic layer at 2.0 m depth.	4	SS	8	
	Approximately 0.7 m sand layer encountered at 3.0 m depth. Silt laminations in Sample 6.	5	SS	33	
		6	SS	8	
205.0 4.5	Silty SAND to SAND, some gravel, trace clay Compact Grey Wet	7	SS	17	
		8	SS	24	17 58 21 4
		9	SS	27	
201.3 8.2	END OF BOREHOLE REFUSAL TO FURTHER CASING ADVANCEMENT				
198.1 11.4	END OF DCPT DCPT REFUSAL Notes: 1. Water level at ground surface (Elev. 209.5 m) upon completion of drilling. 2. DCPT andvanced 0.8 m east of Borehole CE-4.				

Column headings: GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³



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

APPENDIX B

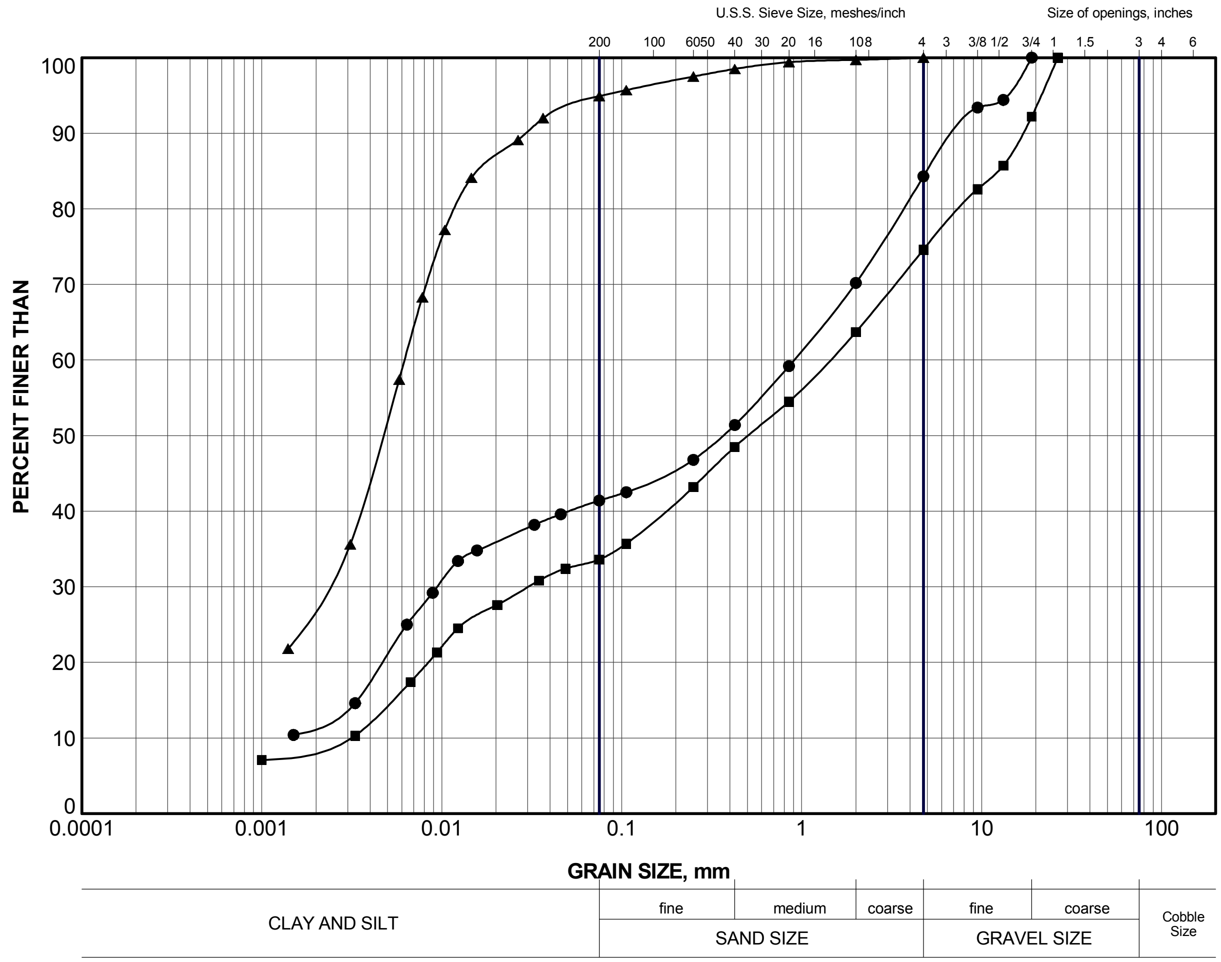
Laboratory Test Results

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

Parameter	Units	Reportable Detection Limit	Result
Dissolved Chloride	mg/L	1	48
Dissolved Sulphate	mg/L	1	2
Conductivity	µohm/cm	1	240
Resistivity	ohm-cm	n/a	4100
pH	n/a	n/a	6.98

Notes: 1. Sample obtained on March 21, 2014.
2. Analytical testing carried out by Maxxam Analytics.

Checked by: AB



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CE-1	5	213.5
■	CE-1	8	210.4
▲	CE-2	3	214.9

PROJECT

HIGHWAY 17
CENTRELINE CULVERT - STA 11+600

TITLE

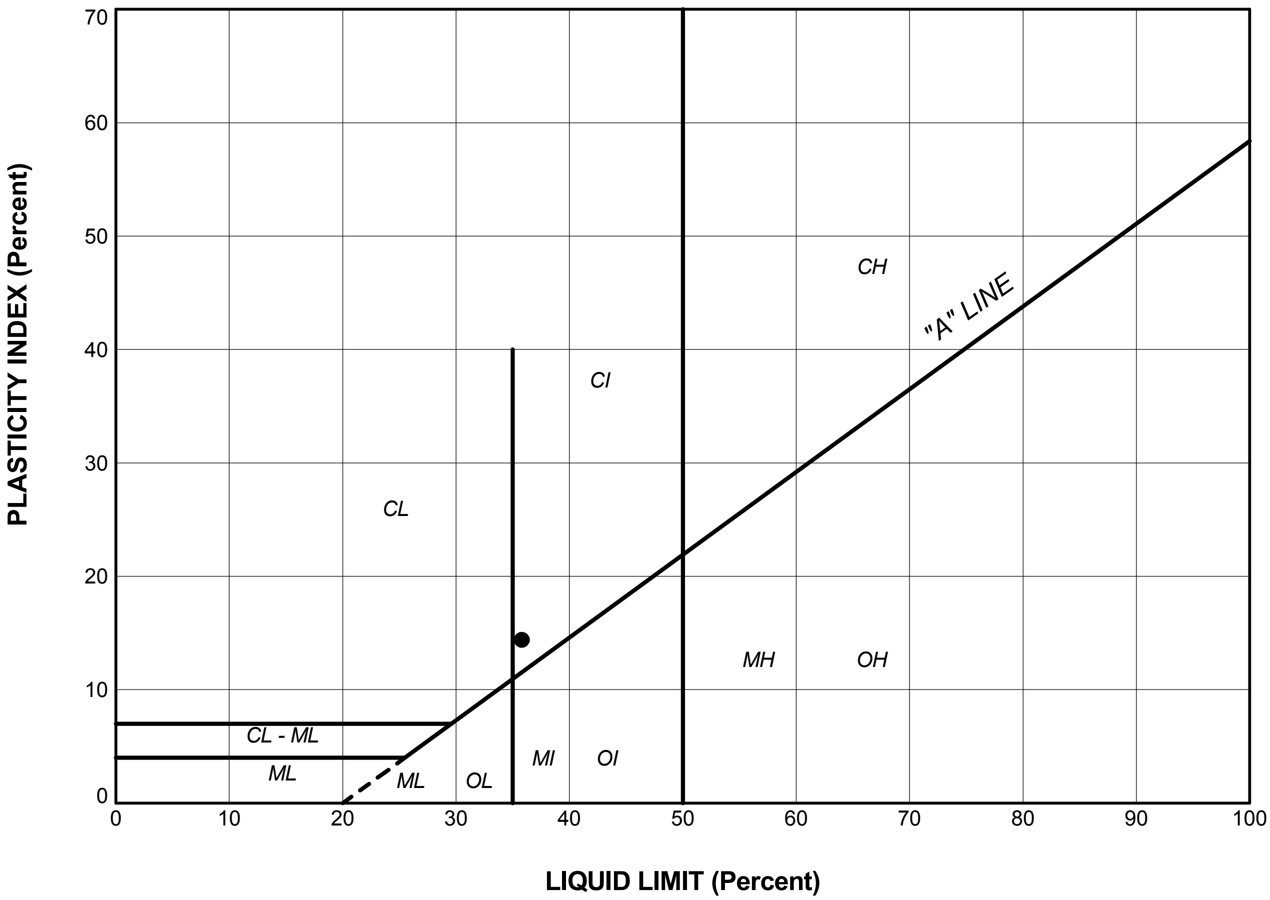
GRAIN SIZE DISTRIBUTION

SILTY SAND and SILTY CLAY (FILL)

PROJECT No.	13-1184-0074		FILE No.	13-1184-0074.GPJ
DRAWN	TB	Oct 2014	SCALE N/A	REV.
CHECK	AB	Oct 2014		
APPR	JMAC	Oct 2014	FIGURE B1	

Golder Associates
SUDBURY, ONTARIO

SUD-MTO GSD (NEW) GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	CE-2	3	35.8	21.4	14.4

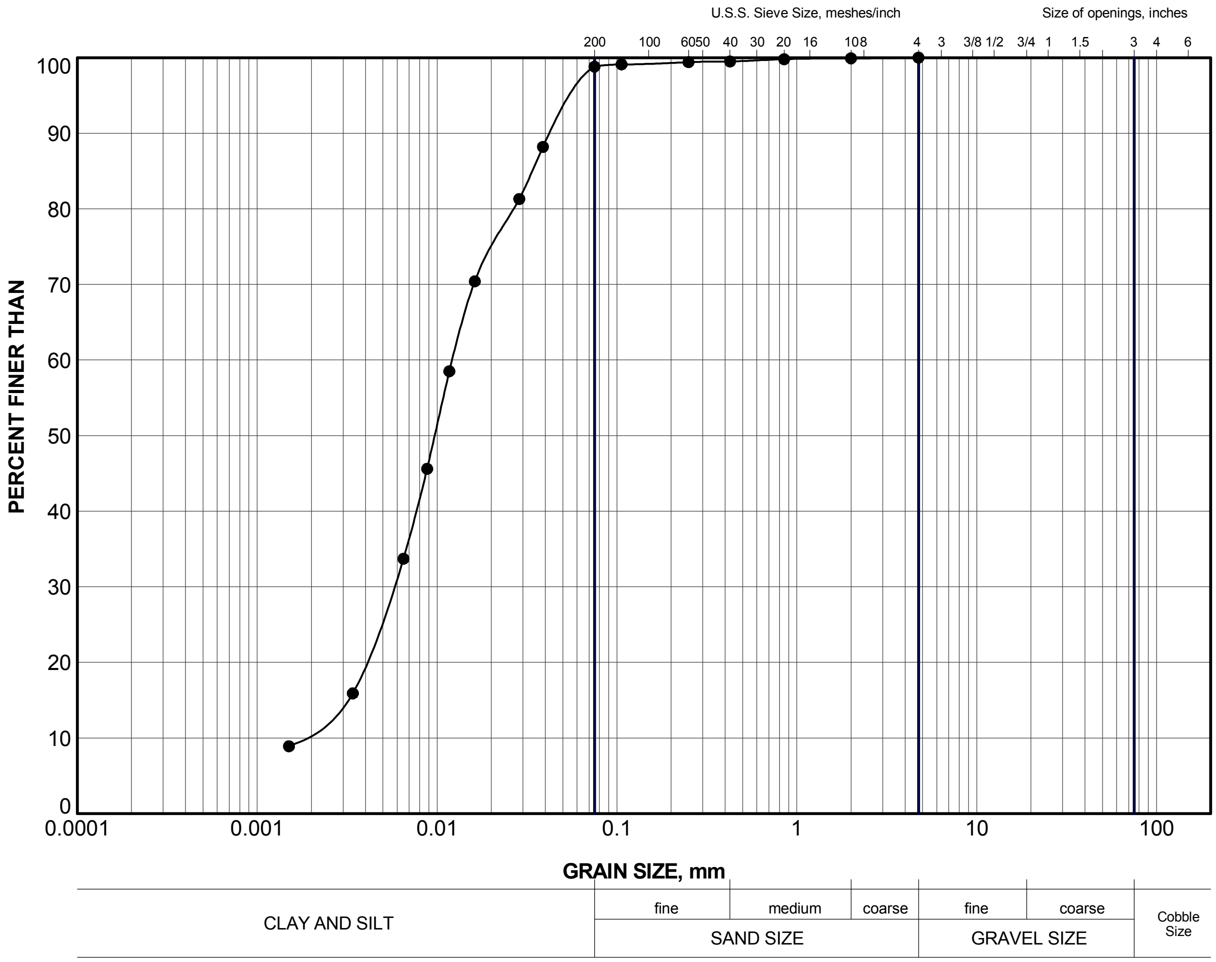
PROJECT
HIGHWAY 17
CENTRELINE CULVERT - STA 11+600

TITLE
PLASTICITY CHART
SILTY CLAY (FILL)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		13-1184-0074	FILE No.	13-1184-0074.GPJ
DRAWN	TB	Sep 2014	SCALE N/A	REV.
CHECK	AB	Sep 2014	FIGURE B2	
APPR		Sep 2014		

SUD-MTO PL (NEW) GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CE-2	6	212.6

PROJECT

HIGHWAY 17
CENTRELINE CULVERT - STA 11+600

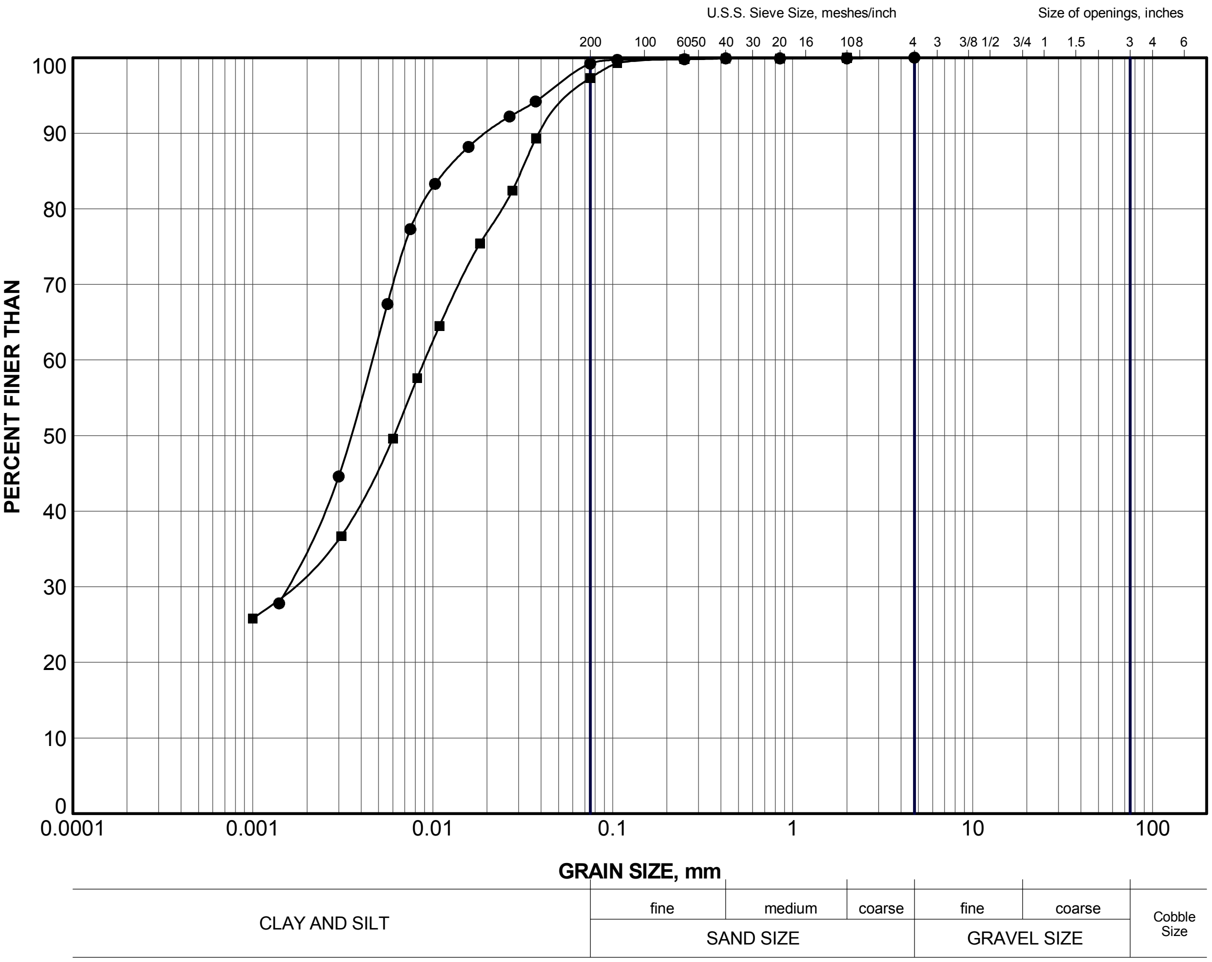
TITLE

GRAIN SIZE DISTRIBUTION

SILT

Golder Associates SUDBURY, ONTARIO	PROJECT No.	13-1184-0074	FILE No.	13-1184-0074.GPJ
	DRAWN TB	Oct 2014	SCALE N/A	REV.
	CHECK AB	Oct 2014	FIGURE B3	
	APPR JMAC	Oct 2014		

SUD-MTO GSD (NEW) GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CE-2	8	210.3
■	CE-2	10	207.3

PROJECT

HIGHWAY 17
CENTRELINE CULVERT - STA 11+600

TITLE

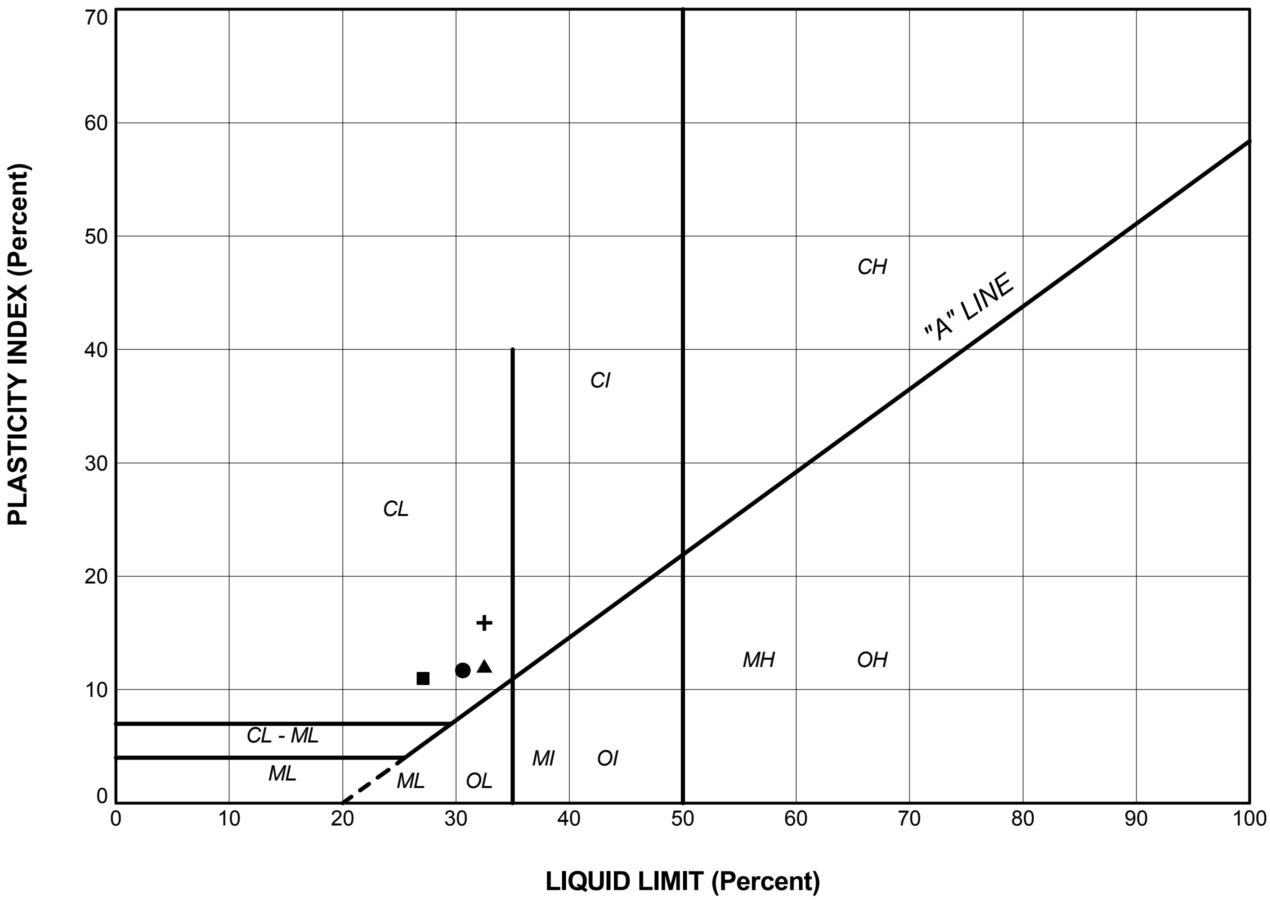
GRAIN SIZE DISTRIBUTION

CLAYEY SILT

Golder Associates
SUDBURY, ONTARIO

PROJECT No.		13-1184-0074	FILE No.	13-1184-0074.GPJ
DRAWN	TB	Oct 2014	SCALE N/A	REV.
CHECK	AB	Oct 2014		
APPR	JMAC	Oct 2014	FIGURE B4	

SUD-MTO GSD (NEW) GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	CE-2	8	30.6	18.9	11.7
■	CE-2	10	27.1	16.1	11.0
▲	CE-4	3	32.5	20.4	12.1
+	CE-4	6	32.5	16.6	15.9

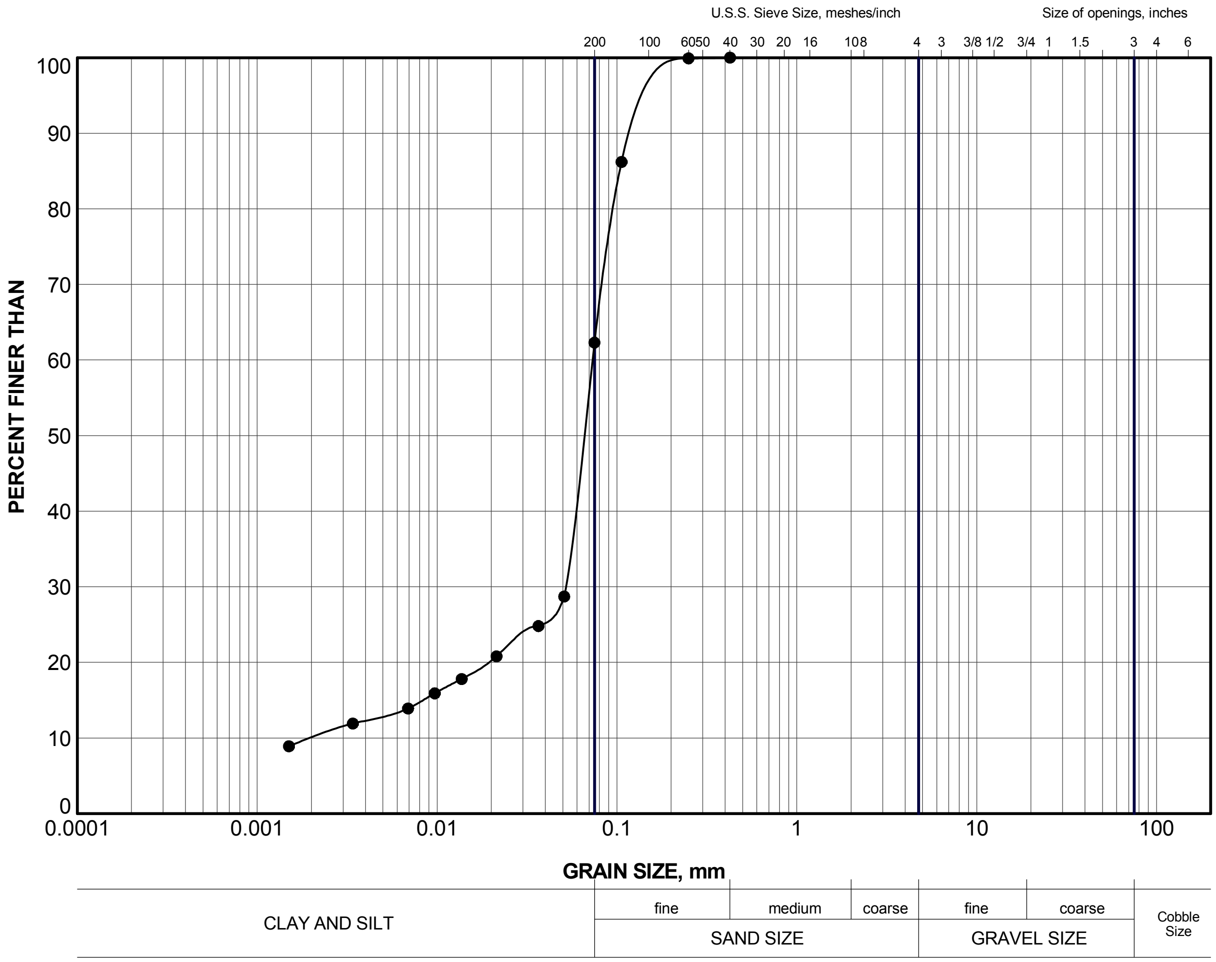
PROJECT
HIGHWAY 17
CENTRELINE CULVERT - STA 11+600

TITLE
PLASTICITY CHART
CLAYEY SILT

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	13-1184-0074		FILE No.	13-1184-0074.GPJ
DRAWN	TB	May 2014	SCALE N/A	REV.
CHECK	DAM	May 2014		
APPR		May 2014	FIGURE B5	

SUD-MTO PL (NEW) GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CE-2	9	208.8

PROJECT

HIGHWAY 17
CENTRELINE CULVERT - STA 11+600

TITLE

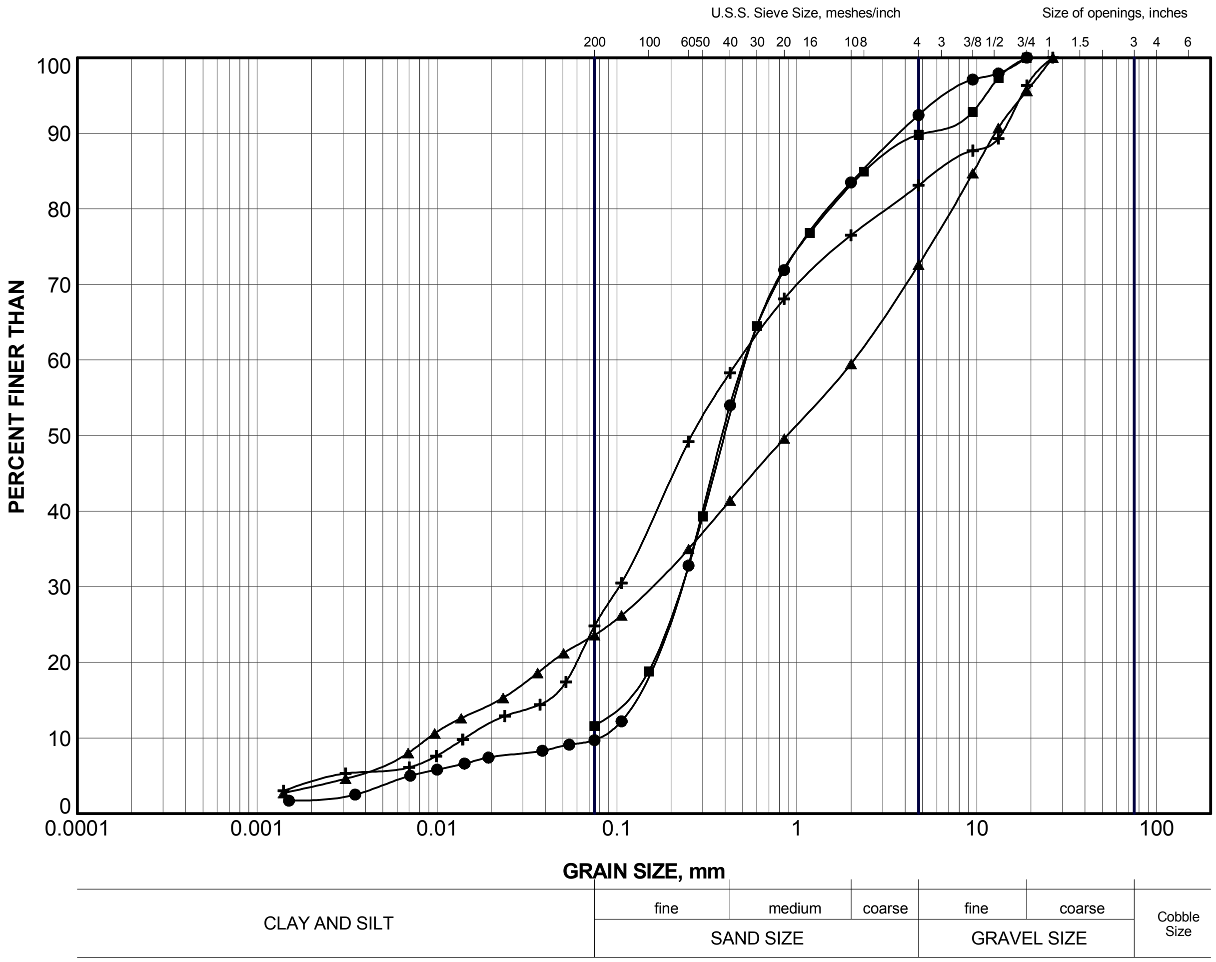
GRAIN SIZE DISTRIBUTION

SILT and SAND (INTERLAYER)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	13-1184-0074		FILE No.	13-1184-0074.GPJ
DRAWN	TB	Oct 2014	SCALE N/A	REV.
CHECK	AB	Oct 2014		
APPR	JMAC	Oct 2014	FIGURE B6	

SUD-MTO GSD (NEW) GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CE-1	11	205.8
■	CE-1	13	202.8
▲	CE-3	3	208.2
+	CE-4	8	203.1

PROJECT

HIGHWAY 17
CENTRELINE CULVERT - STA 11+600

TITLE

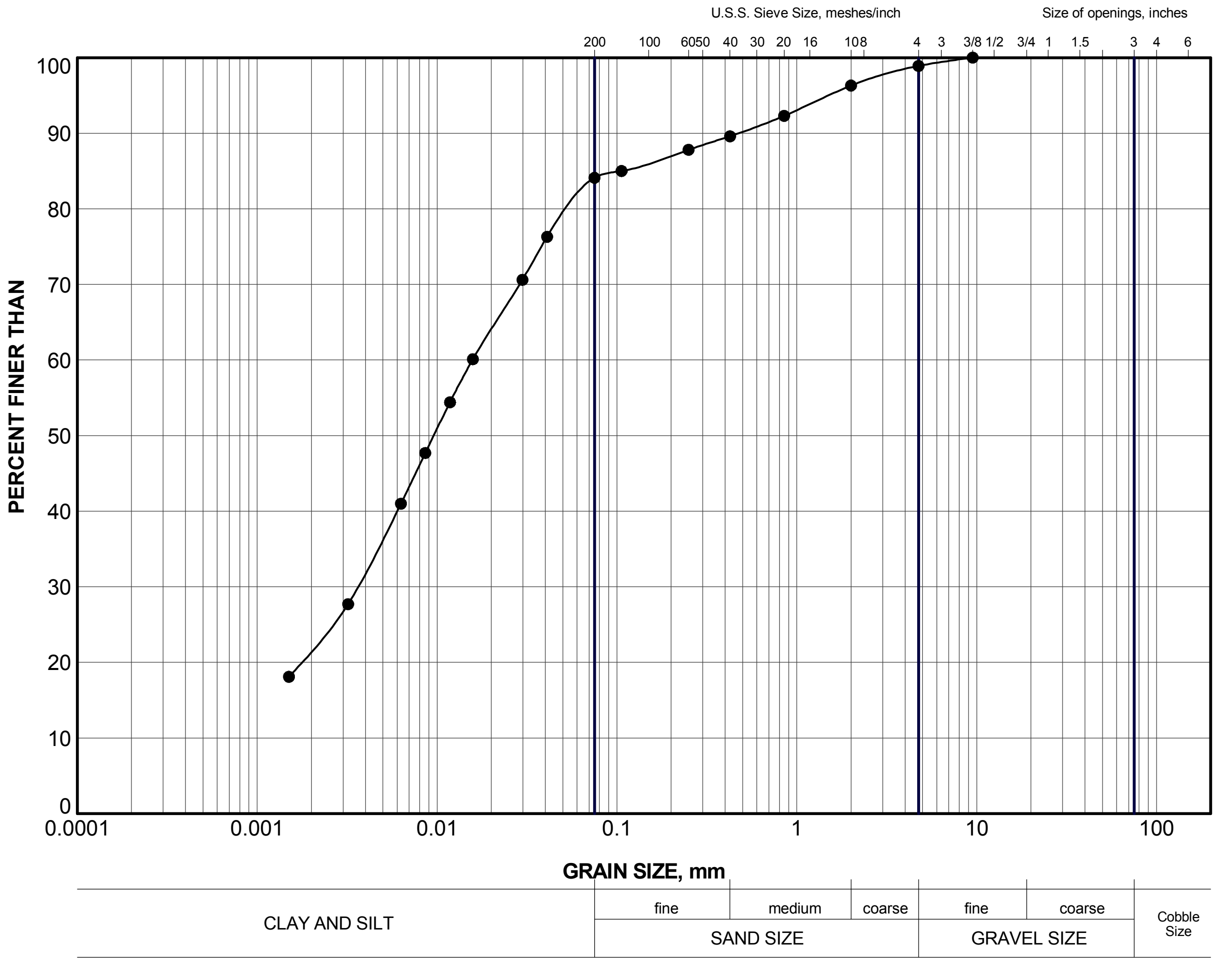
GRAIN SIZE DISTRIBUTION

SILTY SAND to GRAVELLY SAND

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	13-1184-0074		FILE No.	13-1184-0074.GPJ
DRAWN	TB	Oct 2014	SCALE N/A	REV.
CHECK	AB	Oct 2014		
APPR	JMAC	Oct 2014	FIGURE B7	

SUD-MTO GSD (NEW) GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	CE-1	14	201.3

PROJECT	HIGHWAY 17 CENTRELINE CULVERT - STA 11+600
TITLE	**GRAIN SIZE DISTRIBUTION** SILT to CLAYEY SILT (INTERLAYER)

Golder Associates
SUDBURY, ONTARIO

PROJECT No.	13-1184-0074		FILE No.	13-1184-0074.GPJ
DRAWN	TB	Oct 2014	SCALE N/A	REV.
CHECK	AB	Oct 2014		
APPR	JMAC	Oct 2014	**FIGURE B8**	

SUD-MTO GSD (NEW) GLDR_LDN.GDT

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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