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FOUNDATION INVESTIGATION AND DESIGN REPORT

NEW CN RAILWAY EMBANKMENT OVER SWAMPS
HIGHWAY 69 FOUR-LANING FROM 1.7 KM NORTH OF HIGHWAY 529
NORTHERLY TO 3.9 KM NORTH OF HIGHWAY 522
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5344-08-00; WP 5344-08-01

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REPORT

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PART A

FOUNDATION INVESTIGATION REPORT
NEW CN RAILWAY EMBANKMENT OVER SWAMPS
HIGHWAY 69 FOUR-LANING FROM 1.7 KM NORTH OF HIGHWAY 529, NORTHERLY TO 3.9 KM NORTH OF HIGHWAY 522
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5344-08-00; WP 5344-08-01

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by URS Canada Inc. (URS) on behalf of Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for four (4) swamp crossings within the Contract 1 limits of the new Highway 69 alignment near the junction with Highway 522. The proposed work in Contract 1, which is the Canadian National Railway (CNR) re-alignment and Detour embankment to allow construction of the CNR overpass at the existing Highway 69, is part of the four-laning of Highway 69 from 1.7 km north of Highway 529, northerly to 3.9 km north of Highway 522 for a total distance of 19.7 km. The proposed CNR re-alignment and Highway 69 Detour are located approximately 1 km south of the junction of the existing Highway 522 and Highway 69 and extends for a total distance of about 3 km. The general location of this section of the new CNR alignment and Highway 69 Detour is shown on the Site Location Plan on Drawing 1.

The terms of reference and the scope of work for the foundation investigation are outlined in MTO's Request for Proposal, dated December 2008. Golder's proposal for foundation engineering services associated with the Contract 1 swamp crossings is contained in Section 6.8 of URS's Technical Proposal for this assignment. The work has been carried out in accordance with Golder's Supplemental Specialty Quality Control Plan for foundation engineering services for this project, dated April 19, 2010. The Base Plan showing the new alignment of the CNR was provided to Golder by URS in April 2010.

This report addresses the investigation carried out for the Contract 1 swamp crossings only. A detailed list of the Contract 1 swamp crossings is presented in Table 1. Separate reports will be submitted detailing the foundation investigations for the swamp crossings and high fill areas in the other contracts, as well as for the culverts and bridge structures for the project.

The purpose of this investigation is to establish the subsurface conditions along the new alignment of the CNR and Highway 69 Detour at the proposed Contract 1 swamp crossings by methods of borehole drilling, in situ testing and laboratory testing on selected samples. The centreline of the proposed CNR alignment and Highway 69 Detour was staked in the field by Callon Dietz Inc., a professional surveying company retained by URS and the foundation investigation was carried out within the limits of the swamp crossings as defined in the terms of reference. The investigation areas are shown in plan on Drawing 2.

Preliminary subsurface information for this project was available and was supplied by the MTO, in a report titled:

- Preliminary Foundation Investigation & Design Report, Swamp Crossings, Highway 69 Route Selection Study, 3.5 km N of Hwy 559 to 3.8 km N of Hwy 522, GWP 5377-02-00, Highway 69, GEOCRES No. 41H-51, dated September 2005, by Trow Associates Inc.

2.0 SITE DESCRIPTION

The section of the new CNR alignment and Highway 69 Detour being addressed by this report is approximately 11.5 km north of Britt Station, Ontario and is located south of the existing CNR alignment as shown on Drawing 1. The proposed CNR re-alignment associated with the four-laning of the new Highway 69 in Contract 1 includes the CNR NBL and SBL overpass structures, as well as the CNR overpass structure for the proposed Highway 522 extension (i.e. existing Highway 69). The new CNR alignment is oriented generally in a southeast-northwest direction spanning the Township of Mowat on the east end to the Township of Henvey on the west end of the alignment, while the new four-lane Highway 69 alignment is oriented generally in a south-north direction within the project limits spanning from the Township of Wallbridge at the south end to the Township of Mowat at the north end of the alignment. The new Detour embankment will be located along the west side of the existing Highway 69 approximately 1 km south of the Highway 522 junction and is about 1 km in length.

In general, the topography of this section of the overall project limits consists of rolling terrain, including sparsely or densely populated treed areas and numerous bedrock outcrops separated by valleys and by swamps containing areas of standing water and various types of vegetation and organic soils. The ground surface within the limits of the study area varies between about Elevation 180.3 m and Elevation 200.0 m, referenced to Geodetic datum. A detailed description of each investigated swamp crossing is presented in Section 4.0. The locations of these areas are shown on Drawing 2.

3.0 INVESTIGATION PROCEDURES

3.1 Foundation Investigation

The investigation for the Contract 1 swamp crossings was carried out between December 8 and December 22, 2009, January 8 and 19, 2010, and August 16 and September 2, 2010, during which time a total of forty-four (44) boreholes and fifteen (15) Dynamic Cone Penetration Tests (DCPTs) were advanced at the locations of swamp crossings. The locations of the boreholes and DCPTs are summarized in Table 1 and are shown on Drawings A1 to E1 in Appendices A to E.

The field investigation was carried out using a variety of drilling and excavating equipment as a result of the varying nature of the terrain within the Contract 1 project limits. The details of the drilling equipment and suppliers are listed below. Hand excavation methods were used as appropriate depending on the terrain.

Drilling Equipment	Supplied and Operated By
Track Mounted CME-55 Portable Equipment	Landcore Drilling of Sudbury, Ontario
Track Mounted D-50 Turbo	Walker Drilling Ltd. of Utopia, Ontario

The boreholes were advanced through the overburden using 108 mm inside diameter hollow-stem augers or NW or BW casing with wash boring techniques. In general, soil samples were obtained at intervals of depth of about 0.75 m and 1.5 m, using a 50 mm outer diameter (O.D.) split-spoon sampler operated by automatic hammers on the drill rigs, performed in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586, Standard Test Method for Standard Penetration Test). Boreholes advanced by portable equipment employed full weight or half weight hammers lifted manually and dropped from the SPT height. 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. All boreholes were backfilled with bentonite upon completion in accordance with Ontario Regulation 903 Wells (as amended by Ontario Regulation 372).

The boreholes and DCPTs were advanced to depths up to 18.9 m below existing ground surface, generally penetrating 3 m into competent material, which is defined as material that will provide resistance to settlement or instability of the embankments, or to refusal. In general, boreholes and DCPTs locations were terminated on refusal to further auger, casing and/or split-spoon advancement, or cone penetration. These depths to refusal do not confirm bedrock surface elevations, but may be inferred to indicate potential proximity to the bedrock surface. At various borehole locations where refusal was encountered at shallow depth (less than 0.1 m), the bedrock was exposed by hand shovel excavation to confirm the refusal condition.

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 Appendices A to E. Groundwater elevations as encountered in the boreholes may not be representative of static groundwater levels since the groundwater levels in the boreholes may not have stabilized on completion of drilling. Furthermore, groundwater elevations will vary depending on seasonal fluctuations, precipitation and local soil permeability.

The fieldwork was observed by members of our engineering and 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 geotechnical 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 samples. In addition, one-dimensional consolidation (oedometer) tests were carried out on two (2) samples of the cohesive deposits. The results of the laboratory testing for each of the swamp crossings are included in the associated appendices.

The proposed centrelines of the realigned CNR and Highway 69 Detour embankments were staked in the field by Callon Dietz prior to drilling. The as-drilled borehole locations, in stations and offsets, were measured in reference to the centreline alignment and were subsequently converted into MTM NAD 83 coordinates in AutoCAD. Borehole elevations were surveyed by a member of our technical staff in reference to the ground surface elevations at the centreline median and to temporary benchmarks which were then surveyed by Callon Dietz upon completion of the fieldwork. The borehole locations shown on Drawings A1 to E1 in Appendices A to E are positioned relative to MTM NAD 83 northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

As delineated in The Physiography of Southern Ontario[1], this realigned section of the CNR lies within the physiographic region known as the Georgian Bay Fringe, which extends along the east side of Georgian Bay through the Parry Sound and Muskoka areas, then eastward from Muskoka in patches into the area north of the Kawartha Lakes.

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[1] Chapman, L.J. and Putnam, D.F., 1984. *The Physiography of Southern Ontario*, Ontario Geological Survey, Special Volume 2, Third Edition. Accompanied by Map P.2715, Scale 1:600,000.

This part of the Georgian Bay Fringe physiographic region was never submerged during periods of glacial recession. As a result, the surficial soils in this area consist of very shallow deposits of sand, silt and clay underlain by metamorphic bedrock and numerous bare knobs and ridges of bedrock are present throughout the area. Localized low-lying swampy areas, containing peat and/or organic soils overlying soft/loose native soils, are present in valleys between the bedrock knobs and ridges.

The bedrock in the area consists typically of gneisses of the Britt Domain of the Central Gneiss Belt, a subdivision of the Grenville Structural Province, as described in Geology of Ontario, OGS Special Volume 4[2]. Deposition of Palaeozoic strata initially covered by the bedrock and later erosion during glaciation exposed these Precambrian rocks.

4.2 General Overview of Local Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced during this investigation (including excavations by hand shovel), together with the results of the laboratory tests carried out on selected soil samples, are presented on the Record of Borehole sheets and the laboratory test sheets in Appendices A to E. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling, observations of drilling progress and the results of SPTs and in situ testing. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations. The thickness of the overburden in the investigated areas as inferred from the resistance to DCPT results are shown on the Record of Penetration Test sheets in Appendices A to E.

The inferred soil stratigraphy as encountered in the boreholes and DCPTs advanced for the Contract 1 swamp crossings is shown in profile on Drawings A1 to E1, inclusive. The orientation (i.e. north, south, east, west) stated in the text of the report is typically referenced to project north and/or up-chainage. For purposes of this report, the CNR alignment was in an east-west orientation and Highway 69 was in a north-south orientation. Therefore, the directions indicated may differ from that shown on the drawings.

In general, the stratigraphy encountered at the various borehole locations typically consists of alternating layers of cohesive and cohesionless soils. The overburden (soil materials) thickness is variable, ranging from no cover (i.e. bedrock outcrops exposed at ground surface at the edges of the swamps) to 18.9 m. The stratigraphy generally consists of:

- Surficial layers of fibrous and amorphous peat or organic root mat;
- Cohesive deposits of glacio-lacustrine mixtures of silt and clay interbedded with silt and sand seams in some areas; and
- Relatively thin sandy deposits between cohesive deposits and relatively thick sandy deposits over inferred bedrock.

Detailed descriptions of the subsurface conditions at each investigated swamp crossing are provided in the following sections of this report. Where relatively significant thicknesses of overburden were encountered, the various soil types are described in detail for each main deposit or stratum.

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[2] Geology of Ontario, 1991. Ontario Geological Society Special Volume 4, Part 2. Ministry of Northern Development and Mines, Ontario.

4.3 CNR – STA 328+810 to 328+940 (Swamp 101)

The plan and profiles along the centreline and toes of the proposed CNR alignment showing the borehole locations and interpreted stratigraphy between about STA 328+810 and 328+940 are shown on Drawing A1. The alignment extends across a low-lying area with the proposed embankment up to about 4.8 m high above existing grade. A total of eleven (11) boreholes (Boreholes S101-01 to S101-11, inclusive) and five (5) DCPTs (DCPTs S101-DC1 to S101-DC5, inclusive) were completed to investigate the subsurface conditions within this area. The topography in this section of the proposed CNR alignment is gently sloping to a low area between steep ridges beyond the west and east limits of the investigated area, and is moderately tree covered with bedrock exposed at the west limit of the swamp.

The subsurface soils along the alignment in Swamp 101 generally consist of a surficial root mat at ground surface underlain by alternating deposits of silt to clayey silt, silty sand to sandy silt and clayey silt to clay, underlain by inferred bedrock. Resistance to dynamic cone penetration and borehole advancement, indicative of the potential bedrock surface, was encountered at depths of up to about 18.9 m, being deepest in the vicinity of about STA 328+850. A bedrock outcrop was observed at the west end of the investigated area (at about STA 328+935).

Peat (Root Mat)

A 0.1 m to 0.4 m thick deposit of brown peat was encountered at ground surface in all the boreholes with ground surface between Elevation 183.7 m and 180.3 m. The deposit is described as a “root mat” consisting of grass, topsoil, leaves, roots, twigs, etc. In Borehole S101-11, bedrock was exposed by hand shovel excavation to confirm refusal at the bottom of this deposit.

One SPT ‘N’-value measured within this deposit in Borehole S101-03 is 4 blows per 0.3 m of penetration, indicating a soft consistency.

Silt/Clayey Silt

A deposit of brown to grey silt containing trace sand and trace organics was encountered underlying the root mat in Boreholes S101-01 to S101-07. Towards the east end of the site, in Boreholes S101-09 and S101-10, a deposit of grey and brown mottled clayey silt containing trace organics was encountered below the root mat. The top of the silt/clayey silt deposit ranges from Elevation 183.1 m to 180.2 m and the deposit is between 0.7 m and 1.6 m thick.

SPT ‘N’-values recorded within the silt deposit are between 2 blows and 7 blows per 0.3 m of penetration, indicating a very loose to loose relative density. In Boreholes S101-09 and S101-10, in the clayey silt deposit, the SPT ‘N’-values are between 2 blows and 7 blows per 0.3 m of penetration, suggesting a soft to firm consistency.

One grain size distribution of a sample of the clayey silt is shown on Figure A.S101-01, in Appendix A.

The natural water content measured on selected samples of this deposit is between about 32 percent and 53 percent.

Silty Sand to Sand

A deposit of brown to grey, silty sand to sand, containing trace clay and trace organics was encountered underlying the silt/clayey silt deposit in Boreholes S101-01 to S101-03, S101-09 and S101-10, beneath a deposit of organic silty clay to clay in Borehole S101-05 and beneath the root mat in Borehole S101-08. A second layer of silty sand was encountered below the deposit of silty clay to clay with organics in Borehole S101-08. At the west end of the site (i.e. Boreholes S101-01 to S101-05), the deposit is described as silty sand, whereas at the east end of the site (i.e. Boreholes S101-08 to S101-10), the deposit is described as sand. The top of this deposit varies between Elevation 181.9 m and 178.2 m and the deposit ranges in thickness from 0.6 m to 1.5 m.

The SPT ‘N’-values recorded within this deposit are between 0 blows (weight of hammer) and 7 blows per 0.3 m of penetration, indicating a very loose to loose relative density.

Grain size distributions for two selected samples of silty sand to sand are shown on Figure A.S101-02, in Appendix A.

The natural water content measured on samples of this deposit ranges from about 26 percent to 43 percent.

Silt, Slightly Organic to Clay, Organic

A deposit of grey to black slightly organic silt or organic clay was encountered below the silt deposit in Boreholes S101-04 to S101-07 and beneath the silty sand to sand deposit in Borehole S101-08. The thickness of this layer ranges from 1.3 m to 1.6 m and the top of this layer was encountered between Elevation 180.6 m and 178.9 m.

The SPT ‘N’-values measured within this deposit range between 0 blows (weight of hammer) and 3 blows per 0.3 m of penetration. In situ field vane testing carried out within this stratum measured undrained shear strengths of about 14 kPa and 17 kPa and the sensitivity is calculated to be about 2 and 5 for each vane, respectively. The in situ field vane tests indicate the deposit has a very soft to soft consistency.

Atterberg limits testing was carried out on two samples of this deposit, and the test results indicate liquid limits of about 41 percent and 54 percent, plastic limits of about 32 percent and 40 percent and plasticity indices of about 9 percent and 14 percent. The results of the Atterberg limits tests are shown on the plasticity chart on Figure A.S101-03 in Appendix A and indicate that these two samples are classified as slightly organic silt of intermediate to high plasticity.

The measured water content on samples of this deposit ranges between about 35 percent and 103 percent.

The organic content measured on three samples of this deposit is between about 4 percent (slightly organic silt) and 8 percent (organic clay).

Clayey Silt to Clay

A deposit of brown to grey clayey silt to clay, containing sand and silt layers and/or seams throughout, was encountered underlying the silty sand to sand deposit in Boreholes S101-01 to S101-03, S101-05, S101-09 and S101-10 and beneath the deposit of slightly organic silt/organic clay in Boreholes S101-04 and S101-06 to S101-08. The thickness of the deposit ranges from 1.5 m to 7.3 m and the top of the deposit was encountered between Elevation 180.9 m and 177.3 m. In Borehole S101-01, the bottom of this deposit was defined by refusal to further split-spoon and auger advancement.

The SPT 'N'-values measured within this deposit range from 0 blows (weight of hammer) to 1 blow per 0.3 m of penetration. In situ field vane testing carried out within this stratum measured undrained shear strengths ranging from about 10 kPa to 46 kPa, typically increasing with depth, and the sensitivity is calculated to range between about 2 and 12. The in situ field vane tests indicate the deposit has a very soft to firm consistency.

Atterberg limits testing was carried out on eleven samples of clayey silt to clay, and the test results indicate liquid limits ranging from about 22 percent to 57 percent, plastic limits ranging from about 15 percent to 23 percent and plasticity indices ranging from about 7 percent to 37 percent. The results of the Atterberg limits tests are shown on the plasticity chart on Figure A.S101-04 in Appendix A and indicate that the material is classified as a clayey silt of low plasticity to a clay of high plasticity.

A grain size distribution of one select sample of this deposit is shown on Figure A.S101-05, in Appendix A.

Measured water content on samples of this deposit ranges between about 38 percent and 102 percent.

Two laboratory consolidation tests were carried out on specimens of the clay obtained from Boreholes S101-05 and S101-06 and the test results are shown on Figures A.S101-06 and A.S101-07, respectively. The preconsolidation pressure was estimated from the Void Ratio versus logarithmic Pressure plots using the Casagrande method. The relevant consolidation test results are summarized below.

Borehole/Sample Number	Elevation (m)	σ_{vo}' (kPa)	σ_p' (kPa)	$\sigma_p' - \sigma_{vo}'$ (kPa)	OCR	e_o	C_r	C_c	c_v^* (cm^2/s)
S101-05/6	175.4	35	40	5	1.1	2.62	0.14	0.94	3.6×10^{-3}
S101-06/5	177.1	37	70	33	1.9	2.52	0.12	1.50	1.1×10^{-3}

Note: *For approximate stress range of $35 \leq \sigma_v' \leq 140$ kPa

where:

σ_{vo}'	effective overburden pressure in kPa
σ_p'	preconsolidation pressure in kPa
OCR	overconsolidation ratio
e_o	initial void ratio
C_c	compression index (based on void ratio)
C_r	recompression index (based on void ratio)
c_v	coefficient of consolidation in cm^2/s in the normally consolidated range

Sand and Silt to Silt

A deposit of grey sand and silt to silt, containing trace to some clay was encountered underlying the clayey silt to clay deposit in Boreholes S101-02 to S101-10. Clayey silt to silty clay seams up to 300 mm thick were encountered in the lower portion of the deposit in Boreholes S101-02, S101-03 and S101-05 to S101-08. The top of this deposit varies between Elevation 179.4 m and 170.3 m and the deposit ranges in thickness from 0.4 m to 8.5 m. In Borehole S101-08, a 0.3 m thick layer of sandy silt was also encountered underlying the lower clayey silt deposit at Elevation 168.8 m. The bottom of this deposit, including the lower layer in Borehole S101-08, was defined by refusal to further split-spoon and auger advancement in each of these boreholes.

The SPT 'N'-values measured within this deposit are between 0 blows (weight of hammer) and 41 blows per 0.3 m of penetration, indicating a very loose to dense relative density. Typically, the SPT 'N'-values were less than 10 blows per 0.3 m of penetration, indicating that the deposit is generally very loose to loose. In Boreholes S101-04, S101-09 and S101-10, at the base of the deposit where refusal was encountered, the split-spoon sampler did not penetrate the full "N-value" sample thickness and was noted to be bouncing.

Grain size distributions of seven samples of the sand and silt to silt deposit are shown on Figure A.S101-08, in Appendix A. The test result from near the base of the deposit in Borehole S101-07 had an increased percentage of clay sizes, indicative of the clay seams.

The natural water content measured on samples of this deposit ranges from about 19 percent to 35 percent.

An Atterberg limits test was carried out on one sample of a silty clay seam encountered within the sand and silt to silt deposit and measured a liquid limit of 43 percent, a plastic limit of 19 percent and a plasticity index of 24 percent. The results of the Atterberg limits test are shown on the plasticity chart on Figure A.S101-09 and indicate that the seam is a silty clay of intermediate plasticity.

Clayey Silt (Lower)

A 1.8 m thick deposit of grey clayey silt was encountered below the lower stratum of sand and silt to silt in Borehole S101-08 at Elevation 170.6 m.

The SPT ‘N’-values recorded within this deposit are 1 blow per 0.3 m of penetration. An in situ vane test carried out within this stratum measured an undrained shear strength of about 25 kPa, and the sensitivity is calculated to be about 7. The in situ field vane test indicates that this stratum has a soft consistency.

An Atterberg limits test was carried out on one sample of the lower clayey silt deposit and measured a liquid limit of 33 percent, a plastic limit of 21 percent and a plasticity index of 12 percent. The results of the Atterberg limits test are shown on the plasticity chart on Figure A.S101-09 in Appendix A and indicate that the material is classified as a clayey silt of low plasticity.

The natural water content measured on one sample of this deposit is about 40 percent.

Bedrock/Refusal

Bedrock outcropping was noted at the west limit of the swamp at STA 328+935. The inferred bedrock surface at the boreholes and DCPTs was determined by refusal to further auger and/or spoon advancement or dynamic cone penetration at depths between 0.1 m and 18.9 m below ground surface. These refusal depths, while they do not confirm bedrock elevations, may be inferred to indicate potential proximity to the bedrock interface. Refusal was encountered between Elevation 183.6 m (Borehole S101-11) and 162.0 m (DCPT S101-DC4) and, in general, was encountered at greater depth between about STA 328+835 and STA 328+900.

Groundwater Conditions

In general, the samples taken in the boreholes were wet with free water noted in some samples of cohesionless material. Water levels observed in the boreholes upon completion of drilling range from Elevation 180.1 m to 178.5 m, typically measured at depths ranging from 0.7 m to 3.1 m below ground surface. Groundwater levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

4.4 CNR – STA 329+035 to 329+060 (Swamp 102)

The plan and profile along the centreline of the realigned CNR showing the borehole locations and interpreted stratigraphy between about STA 329+035 and 329+060 are shown on Drawing B1. The alignment extends across a low-lying area with the top of the proposed embankment at approximately the same elevation as or up to about 0.3 m high above the existing ground surface. A total of three (3) boreholes (Boreholes S102-01 to S102-03, inclusive) and one (1) DCPT (S102-DC1) were completed to investigate the subsurface conditions within this area. The topography in this section of the proposed CNR alignment is generally flat and is a low area sloping down gently from west to east between steep ridges beyond the north and west limits of the investigated area. An existing snowmobile trail passes through this valley in a north-south direction.

The subsurface soils along this section of the CNR alignment in Swamp 102 generally consist of a surficial root mat underlain by a deposit of sand and silt to silty sand, underlain by inferred bedrock. A thin layer of clayey silt was encountered within the cohesionless deposit in the vicinity of STA 329+060 (towards the west limit of the investigated area). Resistance to dynamic cone penetration and borehole advancement, indicative of the potential bedrock surface, was encountered at depths of up to about 4.2 m below ground surface, being deepest near the east end of the swamp, in the vicinity of about STA 329+040.

Fill

A 0.4 m thick layer of fill consisting of sand and silt was placed by Golder in the area of Borehole S102-02 to facilitate drilling of the borehole. The top of the fill is at Elevation 185.0 m.

One SPT ‘N’-value measured within the fill was 2 blows per 0.3 m of penetration, indicating a very loose relative density.

Peat (Root Mat)

A 0.1 m to 0.2 m thick layer of brown peat was encountered at ground surface in Borehole S102-01 and underlying the fill in Borehole S101-02. The layer is described as an organic “root mat” consisting of grass, topsoil, leaves, roots and twigs. The top of this layer was encountered at Elevation 185.1 m and 184.6 m in Boreholes S102-01 and S102-02, respectively.

Sand and Silt to Silty Sand

A deposit of brown to grey sand and silt to silty sand, containing trace to some clay was encountered at ground surface in Borehole S102-03 and underlying the root mat in Boreholes S102-01 and S102-02. The top of this deposit varies between Elevation 185.3 m and 184.5 m, and the deposit ranges in overall thickness from 3.0 m to 3.6 m. The bottom of this deposit was defined by refusal to further split-spoon and/or auger advancement in all the boreholes.

The SPT ‘N’-values recorded within this deposit are between 0 blows (weight of hammer) and 15 blows per 0.3 m of penetration, indicating a very loose to compact relative density.

Grain size distributions of two selected samples of sand and silt to silty sand are shown on Figure B.S102-01, in Appendix B.

The natural water content measured on samples of this deposit ranges from about 19 percent to 27 percent.

Clayey Silt Interlayer

A 0.8 m thick interlayer of grey clayey silt was encountered within the sand and silt to silty sand deposit in Borehole S102-03 at Elevation 183.6 m.

One SPT ‘N’-value measured within this deposit is 2 blows per 0.3 m of penetration. One in situ field vane test carried out within this stratum measured an undrained shear strength of 7 kPa, and the sensitivity is calculated to be about 4. The in situ field vane test result indicates that the deposit has a very soft consistency.

An Atterberg limits test was carried out on one sample of clayey silt, and measured a liquid limit of about 35 percent, a plastic limit of about 22 percent and a plasticity index of about 13 percent. The result of the Atterberg limits test is shown on the plasticity chart on Figure B.S102-02 in Appendix B and indicates that the material is classified as a clayey silt of low plasticity.

The natural water content measured on one sample of this deposit is about 41 percent.

Bedrock/Refusal

The bedrock surface at the location of the borehole and DCPT was inferred from refusal to further auger and/or split-spoon advancement and dynamic cone penetration at depths between 3.0 m and 4.2 m below ground surface, between Elevation 181.3 m (Borehole S102-01) and 182.3 m (Borehole S102-03). These refusal depths, while they do not confirm bedrock elevations, may be inferred to indicate potential proximity to the bedrock interface. In general, refusal was encountered at greater depth near the east end of the swamp at about STA 329+050.

Groundwater Conditions

In general, the samples taken in the boreholes were wet with free water noted in some samples of cohesionless material. Water levels observed in the boreholes upon completion of drilling range from Elevation 183.6 m to 183.2 m corresponding to measured depths ranging from 1.5 m to 2.1 m below ground surface. Groundwater levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

4.5 CNR – STA 329+185 to 329+305 (Swamp 103)

The plan and profiles along the centreline and toes of the realigned CNR showing the borehole locations and interpreted stratigraphy between about STA 329+185 and STA 329+305 are shown on Drawing C1. The alignment extends across a low-lying area with the proposed embankment approximately 2.9 m high above existing grade at the east end and approximately 0.1 m high above existing grade at STA 329+260. West of STA 329+260, the alignment is in a cut, up to 1.6 m deep at the western end of the swamp area at about STA 329+305. A total of ten (10) boreholes (Boreholes S103-01 to S103-09 and S103-03a) and three (3) DCPTs (DCPTs S103-DC1 to S103-DC3) were completed to investigate the subsurface conditions within this area. The topography in this section of the proposed CNR alignment is generally low-lying with the ground surface sloping down from both the east and west ends of the swamp area being deepest near the east end of the investigated area. Bedrock is exposed at the east limit of the swamp and moderate tree cover is present over the entire area.

The subsurface soils along the alignment in Swamp 103 generally consist of a surficial root mat underlain by alternating deposits of silty clay, sand, clayey silt and silty sand to silt. The boreholes were typically terminated within the lower cohesionless deposit up to 18.9 m below ground surface. Refusal to dynamic cone penetration and borehole advancement, indicative of the potential bedrock surface, was encountered in boreholes at the east end of the swamp only (east of about STA 329+220).

Peat (Root Mat)

A 0.1 m to 0.3 m thick deposit of brown peat was encountered at ground surface between Elevation 187.2 m and 182.3 m in all the boreholes except Borehole S103-04. The deposit is described as a “root mat” consisting of grass, topsoil, leaves, roots and twigs.

Silty Clay/Silt

In Boreholes S103-01 to S103-03/03a, S103-07 and S103-09, located in the western portion of the swamp, a deposit of brown to grey silty clay containing trace sand and trace organics was encountered underlying the root mat. In the eastern portion of the site, Boreholes S103-04 to S103-06 encountered a deposit of brown silt containing trace to some clay and trace organics at ground surface or underlying the root mat. The top of this deposit ranges from Elevation 187.1 m to 182.2 m and the deposit ranges in thickness from 0.5 m to 1.4 m.

SPT ‘N’-values recorded within the silty clay deposit are between 3 blows and 6 blows per 0.3 m of penetration, suggesting a soft to firm consistency. SPT ‘N’-values recorded within the silt deposit are between 2 blows and 6 blows per 0.3 m of penetration, indicating a very loose to loose relative density.

Atterberg limits testing was carried out on two samples of silty clay obtained from the boreholes in the western end of the site (i.e. Boreholes S103-07 and S103-09) and the test results indicate liquid limits of about 43 percent and 44 percent, plastic limits of about 25 percent and plasticity indices of about 18 percent and 19 percent. The results of the Atterberg limits tests are shown on the plasticity chart on Figure C.S103-01 in Appendix C and indicate that the material is classified as a silty clay of intermediate plasticity. An Atterberg limits test was carried out on a sample of the silt deposit obtained from Borehole S103-06, in the east end of the site, and the results indicate that the material is non-plastic.

The natural water content measured on samples of the silty clay deposit is between about 35 percent and 38 percent and the natural water content of two samples of the silt deposit is about 25 percent and 35 percent.

Sand/Sand and Gravel

A deposit of brown sand containing trace silt and trace to some gravel was encountered underlying the silty clay/silt deposits in all of the boreholes except in Boreholes S103-08 and S103-09. In Borehole S103-09, the deposit is coarser in gradation, and is comprised of sand and gravel. The top of this deposit varies between Elevation 185.7 m and 180.8 m and the deposit ranges in thickness from 0.4 m to 3.8 m. In Borehole S103-06, the bottom of this deposit was defined by refusal to further auger advancement.

The SPT ‘N’-values recorded within this deposit are between 3 blows and 28 blows per 0.3 m of penetration, indicating a loose to compact relative density.

Grain size distributions of three samples of the sand deposit are shown on Figure C.S103-02a, in Appendix C. A grain size distribution of one sample of the sand and gravel deposit is shown on Figure C.S103-02b, in Appendix C.

The natural water content measured on samples of this deposit ranges from about 3 percent to 21 percent.

Clayey Silt

A deposit of brown to grey clayey silt was encountered below the sand/sand and gravel deposit in all the boreholes, except Boreholes S103-06 and S103-08. In Boreholes S103-01 to S103-05, sand and silt layers and/or seams were observed within the deposit. The thickness of this deposit ranges from 0.3 m to 4.1 m and the top of this deposit was encountered between Elevation 183.9 m and 178.9 m

The SPT ‘N’-values measured within this deposit range between 0 blows (weight of hammer) and 6 blows per 0.3 m of penetration. In Boreholes S103-01 to S103-04, in situ vane shear strengths taken within this deposit were atypical. The shear strength determined from the second vane in each of two consecutive tests was typically much greater (15 kPa to 77 kPa) than the first vane (7 kPa to 23 kPa), potentially indicative of the presence of silt or sand lenses. The sensitivity associated with the in situ vane shear strengths in Boreholes S103-01 to S103-04 were calculated to range between about 1 and 9. At the west end of the site (Boreholes S103-07 and S103-09), the in situ vane shear strength measurements are more typical, ranging from 31 kPa to 33 kPa (with sensitivity calculated to range between about 2 and 6 for both the first and second sets of consecutive tests). The in situ field vane test results indicate the deposit generally has a very soft to firm consistency.

Atterberg limits testing was carried out on four samples of this deposit and the test results indicate liquid limits ranging from about 26 percent to 34 percent, plastic limits ranging from about 19 percent to 23 percent and plasticity indices ranging from about 4 percent to 12 percent. The results of the Atterberg limits tests are shown on the plasticity chart on Figure C.S103-03 in Appendix C and indicate that the material is classified as clayey silt of low plasticity to silt with slight plasticity. An Atterberg limits test on a sample obtained from Borehole S103-03a indicates that the material in non-plastic, which is also indicative of the presence of sand or silt layers or lenses within the deposit.

The measured water content on samples of this deposit ranges between about 29 percent and 38 percent.

Silty Sand to Silt

A deposit of grey silty sand to silt, containing trace clay was encountered underlying the clayey silt deposit in all boreholes, except Boreholes S103-06 and S103-08. Typically, the deposit ranges in gradation from sand and silt to silt, although in Boreholes S103-03a and S103-05 near the east end of the site, the deposit is comprised of silty sand. The top of this deposit varies between Elevation 181.1 m and 178.6 m and the deposit ranges in thickness from 3.7 m to greater than 14.5 m. The bottom of this deposit was defined by refusal to further auger advancement in Borehole S103-05. Borehole advancement was terminated within this deposit in Boreholes S103-01 to S103-04, S103-07 and S103-09.

The SPT 'N'-values measured within this deposit range between 0 blows (weight of hammer) and 23 blows per 0.3 m of penetration, indicating a very loose to compact relative density. In general, the 'N'-values are less than 10 blows per 0.3 m of penetration, indicating the deposit is generally very loose to loose.

Grain size distributions of eleven samples of the silty sand to silt deposit are shown on Figure C.S103-04 in Appendix C.

The natural water content measured on samples of this deposit ranges from about 14 percent to 26 percent.

Bedrock/Refusal

A bedrock outcrop was observed at the east limit of the swamp at about STA 329+185 and bedrock is exposed at the location of Borehole S103-08a (Elevation 185.6 m). In Boreholes S103-05 and S103-06, near the east end of the swamp, refusal to further auger advancement was encountered at depths of 11.4 m and 5.3 m below ground surface, respectively, corresponding to Elevation 171.2 m and 177.0 m. These refusal depths, while they do not confirm bedrock elevations, may be inferred to indicate potential proximity to the bedrock interface. In the boreholes in the central and western portions of the swamp, the boreholes and DCPTs were terminated within the silty sand to silt deposit.

Groundwater Conditions

In general, the samples taken in the boreholes were wet with free water noted in some samples of cohesionless material. Water levels observed in the boreholes upon completion of drilling range from Elevation 184.8 m to 180.1 m, measured at depths ranging from 1.2 m to 4.5 m below ground surface. Groundwater levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

4.6 CNR – STA 329+680 to 329+780 (Swamp 104)

The plan and profiles along the centreline and toes of the realigned CNR showing the borehole locations and interpreted stratigraphy between about STA 329+680 and 329+780 are shown on Drawing D1. The alignment extends across a low-lying area with the proposed embankment up to 4.2 m high above existing grade. Ten (10) boreholes (Boreholes S104-01 to S104-09, inclusive and S104-04a) and four (4) DCPTs (DCPTs S104-DC1 to S104-DC4, inclusive) were completed to investigate the subsurface conditions within this area. The topography in this section of the proposed CNR alignment is flat and low-lying with ponded water encountered at ground surface. The entire investigated area is covered moderately with trees, shrubs and grass. The existing Highway 69 alignment and proposed Highway 69 Detour, extends across the eastern limit of the investigated area.

Ice and water was encountered at ground surface across the entire site. The subsurface soils generally consist of a layer of peat (fibrous and/or amorphous), underlain by deposits of clay, sand and gravel and sand to sand and silt. The cohesionless deposit of sand to sand and silt is underlain by inferred bedrock. Refusal to dynamic cone penetration and borehole advancement, indicative of the potential bedrock surface, was encountered in each of the boreholes and DCPTs, with the exception of Borehole S104-09 which was terminated within the sand deposit.

Ice/Water

Ice and water was encountered in each of the boreholes to depths ranging from 0.2 m to 1.5 m, being deepest in the area of Borehole S104-04 and DCPT S104-DC1 near STA 329+713.

Peat

Fibrous and amorphous peat was encountered in all boreholes except in Borehole S104-09. The total thickness of the peat deposit is between 0.1 m and 2.3 m and the top of the peat was encountered between Elevation 182.6 m and 181.3 m.

The peat deposit is comprised of a 0.1 m to 1.7 m thick layer of brown fibrous peat which was encountered below the ice and water in Boreholes S104-01, S104-02, S104-04 to S104-08 and S104-04a and a 0.2 m to 1.9 m thick layer of brown amorphous peat which was encountered below the ice and water in Borehole S104-03 and beneath the fibrous peat layer in Boreholes S104-05 to S104-07 and S104-04a. In Borehole S104-07, the bottom of this layer was defined by refusal to further split-spoon advancement.

The SPT ‘N’-values measured within the peat are 0 blows (weight of hammer) or 1 blow per 0.3 m of penetration. One in situ field vane test carried out within this stratum measured an undrained shear strength of about 20 kPa and the sensitivity was calculated to be about 3. The in situ field vane test result indicates that the layer has a soft consistency.

The natural water content measured on samples of this deposit ranges from about 78 percent to 1214 percent.

Clay

A deposit of brown to grey clay was encountered underlying the peat in Boreholes S104-03, S104-06 and S104-08 and beneath the ice and water in Borehole S104-09. In Boreholes S104-08 and S104-09, in the west area of the site, the deposit was found to contain trace to some organics. The thickness of the clay deposit ranges from 0.1 m to 1.5 m and the top of the deposit was encountered between Elevation 182.4 m and 180.3 m.

The SPT ‘N’-values measured within this deposit are between 0 blows (weight of hammer) and 2 blows per 0.3 m of penetration. In situ field vane testing carried out on within this stratum measured undrained shear strengths ranging from about 19 kPa to 21 kPa and the sensitivity was calculated to be about 3. The in situ field vane tests indicate the deposit has a soft consistency.

An Atterberg limits test was carried out on one sample of the clay stratum and measured a liquid limit of about 53 percent, a plastic limit of about 27 percent and a plasticity index of about 26 percent. The result of the Atterberg limits test is shown on the plasticity chart on Figure D.S104-01 in Appendix D and indicates that the material is classified as a clay of high plasticity.

The natural water content measured on one sample of this deposit is about 72 percent.

Sand and Gravel

A deposit of grey sand and gravel, containing trace silt was encountered underlying the fibrous peat layer in Boreholes S104-01 and S104-02, underlying the amorphous peat layer in Boreholes S104-05 and S104-04a, and underlying the silty clay layer in Boreholes S104-03, S104-06, S104-08 and S104-09. The top of this deposit ranges from Elevation 182.5 m to 179.8 m and the deposit is between 0.7 m and 3.0 m thick. The bottom of this deposit was defined by refusal to further casing advancement in Borehole S104-08.

SPT 'N'-values recorded within this deposit are between 8 blows and 67 blows per 0.3 m of penetration, indicating a loose to very dense relative density.

Grain size distributions of four samples of the sand and gravel deposit are shown on Figure D.S104-02, in Appendix D.

The natural water content measured on selected samples of this deposit ranges from about 8 percent to 21 percent.

Sand to Sand and Silt

A deposit of grey sand to sand and silt, containing trace gravel was encountered underlying the fibrous peat in Borehole S104-04 and underlying the sand and gravel deposit in Boreholes S104-01 to S104-03, S104-05, S104-06, S104-09 and S104-04a. The top of this deposit was encountered between Elevation 181.1 m and 177.2 m and the deposit ranges in thickness from 1.2 m to 7.8 m. The bottom of this deposit was defined by refusal to further split-spoon and/or casing advancement in Boreholes S104-01 to S104-06 and S104-04a. Borehole advancement was terminated within this deposit in Borehole S104-09.

A 0.2 m thick interlayer of sand and gravel was also encountered within the sand to silt and sand deposit in Borehole S104-04.

The SPT 'N'-values recorded within this deposit are between 6 blows and 32 blows per 0.3 m of penetration, indicating a loose to dense relative density. At the base of the deposit in Boreholes S104-02, S104-04 and S104-06, where the deposit extends to refusal, the split-spoon sampler did not penetrate the full sampler depth and/or was noted to be bouncing.

Grain size distributions of fourteen samples of the sand to sand and silt deposit are shown on Figures D.S104-03a and D.S104-03b, in Appendix D.

The natural water content measured on samples of this deposit ranges from about 13 percent to 24 percent.

Bedrock/Refusal

In Boreholes S104-01 to S104-08 and S104-04a and in DCPTs S104-DC1 to S104-DC4, refusal to further casing and/or split-spoon advancement or cone penetration was encountered at depths between 1.5 m and 13.6 m below ice surface, that is between 1.2 m and 12.7 m below the top of the ponded water. These refusal depths, while they do not confirm bedrock elevations, may be inferred to indicate potential proximity to the bedrock interface. Refusal was encountered between Elevation 181.3 m (DCPT S104-DC3) and 169.1 m (DCPT S104-DC2). In general, refusal was encountered at greater depth between about STA 329+675 and STA 329+715 in the eastern portion of the site.

Groundwater Conditions

In general, the samples taken in the boreholes were wet with free water noted in some samples of cohesionless material. Water levels observed in the boreholes upon completion of drilling range from Elevation 182.8 m to 182.5 m measured at the ice/water surface in each of the boreholes, which is about 0.2 m to 0.6 m above "ground surface" (i.e. top of peat). Groundwater/surface water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

4.7 Highway 69 Detour – STA 23+400 to 23+650 (Swamp 104)

The plan and profiles along the centreline and west toe of the Highway 69 Detour across the CN Railway realignment showing the borehole locations and interpreted stratigraphy between about STA 23+400 and 23+650 are shown on Drawings E1 and E2. The detour alignment extends across a low-lying area along the west toe of the existing Highway 69 rock fill embankment. The proposed detour embankment is up to 8.8 m high above existing grade and up to 2 m above the existing Highway 69 grade. Eleven (11) boreholes (Boreholes S104-10 to S104-18, S104-10a and S104-22a) and two (2) DCPTs (DCPTs S104-DC5 and S104-DC6) were completed to investigate the subsurface conditions within this area. The topography along the detour alignment is flat and low-lying with ponded water encountered at ground surface across most of the site. The entire investigated area is covered moderately with trees, shrubs and grass. The proposed realigned CNR Right-of-Way intersects the Highway 69 Detour from approximately STA 23+480 to STA 23+530.

Ponded water was encountered across most of the site and the water level was evident slightly below ground surface in non-ponded areas of the site. The subsurface soils generally consist of a layer of peat (fibrous and/or amorphous), underlain by an intermittent deposit of organic clay, in turn underlain by deposits of sand and/or sand and gravel. Refusal to dynamic cone penetration and borehole advancement, indicative of the potential bedrock surface, was encountered in most of the boreholes and DCPTs, with the exception of Boreholes S104-13, S104-15 and S104-22a, in the centre of the swamp, which were terminated within the sand deposit.

Water

Ponded water was encountered at surface in Boreholes S104-10a, S104-11 and S104-14 to depths of 0.3 m and 0.4 m.

Rock Fill

Rock fill was encountered on the existing embankment slope surface in Borehole S104-10 (at the south end of the site, at about STA 23+400). The thickness of the rock fill was not investigated due to difficulties in setting up the drilling equipment on the steep slope of the embankment but is estimated to be about less than 6 m based on site observations of the toe embankment and the exposed bedrock outcrop about 5 m further to the south of the borehole.

Peat/Topsoil

Fibrous and amorphous peat was encountered in each of the boreholes either at ground surface or below the ponded water except in Boreholes S104-10 and S104-18 where it was not present. The thickness of the peat deposit is between 0.5 m and 3.0 m and the top of the peat was encountered between Elevation 182.7 m and 182.3 m. In Borehole S104-18, a layer of brown topsoil was encountered at the ground surface to a depth of 0.1 m.

The peat deposit is comprised of a 0.5 m to 2.3 m thick layer of brown fibrous peat typically underlain by a 0.2 m to 1.2 m thick layer of brown amorphous peat.

The SPT ‘N’-values measured within the peat are 0 blows (weight of hammer) or 1 blow per 0.3 m of penetration, suggesting a very soft consistency.

The natural water content measured on samples of this deposit ranges from about 54 percent to 1099 percent.

Clay, Organic

A deposit of grey and brown organic clay was encountered underlying the peat in Boreholes S104-15 to S104-17. The thickness of the organic clay deposit ranges from 0.2 m to 2.7 m and the top of the deposit was encountered between Elevation 181.1 m and 179.6 m.

SPT ‘N’-values measured within this deposit are 0 blows (weight of hammer) per 0.3 m of penetration, indicating a very soft consistency.

An Atterberg limits test was carried out on one sample of the organic clay stratum and the test result indicates a liquid limit of about 46 percent, a plastic limit of about 26 percent and a plasticity index of about 19 percent. The result of the Atterberg limits test is shown on the plasticity chart on Figure E.S104-01 in Appendix E and indicates that the material is classified as an organic clay of intermediate plasticity.

The natural water content measured on one sample of this deposit is about 92 percent, well above the liquid limit.

The organic content measured on two samples of this deposit is between about 5 percent and 7 percent.

Sand and Gravel

An upper deposit of grey sand and gravel, containing trace silt, was encountered underlying the topsoil in Borehole S104-18, underlying the amorphous peat layer in Boreholes S104-13, S104-14 and S104-22a and underlying the organic clay deposit in Borehole S104-17. A lower deposit of sand and gravel was encountered below the sand deposit (described below) in Boreholes S104-10a and S104-16. The surface of the upper portion of this deposit ranges from Elevation 184.1 m to 180.8 m and the deposit is between 0.4 m and 1.3 m thick, whereas the surface of the lower portion of the deposit is at Elevation 179.8 m and 176.6 m and the deposit is 0.3 m and 1.1 m thick at the respective boreholes. The bottom of this deposit was defined by refusal to further split-spoon and/or casing advancement in Boreholes S104-10a, S104-14 and S104-16 to S104-18. In Borehole S104-16, this deposit was found to contain cobbles.

SPT ‘N’-values recorded within this deposit are between 3 blows and 112 blows per 0.3 m of penetration, indicating a very loose to very dense relative density. At the base of the deposit, in Boreholes S104-10a and S104-14, where the deposit extends to refusal, the SPT ‘N’-values are higher due to the split-spoon sampler bouncing.

A grain size distribution of one sample of the sand and gravel deposit is shown on Figure E.S104-02, in Appendix E.

The natural water content measured on two selected samples of this deposit is about 15 percent and 21 percent.

Sand

A deposit of grey sand, containing trace to some silt and trace to some gravel, was encountered underlying the peat layer in Boreholes S104-10a, S104-11 and S104-12, underlying the organic clay deposit in Boreholes S104-15 and S104-16 and underlying the sand and gravel deposit in Boreholes S104-13 and S104-22a. In Borehole S104-22a, the deposit was found to vary from sand to silty sand. The top of this deposit was encountered between Elevation 181.8 m and 178.7 m and the deposit ranges in thickness from 1.4 m to greater than 8.5 m. Borehole advancement was terminated within this deposit in Boreholes S104-13, S104-15 and S104-22a, located near the middle of the swamp and the bottom of this deposit was defined by refusal to further split-spoon and/or casing advancement in Boreholes S104-11 and S104-12.

The SPT ‘N’-values recorded within this deposit range between 2 blows and 38 blows per 0.3 m of penetration, indicating a very loose to dense relative density. At the base of the deposit, in Borehole S104-11, where the deposit extends to refusal, the split-spoon sampler was noted to be bouncing.

Grain size distributions of eight samples of the sand deposit and one sample of the silty sand from Borehole S104-22a are shown on Figure E.S104-03, in Appendix E.

The natural water content measured on samples of this deposit ranges from about 14 percent to 25 percent.

Bedrock/Refusal

A bedrock outcrop was observed at the east limit of the swamp, at about STA 23+395, in the vicinity of Borehole S104-10 at Elevation 187.5 m. In Boreholes S104-10a, S104-11, S104-12, S104-14 and S104-16 to S104-18, and in DCPTs S104-DC5 and S104-DC6, refusal to further casing and/or split-spoon advancement or cone penetration was encountered at depths between 0.5 m and 8.5 m below ground surface corresponding to between Elevation 183.7 m (Borehole S104-18) and 174.2 m (DCPT S104-DC5). These refusal depths, while they do not confirm bedrock elevations, may be inferred to indicate potential proximity to the bedrock interface. In general, refusal was encountered at greater depth between about STA 23+500 and STA 23+550, in the middle portion of the site. Refusal was not encountered in Boreholes S104-13, S104-15 and S104-22a to as low as Elevation 170.9 m.

Groundwater Conditions

In general, the samples taken in the boreholes were wet with free water noted in some samples of cohesionless material. Water levels observed upon completion of drilling range from Elevation 182.7 m (ponded water or ground surface) to 182.5 m (0.3 m below "ground surface", i.e. top of peat). Groundwater/surface water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

5.0 CLOSURE

The field personnel supervising the drilling program were Mr. Ed Savard and Mr. Indulis Dumpis. This report was prepared by Mr. Luigi Gianfrancesco, EIT under the supervision of Mr. André Bom, P.Eng. The technical aspects were reviewed by Ms. E. M. Sarah Coyne, P.Eng., Associate, and Mr. Jorge M. A. Costa, P.Eng., Principal and Golder's Designated MTO Contact for this project, carried out a quality control review of the report.

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PART B

FOUNDATION DESIGN REPORT
NEW CN RAILWAY EMBANKMENT OVER SWAMPS
HIGHWAY 69 FOUR-LANING FROM 1.7 KM NORTH OF HIGHWAY 529, NORTHERLY TO 3.9 KM NORTH OF HIGHWAY 522
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5344-08-00; WP 5344-08-01

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides an interpretation of the geotechnical data obtained during the investigation 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 it affects their proposed construction methods, costs, equipment selection, scheduling and the like.

6.1 General

Golder was retained by URS to provide recommendations on foundation aspects for the detail design of embankments crossing over swamps at various locations (about 375 m total length) along the proposed CNR alignment, associated with the “Four-laning of Highway 69 from 1.7 km north of Highway 529 northerly to 3.9 km north of Highway 522 for a total distance of 19.7 km”. In addition, a roadway detour will be required crossing a 250 m long swamp in order to reroute traffic from the existing Highway 69 for the construction of the new CNR Overhead structure (for the future West Service Road/Highway 522 extension). The proposed CNR alignment crosses the existing Highway 69 approximately 1 km south of the existing Highway 522/Highway 69 intersection and extends for a total distance of about 3 km in a southeast-northwest direction.

Table 1 summarizes the locations of the swamp areas investigated within the Contract 1 project limits for the CNR alignment that require foundation design. This report presents the results of embankment stability and settlement analyses and provides recommendations for stable embankment geometry and embankment fill materials and implementation of mitigation alternatives that may be required as a means to reduce settlements and to improve stability (if necessary). The stability analyses incorporates live loading for a typical train as further discussed in Section 6.2.4 and outlined in the American Railway Engineering and Maintenance-of-Way Association (AREMA) 2009 Manual for Railway Engineering. The report also addresses potential construction concerns and geotechnical problems associated with embankment construction, sub-excavating soft/organic materials and placement of new fill materials.

6.2 Embankments over Swamps

Based on the profiles provided by URS, the new railway alignment crossing over swamps will require fill embankments ranging in height from about 0.5 m up to about 4.5 m. The detour embankment will require filling from about 1.7 m at the south end up to 8.8 m at the north end above existing ground surface in this swamp. Sections 6.2.2 and 6.2.3 of this report summarize the methods used to analyze the stability and settlement of embankments over the swamps and Section 6.2.4 summarizes the method used to model the train loading in the analysis. Section 6.3 provides discussions related to recommendations of potential alternatives for mitigating stability and settlement related design and construction issues. The results of the analyses and recommendations for mitigating stability and time-dependent settlements in the swamp crossing areas, where applicable for each individual crossing, are presented in Section 6.4.

At all areas, the analysis assumes that the peat and near surface organic soils (encountered at the ground surface during drilling operations) will be removed prior to construction of the new embankments. For design purposes, the groundwater level is based on the piezometric conditions observed during drilling.

6.2.1 Embankment Fill Types

Different embankment fill alternatives (i.e. rock fill and granular fill) provide relative advantages and disadvantages in terms of availability, weight (i.e. driving force and applied load to the founding stratum), construction cost and time, ease of construction and post-construction performance.

Rock fill is the preferred embankment fill material for this project due to the availability from rock blasting required elsewhere on the project. In this regard, the stability and settlement analyses discussed in Section 6.4 have been carried out on the basis that the majority of the railway embankment will be constructed of rock fill.

Rock Fill

The main advantage of constructing embankments using rock fill is the ability to achieve steeper side slopes (1.25H:1V) thereby reducing the overall quantity of material required for the project as well as reducing the width of the right-of-way required. However, based on the AREMA manual and typical drawings provided by CNR, the railway rock fill embankment side slopes will be constructed at 1.5H:1V. Rock fill will likely be available from either excavations in deep cuts through existing bedrock outcrops within this and other phases of the project or from rock borrow areas close to the project limits. The disadvantage of using rock fill for the construction of high embankments is that some post-construction settlement of the embankment fill itself will occur, although mostly within about the first year post-construction. Settlement of rock fill is discussed in detail in Section 6.2.3.3. Where rock fill is used to backfill sub-excavated areas under water, settlement will also occur post-construction.

Granular Fill

The main advantage of using granular fill for embankment construction is the ease of construction and negligible post-construction settlement within the embankment fill itself. However, this option will require a larger volume of fill and wider right-of-way because the side slopes of granular fill embankments (2H:1V) are flatter than those of rock fill. For this project, acceptable granular fill is considered to be well graded, locally available and/or imported sand and gravel material. Should granular fill be considered, a constraint limiting the fines content should be included in the Contract. On this project, embankments are not likely to be constructed of granular fill.

6.2.2 Stability

The following sections outline the methodology and present the parameters used to evaluate embankment stability at the swamp crossings. The results of the analyses are presented in Section 6.4 for each swamp crossing where they are discussed together with the results of the settlement analyses and recommendations regarding possible design and construction mitigation alternatives.

6.2.2.1 Methodology

Stability analyses were performed for the critical sections of the proposed fill embankments in each swamp crossing area. Critical sections correspond to the greatest new embankment height and/or the maximum thickness of soft, compressible cohesive soils. Typically, there is one critical section per area; however, in some areas, two critical sections have been identified as a result of non-uniform soil strata or grades. In all areas where cohesive strata were encountered in the subsurface, the stability of the proposed new embankment section(s) was analyzed using limit equilibrium methods. In areas where the subsoils consist of cohesionless soils only, the stability of the proposed embankment section was assessed based on precedent experience in similar soil conditions.

All limit equilibrium slope stability analyses were performed using the commercially available program GeoStudio 2007 (Version 7.15), 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 for the design of embankment slopes under static conditions for MTO sites. Given the level of investigation completed for these sites, a FoS of 1.3 is also applicable based on the AREMA manual. This FoS is considered adequate for the embankments at these sites 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 railway/roadway. The stability analyses were performed to check that the target minimum FoS was achieved for the various embankment heights and geometries.

6.2.2.2 Parameter Selection

The simplified stratigraphy together with the associated strength and unit weight employed for the existing fills and the different native soil types for the critical sections in each swamp crossing are summarized in Table 2. The new rock fill modelled in the analyses is assumed to have a unit weight of 19 kN/m^3 and an effective friction angle of 40°. The stability of the CNR and Highway 69 detour embankments was analyzed for a slope geometry of 1.5H:1V and 1.25H:1V side slopes, respectively.

The subsoils encountered in the various areas are composed of granular soils only (silts, sands, sandy silt/silty sand, and/or sand and gravel) or a combination of cohesive deposits (clayey silt, silty clay and/or clay) and granular soils. For granular soils, effective stress parameters were employed in the analyses assuming drained conditions. The effective stress parameters (effective friction angle and effective cohesion) for the granular (and peat/root mat) soils were estimated from empirical correlations using the results of in situ SPT, in conjunction with engineering judgement based on experience in similar soil conditions.

For cohesive deposits, total stress parameters were employed in the analyses assuming undrained conditions. The total stress parameters (i.e. average mobilized undrained shear strength – s_u) for the cohesive soils were assessed based on the results of in situ field vane shear tests, inferred from the laboratory consolidation tests results, and estimated from correlations with the SPT results and other laboratory test data (natural water content). For the consolidation tests, the following correlation proposed by Mesri (1975) was employed to estimate the undrained shear strength:

$$s_u = 0.22\,\sigma_p'$$

where:

s_u = average mobilized undrained shear strength (kPa)
σ_p' = preconsolidation pressure (kPa)

Where appropriate, Bjerrum's correction factor was employed to estimate the average mobilized undrained shear strength from the results of the in situ field vane tests as follows:

$$s_{u(mob)} = \mu s_{u(FV)} \qquad \text{(after Bjerrum, 1973)}$$

where:

$s_{u(mob)}$ = average mobilized undrained shear strength (kPa)
$s_{u(FV)}$ = undrained shear strength from field vane test (kPa)
μ = Bjerrum's correction factor based on Plasticity Index

6.2.3 Settlement

The following sections outline the methods and present the parameters used to conduct the settlement analyses at the various sites. The results of the analyses are presented in Section 6.4 for each swamp crossing area where they are discussed in combination with the results of the stability analyses and possible design and construction mitigation alternatives.

6.2.3.1 Methodology

To estimate the magnitude of the expected settlements, analyses were carried out on the critical sections of the proposed fill embankments using the commercially available program Settle3D (Version 2.0) produced by Rocscience Inc. and/or hand/spreadsheet calculations. Critical sections correspond to the greatest new embankment height and/or the maximum thickness of soft, compressible cohesive soils.

The sources of settlement were considered to include:

- Primary time-dependent consolidation of the cohesive deposits (using Terzaghi's one dimensional consolidation theory);
- Secondary time-dependent (creep) consolidation of the cohesive deposits (long term);
- Immediate settlement of the native granular soils; and
- Self weight compression of the embankment fill materials.

The thickness of the compressible foundation soils and the height of the embankments vary along the proposed alignments within each swamp crossing and as such the settlements along the length of a given swamp section will similarly vary. Given that the analyses were carried out in the critical sections of each swamp crossing area, the settlements estimated will generally represent the maximum value along a given section.

6.2.3.2 Parameter Selection

The simplified stratigraphy together with the associated deformation and time rate consolidation parameters employed for the different native soil types for the critical sections in each swamp crossing are given in Table 2.

The immediate compression of the silt, sandy silt to silty sand, sand and sand and gravel layers was modelled by estimating an elastic modulus of deformation based on the SPT ‘N’-values and using correlations proposed by Bowles (1984) and Kulhawy and Mayne (1990). These estimated values were compared with the typical range of expected values for similar soil types, as outlined in CHBDC (2006) and adjusted, if necessary.

The consolidation settlement of the cohesive deposits was assessed using the results of the laboratory consolidation tests and/or in situ field vane tests to estimate the deformation parameters for the clayey foundation soils. In addition, the results of the laboratory index testing were also employed to further assess deformation parameters (i.e. recompression and compression indices) using empirical correlations proposed in literature by Koppula (1986), Terzaghi and Peck (1967), Kulhawy and Mayne (1990) and Azzouz et al. (1976). The correlation by Koppula (1986) relating the natural water content and liquid limit to the compression index was found to be the most consistent with the results of laboratory consolidation tests for the clayey soils at this site.

The following correlation relating in situ undrained shear strength to preconsolidation pressure (Mesri, 1975) was employed:

$$\sigma_p' = \frac{s_{u(mob)}}{0.22}$$

where:

$s_{u(mob)} = \mu s_{u(FV)}$ (after Bjerrum, 1973)
σ_p' = preconsolidation pressure (kPa)
$s_{u(mob)}$ = average mobilized undrained shear strength (kPa)
$s_{u(FV)}$ = undrained shear strength from field vane test (kPa)
μ = Bjerrum’s correction factor based on Plasticity Index

The coefficient of consolidation, c_v (cm^2/s), required in the time rate analysis was established using the results of the consolidation tests and/or estimated from NAVFAC (1982) correlation with liquid limits assuming normally consolidated soils.

In addition to primary consolidation within clays, secondary compression may also occur. Secondary compression is referred to as creep settlement and occurs over a long period of time, after full dissipation of excess pore pressure under a constant stress. The following relationships have been employed for estimating the magnitude of creep settlement for the design life following the completion of primary settlement at each location.

$$S_c = HC_{\alpha\varepsilon} \log\left(\frac{t}{t_{EoP}}\right)$$

$$C_{\alpha\varepsilon} \sim \frac{w_n}{10{,}000} \quad \text{(after Mesri, 1975)}$$

where :

S_c = secondary (creep) settlement (mm)
$C_{\alpha\varepsilon}$ = secondary compression index (strain)
H = initial thickness of compressible clay deposit (mm)
t = post-construction period of interest (20 years for this project)
t_{EoP} = time to reach end of primary consolidation (year)
w_n = natural water content (%)

In some swamp crossings, the cohesive deposit was too thin or was intermittent as to prevent obtaining Shelby tube samples. Therefore, the results of consolidation testing carried out in selected swamps were reviewed to provide a larger set of parameters to evaluate for all swamps. It is considered that all the swamp crossings exhibited sufficiently similar soil mineralogy and geology that correlations based on all of the data are justified. Having developed the area-specific correlations, the test results for each individual swamp area were examined and the design lines developed accordingly. The design parameters selected for each swamp area are summarized in Table 2.

6.2.3.3 Settlement of Embankment Fill

Where rock fill is used for the construction of the proposed embankments, there will be settlement due to compression of the rock fill itself under self weight, in addition to the settlement of the underlying foundation soils as described above. The magnitude of settlement of the rock fill depends on the following factors:

- Type of rock/strength of particles;
- Size and shape of rock particles;
- Gradation of rock fill;
- Total height/thickness of rock fill (stress level); and
- Method of construction and sequence of placement (including lift thickness, compactive effort and state of packing).

The settlement of rock fill occurs as a result of re-arrangement of rock particles under load and wetting and as a result of localized crushing of rock particles at point contacts. The magnitude of both the short-term and long-term post-construction settlement of the rock fill is a function of the height of fill as well as the method of fill placement (i.e. compacted versus dumped rock fill) as outlined in MTO Foundations Guideline, “Post-Construction Rock Fill Settlement and Guidelines For Estimating Rock Fill Quantity”, dated September 14, 2010.

Rock fill should be placed, whenever possible, in a controlled manner (i.e. not end-dumped) in accordance with SP 206S03 (Rock Embankments). Blading, dozing and ‘chinking’ the rock fill to form a dense, compact mass is required to minimize voids and bridging and reduce settlements and should be used to construct rock fill embankments above the existing groundwater table. Where rock fill cannot be placed in a controlled manner (i.e. below the groundwater table), the post-construction settlement of the rock fill is expected to be greater.

Short-Term Rock Fill Settlement

The magnitude of short-term post-construction settlement associated with compacted and end-dumped rock fill may be estimated in accordance with the MTO Foundations Guideline (September 2010), as follows:

Total Height of Rock Fill, H	**Short-Term Rock Fill Settlement**	
	Compacted Rock Fill	**Dumped Rock Fill**
Up to 5 m	0.5% H	1.0% H
>5 m to 10 m	0.75% H	1.5% H
>10 m to 15 m	1.0% H	2.0% H

Approximately 90 percent of the short-term settlement may be expected to occur within the first six (6) months following construction of the embankment to full height. The short-term settlement is expected to be fully completed within one (1) year following the completion of embankment construction to full height.

Long-Term Rock Fill Settlement

The magnitude of long-term post-construction settlement for compacted and end-dumped rock fill may be estimated in accordance with the MTO Foundations Guideline (April 2010), as follows:

Total Height of Rock Fill, H	**Long-Term Rock Fill Settlement**	
	Compacted Rock Fill	**Dumped Rock Fill**
Up to 15 m	0.1% H	0.2% H

The long-term rock fill settlement is expected to occur from one (1) year following the completion of construction over the life of the embankment.

There are no specific rock fill settlement guidelines in the AREMA manual; therefore, the MTO guideline has been used to estimate settlement for the railway embankments.

6.2.4 Train Loading

As indicated in the AREMA 2009 Manual for Railway Engineering Section 1.23.2a, the foundation soils below a railway embankment should be capable of supporting the weight of the embankment as well as live loads from train traffic (Cooper E-80). The magnitude of the live load is specified in Chapter 8 (Concrete Structures) Section 2.2.3 and Chapter 15 (Steel Structures) Section 1.3.3. The train live load has been applied as a distributed pressure in the analysis at the top of the railway embankment with a value of 50 kPa distributed over a width of 2.4 m, equivalent to the width of standard railway ties.

6.3 Stability and Settlement Mitigation Options

At each swamp crossing, stability and settlement have been assessed based on existing subsurface conditions and proposed embankment fill height. The presence of weak/soft, compressible soils underlying a proposed embankment can lead to the potential for instability or unacceptably large settlements with the placement of rock fill. There are a number of options for mitigating the potential for settlements and/or instability. A brief general discussion on these alternatives is given below.

Details of the stability/settlement mitigation options for critical swamp crossings are provided in Section 6.4. The advantages, disadvantages, relative costs and risks/consequences for each critical swamp are summarized in the evaluation of stability/settlement mitigation options tables in the respective appendices. In addition, for the two main mitigation alternatives being considered (i.e. Preload and Full Sub-excavation), a detailed comparative analysis of the estimated post-construction settlement over a twenty (20) year period following construction was carried out for each of the swamps. The results of the analysis are summarized in Table 3.

A summary of the proposed works, recommended embankment fill type and side slope, maximum depth of organics encountered, preferred stability/settlement mitigation option, estimated settlement (during construction and post-construction), recommended width of platform widening and recommended excavation guideline for each swamp crossing area is provided in Table 4. Depending on the area, one alternative or a combination of alternatives may be more advantageous than others.

In areas where the foundation soils consist of granular soils only, it is not anticipated that there will be embankment stability issues or significant settlement problems, provided all organic layers (i.e. peat) are removed prior to construction and the requirements for mid-height berms are incorporated into the embankment design, as necessary. As such, in these areas there is no need to implement any special construction procedures to maintain stability or to minimize long-term foundation settlements or to adjust the construction schedule.

6.3.1 Full Sub-Excavation

Sub-excavation of the weak/soft and compressible (i.e. clayey) soils underlying the footprint of a proposed embankment in advance of the placement of rock fill is a viable option for improving the stability and controlling long-term settlement of the proposed embankments at this site. The removal of the soft, compressible cohesive soils would result in improved stability and significantly reduce settlements within the areas underlain by clayey deposits. The additional below grade rock fill embankment should be constructed with the same side slope profile as that of the above grade embankment (i.e. 1.25H:1V for highway rock fill embankments and 1.5H:1V for CNR rock fill embankments) since the natural slope of the rock fill should not be affected by underwater placement. This option has the advantage that construction of the above grade embankment could proceed upon completion of sub-excavation and replacement without concerns of instability. However, full sub-excavation may produce a large volume of spoil material for disposal and may require a large volume of rock fill replacement. The necessity to develop stable side slopes or back slopes within the excavation may result in slope geometries ranging from 1H:1V to as flat as 3H:1V. Flatter slopes would increase the lateral extent of the excavation and may require a wider right-of-way which, in this case, impacts the length of the new Highway 69 overpasses. Further, the increase in thickness of fill would result in additional post-construction settlement of the embankment rock fill itself (see Section 6.2.3.3). For purposes of property requirements, a 3H:1V back slope should be assumed in the swamp area where sub-excavation is required.

Based on the results of the subsurface investigation at the swamp sites, the depth to the bottom of the weak/soft, compressible soils within the swamp crossing areas varies, ranging from about 1.5 m to about 10.2 m below existing ground surface. In general, groundwater was encountered at ground surface at all swamp locations. We understand that based on MTO field experience on similar embankment construction projects, the practical maximum depths that can be reached with conventional and long stick excavator equipment is about 6 m and 12 m, respectively. Below a depth of 12 m, specialized drag-line equipment would be required. As such, in the absence of unforeseen conditions which would prohibit its application, sub-excavation of organic and soft compressible soils and replacement with rock fill is considered a generally feasible option for construction of the railway/roadway embankments and would result in enhanced stability and reduced settlement of the embankments on this project.

This option is most suited for areas where there is a limited thickness of organics (peat) and weak/soft compressible soils underlying the proposed embankment, making their removal feasible where there are no requirements for setbacks and adequate right-of-way is available, and where there are no conflicts with encroachment on existing adjacent features.

The advantages of this option are:

- Improved stability;
- Reduced post-construction settlements of the foundation;
- Reduced delay in construction; and
- No requirement for stabilizing toe berms.

The disadvantages of this option are:

- Generation of large volume of excavation spoil requiring disposal/management;
- Potential need for a larger corridor of land acquisition;
- Greater quantities of rock fill required; and
- Post-construction settlement of rock fill itself.

6.3.2 Preloading (with Toe Berms and/or Staged Construction)

As an alternative to sub-excavation and replacement of the weak/soft, compressible foundation soils, preloading may be considered for improving the stability and reducing post-construction settlements of the proposed embankments. Preloading refers to the placement of fill to the proposed profile grade of the embankment (in one or more stages) in advance of final construction in order to preconsolidate the underlying compressible soils. The fill placed should be rock fill for the subgrade level followed by SP 110S13 (Aggregates) Granular B Type II material for the profile grade. Preloading reduces the magnitude of long-term, post-construction settlements by promoting such settlements to occur under embankment fill loads in advance of final grading of the embankment. It also increases the strength of the clayey subsoils underlying the embankment footprint, thereby improving stability.

Preloading requires placement of embankment fill and monitoring of settlements, and possibly pore pressures, for a period of time corresponding to approximately the ‘End of Primary’ (EoP) consolidation of clayey subsoils. EoP consolidation times will vary depending on the properties of the clayey subsoils, the thickness of the clayey deposits, and the height of the embankment. Once the estimated EoP consolidation has occurred, final grading for construction can proceed. Long-term secondary (creep) settlements will still continue to occur over the design life of the embankment; however, such settlements would be less than primary consolidation settlements. Where secondary (creep) settlements are considered to be large enough to affect the long-term performance of the railway/roadway, these can be reduced by surcharging as discussed in Section 6.3.3.

In areas where clayey deposits are thick and/or very soft, and where such conditions coincide with proposed high embankment fills, it may be necessary to construct stability berms along the embankment toes or to place the embankment fill in stages in layers of limited thickness to ensure that the stability of the embankment is maintained. Toe berms consist of rock fill buttresses placed against the toe of the proposed embankment fill, producing a stepped embankment cross-section geometry. This stepped configuration produces a similar effect (i.e. increased stability) as using flatter embankment slopes, but often requires less fill material. Depending on the subsurface conditions and the proposed embankment height, toe berms will typically be on the order of about one third to one half of the height of the final embankment. The lateral extent (width) of toe berms will vary depending on the results of the stability analyses, but could range from half to one times the highway embankment height or greater. Where staged construction is required, the individual layers of fill would have limited thickness and each construction phase would be separated by a suitable time interval to allow pore pressures to dissipate and strength gain to occur in the underlying clayey soils while limiting the potential for instability of the embankment.

It should also be noted that with preloading, it is still required that the existing organic material be sub-excavated prior to placement of any fill, because organic soils are highly compressible and undergo significant secondary (creep) settlement rates.

This option is most suited for areas where removal of clayey soils and their replacement with rock fill is not considered practical, where the thickness of the existing compressible soils is nominal (less than about 4 m) and where a delay in the construction schedule is acceptable or can be accommodated.

The advantages of this option are:

- Substantially reduced generation of excess excavation spoil compared with full sub-excavation;
- No need for additional corridor of land, unless toe berms are required; and
- The quantity of rock fill is limited to that required for sub-excavation and replacement of the near surface organics (if toe berms not required), and to compensate for consolidation and foundation soil settlements.

The disadvantages of this option are:

- Construction is delayed to allow for primary consolidation to be completed and possibly for staged construction (if required);
- Increased quantity of rock fill if toe berms are required for stability;

- An instrumentation and monitoring program may be required to assess when EoP consolidation is reached (as discussed in Section 6.3.6); and
- Re-grading is required to account for settlement prior to construction of the final railway/pavement structure.

6.3.3 Surcharging (with Toe Berms and/or Staged Construction)

Similar to preloading, surcharging refers to the placement of embankment fill in advance of final railway/pavement construction to reduce long-term, post-construction settlements (including creep). The difference between preloading and surcharging is the amount of fill placed and the time required for consolidation to be achieved. With surcharging, the preload is placed as described above, followed by an additional lift of fill (the surcharge) above that required to construct the final embankment geometry. This additional lift of fill applies greater stress to the underlying clayey soils and increases the rate of primary consolidation over that achieved by preloading only, resulting in overconsolidation of the underlying compressible foundations soils. At the EoP consolidation, the portion of the surcharge fill remaining above the required embankment height (sub base level) is removed. The surcharge fill can also be left in place for a longer duration to reduce the long-term, secondary (creep) settlements.

As with preloading alone, it may be necessary to construct toe berms or stage the placement of preload and surcharge to limit the potential for instability. Upon completion of primary consolidation, the removed surcharge may be re-used on other parts of the site.

Surcharging is most suited to those areas considered appropriate for preloading, where the stability of the higher surcharged embankment can be practically maintained by reasonably sized toe berms or staged construction, but where sufficient time for primary consolidation settlements to occur under preload fill loads alone is not available. Surcharging is also best suited for areas where large secondary (creep) settlements are expected.

The advantages of this option are:

- Reduced generation of excess excavation spoil over full sub-excavation;
- Reduction of secondary (creep) settlement;
- No need for additional larger right-of-way, unless toe berms are required;
- The quantity of rock fill is limited to that required for sub-excavation and replacement of organics, and to compensate for consolidation and foundation soil settlement (if toe berms not required); and
- Decreased delay time for construction over preloading alone.

The disadvantages of this option are:

- Construction is delayed, albeit less than for preloading, to allow for primary consolidation to occur;
- Longer construction time if staged construction is required;
- Larger quantity of rock fill if toe berms are required for stability as compared to preloading alone;

- An instrumentation and monitoring program may be required to assess when EoP consolidation is reached (as discussed in Section 6.3.6); and
- Increased handling of rock fill (or Granular B) to remove the surcharge.

6.3.4 Wick Drains

Where sub-excavation is not practical (i.e. due to the thickness of or depth to the compressible soil deposits), but it is considered feasible to preload or surcharge the foundation subsoils, consideration may be given to installing wick drains in conjunction with preloading or surcharging to further accelerate the rate of primary consolidation. Wick drains are prefabricated geotextile drains installed vertically from ground surface into or through the soft, compressible foundation soils in order to increase the rate of excess pore pressure dissipation. Typically, wick drains are installed on a 1 m to 3 m triangular grid spacing over the embankment footprint.

Use of wick drains are most suited to areas with thick (i.e. greater than about 5 m) deposits of soft, compressible foundation soils and high proposed embankment fills where primary consolidation times are large even under surcharge conditions.

It would still be necessary to sub-excavate and remove surficial organics and place a granular drainage blanket at ground surface level prior to the installation of the wick drains.

The advantages of this option are:

- Substantially decreased consolidation time under preloading or surcharging; and
- Increased rate of staged construction if required to maintain stability during construction.

The disadvantages of this option are:

- Additional time and expense to install wick drains prior to embankment construction;
- May require pre-drilling if a compact/very stiff surface layer is present incurring additional time and expense;
- Additional long-term settlements due to secondary consolidation (i.e. creep settlement) of the cohesive layer (if not compensated for by surcharging); and
- An instrumentation and monitoring program is required to assess when EoP consolidation is reached (as discussed in Section 6.3.6).

6.3.5 Lightweight Fill

Another alternative for reducing the magnitude of long-term settlement and improving stability in areas of soft, compressible foundation soils is to use lightweight fill, such as expanded polystyrene (EPS), for embankment construction.

The use of lightweight fill reduces the load applied to the foundation soils due to the low density of the fill materials. This in turn reduces the magnitude of post-construction settlement and reduces the potential for instability.

Lightweight fill is not considered a practical option for general use over large areas due to the expense and/or shipping costs for the supply of these types of fills. Rather, lightweight fill is most suited for areas underlain by deep compressible subsoil conditions, where sub-excavation is not practical or feasible, and where there is no available time in the construction schedule for a preload or surcharge period (typically near bridge structures).

The advantages of this option are:

- Improved stability;
- Reduced post-construction settlements;
- No significant delay in construction; and
- Elimination of the need for stabilizing toe berms.

The disadvantages of this option are:

- Significant additional expense of lightweight fill (depending on the volume required); and
- Not feasible to install in low height embankments (due to minimum conventional soil cover requirements over EPS).

6.3.6 Instrumentation and Monitoring

For some areas where the preloading and surcharging options are adopted and in all areas where staged construction and/or wick drains foundation options are adopted, the magnitude and time rate of settlement as well as dissipation of pore pressures during and after construction of embankments over swamps should be assessed with monitoring instrumentation. Such monitoring would consist of installing settlement pins/stakes (SSs), settlement plates (SPs) and vibrating wire piezometers (VWPs) below the embankment and taking regular measurements/readings at given intervals of time during and after construction of the embankment for the duration of the preloading/surcharging period. In addition, standpipe piezometers (SPPs) may be required and are usually installed to provide background pore pressure readings for the vibrating wire piezometers. This monitoring instrumentation is particularly important where it is considered necessary to carefully monitor the stability of the subsoils during staged placement of fill.

The extent of instrumentation and the frequency of monitoring required will depend on the foundation treatment alternative chosen for a given site and the height of the proposed embankment fill. Specifications for the type, number and layout of the instrumentation, together with the supply, installation, protection and monitoring should be included as Non-Standard Special Provisions in the Contract.

6.4 Results of Analysis

The results of the stability and settlement analyses for each swamp crossing area are provided in the following sections. In addition, the options and recommendations for achieving the target FoS for the required embankment geometry and for minimizing the time-dependent, post-construction settlements are also discussed. For swamp crossings that require stability and/or settlement mitigation, the advantages, disadvantages, relative costs, and risks / consequences of various alternatives for these areas are summarized and ranked in the respective tables in the appendices.

In areas where the foundation soils consist of cohesionless deposits only, it is anticipated that there will not be any significant risk of instability of the embankments. Similarly, the settlement of the foundation soils in these areas is expected to occur during or shortly after construction, as a result of the estimated relatively high permeability of these soils. As such, in these areas there is typically no need to implement any special construction procedures or schedule to maintain stability or to mitigate settlement of the foundation soils.

In areas where the foundation soils are comprised of cohesive subsoils, time-dependent settlements of the new embankments are expected. In addition, in some of these areas, the presence of weak/soft cohesive deposits constitutes zones of potential instability of the proposed embankments. In these areas, consideration must be given to an enhanced design and/or to follow a construction sequence that will achieve the minimum target FoS of 1.3 for the proposed new embankment height and geometry and limit the post-construction settlements and subsequent maintenance on the new railway or roadway pavement structure.

For new embankments constructed with rock fill or where sub-excavation and backfilling with rock fill is recommended, settlement of the embankment rock fill is also expected due to compression of the rock fill itself (see Section 6.2.3.3). In these areas, it is recommended that the embankments be constructed to the full height at least 6 months prior to final railway/pavement construction, to reduce post-construction settlements of the rock fill.

6.4.1 CNR – STA 328+810 to 328+940 (Swamp 101)

The area extending from about STA 328+810 to 328+940 along the proposed CNR alignment through a swamp requires a new embankment up to 4.8 m high to achieve the proposed vertical profile. The topography of this section of proposed CNR alignment is gently sloping to a low area between steep ridges beyond the east and west limits of the investigated area, and is moderately tree covered with bedrock exposed at the west limit of the swamp.

The subsoils in this swamp area generally consist of a surficial root mat at ground surface underlain by alternating deposits of silt to clayey silt, silty sand to sandy silt and clayey silt to clay, underlain by inferred bedrock. Resistance to dynamic cone penetration and borehole advancement, indicative of the potential bedrock surface, was encountered at depths of up to about 18.9 m below ground surface, being deepest in the vicinity of about STA 328+850. A bedrock outcrop was observed at the west end of the investigated area (at about STA 328+935).

Details of the subsurface conditions for this swamp crossing are presented in Section 4.3 and shown on Drawing A1 in Appendix A.

As indicated in Section 6.2, the new railway embankment was analyzed assuming a rock fill composition and 1.5H:1V side slopes. The stability and settlement analysis assumes that the organic soils (up to 3.1 m deep) encountered at the site under the embankment footprint have been removed and replaced in accordance with OPSD 203.010 (Embankments Over Swamp) prior to construction of the new embankment. The simplified stratigraphy and the associated unit weight, strength, deformation and time rate consolidation parameters employed for the different soil types encountered in this area are summarized in Table 2. The piezometric condition used in the analyses is the water table at 1.0 m below ground surface, based on the groundwater levels noted during drilling.

6.4.1.1 Stability

Based on the results of the subsurface investigation and review of the profile drawings, the critical section (i.e. greatest embankment height and/or maximum thickness of soft compressible foundation soils) for this swamp crossing is located at approximately STA 328+880. The stability analysis performed on the critical section indicates that after the completion of embankment construction (including removal and replacement of the organic deposits including the upper cohesionless layers within the organic deposits), the embankment will have a FoS less than 1.0 (i.e. slope failure) for a deep-seated, global failure surface that would impact the operation of the railway.

To achieve a FoS equal to or greater than 1.3 for the proposed approximately 4.8 m high embankment will require implementing mitigation measures consisting of either full sub-excavation of the cohesive deposit or the construction of rock fill berms along the toes of the embankment.

6.4.1.2 Settlement

To estimate the magnitude of the expected settlements due to new construction, analyses were carried out on the critical section at about STA 328+880. For the condition where the organic materials are sub-excavated and replaced with rock fill but the cohesive deposits are left in place, it is estimated that the settlement of the foundation soils within the vicinity of the critical section will be about 725 mm. This total settlement is estimated to comprise about 15 mm of immediate settlement due to compression of the cohesionless deposits and about 710 mm of primary consolidation of the 7.3 m thick cohesive deposit.

Based on an average coefficient of consolidation (c_v) of about 2.35 x 10^{-3} cm^2/s estimated for the cohesive deposit based on the results of laboratory consolidation tests on samples of similar material and correlations with laboratory data, the imposed loading conditions for the approximately 4.8 m high embankment plus 3.1 m backfill for replacement of the organic/cohesionless deposits, and assuming two-way drainage of the cohesive deposit, it is estimated that about 90 percent of the primary consolidation settlement will be completed in about 18 months as shown on Figure A2 in Appendix A.

The magnitude of secondary (creep) settlement for the cohesive deposit is estimated to be about 45 mm per log cycle of time. Therefore, about 55 mm of creep will occur over the design life of the approach embankment (i.e. 20 years).

In addition, the settlement of the rock fill embankment itself at the critical section is estimated to be up to about 75 mm (based on a 4.8 m high embankment plus up to 3.1 m of additional rock fill required after removal of the organic/cohesionless deposits) with about 55 mm expected to occur within six months of construction and about 20 mm expected to occur over the remaining design life of the railway embankment.

The estimated total post-construction settlement of the subsoil and embankment rock fill after completion of embankment construction is approximately 840 mm and, therefore, mitigation measures to reduce the magnitude of post-construction settlement are required.

6.4.1.3 Mitigation of Stability Issues and/or Time-Dependent Settlements

The presence of an up to 7.3 m thick clayey silt to clay deposit influences both the stability and the settlement of the proposed 4.8 m high embankment. In order to construct the embankment to achieve a FoS equal to or greater than 1.3, and to minimize post-construction settlements, the alternatives presented below can be considered. The alternatives described have been evaluated and ranked on the basis of the advantages, disadvantages, relative costs and risk/consequences and are summarised in Table A1 in Appendix A. Considering the relatively small area requiring foundation treatment and the overall benefits for improving stability and reducing primary consolidation settlement, full sub-excavation is ranked as the preferred mitigation option for this swamp crossing.

For all options, preloading may still be required to reduce the post-construction settlement of the rock fill itself, due to the height of embankment and depth of organics and/or cohesive deposits, which will be sub-excavated and replaced with rock fill.

Full Sub-Excavation

The bottom of the cohesive deposit is up to 10.2 m below existing ground surface within the proposed embankment footprint. Full sub-excavation of the cohesive deposit to this depth is considered feasible and would be the best technical solution in terms of the long-term performance of the railway embankment. Sub-excavation of the cohesive deposit up to 10.2 m depth would be required between STA 328+875 and STA 328+900 to achieve a FoS of greater than 1.3 (presented on Figure A1). The base of the sub-excavation east of STA 328+875 and west of STA 328+900 to the ends of the swamp would be about 6 m or less.

Since the groundwater table is near the ground surface, the majority of the sub-excavation would have to be carried out ‘in the wet’, i.e. below the water level. Excavation ‘in the wet’ results in less risk of instability and base heave than under dry conditions but will create more uncertainty regarding full removal of the cohesive deposits. Excavation ‘in the wet’ to remove the cohesive deposit in this area should be carried out with side slopes no steeper than 1H:1V to limit the risk of instability. Complete removal of the cohesive deposit should extend to a horizontal distance beyond the toe of the proposed embankment equal to the horizontal component of the side slope profile (i.e. 1.5 for rock fill) multiplied by the depth to the bottom of the cohesive deposit below the ground surface in accordance with OPSD 203.010 (Embankments Over Swamp).

It should be noted, however, that full sub-excavation of the cohesive deposit would increase the effective thickness of the new embankment fill by up to about an additional 7.1 m, because of the additional rock fill required below the existing ground surface. The additional below grade rock fill would need to be constructed with the same side slope profile as that used for the above grade embankment (OPSD 203.010). The increase in rock fill thickness will result in an additional 125 mm of post-construction settlement of the rock fill embankment. The total settlement of the rock fill embankment after completion of embankment construction is estimated to be about 200 mm, with about 155 mm occurring within the six months after construction of the embankment to the design surface elevation and 45 mm of long-term (after six months following embankment construction) settlement. Given this magnitude of rock fill settlement over the approximately 25 m length of embankment, consideration should be given to preloading the embankment for a period of up to six (6) months to reduce the post-construction settlement of the rock fill.

Preloading and Toe Berms

The results of the stability analyses indicate that a FoS greater than 1.3 can be achieved for the option comprised of embankment construction without sub-excavation of the cohesive deposit but with the inclusion of toe berms along the toes of the embankment. For this site, rock fill toe berms about 1 m high above existing ground surface (i.e. Elevation 180.5 m) and 10 m wide would be required between STA 328+875 and STA 328+900. East and west of these stations, the toe berms can taper to the swamp ends. Sub-excavation of the organic/cohesionless deposits (as discussed above) must also be carried out below the embankment and full extent of the toe berms.

It is estimated that 90 percent of primary consolidation settlement will be completed in about 18 months after construction of the embankment to the design surface elevation. Instrumentation and settlement monitoring during and after the construction of the embankment will be required. If the construction schedule can accommodate this preload period, by constructing the embankment as early as possible, preloading the foundation soils can be considered.

The estimated total post-construction settlement of the subsoils (remaining primary consolidation and creep and long-term rock fill settlement) after the 18-month preload period is 140 mm. To reduce this magnitude of settlement, surcharging the embankment would be required.

Surcharging and Toe Berms

As noted above for the preload alternative, it is estimated that 90 percent of primary consolidation settlement will be completed in about 18 months for an embankment constructed to the final surface elevation. However, if surcharging is adopted as the foundation mitigation option at this location, a recommended preload period of 14 months should be included in the schedule to reduce the post-construction settlement to less than about 70 mm (creep and long-term rock fill settlement). However, based on stability analysis for a 2 m high surcharge, a toe berm 1 m high above existing ground surface by 15 m wide (at STA 328+875 and STA 328+900) along the embankment toes would be required tapering to the ends of the swamp crossing in order to maintain a FoS equal to or greater than 1.3.

Toe berms of this size could be prohibitively large and staged construction sequence to maintain stability will likely result in a construction period equal or greater than for the preload only case.

Wick Drains

Given the layered nature of the deposit (i.e. sand and silt layers/seams), the use of wick drains in this swamp area is considered technically feasible to reduce the length of the time period required for primary consolidation settlement. However, due to the limited extent and variable thickness of the cohesive deposit within the swamp, the extra costs associated with the additional investigation, design and construction of wick drains is not considered to be practical for this area. It is also likely that staged construction and/or toe berms could still be required to maintain stability.

Lightweight Fill

In order to reduce the loads imposed by the 4.8 m high embankment on the compressible foundation soils, the use of lightweight fill (i.e. expanded polystyrene (EPS)) could be considered for this area. The use of this material for the embankment fill would eliminate the need for stabilizing toe berms and would result in very little long-term time-dependent (consolidation) settlement of the foundation soils. However, considering the volume of EPS fill required to construct the embankment up to 4.8 m high by about 130 m long, the cost for this alternative is estimated to be an order of magnitude higher than other mitigation options and therefore this option is not considered cost-effective.

6.4.2 CNR – STA 329+035 to 329+060 (Swamp 102)

The area extending from about STA 329+035 to 329+060 along the proposed CNR alignment through a swamp has a proposed vertical profile at or up to 0.3 m above the existing ground surface. The topography of this section of proposed alignment is generally flat and is a low area sloping down gently from east to west between steep ridges beyond the east and west limits of the investigated area. An existing snowmobile trail passes through this valley in a north-south direction.

The subsurface soils along this section of the CNR alignment in Swamp 102 generally consist of a surficial root mat underlain by a deposit of sand and silt to silty sand, underlain by inferred bedrock. A 0.8 m thick layer of clayey silt was encountered within the cohesionless deposit in the vicinity of STA 329+060 (towards the west limit of the investigated area). Refusal to borehole advancement or dynamic cone penetration in the area around the swamp was encountered at depths between about 3.0 m and 4.2 m below ground surface. In general, refusal was encountered at a greater depth at about STA 329+040.

Details of the subsurface conditions for this swamp crossing are presented in Section 4.4 and are shown on Drawing B1 in Appendix B.

Since there is essentially no embankment loading (less than 0.3 m) in this swamp, consolidation settlement of the 0.8 mm thick clayey silt layer encountered at the west end of the swamp will be less than 10 mm.

Given the vertical profile through this swamp and the negligible settlement expected (less than 25 mm for the embankment rock fill, cohesionless soils and the cohesive layer), no settlement or stability mitigation is required in this swamp. All organic deposits must be sub-excavated and replaced in accordance with OPSD 203.010 (Embankments Over Swamp).

6.4.3 CNR – STA 329+185 to 329+305 (Swamp 103)

The area extending from about STA 329+185 to 329+305 along the proposed CNR alignment through a swamp requires a new embankment up to 2.9 m high to achieve the proposed vertical profile. The topography in this section of the proposed CNR alignment is generally low-lying with the ground surface sloping down from both the east and west ends of the swamp area being deepest near the east end of the investigated area. Bedrock is exposed at the east limit of the swamp and moderate tree cover is present over the entire area.

The subsurface soils along the alignment in Swamp 103 generally consist of a surficial root mat underlain by alternating deposits of silty clay, sand, clayey silt and silty sand to silt. The boreholes were typically terminated within the lower cohesionless deposit up to 18.9 m below ground surface. Refusal to dynamic cone penetration and borehole advancement, indicative of the potential bedrock surface, was encountered in boreholes at the east end of the swamp only (east of about STA 329+220).

Details of the subsurface conditions for this swamp crossing are presented in Section 4.5 and shown on Drawing C1 in Appendix C.

As indicated in Section 6.2, the new railway embankment was analyzed assuming a rock fill composition and 1.5H:1V side slopes. The stability and settlement analysis assumes that the organic soils (up to 0.3 m deep) encountered at the site under the embankment footprint have been removed and replaced in accordance with OPSD 203.010 (Embankments Over Swamp) prior to construction of the new embankment. The simplified stratigraphy and the associated unit weight, strength, deformation and time rate consolidation parameters employed for the different soil types encountered in this area are summarized in Table 2. The piezometric condition used in the analyses is the water table at 1.2 m below the ground surface, based on the groundwater levels noted during drilling.

6.4.3.1 Stability

Based on the results of the subsurface investigation and review of the profile drawings, two critical sections (i.e. greatest embankment height and/or maximum thickness of soft, compressible foundation soils) have been identified for this swamp crossing. These sections are located at about STA 329+210 (2.9 m high embankment overlying a 0.3 m thick clayey silt deposit at depth) and STA 329+235 (1.2 m high embankment overlying a 4.1 m thick clayey silt deposit at depth). The stability analysis performed on the critical sections indicate that after the completion of construction (including removal and replacement of the 0.3 m of organic soils), 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 and therefore stability mitigation is not required. The results of the stability analyses are shown on Figures C1 and C2 in Appendix C.

6.4.3.2 Settlement

To estimate the magnitude of the expected settlements due to new construction, analyses were carried out at the critical sections. At STA 329+235, where the clayey silt is 4.1 m thick and the embankment is about 1.2 m high, it is estimated that the settlement of the foundation soils within the vicinity of the critical section will be about 100 mm. This total settlement is estimated to comprise about 30 mm of immediate settlement due to compression of the cohesionless deposits and about 70 mm of primary consolidation of the cohesive deposit. At about STA 329+210, the total settlement of the foundations soils will be about 170 mm, comprising mainly of immediate settlement due to compression of the cohesionless deposits.

Based on an average coefficient of consolidation (c_v) of about 2.35 x 10^{-3} cm^2/s estimated for the cohesive deposit based on the results of a laboratory consolidation tests on samples of similar material in Swamp 103 and correlations with laboratory data, the imposed loading conditions for the approximately 1.2 m high embankment at STA 329+235 plus 0.3 m of backfill for replacement of the organics, and assuming two-way drainage of the cohesive deposit, it is estimated that about 90 percent of the primary consolidation settlement will be completed in about 6 months as shown on Figure C3 in Appendix C.

The magnitude of secondary (creep) settlement for the cohesive deposit is estimated to be about 15 mm per log cycle of time. Therefore, about 25 mm of creep will occur over the design life of the approach embankment (i.e. 20 years).

In addition, the settlement of the rock fill embankment itself in this swamp is estimated to be up to about 25 mm at STA 329+210 (based on a 2.9 m high embankment plus up to 0.3 m of additional rock fill required after removal of the organic deposits) with about 20 mm expected to occur within the six months after construction and about 5 mm expected to occur over the remaining design life of the railway.

The estimated total post-construction settlement of the subsoils and embankment rock fill after completion of embankment construction ranges from approximately 25 mm (mainly rock fill) at STA 320+210 to 110 mm (from cohesive deposit and rock fill) at STA 329+235. Therefore, mitigation measures to reduce the magnitude of post-construction settlement are required.

6.4.3.3 Mitigation of Time-Dependent Settlements

As noted above, provided the organic deposits are removed and replaced with rock fill prior to embankment construction, stability mitigation measures are not required. However, the presence of the 4.1 m thick clay deposit influences the magnitude of post-construction settlement of the proposed up to 1.2 m high embankment at the critical section (STA 329+235). In order to minimize post-construction settlements, the alternatives presented below can be considered. The alternatives have been evaluated and ranked on the basis of the advantages, disadvantages, relative costs and risk/consequences and are summarised in Table C1 in Appendix C. Given the availability in the schedule and the overall benefits for reducing primary consolidation settlement, preloading for 6 months (with instrumentation and monitoring) is ranked as the preferred mitigation option for this swamp crossing. A further benefit is the advantage of construction staging with construction of the CNR overhead NBL and SBL structures.

Preloading

Based on the estimated coefficient of consolidation for the cohesive deposit, it is estimated that 90 percent of primary consolidation settlement of the silty clay deposit will be completed in about 6 months, which we recommend as a preload period provided that instrumentation is used. In order to eliminate the need for instrumentation and settlement monitoring during and after the construction of the embankment, a minimum preload period of 1 year should be specified. The total post-construction settlement after completion of the preload period for this option is about 40 mm (including remaining primary, creep settlement and long-term rock fill settlement).

If the construction schedule can accommodate a 6 or 12 month preload period, by constructing the embankment as early as possible, preloading the foundation soils is considered the preferred mitigation option for this swamp crossing and would provide the best long-term performance of the railway embankment.

Full Sub-Excavation

The bottom of the main clayey silt deposit is up to 5.2 m below existing ground surface within the proposed embankment footprint east of STA 329+260. Full sub-excavation of the cohesive deposit to this depth is considered feasible and would provide a technical solution that minimizes post-construction settlement of the embankment. Settlement analysis indicates that full sub-excavation of the cohesive deposit up to 5.2 m depth would be required between STA 329+220 and STA 329+260. Sub-excavation of the clayey silt deposit where present east of about STA 329+220 is not required, as settlement of the clayey deposit is negligible. This swamp area west of about STA 329+260 is in a cut and sub-excavation is not required.

Since the groundwater table is between 1.2 m and 4.5 m below ground surface, sub-excavation would generally have to be carried out ‘in the wet’, i.e. below the water level. Excavation ‘in the wet’ results in less risk of instability and base heave than under dry conditions, but will create more uncertainty regarding full removal of the cohesive deposits. Excavation ‘in the wet’ to remove the cohesive deposit in this area should be carried out with side slopes no steeper than 1H:1V to limit the risk of instability. Complete removal of the cohesive deposit should extend to a horizontal distance beyond the toe of the proposed embankment equal to the horizontal component of the side slope profile (i.e. 1.5 for rock fill) multiplied by the depth to the bottom of the cohesive deposit below the ground surface in accordance with OPSD 203.010 (Embankments Over Swamp).

It should be noted, however, that full sub-excavation of the cohesive deposit would increase the effective thickness of the new embankment fill by up to about an additional 4.9 m, because of the additional rock fill required below the existing ground surface. The additional below grade rock fill would need to be constructed with the same side slope profile as that used for the above grade embankment (OPSD 203.010). The total settlement of the rock fill embankment at STA 329+235 after completion of embankment construction is estimated to be about 60 mm, with about 50 mm occurring within the six months after construction of the embankment to the design surface elevation and 10 mm of long-term (after 6 months following embankment construction) settlement.

Surcharging

As the post-construction settlement under the preload only case is less than 40 mm, surcharging is not necessary at this location.

Wick Drains

Given the layered nature of the deposit (i.e. sand and silt layers/seams), the use of wick drains in this swamp area is considered technically feasible to reduce the length of the time period required for primary consolidation settlement. However, due to the limited extent and variable thickness of the cohesive deposit within the swamp and the extra costs associated with the additional investigation, design and construction of wick drains is not considered to be practical for this area.

Lightweight Fill

Given the short duration recommended for the preloading mitigation option and the absence of stability issues associated with the proposed embankment geometry, the use of expensive lightweight fill (i.e. expanded polystyrene (EPS)) is not considered necessary or practical for this area as the full sub-excavation or preloading/surcharging settlement mitigation alternatives are more cost-effective.

6.4.4 CNR – STA 329+680 to 329+780 (Swamp 104)

The area extending from about STA 329+680 to 329+780 along the proposed CNR alignment through a swamp area requires a new embankment up to 4.2 m high to achieve the proposed vertical CNR alignment profile. The topography in this section of the proposed CNR alignment is flat and low-lying with ponded water encountered at ground surface. The entire investigated area is covered moderately with trees, shrubs and grass. The existing Highway 69 alignment and proposed Highway 69 Detour, extends across the eastern limit of the investigated area.

Ice and water was encountered at the borehole locations across the entire site. The subsurface soils generally consist of a layer of peat (fibrous and/or amorphous), underlain by deposits of sand and gravel and sand to sand and silt. A surficial deposit of clay was encountered at the west end of the site at about STA 329+775. The cohesionless deposits are underlain by inferred bedrock. Refusal to dynamic cone penetration and borehole advancement, indicative of the potential bedrock surface, was encountered in each of the boreholes and DCPTs, at depths between about 1.5 m and 13.6 m below ground surface. In general, refusal was encountered at greater depth between about STA 329+675 and STA 329+715 in the eastern portion of the site.

Details of the subsurface conditions for this swamp crossing are presented in Section 4.6 and are shown on Drawing D1 in Appendix D.

The stability analyses assume that removal of the up to 2.3 m thick peat and surficial clay deposit along the alignment is carried out in accordance with OPSD 203.010 (Embankments Over Swamp). In this case, there are no stability issues anticipated for the proposed up to 4.2 m high embankment. Settlement due to compression of the cohesionless soil deposits is estimated to be about 220 mm and is expected to occur rapidly (i.e. during or shortly after completion of embankment construction) in response to filling.

In addition, the settlement of the rock fill embankment itself for this section of the embankment is estimated to be up to about 55 mm with about 40 mm expected to occur within the six months after construction and about 5 mm expected to occur over the remaining design life of the railway.

Since no stability or settlement issues have been identified at this site, mitigation measures are not required at this location.

6.4.5 Highway 69 Detour – STA 23+400 to 23+650 (Swamp 104)

The area extending from about STA 23+400 to 23+650 along the proposed Highway 69 Detour through a swamp area requires a new embankment up to 8.8 m high. The topography along the detour alignment is flat and low-lying with ponded water encountered at ground surface across most of the site. The entire investigated area is covered moderately with trees, shrubs and grass. The proposed realigned CNR Right-of-Way intersects the Highway 69 Detour from approximately STA 23+480 to STA 23+530.

Ponded water was encountered across most of the site and the water level was evident slightly below ground surface in non-ponded areas of the site. The subsurface soils generally consist of a layer of peat (fibrous and/or amorphous), underlain by deposits of sand and/or sand and gravel. A layer of organic silty clay was encountered in the northern portion of the site, north of approximately STA 23+550. Refusal to dynamic cone penetration and borehole advancement, indicative of the potential bedrock surface, was encountered in most of the boreholes and DCPTs, at depths between 0.5 m and 8.5 m below ground surface.

In general, refusal was encountered at greater depth between about STA 23+500 and STA 23+550, in the middle portion of the site near the CNR Right-of-Way. Refusal was not encountered in Boreholes S104-13, S104-15 and S104-22a to as low as Elevation 170.9 m.

Details of the subsurface conditions for this swamp crossing are presented in Section 4.7 and are shown on Drawing E1 in Appendix E.

The stability analyses assume that removal of the up to 4.0 m of peat and organic silty clay (north of STA 23+550) along the alignment is carried out in accordance with OPSD 203.010 (Embankments Over Swamp). In this case, there are no stability issues anticipated for the proposed up to 8.8 m high embankment. Settlement due to compression of the cohesionless soil deposits is estimated to be about 200 mm and is expected to occur rapidly (i.e. during or shortly after completion of embankment construction) in response to filling.

In addition, the total settlement of the rock fill embankment (based on a maximum rock fill thickness of about 10.3 m for the embankment and peat/ organic silty clay replacement depth) after completion of embankment construction is estimated to be about 125 mm, with about 100 mm occurring within the six months after construction of the embankment to the design surface elevation and 25 mm of long-term (after 6 months following embankment construction) settlement. Given the temporary nature of the detour, preloading to reduce long-term rock fill settlement is not considered necessary from a foundations perspective.

Since no stability or long-term settlement issues have been identified at this site, mitigation measures are not required at this location. Careful excavation of the peat/ organic silty clay will have to take place adjacent to the existing highway, which will be in operation. Section 6.5 provides details of the embankment construction in this area.

6.5 Subgrade Preparation and Embankment Construction

The following sections discuss general aspects of subgrade preparation and embankment construction for the swamp crossings for the new CN Railway embankment and Highway 69 Detour, including: removal of surficial and near surface organic materials; excavation and replacement of soft, cohesive subsoils; recommendations for temporary support/protection systems, where required; staged excavation; groundwater control where required; and embankment fill placement.

A summary of the recommended (preferred) foundation mitigation option for each swamp crossing area is presented in Table 4. The summary contains: recommendations on embankment fill types and side slope profiles; estimated maximum depth of organic encountered; and the estimated settlement (during and post construction) for the embankment materials and the subsoils for the recommended/preferred mitigation option.

6.5.1 Removal of Organics

Based on the information from the boreholes advanced during the field investigation, the thickness of organic deposits (i.e. topsoil, peat, root mat, organic clay and/or slightly organic silt) in the swamps ranges from about 0.1 m to 4.0 m. After clearing and grubbing of the swamp areas and prior to the placement of any fill for the new construction, these deposits within swamp areas should be stripped from the plan limits of the proposed works, including toe berms, if applicable. The organic materials should be removed using construction procedures in accordance with OPSS 209 (Embankments Over Swamps and Compressible Soils).

In areas where new embankments are being constructed away from existing embankments, the excavation limits should be consistent with OPSD 203.010 (Embankments Over Swamp, New Construction) modified to remove the restrictions on the height of the embankment and the depth of excavation (i.e. Note A).

In areas where new fill embankments will be constructed immediately adjacent to, or on top of, existing embankments (detour embankment at Swamp 104), the excavation limits should incorporate the guidelines of OPSD 203.030 (Embankments Over Swamp, Existing Slopes Maintained). These guidelines require that the slopes of the existing embankment be temporarily excavated at a 1H:1V profile to allow for the potential removal of a larger extent of organic material.

6.5.2 Excavation and Replacement of Soft Subsoils

In areas where stability and/or post-construction settlements require mitigation measures to enhance the performance of the embankment, excavation and replacement, either fully or partially, of soft subsoils is recommended. Excavation up to about 10 m below existing ground surface is anticipated in some areas of the Contract 1 section of the project where sub-excavation and replacement of soft materials is recommended as the preferred mitigation option. Conventional (or long stick type) equipment is considered suitable for the excavation of these soft subsoils. For the Highway 69 Detour in Swamp 104, staged excavation and/or temporary protection systems may be required to maintain stability and/or protect existing roadways.

All excavations must be carried out in accordance with the latest edition of the Ontario Occupational Health and Safety Act and Regulations for Construction Projects. In addition, provisions for traffic control measures should be included in the Contract to maintain the safe operation of Highway 69 and any associated side roads or detours during excavation operations.

6.5.2.1 Temporary Protection Systems

Where there is restriction in space for open excavation due to the proximity to an existing roadway, open waterway or property restrictions, temporary support/protection systems may be required to support the excavation. All temporary excavation support systems should be designed/constructed in accordance with OPSS 539 (Temporary Protection Systems). Temporary excavation support systems should be designed to Performance Level 3 (i.e. maximum angular distortion of 1:100 and maximum horizontal displacement of 50 mm) for any excavation adjacent to the existing roadway.

The use of temporary protection systems and/or staged excavation in strips of limited width will be required in Swamp 104 where excavations adjacent to the existing roadway cannot be carried out in open cut without stability issues (as discussed in Section 6.4.5).

6.5.2.2 Staged Excavation

Where there is restriction in space due to proximity to an existing roadway, such as for the Highway 69 Detour adjacent to the existing Highway 69, staged excavation in strips of limited width can be considered as a method to maintain stability and to protect the existing railway/roadway during sub-excavation and replacement operations. The recommendations for staged excavation are as follows:

- Work may be carried out simultaneously starting from both ends of the swamp and progressing towards the centre, along the existing embankment footprint.
- Removal of the organic and/or soft compressible deposits within the proposed embankment footprint should be carried out in accordance with OPSS 209 (Embankments Over Swamp and Compressible Soils) in sections perpendicular to the proposed railway/roadway alignment.
- Temporary excavation side slopes or back slopes through the organic and soft compressible deposits should be no steeper than 1.25H:1V, except adjacent to the existing railway/roadway where they should be in accordance with OPSD 203.020 (Embankments Over Swamp, Existing Slope Excavated to 1H:1V).
- Some distress to the existing roadway may occur during the staged excavation and, as such, provisions for traffic control measures should be included in the Contract to maintain the safe operation of Highway 69 during the excavation and backfilling operations.

The recommendations provided above should be incorporated into a Non-Standard Special Provision (NSSP) in the Contract (an example is included in Appendix F).

It should be noted that even following the above procedures may still result in some organics and/or soft compressible subsoils remaining in place in the transition area below or between the existing and new embankment. However, if the remaining organics or soft compressible deposits are confined to beneath the toe area of the proposed embankment, it should not have a significant effect (stability and settlement) on the performance of either the existing or new railway/roadway embankment.

6.5.3 Groundwater and Surface Water Control

Excavation within the plan limits of the proposed works will be required to remove organic and/or soft deposits prior to embankment fill placement, which will extend below the water table. Groundwater flow into the excavations will occur due to the relatively permeable subsoils and high groundwater levels observed at all swamp and pond crossing areas. Dewatering is not required for the excavation and backfilling in the swamp/pond areas as per OPSS 209. Surface water should be directed away from the excavations at all times.

Excavations for the removal of the organics and/or soft compressible deposits will extend below the water table. Conventional (or long stick type) excavators should be suitable for most of the excavating operations through the swamp and pond crossing areas as the maximum depth of removal is about 10 m below the ground surface (Swamp 101).

6.5.4 Backfilling

It is recommended that rock fill be used for replacement of the sub-excavated material. Where sub-excavation of soft subsoils is being carried out as a foundation mitigation option, it will not likely be possible to place rock fill in accordance with SP 206S03 (Rock Excavation, Grading), as discussed in Section 6.5.5. The rock fill is anticipated to be end dumped (typically below the water table) as the excavation advances and settlement has been estimated accordingly.

6.5.5 Embankment Fill Placement

Placement of all rock fill material above the water table for construction of new embankments should be carried out in accordance with the requirements as outlined in SP 206S03 (Rock Excavation, Grading, Rock Embankment). As noted in the Special Provision, the rock should not be dumped in final position, but should be deposited on and pushed forward over the end of the layer being constructed. Voids and bridging should be minimized by blading, dozing and ‘chinking’ the rock to form a dense, compacted mass. Side slopes for rock fill embankments should be no steeper than 1.5H:1V for conformance with AREMA recommendations for the railway embankments and 1.25H:1V for the detour embankment.

7.0 CLOSURE

This report was prepared by Mr. Luigi Gianfrancesco, EIT, and Mr. André Bom, P.Eng., and the technical aspects were reviewed by Ms. Sarah E. M. Coyne, P.Eng., Associate. Mr. Jorge M. A. Costa, P.Eng., Golder’s Designated MTO Contact for this project and Principal, conducted an independent quality control review of the report.

Report Signature Page

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Http://capws/sites/0911116014highway69FourLaning/Contract 1 CN Realignment/Reporting/Final/CNR Embankments over Swamps/09-1111-6014 FNL RPT 11Aug23 CNR Embankment FIDR.docx

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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 (Version 7.13) by Geo-Slope International Ltd.

Settle 3D (Version 2.003) by Rocscience Inc.

Ministry of Transportation Ontario Guideline for Rockfill in the Foundation Design for Post-Construction Rock Fill Settlement Calculation and Estimate of Rock Fill Quantity, September 14, 2010.

Ministry of Transportation Ontario Special Provisions

SP 110S13	Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill
SP 206S03	Earth Excavation, Grading; Rock Embankment

Ontario Provincial Standard Drawings

OPSD 203.010	Embankments Over Swamp, New Construction
OPSD 203.020	Embankments Over Swamp, Slope Excavation to 1H:1V
OPSD 208.010	Benching of Earth Slopes

Ontario Provincial Standard Specifications

OPSS 209	Construction Specification for Embankments over Swamps and Compressible Soils
OPSS 539	Construction Specification for Temporary Protection Systems

Ontario Water Resources Act

Ontario Regulation 372/97	Amendment to Ontario Regulation 903
Ontario Regulation 903/90	Wells

Table 1: Summary of Swamp Crossings

Approx. Station	Designation	Maximum Proposed Embankment Height[1]	Boreholes/DCPT
CNR STA 328+810 to 328+940	Swamp 101	4.8 m	11 Boreholes (S101-01 to S101-11) 5 DCPTs (S101-DC1 to S101-DC5)
CNR STA 329+035 to 329+060	Swamp 102	0.3 m	3 Boreholes (S102-01 to S102-03) 1 DCPT (S102-DC1)
CNR STA 329+185 to 329+305	Swamp 103	2.9 m	10 Boreholes (S103-01 to S103-09, S103-03a) 3 DCPTs (S103-DC1 to S103-DC3)
CNR STA 329+680 to 329+780	Swamp 104	4.2 m	10 Boreholes (S104-01 to S101-09, S104-04a) 4 DCPTs (S104-DC1 to S104-DC4)
Highway 69 Detour STA 23+400 to 23+650	Swamp 104 (Detour)	8.8 m	11 Boreholes (S104-10 to S104-18, S104-10a, S104-22a) 2 DCPTS (S104-DC5 and S104-DC6)

Note: 1. Based on centreline profile of CNR alignment and existing ground surface profiles provided by URS. Embankment height is approximate and is relative to top of peat/original ground.

Table 2: Summary of Foundations Engineering Parameters

Approx. Station (Swamp Crossing)	Stratigraphic Unit	Top Elevation (m)	Thickness (m)	γ' (kN/m^3)	ϕ' ($^\circ$)	c' (kPa)	S_u (kPa)	σ_p' (kPa)	e_o	C_c	C_r	m_v (kPa^{-1})	E' (MPa)	c_v (cm^2/s)
STA 328+810 to 328+940 (Swamp 101)	Peat (Root Mat)[1]	183.7 to 180.3	0.1 to 0.4	12	27	1	-	-	-	-	-	-	-	-
	Silt/Clayey Silt[1]	183.1 to 180.2	0.7 to 1.6	18	27	0	-	-	-	-	-	-	-	-
	Silty Sand to Sand[1]	181.9 to 178.2	0.6 to 1.5	19	28	0	-	-	-	-	-	-	-	-
	Slightly Organic Silt to Organic Clay[1]	180.6 to 178.9	1.3 to 1.6	15	-	-	15	-	-	-	-	-	-	-
	Clayey Silt to Clay[2]	180.9 to 177.3	1.5 to 7.3	15	-	-	Upper-12 Lower-20	45-75	2.6	1.2	0.12	-	-	2.35 x10^{-3}
	Sand and Silt to Silt	179.4 to 170.3	0.4 to 8.5	19	28	0	-	-	-	-	-	-	5	-
STA 329+035 to 329+060 (Swamp 102)	Peat (Root Mat) [1]	185.1 to 184.6	0.1 to 0.2	12	27	1	-	-	-	-	-	-	-	-
	Sand and Silt to Silty Sand	185.3 to 184.5	3.0 to 3.6	19	28	0	-	-	-	-	-	-	10	-
	Clayey Silt Interlayer[2]	183.6	0.8	15	-	-	7	40	2.6	1.2	0.12	-	-	2.35 x10^{-3}
STA 329+185 to 329+305 (Swamp 103)	Peat[1]	187.2 to 182.3	0.1 to 0.3	12	27	1	-	-	-	-	-	-	-	-
	Silty Clay[2]	187.1 to184.0	0.4 to 1.4	18	-	-	25	110	1.0	0.4	0.04	-	-	2.54 x10^{-3}
	Silt	184.0 to 182.2	0.6 to 1.4	18	28	0	-	-	-	-	-	-	5	-
	Sand/Sand and Gravel	185.7 to 180.8	0.4 to 3.8	19	30	0	-	-	-	-	-	-	10	-
	Clayey Silt[2]	183.9 to 181.5	0.3 to 4.1	15	-	-	30 decreasing to 8	45-140	1.0	0.4	0.04	-	-	2.35 x10^{-3}
		181.5 to 178.9					8							
	Silty Sand to Silt	181.1 to 178.6	3.7 to >14.5	19	28	0	-	-	-	-	-	-	5	-
STA 329+680 to 329+780 (Swamp 104)	Peat (Root Mat) [1]	182.6 to 181.3	0.1 to 2.3	12	27	1	-	-	-	-	-	-	-	-
	Clay[2]	182.4 to 180.3	0.1 to 1.5	15	-	-	20	-	2	1.0	0.1	-	-	1.47 x10^{-3}
	Sand and Gravel	182.5 to 179.8	0.7 to 3.0	19	30	0	-	-	-	-	-	-	15	-
	Sand to Sand and Silt	181.1 to 177.2	1.2 to 7.8	19	28	0	-	-	-	-	-	-	5	-
STA 23+400 to 23+650 (Swamp 104)	Peat/Topsoil[1]	182.7 to 182.3	0.5 to 3.0	12	27	1	-	-	-	-	-	-	-	-
	Organic Clay[1]	181.1 to 179.6	0.2 to 2.7	15	-	-	8	-	-	-	-	-	-	-
	Sand and Gravel	184.1 to 180.8	0.4 to 1.3	19	30	0	-	-	-	-	-	-	15	-
	Sand	181.8 to 178.7	1.4 to >8.5	19	28	0	-	-	-	-	-	-	5	-

Note:

1. In all swamp crossings, removal of organic deposits (i.e. topsoil, peat, slightly organic silt and/or organic clay including cohesionless interlayers) is required prior to embankment construction.
2. Engineering parameters based on two laboratory oedometer tests on samples from Swamp 101 as well as correlations from other laboratory data.

Table 3: Summary of Settlement Analyses

Foundation Investigation Area	Settlement (mm) / Delay Time[6]	Estimated Post-Construction Settlement Over 20-Year Period at the Critical Section (mm)[1]					Preferred Mitigation Options
		No Foundation Mitigation[2]	Full Sub-Excavation of Clay without Preloading[3]	Full Sub-Excavation of Clay with Preloading[3,4]	Preloading without Sub-Excavation of Clay[5]	Surcharging without Sub-Excavation of Clay[5]	
CNR STA 328+810 to 328+940 (Swamp 101)	$\delta_{primary}$ $\delta_{secondary}$ $\delta_{rock\ fill}$ **δ_{total}** t_{delay}	710 55 75 **840**	- - 200 **200**	- - 45 **45**	70 55 15 **140** 18 month preload with monitoring, 10 m wide toe berms	0 55 15 **70** 14 month preload with monitoring, 15 m wide toe berms	Full Sub-Excavation (up to 10.2 m) with preloading (6 months for rock fill)
CNR STA 329+035 to 329+060 (Swamp 102)	$\delta_{primary}$ $\delta_{secondary}$ $\delta_{rock\ fill}$ **δ_{total}**	- - ~0 ~0	NA	NA	NA	NA	No foundation mitigation required
CNR STA 329+185 to 329+305 (Swamp 103)	$\delta_{primary}$ $\delta_{secondary}$ $\delta_{rock\ fill}$ **δ_{total}** t_{delay}	70 25 15 **110** (at STA 329+235)	- - 60 **60**	NA	10 25 5 **40** 6 month preload without monitoring	NA	Preloading 6 months
CNR STA 329+680 to 329+780 (Swamp 104)	$\delta_{primary}$ $\delta_{secondary}$ $\delta_{rock\ fill}$ **δ_{total}**	0 0 55 **55**	NA	NA	NA	NA	No foundation mitigation required
Highway 69 Detour STA 23+400 to 23+650 (Swamp 104)	$\delta_{primary}$ $\delta_{secondary}$ $\delta_{rock\ fill}$ **δ_{total}**	0 0 125 **125**	NA	NA	NA	NA	No foundation mitigation required

NA – Not applicable

Notes:

1. Design performance criteria is less than about 50 mm to 60 mm of post-construction settlement in twenty (20) years.
2. In all swamp crossings, removal of organic deposits (i.e. topsoil, peat and/or organic silty clay and organic silt/sand) is required prior to embankment construction.
3. Full sub-excavation implies complete removal of soft, compressible cohesive deposits.
4. Six month preloading period recommended to reduce long term rock fill settlement.
5. Refer to Sections 6.4.1.3 and 6.4.3.3 and Tables A1 and C1 for details of sub-excavation depths and recommended preload duration.
6. Delay time refers to the preload or surcharge time.

Table 4: Summary of Preferred Foundation Mitigation Options

Foundation Investigation Area	Proposed Work (Maximum Fill Height Above Existing Top of Peat)	Topography and Surface Conditions	Recommended Rock Fill Embankment Side Slope	Maximum Thickness of Organics/ Cohesive Deposit Encountered Along Alignment[1]	Preferred Stability / Settlement Mitigation Option[2,3,4]	Estimated Settlement (δ) During Construction	Estimated Post-Construction Settlement (δ)	Swamp Excavation / Organic Removal Specification
CNR STA 328+810 to 328+940 (Swamp 101)	CNR Realignment over Swamp (4.8 m)	Gently sloping to a low area between steep ridges beyond the east and west limits of the investigated area, and is moderately tree covered with bedrock exposed at the north limit of the swamp.	1.5H : 1V	Organic Deposits = 3.1 m Cohesive = 7.3 m	Full Sub-Excavation of organics and clay (maximum 10.2 m deep). Preload embankment for 6 months to reduce post-construction settlement of rock fill	$\delta_{Primary}$ = 0 mm $\delta_{Immediate}$ = 15 mm $\delta_{Rock\ Fill}$ = 155 mm	$\delta_{Primary}$ = 0 mm $\delta_{Secondary}$ = 0 mm $\delta_{Rock\ Fill}$ = 45 mm	OPSD 203.010
CNR STA 329+035 to 329+060 (Swamp 102)	CNR Realignment over Swamp (0.3 m)	Generally flat and is a low area sloping down gently from east and west between steep ridges beyond the east and west limits of the investigated area. An existing snowmobile trail passes through this valley in an east-west direction.	1.5H : 1V	Peat = 0.2 m Cohesive = 0.8 m	No foundation mitigation required	$\delta_{Primary}$ = 0 mm $\delta_{Immediate}$ = ~0 mm $\delta_{Rock\ Fill}$ = ~0 mm	$\delta_{Primary}$ = 0 mm $\delta_{Secondary}$ = 0 mm $\delta_{Rock\ Fill}$ = ~0 mm	OPSD 203.010
CNR STA 329+185 to 329+305 (Swamp 103)	CNR Realignment over Swamp (2.9 m)	Generally low-lying with the ground surface sloping down from both the east and west ends of the swamp area being deepest near the east end of the investigated area. Bedrock is exposed at the east limit of the swamp and moderate tree cover is present over the entire area.	1.5H : 1V	Peat = 0.3 m Cohesive = 4.1 m	Preloading (6 months)	$\delta_{Primary}$ = 60 mm $\delta_{Immediate}$ = 30-170 mm $\delta_{Rock\ Fill}$ = 10-20 mm	$\delta_{Primary}$ = 10 mm $\delta_{Secondary}$ = 15 mm $\delta_{Rock\ Fill}$ = ~5 mm	OPSD 203.010
CNR STA 329+680 to 329+780 (Swamp 104)	CNR Realignment over Swamp (4.2 m)	Flat and low-lying with ponded water at ground surface. The entire investigated area is covered moderately with trees, shrubs and grass. The existing Hwy 69 alignment and proposed Highway 69 Detour, extends across eastern limit of the investigated area	1.5H : 1V	Peat and surficial clay = 2.3 m	No foundation mitigation required	$\delta_{Primary}$ = 0 mm $\delta_{Immediate}$ = 220 mm $\delta_{Rock\ Fill}$ = 0 mm	$\delta_{Primary}$ = 0 mm $\delta_{Secondary}$ = 0 mm $\delta_{Rock\ Fill}$ = 55 mm	OPSD 203.010

Foundation Investigation Area	**Proposed Work (Maximum Fill Height Above Existing Top of Peat)**	**Topography and Surface Conditions**	**Recommended Rock Fill Embankment Side Slope**	**Maximum Thickness of Organics/ Cohesive Deposit Encountered Along Alignment[1]**	**Preferred Stability / Settlement Mitigation Option[2,3,4]**	**Estimated Settlement (δ) During Construction**	**Estimated Post-Construction Settlement (δ)**	**Swamp Excavation / Organic Removal Specification**
Highway 69 Detour STA 23+400 to 23+650 (Swamp 104)	Hwy 69 Detour over Swamp (8.8 m)	Flat and low lying with ponded water encountered at ground surface across most of the site. The entire investigated area is covered moderately with trees, shrubs and grass. The proposed realigned CNR Right of Way intersects the Highway 69 Detour from approximately STA 23+480 to STA 23+530.	1.25H : 1V	Peat and organic clay (to be removed) = 4.0 m	No foundation mitigation required	$\delta_{Primary}$ = 0 mm $\delta_{Immediate}$ = 200 mm $\delta_{Rock\ Fill}$ = 0 mm	$\delta_{Primary}$ =0 mm $\delta_{Secondary}$ = 0 mm $\delta_{Rock\ Fill}$ = 125 mm[5]	OPSD 203.020 (NSSP required for staged excacvation)

Notes:

1. Depths do not include any ponded water that may be present over the peat.
2. In all swamp crossings, removal of organic deposits (i.e. topsoil, peat, slightly organic silt and/or organic clay) is required prior to embankment construction.
3. Full sub-excavation implies complete removal of soft, compressible cohesive deposits.
4. Design performance criteria is less than about 50 mm to 60 mm of post-construction settlement in twenty (20) years.
5. Settlement greater than design performance criteria is acceptable for a detour embankment.

MINISTRY OF TRANSPORTATION, ONTARIO

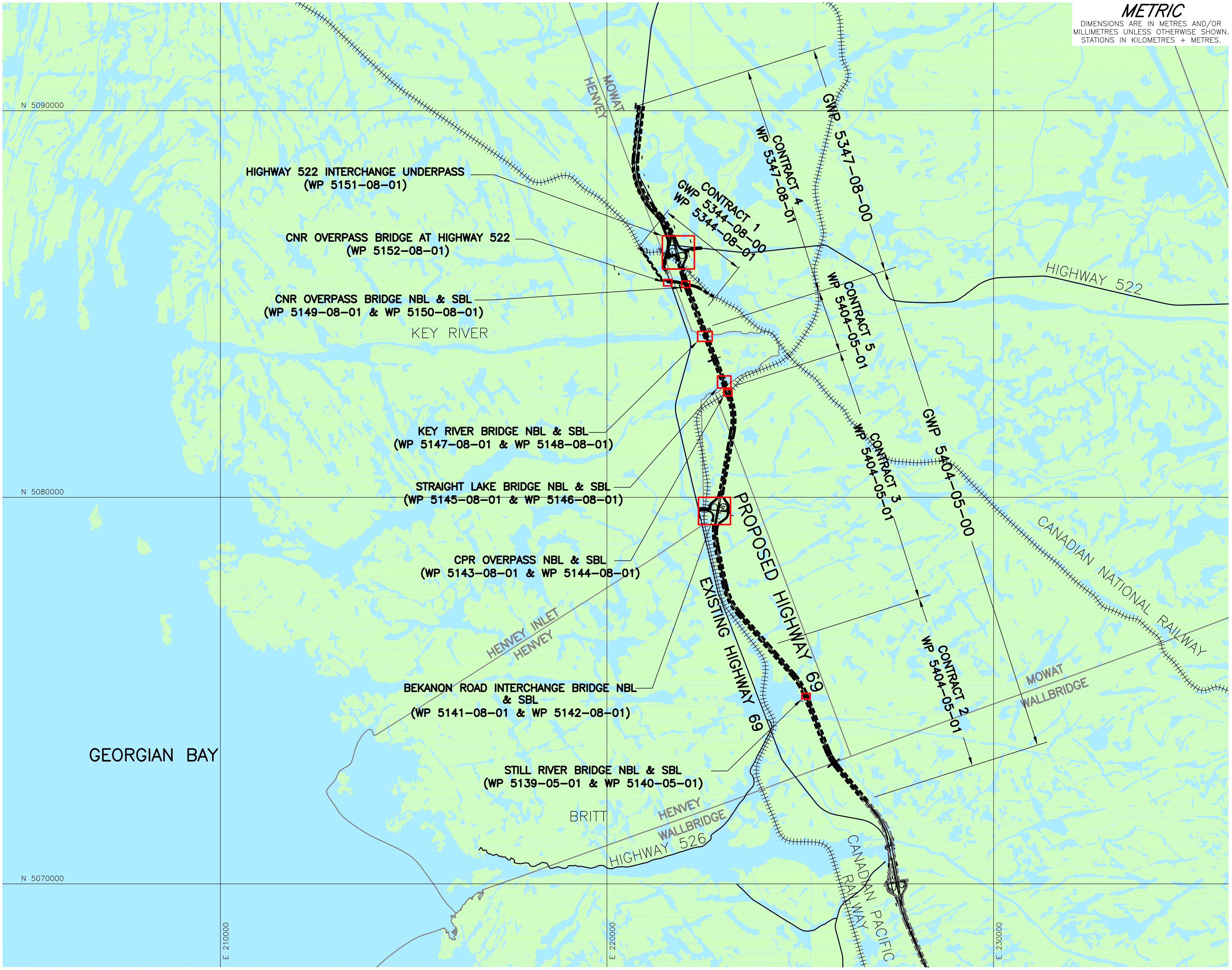
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 5404–05–00

SHEET

HIGHWAY 69
SITE LOCATION PLAN

Golder Associates
Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



KEY PLAN
NOT TO SCALE

PLAN

SCALE
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REFERENCE
Base Data – MNR NRVIS, obtained 2004, CANMAP v2008
Produced by Golder Associates Ltd under licence from
Ontario Ministry of Natural Resources, © Queens Printer 2008
Datum : NAD 83 Projection : MTM Zone 10

NO.	DATE	BY	REVISION

Geocres No.

HWY. 69		PROJECT NO. 09–1111–6014	DIST.
SUBM'D. LG	CHKD. AB	DATE: AUG 2011	SITE:
DRAWN: JJL	CHKD. SEMC	APPD. JMAC	DWG. 1

PLOT DATE: August 17, 2011
FILENAME: \\capws\sites\09111116014highway69FourLaning\Contract 1 CN Realignment\Drafting\Drawings\Drawing 1\09111116014CA001.dwg

MINISTRY OF TRANSPORTATION, ONTARIO

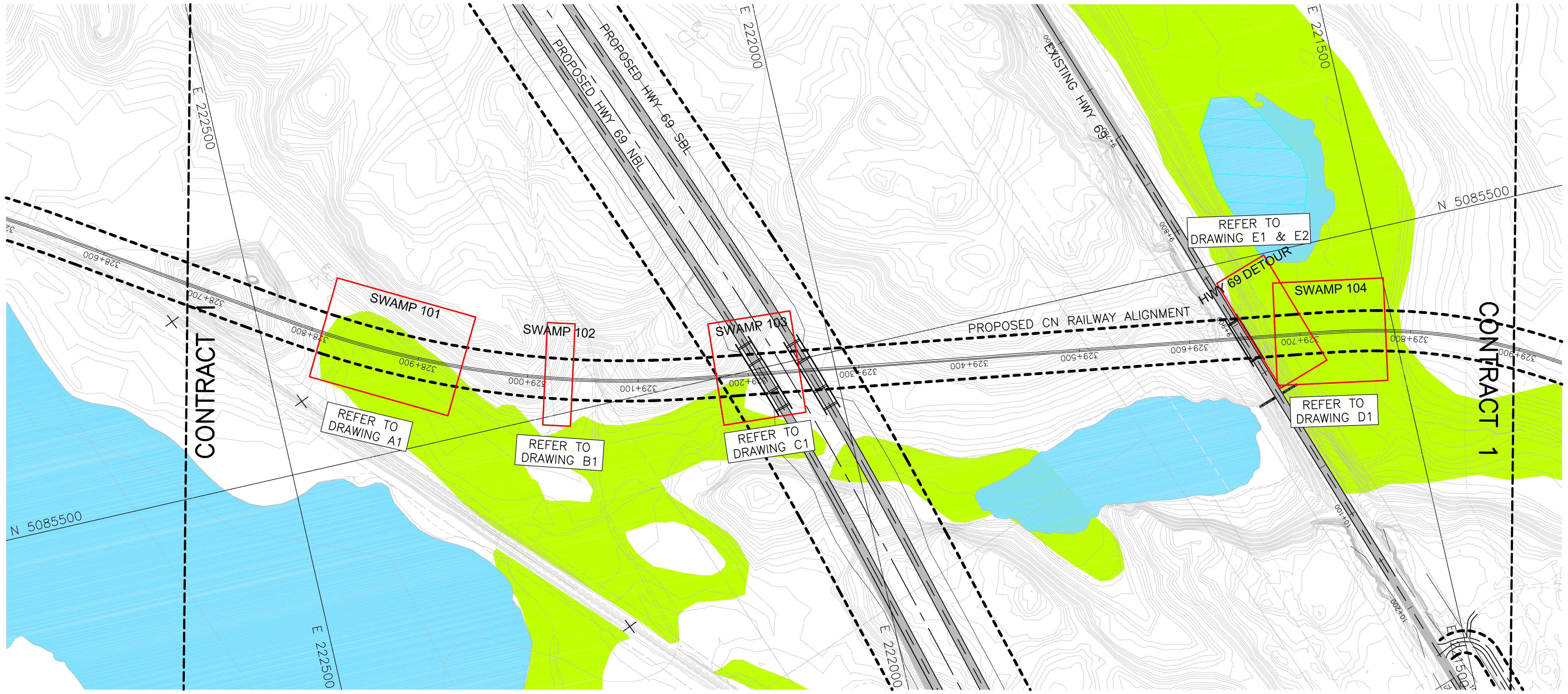
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5344-08-01

SHEET

CN RAILWAY
SWAMP CROSSINGS
INDEX PLAN

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN

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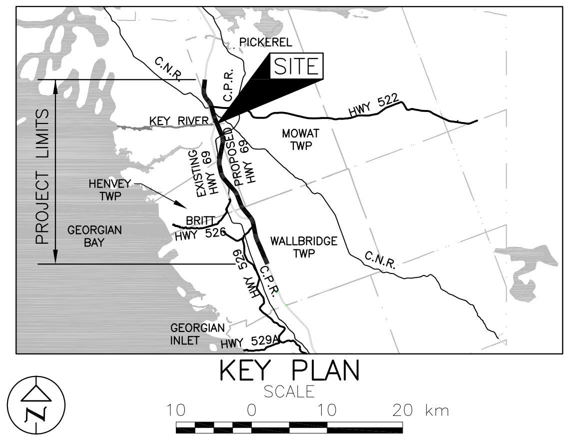

KEY PLAN

SCALE
10 0 10 20 km

LEGEND

🟩	SWAMP AREA
🟦	OPEN WATER

REFERENCE

Base plans provided in digital format by URS, drawing file HWY69_plan.dwg received Feb. 17, 2010. Railroad Contours provided in digital format by URS, drawing file Railroad Contours.dwg, received Jan. 21, 2010. Key plan provided in digital format by URS, drawing file Keyplan.dwg received Apr. 16, 2010.

NO.	DATE	BY	REVISION

Geocres No.

HWY. CNR		PROJECT NO. 09-1111-6014	DIST.
SUBM'D. LG	CHKD. AB	DATE: AUG 2011	SITE:
DRAWN: JJL	CHKD. SMEC	APPD. JMAC	DWG. 2

PLOT DATE: August 23, 2011
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LIST OF SYMBOLS

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

1. GENERAL

π	3.1416
in 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
V	volume
W	weight

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma\text{-}u$)
σ_{vo}	initial effective overburden stress
σ_1, σ_2, σ_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 ($\gamma' = \gamma\text{-}\gamma_w$)
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	liquid limit
w_p	plastic limit
I_p	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_a	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation pressure
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

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

II. PENETRATION RESISTANCE

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

Dynamic Cone Penetration Resistance; N_d:
The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 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) 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.

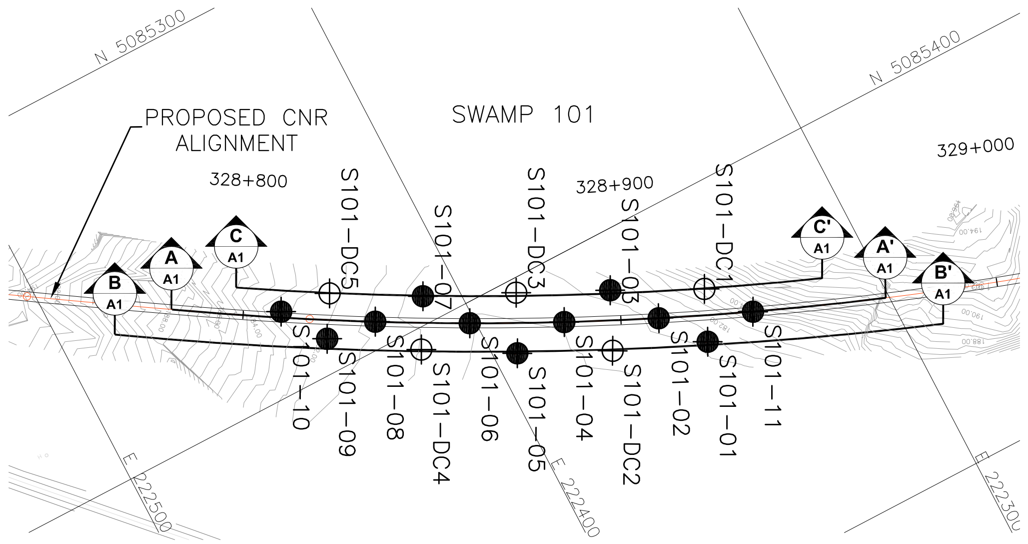
V. MINOR SOIL CONSTITUENTS

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

APPENDIX A

CNR – STA 328+810 to STA 328+940 (Swamp 101)

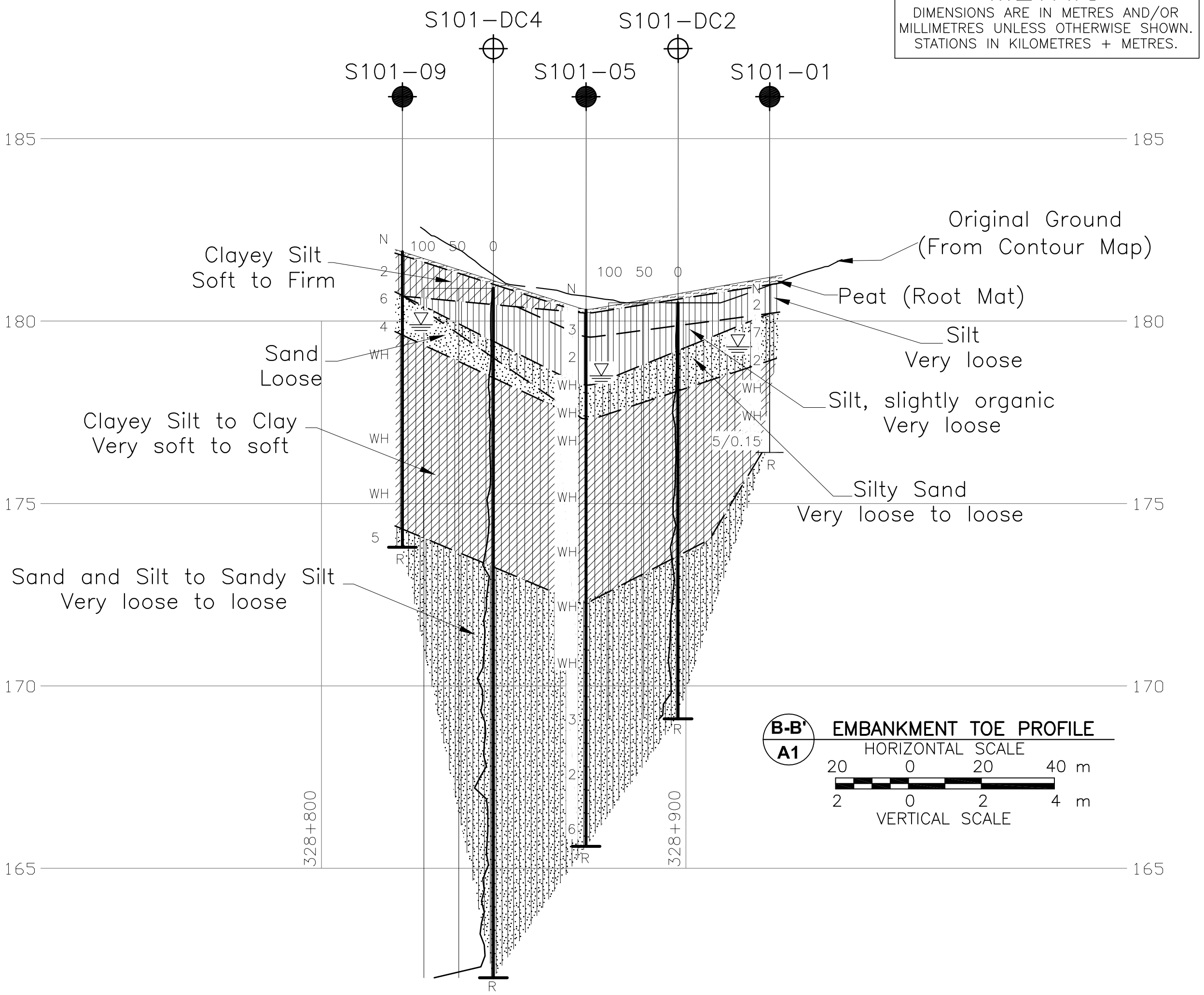
MINISTRY OF TRANSPORTATION, ONTARIO



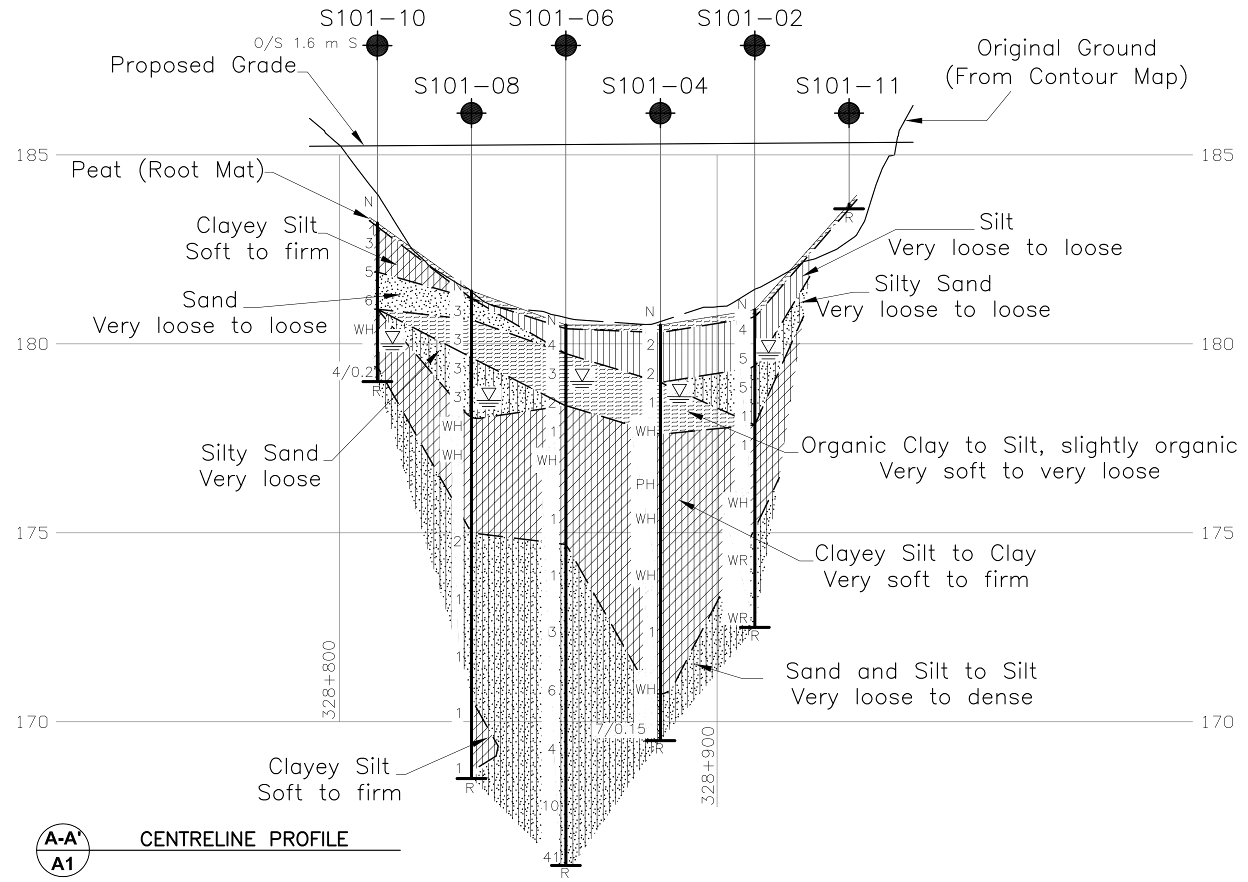
PLAN

SCALE
20 0 20 40 m

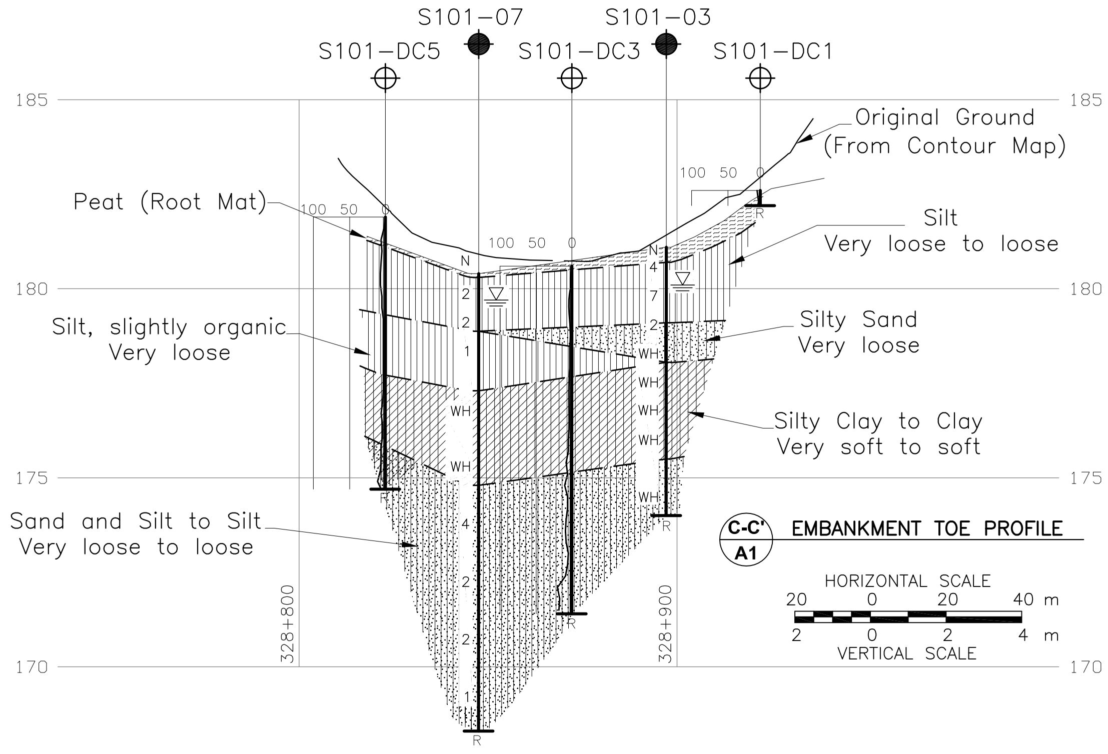
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.



B-B' A1 EMBANKMENT TOE PROFILE
HORIZONTAL SCALE
20 0 20 40 m
2 0 2 4 m
VERTICAL SCALE



A-A' A1 CENTRELINE PROFILE
HORIZONTAL SCALE
20 0 20 40 m
2 0 2 4 m
VERTICAL SCALE



C-C' A1 EMBANKMENT TOE PROFILE
HORIZONTAL SCALE
20 0 20 40 m
2 0 2 4 m
VERTICAL SCALE

S.E.M. COYNE 90471921 AUG 23, 2011

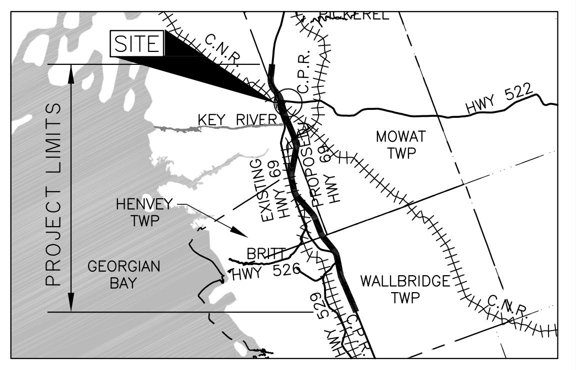
J.M.A.COSTA AUG 23, 2011

CONT No.
WP No.5344-08-01

SHEET

CN RAILWAY
STA 328+810 TO STA 328+940
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



KEY PLAN

SCALE
6 0 6 12 km

LEGEND

●	Borehole
⊕	Dynamic Cone Penetration Test
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
▽	WL upon completion of drilling
R	Refusal

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
S101-01	181.2	5085438.6	222348.0
S101-02	180.9	5085427.1	222356.6
S101-03	181.1	5085414.6	222364.5
S101-04	180.5	5085416.4	222379.2
S101-05	180.3	5085417.9	222394.0
S101-06	180.5	5085405.1	222401.5
S101-07	180.4	5085393.1	222409.2
S101-08	181.4	5085393.1	222423.4
S101-09	181.9	5085391.2	222436.8
S101-10	183.2	5085379.3	222444.3
S101-11	183.7	5085437.1	222333.7
S101-DC1	182.6	5085425.8	222342.3
S101-DC2	180.5	5085429.1	222371.4
S101-DC3	180.6	5085403.6	222386.9
S101-DC4	180.9	5085405.3	222416.1
S101-DC5	182.0	5085380.9	222430.7

NOTES

This drawing is for subsurface information only. The proposed site 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 URS, drawing file HWY69_plan.dwg received Feb. 17, 2010. Railroad Contours provided in digital format by URS, drawing file Railroad Contours.dwg, received Jan. 21, 2010. Key plan provided in digital format by URS, drawing file Keyplan.dwg received Apr. 16, 2010.

NO.	DATE	BY	REVISION

Geocres No. 41H-91

HWY. CNR		PROJECT NO. 09-1111-6014	DIST.
SUBM'D. LG	CHKD. AB	DATE: AUG 2011	SITE:
DRAWN: JJL	CHKD. SEMC	APPD. JMAC	DWG. A1

PLOT DATE: August 23, 2011

RECORD OF BOREHOLE No S101-01

1 OF 1 **METRIC**

PROJECT 09-1111-6014

W.P. 5344-08-00

DIST

HWY CNR

DATUM Geodetic

LOCATION N 5085438.6; E 222348.0

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

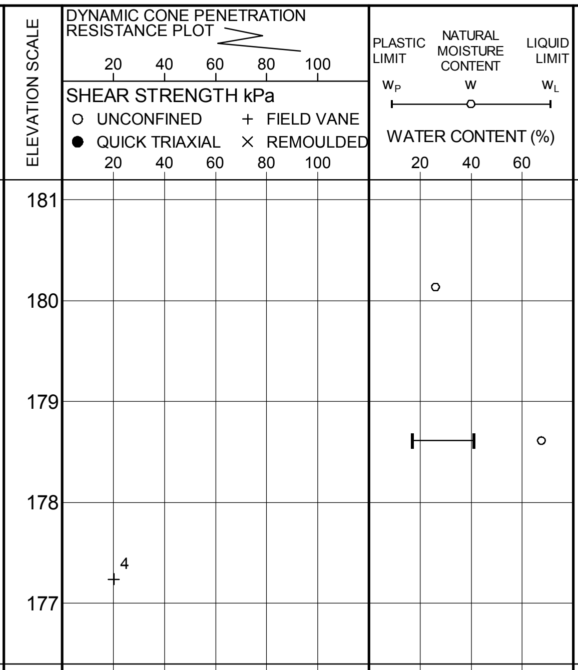
DATE December 8, 2009

ORIGINATED BY EHS

COMPILED BY LG

CHECKED BY AB

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
181.2	GROUND SURFACE						
0.0	PEAT (Root Mat)						
0.2	Brown Moist SILT, trace sand, trace organics Very loose	1	SS	2			
180.2 1.0	Brown and grey Moist Silty SAND, trace clay Very loose to loose Brown to grey Wet	2	SS	7			
		3	SS	2	∇		
178.9 2.3	SILTY CLAY, sand and silt layers / seams Very soft to soft Grey Wet	4	SS	WH			
		5	SS	WH			
176.4		6	SS	5/0.15			
4.8	END OF BOREHOLE SPOON AND AUGER REFUSAL						



Note:

1. Water level at a depth of 1.9 m below ground surface (Elev. 179.3 m) upon completion of drilling.

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

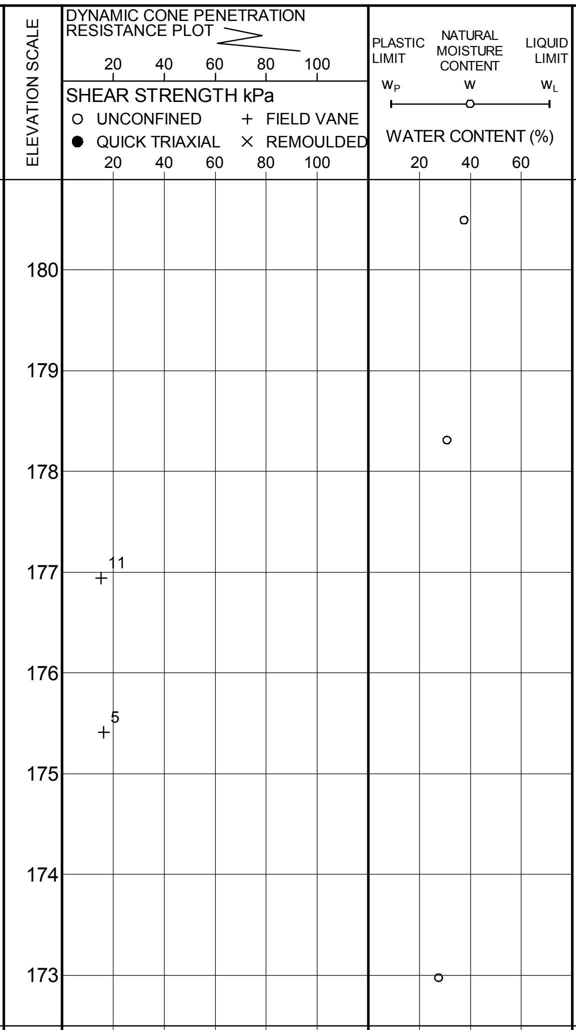
$\bigcirc^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No S101-02

1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
LOCATION N 5085427.1; E 222356.6
ORIGINATED BY EHS
DIST
HWY CNR
BOREHOLE TYPE 108 mm I.D. Continuous Flight, Hollow Stem Augers
COMPILED BY LG
DATUM Geodetic
DATE December 8, 2009
CHECKED BY AB

ELEV DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLES – NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
180.9	GROUND SURFACE									
0.0	PEAT (Root Mat)									
0.2	Brown Moist SILT, trace sand, trace organics Loose Brown and grey Wet	1	SS	4						
		2	SS	5	∇					
179.4 1.5	Silty SAND, trace clay Very Loose to loose Grey Wet	3	SS	5						
		4	SS	1			0	61	30	9
177.9 3.0	SILTY CLAY, sand and silt layers / seams Very soft to soft Grey Wet	5	SS	1						
		6	SS	WH						
175.1 5.8	SAND and SILT, some clay Very loose Grey Wet	7	SS	WR						
	Clayey seams encountered at 7.6 m depth.	8	SS	WR			0	33	55	12
172.5 8.4	END OF BOREHOLE AUGER RUFUSAL									



Note:

1. Water level at a depth of 1.1 m below ground surface (Elev. 179.8 m) upon completion of drilling.

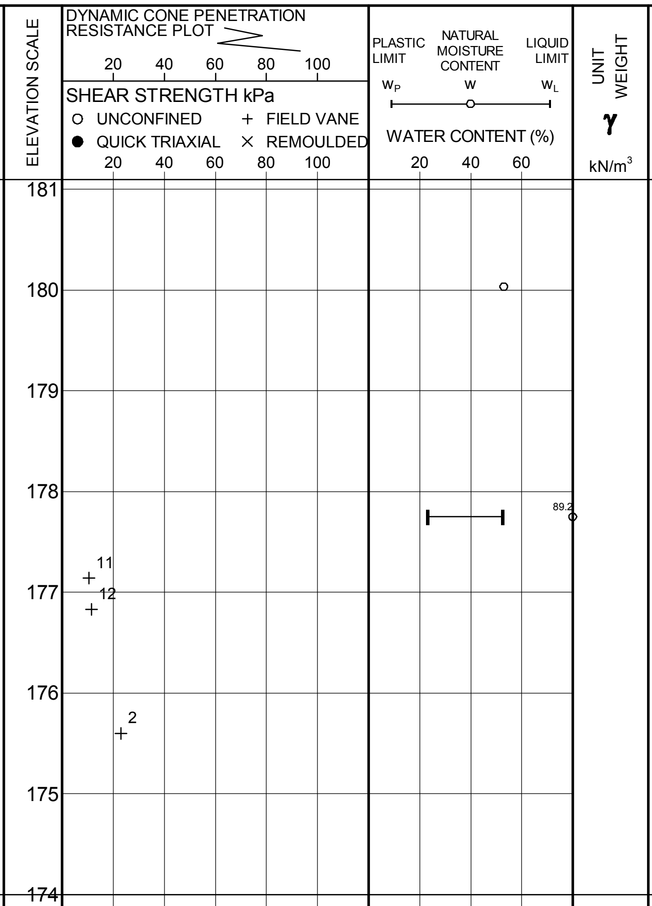
+3, ×3: Numbers refer to Sensitivity ○3% STRAIN AT FAILURE

RECORD OF BOREHOLE No S101-03

1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
LOCATION N 5085414.6; E 222364.5
ORIGINATED BY EHS
DIST
HWY CNR
BOREHOLE TYPE 108 mm I.D. Continuous Flight, Hollow Stem Augers
COMPILED BY LG
DATUM Geodetic
DATE December 10, 2009
CHECKED BY AB

ELEV DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLES – NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
181.1	GROUND SURFACE								
0.0	PEAT (Root Mat) Soft Brown Moist	1	SS	4					
180.7 0.4	SILT some clay, trace sand, trace organics Very loose to loose Brown Moist to wet	2	SS	7	▽	0	3	68	29
		3	SS	2					
179.1 2.0	Silty SAND, trace clay Very loose Grey Wet	4	SS	WH					
178.1 3.0	SILTY CLAY to CLAY, sand and silt layers / seams Very soft to soft Grey Wet	5	SS	WH					
		6	SS	WH					
175.5 5.6	SAND and SILT, trace to some clay Very loose Grey Wet Clayey seams encountered at 6.3 m depth.	7	SS	WH					
174.0 7.1	END OF BOREHOLE AUGER REFUSAL Note: 1. Water level at a depth of 1.0m below ground surface (Elev. 180.1 m) upon completion of drilling.								



+3, ×3: Numbers refer to Sensitivity

○3% STRAIN AT FAILURE

SUD-MTO V2.0 09-1111-6014 BH SWAMP LOGS METRIC.GPJ GAL-MISS.GDT 18/08/11 DATA INPUT:

RECORD OF BOREHOLE No S101-04

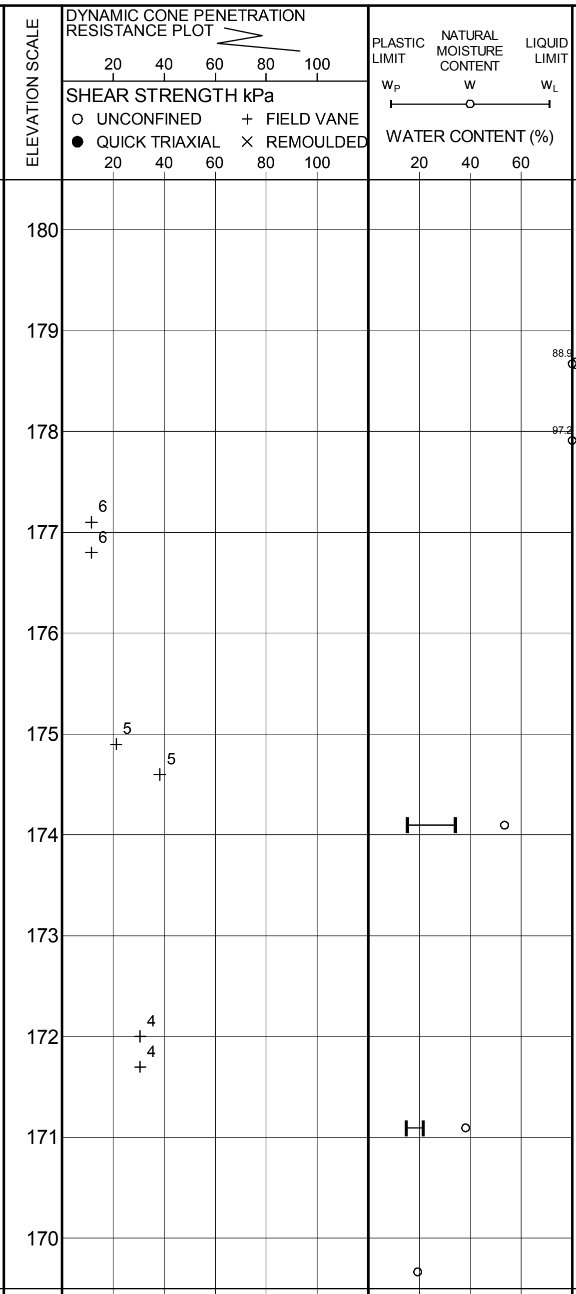
1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST ____ HWY CNR
DATUM Geodetic

LOCATION N 5085416.4; E 222379.2
BOREHOLE TYPE 108 mm I.D. Continuous Flight, Hollow Stem Augers
DATE December 10, 2009

ORIGINATED BY ID
COMPILED BY LG
CHECKED BY AB

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
180.5	GROUND SURFACE						
0.0	PEAT (Root Mat) Brown Moist	1	SS	2			
0.2	SILT, trace sand, trace organics Very loose Brown and grey Moist	2	SS	2			
179.0 1.5	CLAY, organic Very soft Black Wet	3	SS	1	∇	OC = 8.1%	
		4	SS	WH			
177.6 2.9	CLAYEY SILT, sand and silt layers / seams Very soft to firm Grey Wet No recovery in Shelby Tube at 3.8 m depth.	-	TO	PH			
		5	SS	WH			
		6	SS	WH			
		7	SS	1			
		8	SS	WH			
170.3 10.2	SAND and SILT, trace to some clay Loose Grey Wet	9	SS	7/0.15			
169.5 11.0	END OF BOREHOLE SPOON AND AUGER REFUSAL Note: 1. Water level at a depth of 1.9 m below ground surface (Elev. 178.6 m) upon completion of drilling.						



+3, ×3: Numbers refer to Sensitivity

O 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No S101-05

1 OF 2 **METRIC**

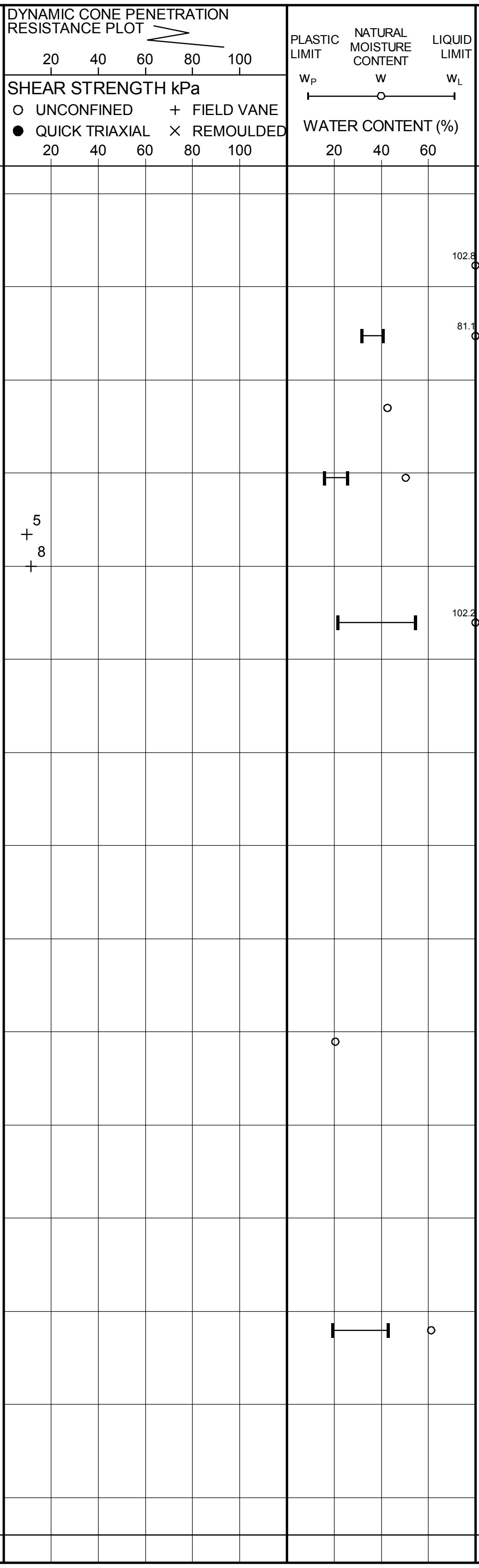
PROJECT 09-1111-6014			
W.P. 5344-08-00	LOCATION N 5085417.9; E 222394.0		ORIGINATED BY ID
DIST	HWY CNR	BOREHOLE TYPE 108 mm I.D. Continuous Flight, Hollow Stem Augers	COMPILED BY LG
DATUM Geodetic		DATE December 14, 2009	CHECKED BY AB

SOIL PROFILE

ELEV DEPTH	DESCRIPTION	STRAT PLOT
180.3	GROUND SURFACE	
0.0 0.1	PEAT (Root Mat) Brown Moist	
179.5 0.8	SILT, trace organics Very loose Brown Moist	
	SILT, slightly organic, intermediate plasticity Very loose Black Moist to wet	
178.2 2.1	Silty SAND, trace organics Very loose Grey Wet	
177.3 3.0	CLAYEY SILT to CLAY, sand and silt layers / seams Very soft to soft Grey Wet	
172.2 8.1	SAND and SILT, trace to some clay Very loose to loose Grey Wet Silty Clay seams encountered at 12.2 m and 13.7 m depths.	
165.6 14.7		

SAMPLES

NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	3		180		
2	SS	2		179		
3	SS	WH	∇			
4	SS	WH		178		
5	SS	WH		177		
6	TO	WH		175	14.5	C
7	SS	WH		174		
8	TO	WH		172		
9	SS	WH		171		0 47 46 7
10	SS	3		169		
11	SS	2		168		
12	SS	6		166		



Continued Next Page

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

RECORD OF BOREHOLE No S101-05

2 OF 2 **METRIC**

PROJECT 09-1111-6014

W.P. 5344-08-00

LOCATION N 5085417.9; E 222394.0

ORIGINATED BY ID

DIST

HWY CNR

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

COMPILED BY LG

DATUM Geodetic

DATE December 14, 2009

CHECKED BY AB

SOIL PROFILE			SAMPLES					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		REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION --- *CONTINUED FROM PREVIOUS PAGE* ---	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE			UNIT WEIGHT γ kN/m^3	GR SA SI CL
	END OF BOREHOLE AUGER REFUSAL Note: 1. Water level at a depth of 1.8 m below ground surface (Elev. 178.5 m) upon completion of drilling.										

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

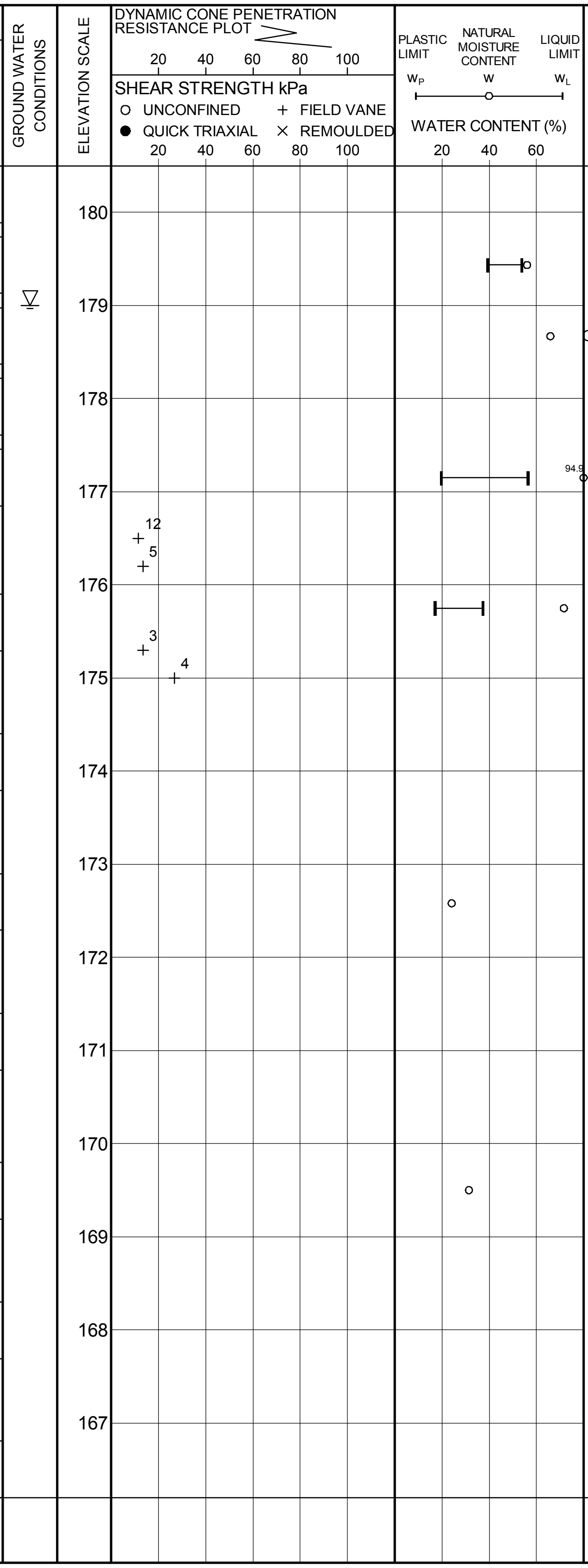
$\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No S101-06

1 OF 2 **METRIC**

PROJECT	09-1111-6014	ORIGINATED BY	ID
W.P.	5344-08-00	LOCATION	N 5085405.1; E 222401.5
DIST		HWY	CNR
BOREHOLE TYPE	108 mm I.D. Continuous Flight, Hollow Stem Augers	COMPILED BY	LG
DATUM	Geodetic	DATE	December 15, 2009
CHECKED BY	AB		

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
180.5	GROUND SURFACE					
0.0 0.1	PEAT (Root Mat) Brown Moist	1	SS	4		
179.7 0.8	SILT, some clay, trace organics Loose Brown Moist	2	SS	3		
	SILT, slightly organic Very loose Black Moist to wet	3	SS	2		OC = 4.0%
178.4 2.1	SILTY CLAY to CLAY, sand and silt layers / seams Very soft to soft Grey Wet	4	SS	1		
		5	TO	WH	14.7	C
	Sand seam 300 mm thick at 4.9 m depth.	6	SS	1		
174.7 5.8	SAND and SILT, trace to some clay Very loose to dense Grey Wet	7	SS	1		
		8	SS	3		1 33 58 8
		9	SS	6		
		10	SS	4		0 47 38 15
		11	SS	10		
	Clayey seam 300 mm thick encountered at 13.7 m depth.	12	SS	41		
166.2 14.3						



Continued Next Page

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

Foundation Design

RECORD OF BOREHOLE No S101-06

2 OF 2 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
LOCATION N 5085405.1; E 222401.5
ORIGINATED BY ID
DIST HWY CNR
BOREHOLE TYPE 108 mm I.D. Continuous Flight, Hollow Stem Augers
COMPILED BY LG
DATUM Geodetic
DATE December 15, 2009
CHECKED BY AB

SOIL PROFILE			SAMPLES			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
ELEV DEPTH	DESCRIPTION --- CONTINUED FROM PREVIOUS PAGE ---	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	END OF BOREHOLE SPOON AND AUGER REFUSAL Note: 1. Water level at a depth of 1.6 m below ground surface (Elev. 178.9 m) upon completion of drilling.										

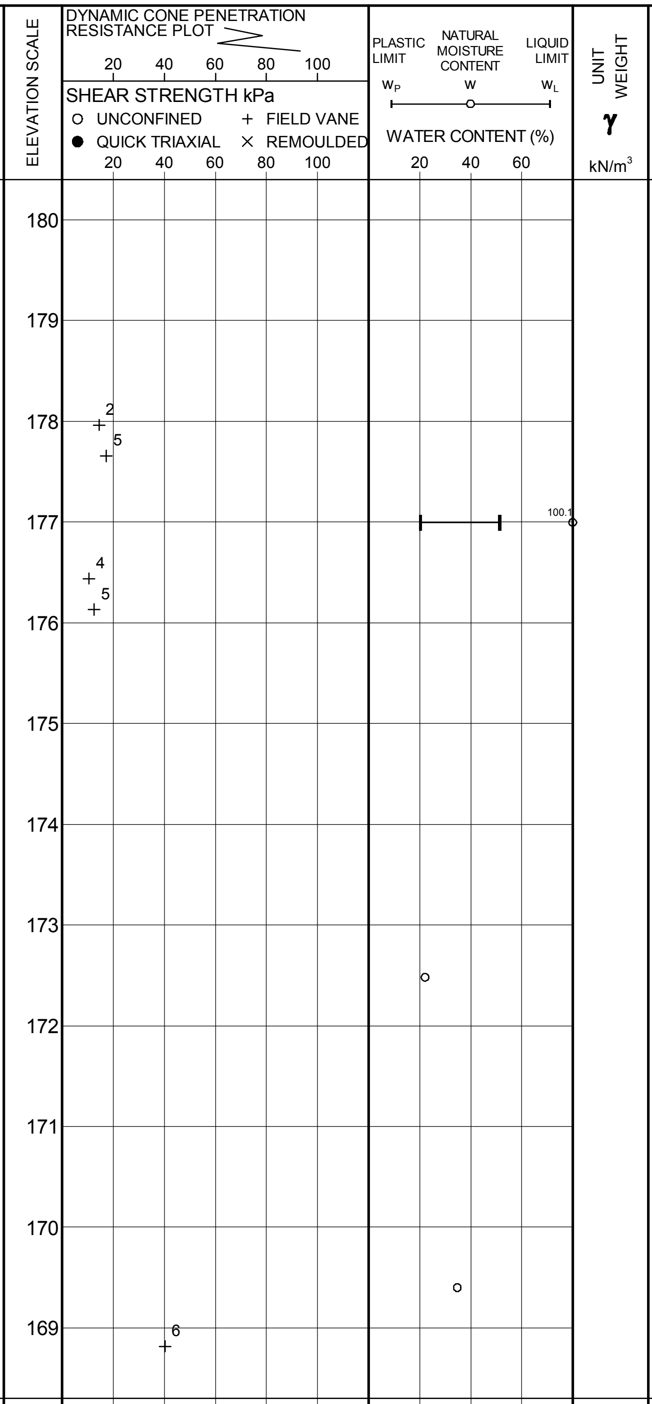
$+^3, \times^3$: Numbers refer to Sensitivity ○ $^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No S101-07

1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST
HWY CNR
DATUM Geodetic
LOCATION N 5085393.1; E 222409.2
BOREHOLE TYPE 108 mm I.D. Continuous Flight, Hollow Stem Augers
DATE December 15 and 16, 2009
ORIGINATED BY ID
COMPILED BY LG
CHECKED BY AB

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
180.4	GROUND SURFACE								
0.0	PEAT (Root Mat) Brown Moist	1	SS	2	∇				
0.1	SILT, some clay, trace organics Very loose Brown Moist to wet	2	SS	2					
178.9 1.5	SILT, slightly organic Very loose Black Wet	3	SS	1					
177.3 3.1	SILTY CLAY to CLAY, sand and silt layers / seams Very soft to soft Grey Wet	4	SS	WH					
		5	TO	WH					
174.8 5.6	Sandy SILT to SILT, trace to some clay Very loose to loose Grey Wet	6	SS	4					
		7	SS	2		0	18	74	8
		8	SS	2					
	Clayey seams encountered at 10.6 m depth.	9	SS	1		0	23	52	25
168.3 12.1	END OF BOREHOLE AUGER REFUSAL Note: 1. Water level at a depth of 0.7 m below ground surface (Elev. 179.7 m) upon completion of drilling.								



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

RECORD OF BOREHOLE No S101-08

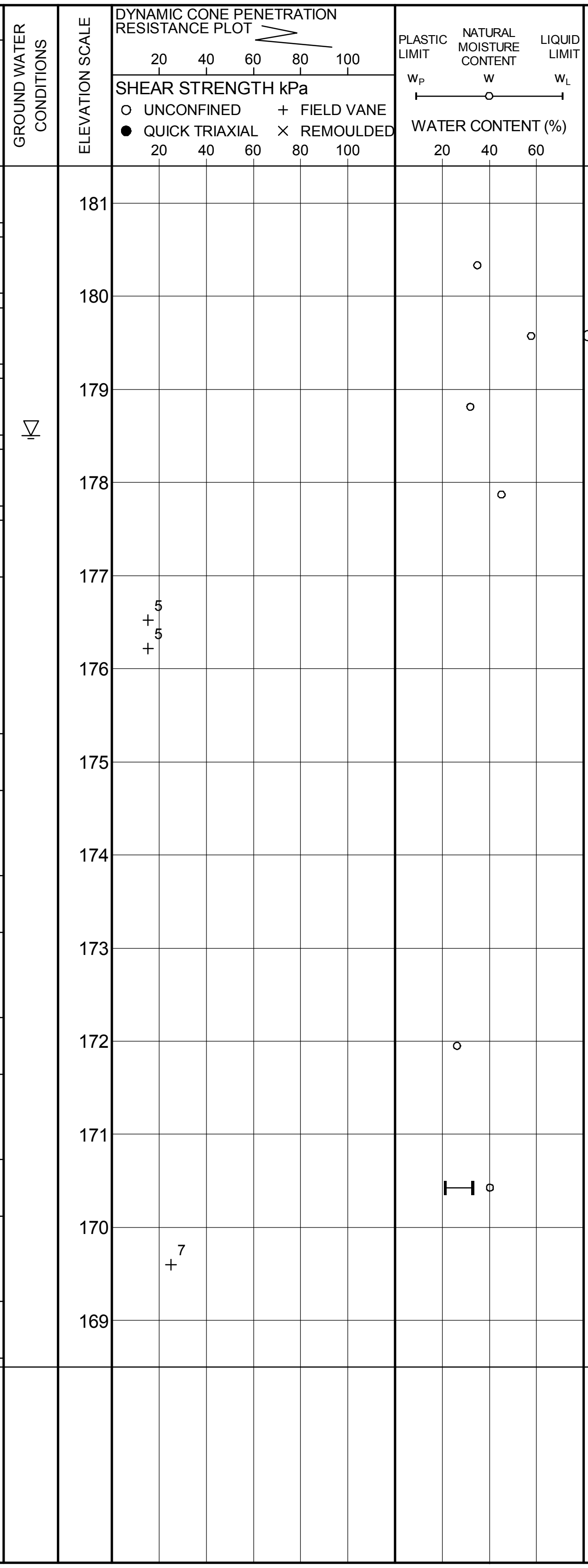
1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST ____ HWY CNR
DATUM Geodetic
LOCATION N 5085393.1; E 222423.4
BOREHOLE TYPE 108 mm I.D. Continuous Flight, Hollow Stem Augers
DATE December 16 and 17, 2009
ORIGINATED BY ID
COMPILED BY LG
CHECKED BY AB

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
181.4	GROUND SURFACE								
0.0	PEAT (Root Mat)								
0.2	Brown Moist	1	SS	3					
180.6 0.8	SAND, trace silt Very loose Brown Moist	2	SS	3					
	CLAY, organic, some sand Soft Grey and black Moist	3	SS	3	OC = 7.1%				
179.1 2.3	Silty SAND, some clay, trace organics Very loose Grey Wet	4	SS	3					
178.0 3.4	CLAYEY SILT, sand and silt layers / seams Very soft to soft Grey Wet	5a 5b	SS	WH		0	27	48	25
		6	TO	WH					
175.0 6.4	Sandy SILT to SILT, trace to some clay Very loose Grey Wet	7	SS	2					
	Clayey seams encountered at 7.6 m depth.	8	SS	1					
		9	SS	1		0	6	81	13
170.6 10.8	CLAYEY SILT Soft to firm Grey Wet	10	SS	1					
	Could not push vane to 11.9 m depth.								
168.8	Sandy SILT, trace to some clay	11	SS	1					
168.5 12.9	Very loose Grey Wet END OF BOREHOLE AUGER REFUSAL								

Note:

1. Water level at a depth of 2.9 m below ground surface (Elev. 178.5 m) upon completion of drilling.



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

RECORD OF BOREHOLE No S101-09

1 OF 1 **METRIC**

PROJECT 09-1111-6014

W.P. 5344-08-00

DIST

HWY CNR

DATUM Geodetic

LOCATION N 5085391.2; E 222436.8

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

DATE December 16, 2009

ORIGINATED BY ID

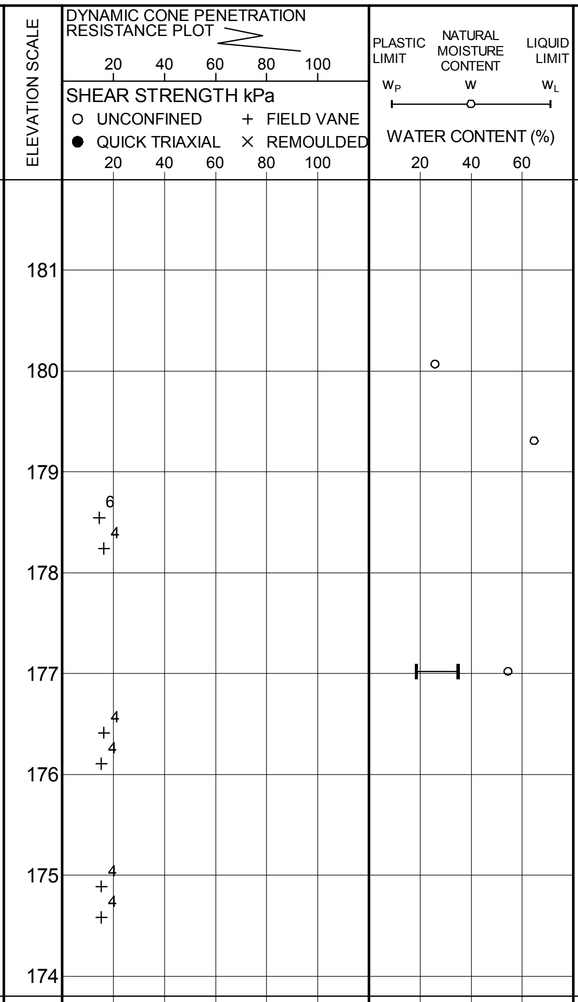
COMPILED BY LG

CHECKED BY AB

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
181.9	GROUND SURFACE						
0.0	PEAT (Root Mat) Brown Moist	1	SS	2			
0.1	CLAYEY SILT, trace organics Soft to firm Grey and brown, mottled Moist	2	SS	6			
180.7 1.2	SAND, trace to some silt, trace clay, trace organics Loose Brown Moist	3	SS	4	▽		0 85 9 6
179.6 2.3	SILTY CLAY, sand and silt layers / seams Very soft to soft Grey Wet	4	SS	WH			
		5	SS	WH			
		6	SS	WH			
174.3 7.6	Sandy SILT, trace to some clay Loose Grey Wet	7	SS	5			
173.8 8.1	END OF BOREHOLE SPOON AND AUGER REFUSAL						

Note:

1. Water level at a depth of 2.0 m below ground surface (Elev. 179.9 m) upon completion of drilling.



+³, ×³: Numbers refer to Sensitivity

○³% STRAIN AT FAILURE

SUD-MTO V2.0 09-1111-6014 BH SWAMP LOGS METRIC.GPJ GAL-MISS.GDT 18/08/11 DATA INPUT:

RECORD OF BOREHOLE No S101-10

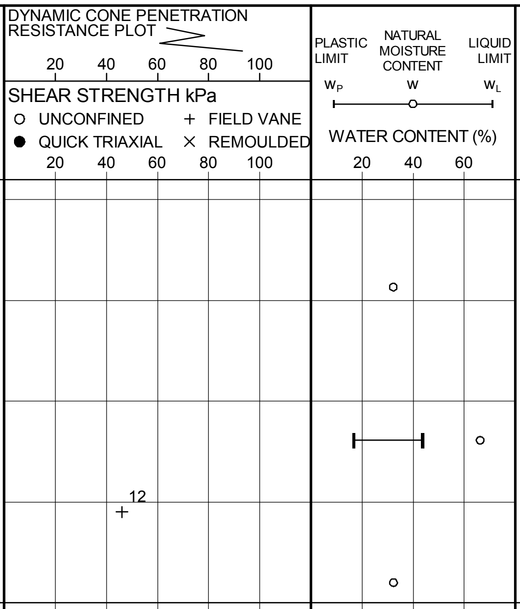
1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
LOCATION N 5085379.3; E 222444.3
ORIGINATED BY ID
DIST HWY CNR
BOREHOLE TYPE 108 mm I.D. Continuous Flight, Hollow Stem Augers
COMPILED BY LG
DATUM Geodetic
DATE December 18, 2009
CHECKED BY AB

ELEV DEPTH	SOIL PROFILE: DESCRIPTION	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
183.2	GROUND SURFACE							
0.0 0.1	PEAT (Root Mat) Brown Moist	1	SS	3		183		
181.9	CLAYEY SILT, trace organics Soft to firm Grey and brown, mottled Moist	2	SS	5		182		
180.9 1.3	SAND, trace silt, trace clay, trace organics Loose Brown Moist	3	SS	6		181		
179.4 2.3	SILTY CLAY, sand and silt layers / seams Very soft to firm Grey Wet	4	SS	WH	▽	180		
179.0	Sandy SILT, some clay Very loose Grey Wet	5	SS	4/0.2		179		
4.2	END OF BOREHOLE SPOON AND AUGER REFUSAL							

Note:

1. Water level at a depth of 3.1 m below ground surface (Elev. 180.1 m) upon completion of drilling.



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

RECORD OF BOREHOLE No S101-11

1 OF 1 **METRIC**

PROJECT 09-1111-6014

W.P. 5344-08-00

LOCATION N 5085437.1; E 222333.7

ORIGINATED BY ID

DIST

HWY CNR

BOREHOLE TYPE Hand Shovel

COMPILED BY LG

DATUM Geodetic

DATE December 16, 2009

CHECKED BY AB

SOIL PROFILE		SAMPLES									
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/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
183.7	GROUND SURFACE										
0.0 0.1	PEAT (Root Mat) Brown Moist										
	END OF BOREHOLE BEDROCK EXPOSED Note: 1. Borehole dry upon completion of drilling. 2. Borehole located on generally exposed bedrock outcrop.										

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

$\bigcirc^{3\%}$ STRAIN AT FAILURE

Golder Associates

PROJECT 09-1111-6014

RECORD OF PENETRATION TEST No S101-DC1

1 OF 1 **METRIC**

W.P. 5344-08-00

LOCATION N 5085425.8; E 222342.3

ORIGINATED BY EHS

DIST

HWY CNR

BOREHOLE TYPE Dynamic Cone Penetration Test

COMPILED BY LG

DATUM Geodetic

DATE December 8, 2009

CHECKED BY AB

SOIL PROFILE			SAMPLES			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
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
182.6	GROUND SURFACE										
0.0 182.2											
0.4	END OF DCPT REFUSAL TO FURTHER PENETRATION (HAMMER BOUNCING)										

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

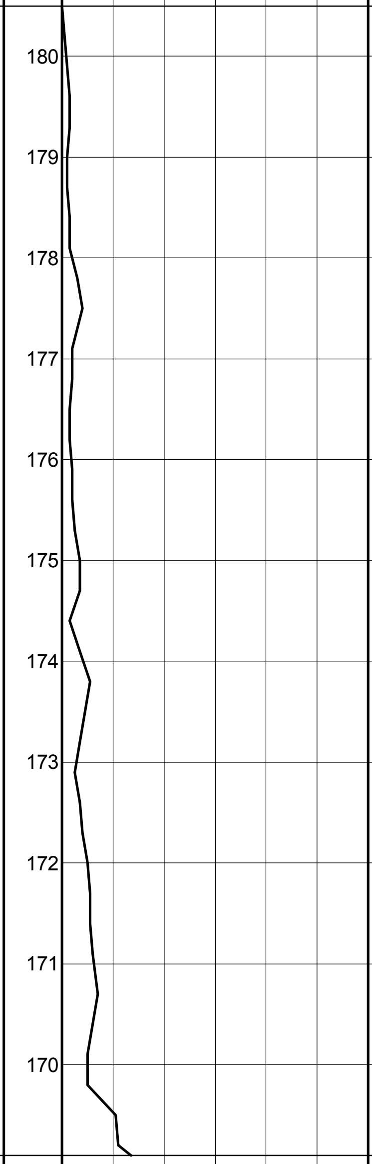
○ $^{3\%}$ STRAIN AT FAILURE

RECORD OF PENETRATION TEST No S101-DC2

1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST
HWY CNR
DATUM Geodetic
LOCATION N 5085429.1; E 222371.4
BOREHOLE TYPE Dynamic Cone Penetration Test
DATE December 17, 2009
ORIGINATED BY ID
COMPILED BY LG
CHECKED BY AB

SOIL PROFILE: ELEV DEPTH	SOIL PROFILE: DESCRIPTION	SOIL PROFILE: STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "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
180.5 0.0	GROUND SURFACE										
169.1 11.4	END OF DCPT REFUSAL TO FURTHER PENETRATION (HAMMER BOUNCING)										



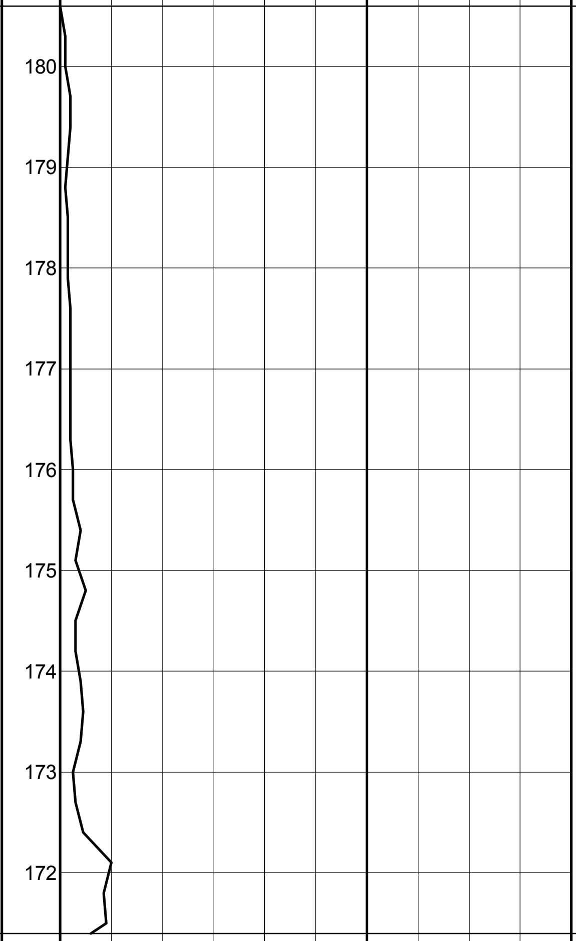
+³, ×³: Numbers refer to Sensitivity ○³% STRAIN AT FAILURE

RECORD OF PENETRATION TEST No S101-DC3

1 OF 1 **METRIC**

PROJECT	09-1111-6014		
W.P.	5344-08-00	LOCATION	N 5085403.6; E 222386.9
DIST		HWY	CNR
BOREHOLE TYPE	Dynamic Cone Penetration Test		
DATUM	Geodetic	DATE	December 17, 2009
ORIGINATED BY	ID		
COMPILED BY	LG		
CHECKED BY	AB		

SOIL PROFILE			SAMPLES			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
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
180.6	GROUND SURFACE										
0.0							180 179 178 177 176 175 174 173 172				
171.4 9.2	END OF DCPT REFUSAL TO FURTHER PENETRATION (HAMMER BOUNCING)										



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

RECORD OF PENETRATION TEST No S101-DC4

1 OF 2 **METRIC**

PROJECT 09-1111-6014

W.P. 5344-08-00

DIST

HWY CNR

DATUM Geodetic

LOCATION N 5085405.3; E 222416.1

BOREHOLE TYPE Dynamic Cone Penetration Test

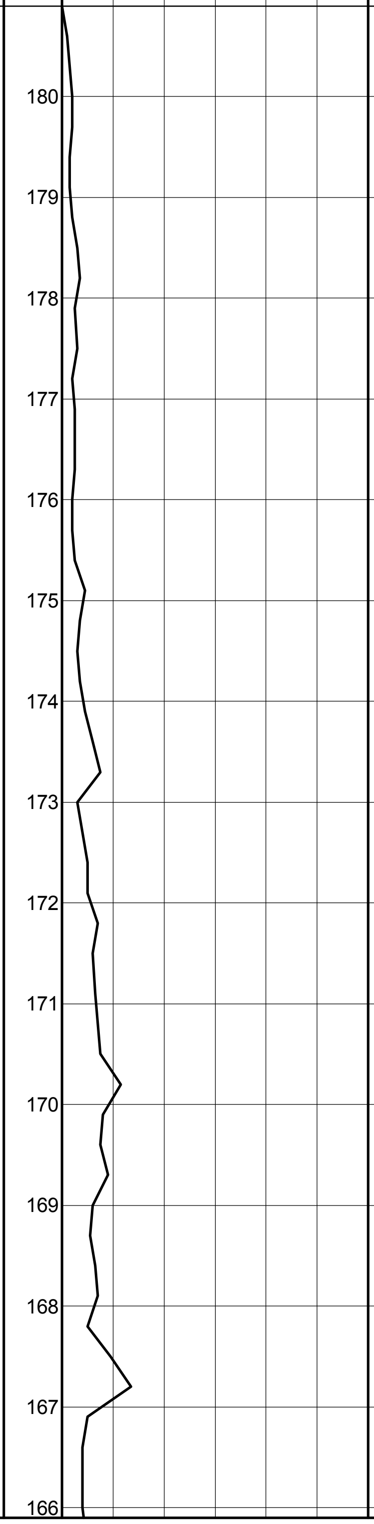
DATE December 17, 2009

ORIGINATED BY ID

COMPILED BY LG

CHECKED BY AB

SOIL PROFILE			SAMPLES									
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 O 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	
180.9 0.0	GROUND SURFACE											



Continued Next Page

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

O $^{3\%}$ STRAIN AT FAILURE

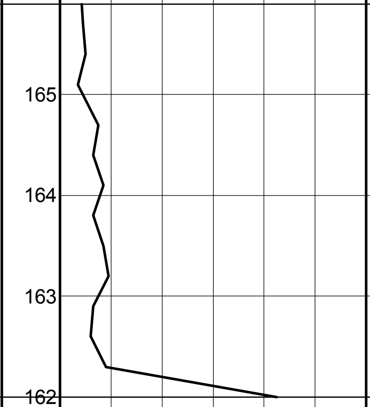
Golder Associates

RECORD OF PENETRATION TEST No S101-DC4

2 OF 2 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST
HWY CNR
DATUM Geodetic
LOCATION N 5085405.3; E 222416.1
BOREHOLE TYPE Dynamic Cone Penetration Test
DATE December 17, 2009
ORIGINATED BY ID
COMPILED BY LG
CHECKED BY AB

SOIL PROFILE			SAMPLES									
ELEV DEPTH	DESCRIPTION --- CONTINUED FROM PREVIOUS PAGE ---	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
162.0 18.9	END OF DCPT REFUSAL TO FURTHER PENETRATION						165 164 163 162				



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

SUD-MTO V2.0 09-1111-6014 BH SWAMP LOGS METRIC.GPJ GAL-MISS.GDT 18/08/11 DATA INPUT:

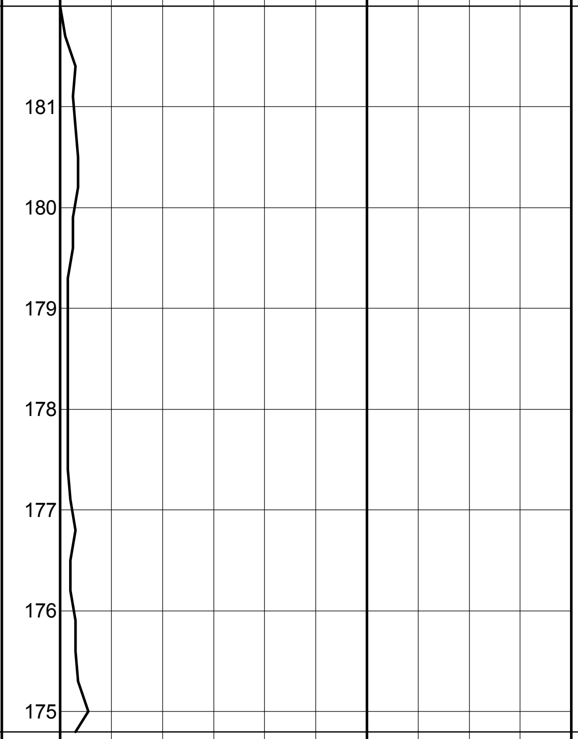
Golder Associates

RECORD OF PENETRATION TEST No S101-DC5

1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST
HWY CNR
DATUM Geodetic
LOCATION N 5085380.9; E 222430.7
BOREHOLE TYPE Dynamic Cone Penetration Test
DATE December 17, 2009
ORIGINATED BY ID
COMPILED BY LG
CHECKED BY AB

SOIL PROFILE			SAMPLES								
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 O 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
182.0 0.0	GROUND SURFACE										
174.8 7.2	END OF DCPT REFUSAL TO FURTHER PENETRATION (HAMMER BOUNCING)										



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

Table A1
Evaluation of Stability/Settlement Mitigation Options
CNR – STA 328+810 to 328+940 (Swamp 101)

Stability/Settlement Mitigation Option	Rank	Advantages	Disadvantages	Relative Costs	Risks/Consequences
Full Sub-Excavation (up to 10.2 m deep)	1	■ Improved stability. ■ Reduced total settlement. ■ No delay in construction. ■ Toe berms are not required.	■ Additional effort required for sub-excavation and replacement. ■ Additional post-construction settlement of rock fill itself. ■ Generation of large volume of excess excavation spoil (could be used for slope flattening). ■ Greater quantity of rock fill required.	■ Additional costs associated with sub-excavation, disposal and replacement of weak/ soft, compressible deposits.	■ Six months preloading may be required to reduce post-construction settlement of rock fill.
Preloading (18 months) and Toe Berms (with instrumentation and monitoring)	2	■ Standard construction operation. ■ Smaller volume of excavation, disposal of spoil and replacement backfill.	■ Significant delay in construction to allow for at least 90% primary consolidation to be completed. ■ Re-grading is required to account for settlement prior to railway construction. ■ Toe berms 1 m high above existing ground surface by 10 m wide required for stability. ■ May need to acquire additional right-of-way for the toe berms.	■ Schedule impacts would increase overall project costs.	■ Some secondary consolidation (creep) may occur. ■ Some risk with respect to maintaining stability of fill on weak/soft foundation soils. ■ Post-construction settlement may not meet criteria without surcharging or even longer preload duration.

Table A1
Evaluation of Stability/Settlement Mitigation Options
CNR – STA 328+810 to 328+940 (Swamp 101)

Stability/Settlement Mitigation Option	Rank	Advantages	Disadvantages	Relative Costs	Risks/Consequences
Surcharging (14 months) and Toe Berms (with instrumentation and monitoring)	3	■ Standard construction operation. ■ Reduced secondary (creep) consolidation settlement. ■ Reduced time to reach 90% primary consolidation as compared with preloading only.	■ Increased handling of fill to remove surcharge. ■ Toe berms 2 m high and 15 m wide required for stability. ■ May need to acquire additional right-of-way for the larger toe berms.	■ Increased costs associated with construction and materials for 2 m high surcharge and 2 m above existing ground surface and 15 m long toe berms as compared with preload only option.	■ Some risk with respect to maintaining stability of higher (surcharged) fills on weak/soft foundation soils.
Wick Drains (with or without surcharge)	4	■ Substantially reduce time to reach 90% primary consolidation compared with preloading and/or surcharging; aided by silt layers/seams within cohesive deposit	■ Increased time for installation of wick drains. ■ Instrumentation and monitoring program required to monitor staged construction and to assess when end of primary consolidation is reached. ■ Wick drain design required. ■ Toe berms still required to maintain stability of the embankment.	■ Additional costs associated with toe berms, wick drain design and installation and instrumentation and monitoring program.	■ Increased secondary consolidation (creep) may occur if surcharge is not applied.

Table A1
Evaluation of Stability/Settlement Mitigation Options
CNR – STA 328+810 to 328+940 (Swamp 101)

Stability/Settlement Mitigation Option	Rank	Advantages	Disadvantages	Relative Costs	Risks/Consequences
Lightweight Fill (EPS)	NF	■ Improved stability. ■ Reduced post-construction settlement. ■ No delay in construction. ■ Toe berms are not required.	■ High cost of construction materials. ■ Restricted use within the embankment cross-section to above water table and about 1.5 m below railway embankment surface. ■ Additional design required to assess extent of EPS practical for the embankment configuration and compressibility for train loadings	■ Reduced costs for disposal/management of excavation spoil as compared with full sub-excavation option. ■ Relative cost of EPS fill is at least an order of magnitude higher than fill required for the other options.	■ Very low risk with respect to stability and long-term settlement of foundation soils. ■ Risk of using this technology in railway situations (may not be approved by CNR)

NF indicates that alternative has been considered but is not feasible.

Slope Stability Analysis
CNR- STA 328+810 to 328+940 (Swamp 101) - Full Sub-Excavation

FIGURE A1

Rock Fill
Unit Weight: 19 kN/m³
Phi: 40˚

Backfill
Unit Weight: 15 kN/m³
Phi: 27˚

Peat
Unit Weight: 12 kN/m³
Phi: 27˚
Su: 1 kPa

Organic Silty Clay
Unit Weight: 15 kN/m³
Phi: 15˚

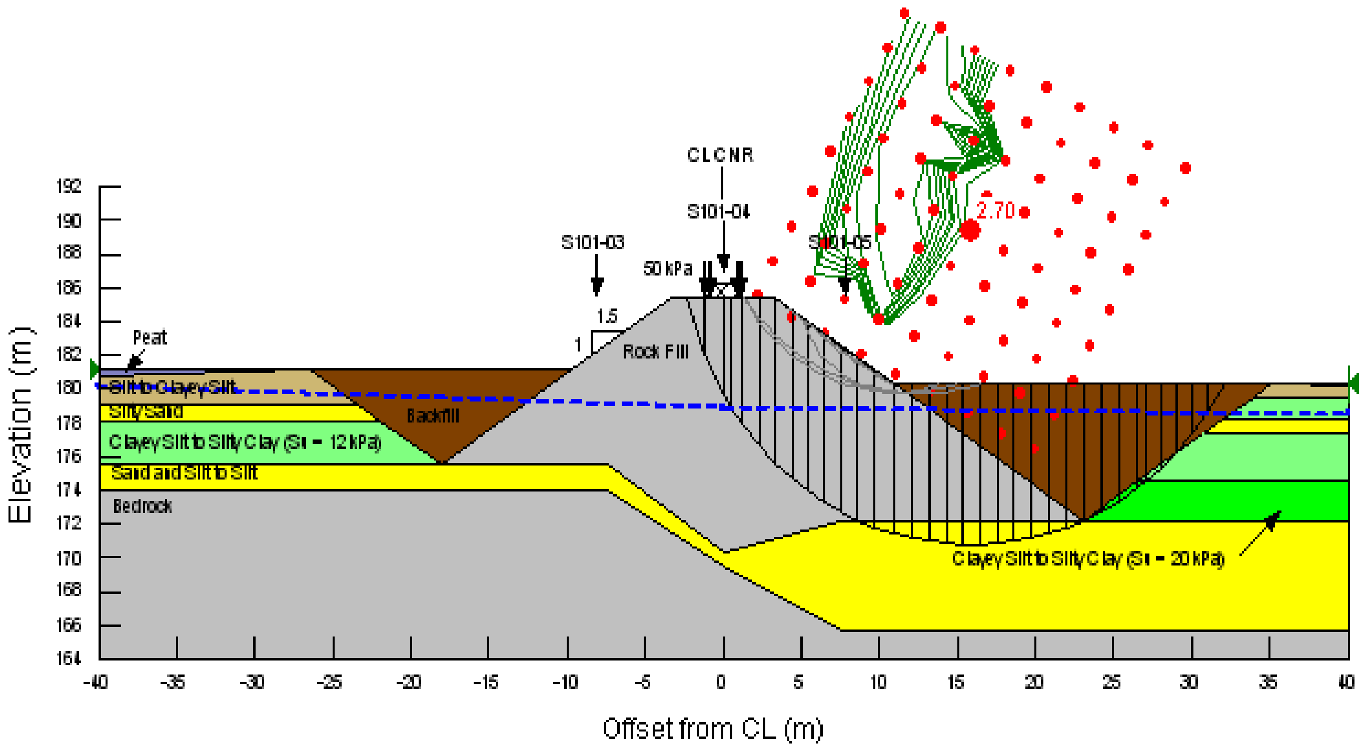
Silt to Clayey Silt
Unit Weight: 18 kN/m
Phi: 27˚

Silty Sand
Unit Weight: 19 kN/m³
Phi: 28˚

Upper Clayey Silt to Silty Clay
Unit Weight: 15 kN/m³
Su: 12 kPa

Lower Clayey Silt to Silty Clay
Unit Weight: 15 kN/m³
Su: 20 kPa

Sand and Silt to Silt
Unit Weight: 19 kN/m³
Phi: 28˚



DATE: August 2011

PROJECT: 09-1111-6014-1520

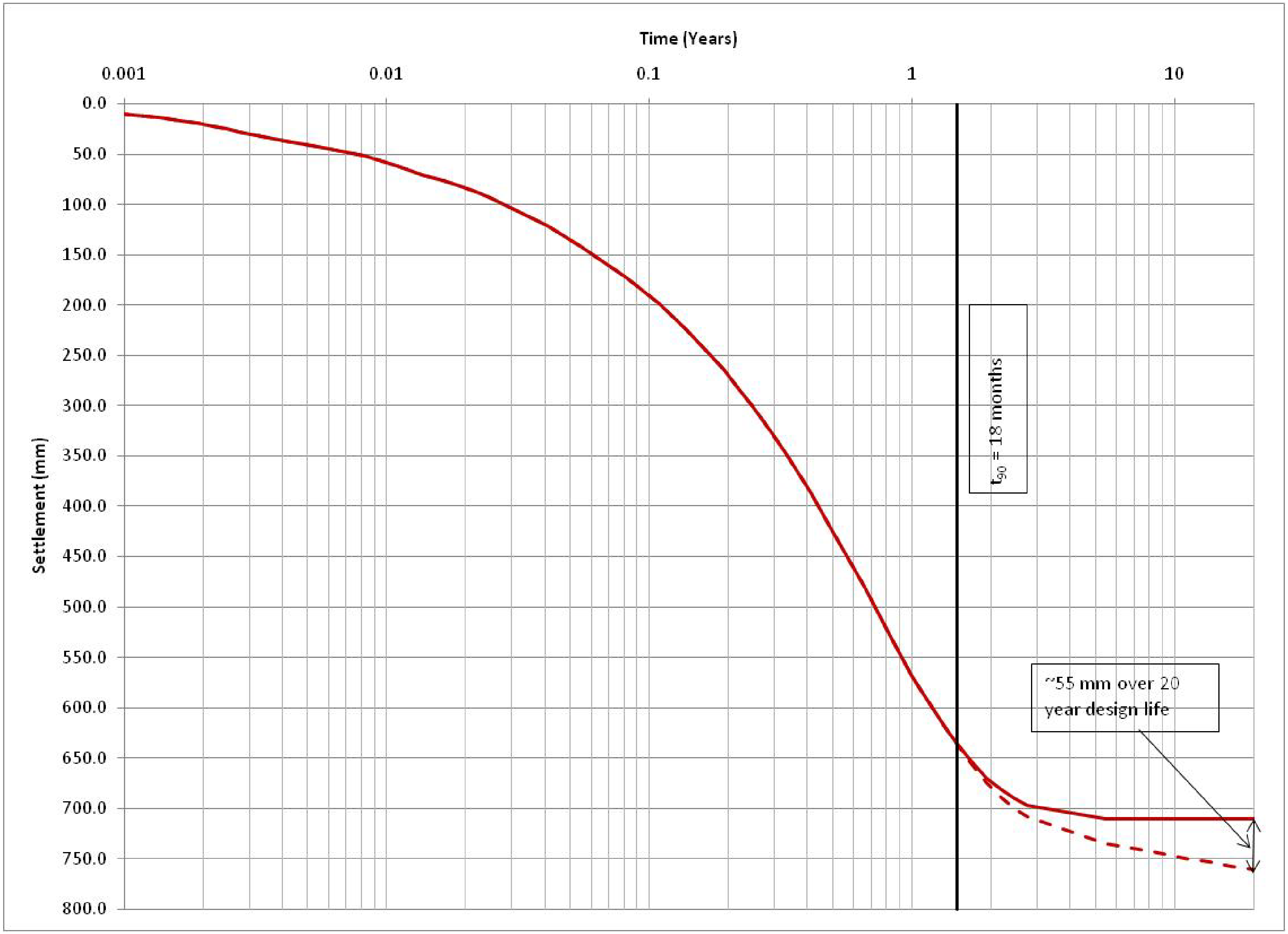
Golder Associates

Drawn by: LG

Checked by: SEMC

Estimated Consolidation Settlement vs. Log Time
Swamp 101 (STA 328+880) – No Mitigation

FIGURE A2



t_{90} = 18 months

~55 mm over 20 year design life

DATE: August 2011

PROJECT: 09-1111-6014-1520

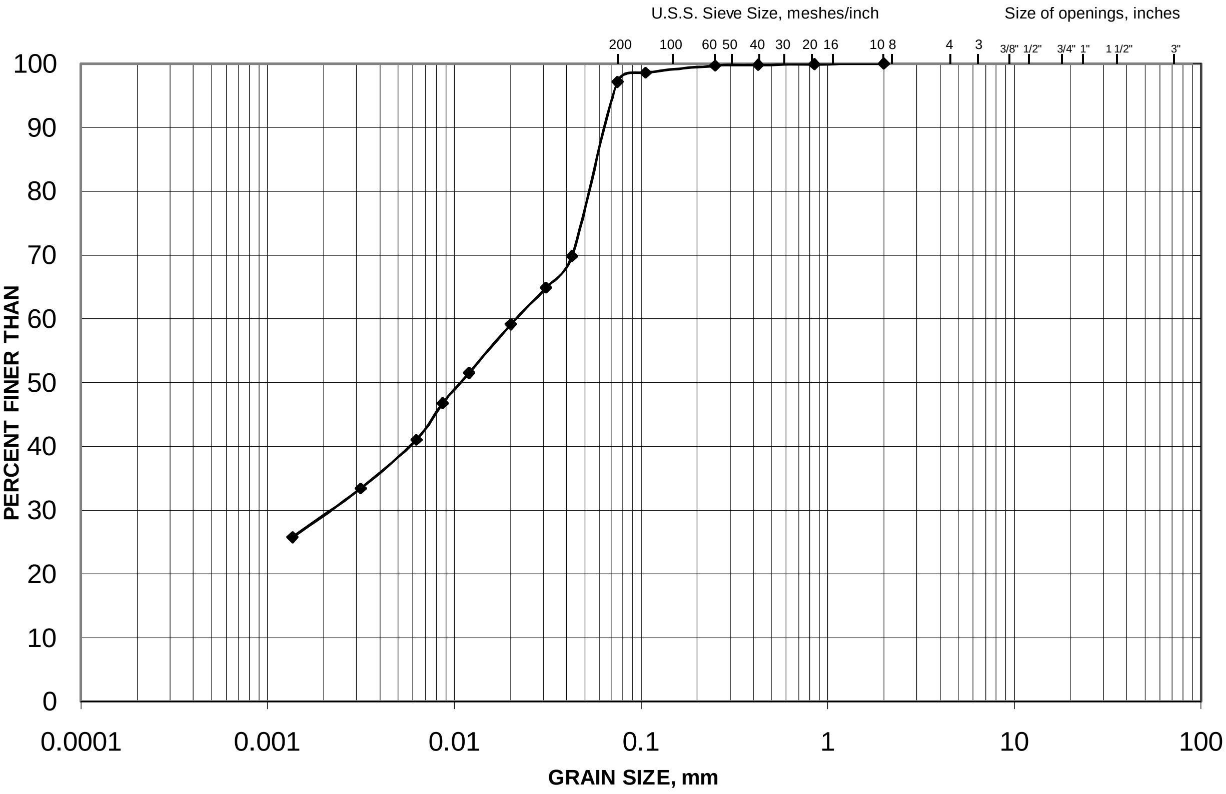
Golder Associates

Drawn by: SEMC Checked by: AB

GRAIN SIZE DISTRIBUTION

Clayey Silt
CNR - STA 328+810 to STA 328+940 (Swamp 101)

FIGURE A.S101-01



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
—◆—	S101-03	2	180.1

Project Number: 09-1111-6014-1520

Checked By: SEMC

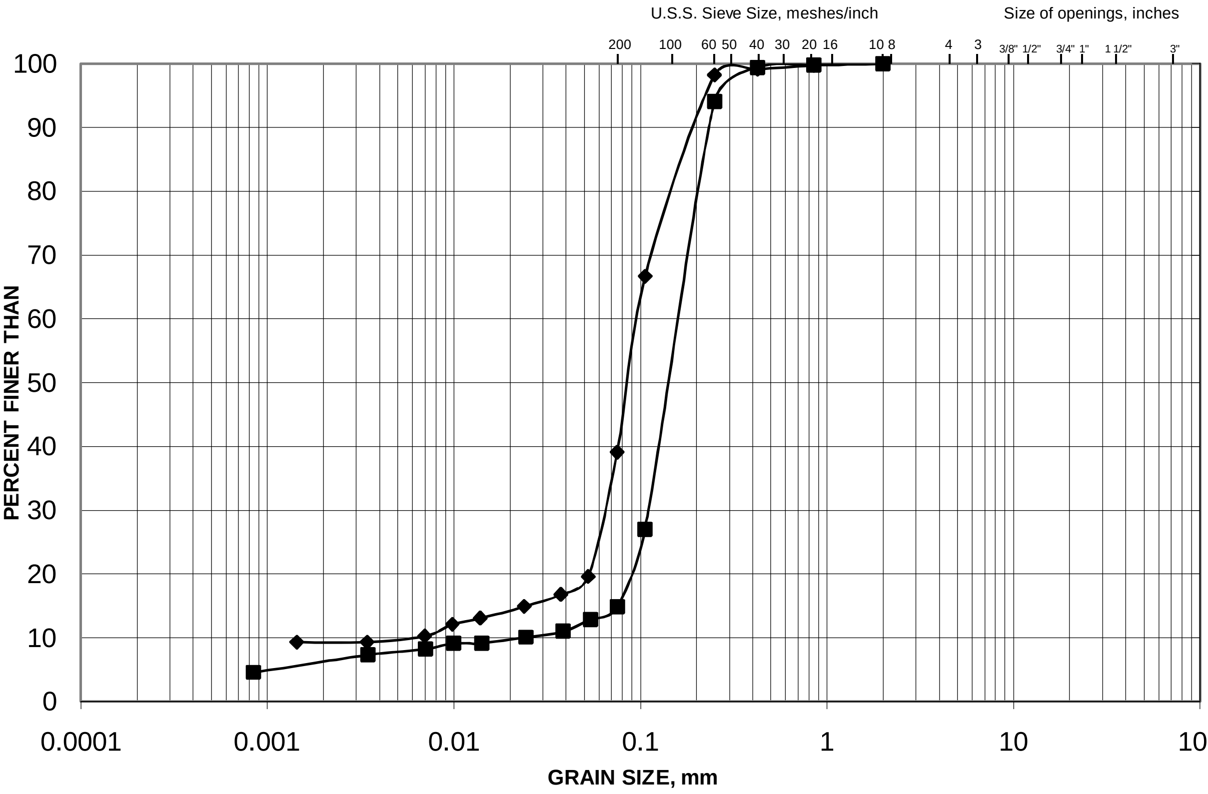
Golder Associates

Date: August 2011

GRAIN SIZE DISTRIBUTION

Silty Sand to Sand
CNR - STA 328+810 to STA 328+940 (Swamp 101)

FIGURE A.S101-02



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
—◆—	S101-02	4	178.3
—■—	S101-09	3	180.1

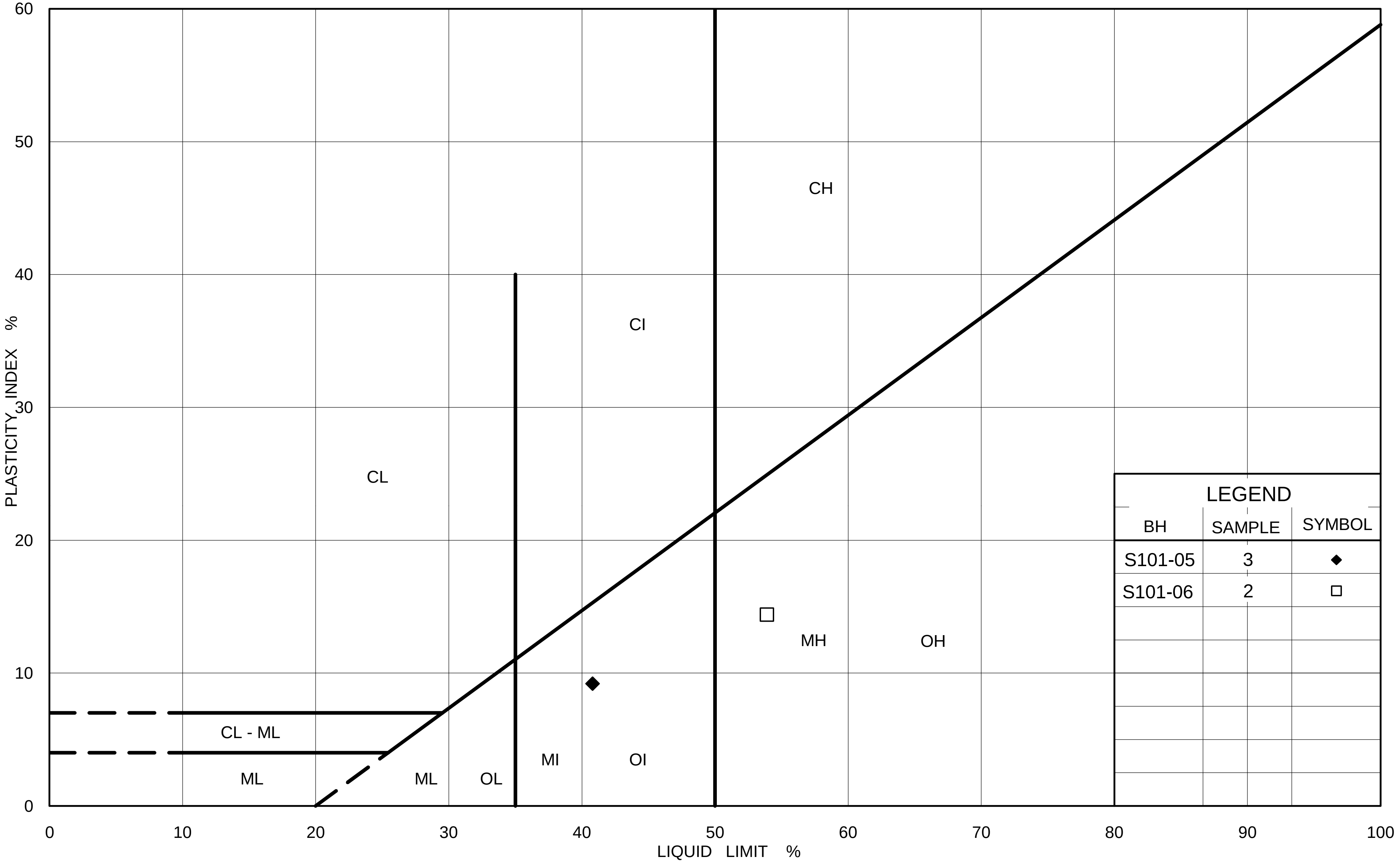
Project Number: 09-1111-6014-1520

Checked By: SEMC

Golder Associates

Date: August 2011

Oct 75, FF-S-21



LEGEND

BH	SAMPLE	SYMBOL
S101-05	3	◆
S101-06	2	☐

Ministry of Transportationno
Ontario

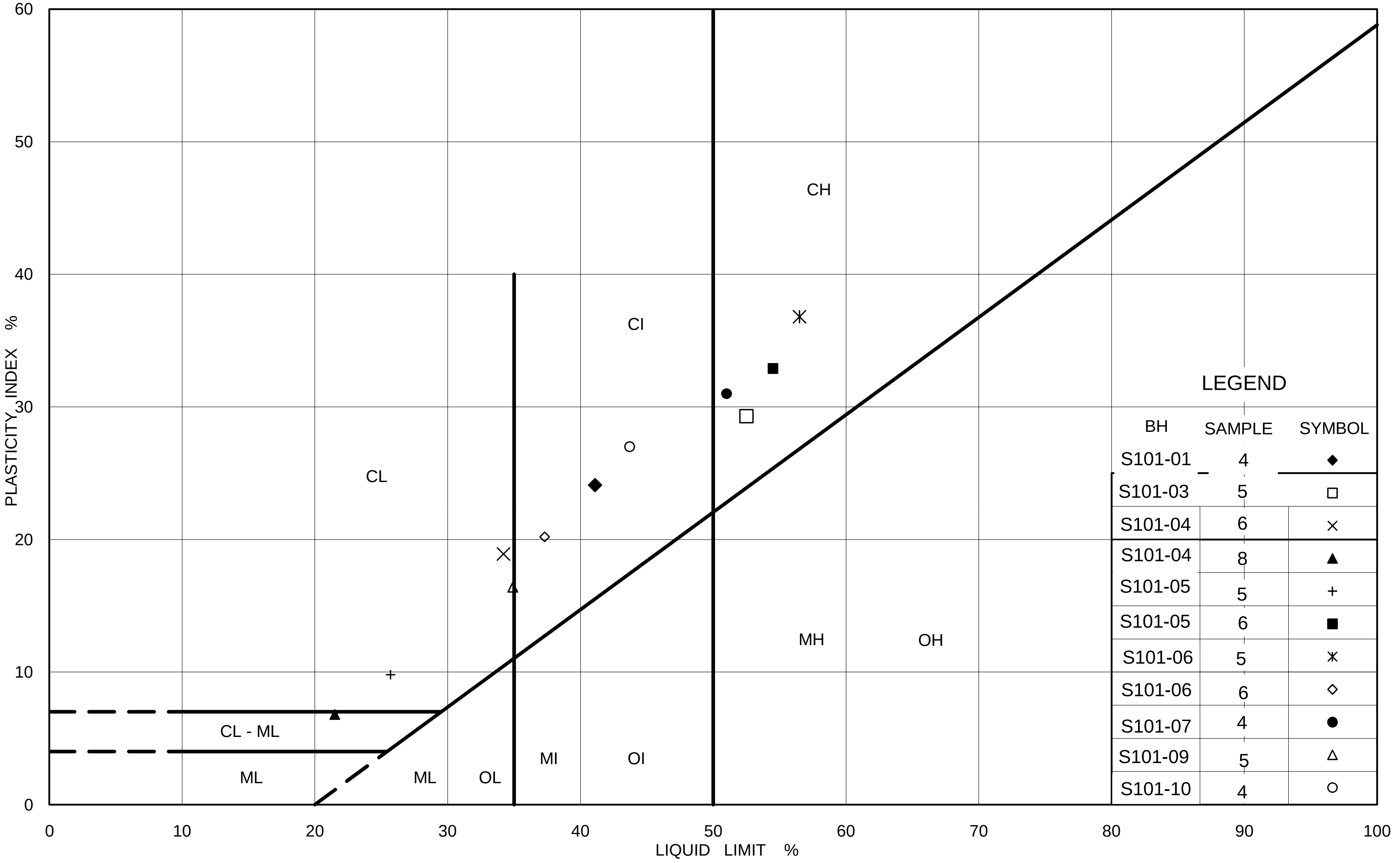
PLASTICITY CHART
Silt, Slightly Organic
CNR - STA 328+810 to STA 328+940 (Swamp 101)

Figure A.S101-03

Project No. 09-1111-6014-1520

Checked By: SEMC

Oct 75, FF-S-21



BH	SAMPLE	SYMBOL
S101-01	4	◆
S101-03	5	□
S101-04	6	×
S101-04	8	▲
S101-05	5	+
S101-05	6	■
S101-06	5	⚹
S101-06	6	◇
S101-07	4	●
S101-09	5	△
S101-10	4	○

Ministry of Transportation
Ontario

PLASTICITY CHART
Clayey Silt to Clay
CNR - STA 328+810 to STA 328+940 (Swamp 101)

Figure A.S101-04

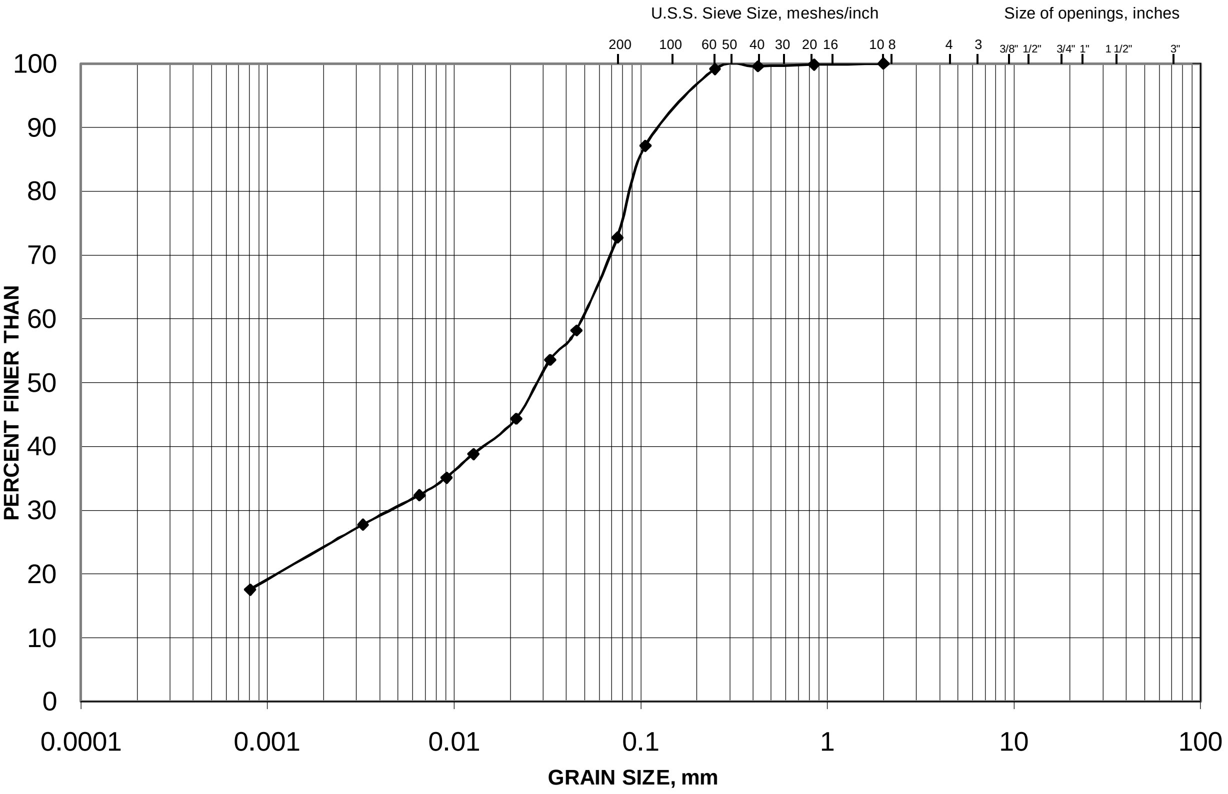
Project No. 09-1111-6014-1520

Checked By: SEMC

GRAIN SIZE DISTRIBUTION

Clayey Silt
CNR - STA 328+810 to STA 328+940 (Swamp 101)

FIGURE A.S101-05



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
—◆—	S101-08	5b	177.8

Project Number: 09-1111-6014-1520

Checked By: SEMC

Golder Associates

Date: August 2011

CONSOLIDATION TEST SUMMARY

FIGURE A.S101-06

Page 1 of 4

SAMPLE IDENTIFICATION

Project Number	09-1111-6014	Sample Number	6
Borehole Number	S101-05	Sample Depth (m)	4.9

TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	1		
Date Started	February 19/10		
Date Completed	March 4/10		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	2.538	Unit Weight, kN/m^3	14.53
Sample Diameter, cm	6.342	Dry Unit Weight, kN/m^3	7.31
Area, cm^2	31.59	Specific Gravity, assumed	2.70
Volume, cm^3	80.17	Solids Height, cm	0.700
Water Content, %	98.86	Volume of Solids, cm^3	22.13
Wet Mass, g	118.80	Volume of Voids, cm^3	58.05
Dry Mass, g	59.74	Degree of Saturation, %	101.7

TEST COMPUTATIONS

Pressure kPa	Primary Consolidation	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv. cm^2/s	mv m^2/MN	k cm/s	Total Work kJ/m3
0	0	2.538	2.624	2.538					
8.9	0.01	2.537	2.622	2.537	400	0.00341	0.0485	1.62E-08	0.002
17.9	0.11	2.526	2.606	2.531	441	0.00308	0.4851	1.46E-07	0.060
35.1	0.44	2.482	2.543	2.504	729	0.00182	1.0075	1.80E-07	0.521
69.2	1.50	2.332	2.329	2.407	1936	0.00063	1.7340	1.08E-07	3.671
142.6	2.40	2.092	1.987	2.212	2916	0.00036	1.2872	4.49E-08	14.569
284.9	1.50	1.942	1.772	2.017	2025	0.00043	0.4154	1.73E-08	29.897
284.9	-0.02	1.944	1.775	1.943					
69.2	-0.28	1.972	1.815	1.958					
17.9	-0.39	2.011	1.871	1.991					
4.5	-0.34	2.045	1.920	2.028					

Note:

k calculated using cv based on t_{90} values.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

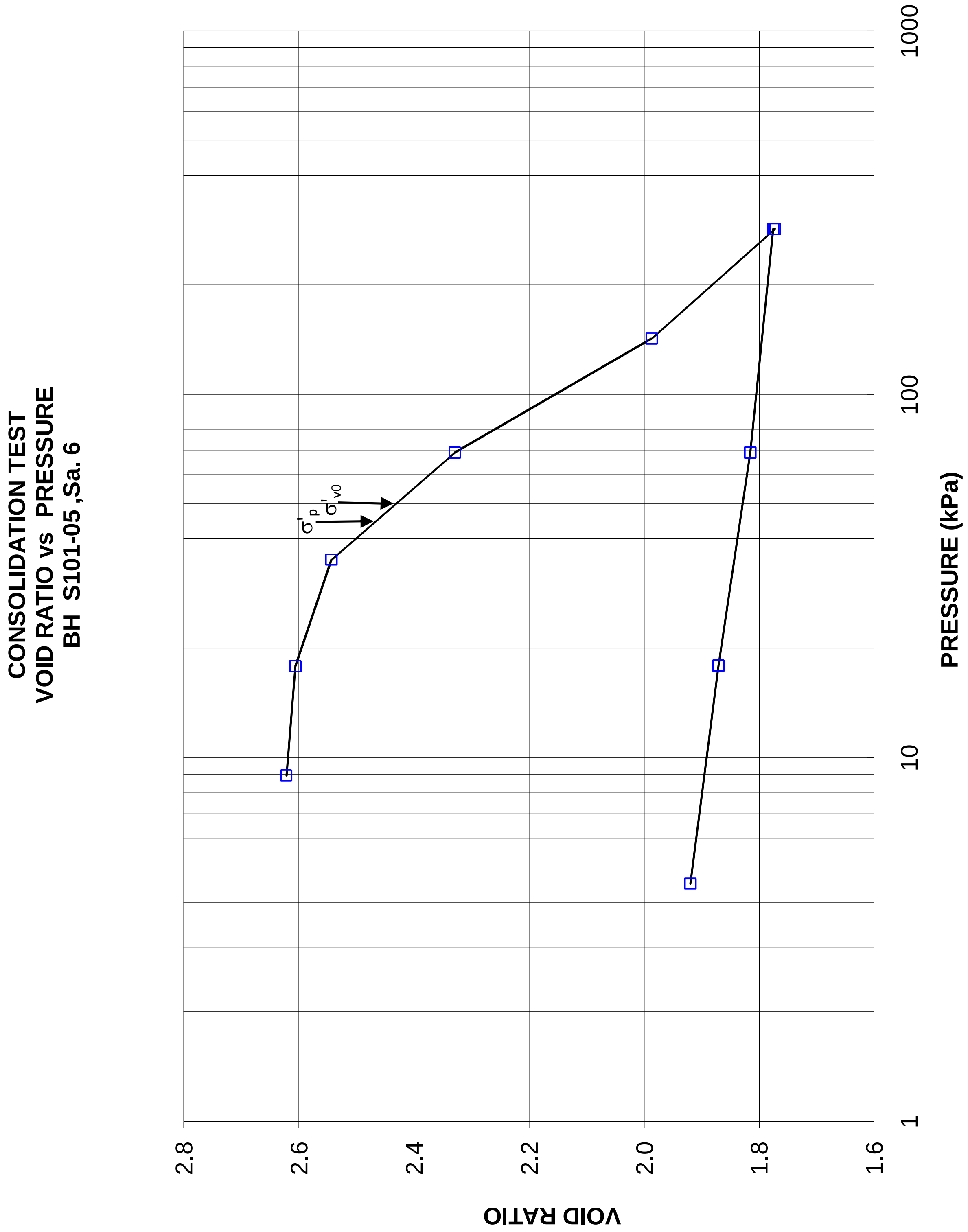
Sample Height, cm	2.045	Unit Weight, kN/m^3	13.58
Sample Diameter, cm	6.34	Dry Unit Weight, kN/m^3	9.07
Area, cm^2	31.59	Specific Gravity, assumed	2.70
Volume, cm^3	64.60	Solids Height, cm	0.700
Water Content, %	49.77	Volume of Solids, cm^3	22.13
Wet Mass, g	89.47	Volume of Voids, cm^3	42.47
Dry Mass, g	59.74		

Prepared By: TG

Golder Associates

Checked By: SEMC

CONSOLIDATION TEST VOID RATIO VS LOG PRESSURE	FIGURE A.S101-06 Page 2 of 4



Project No. 09-1111-6014-1520

Prepared By: TG

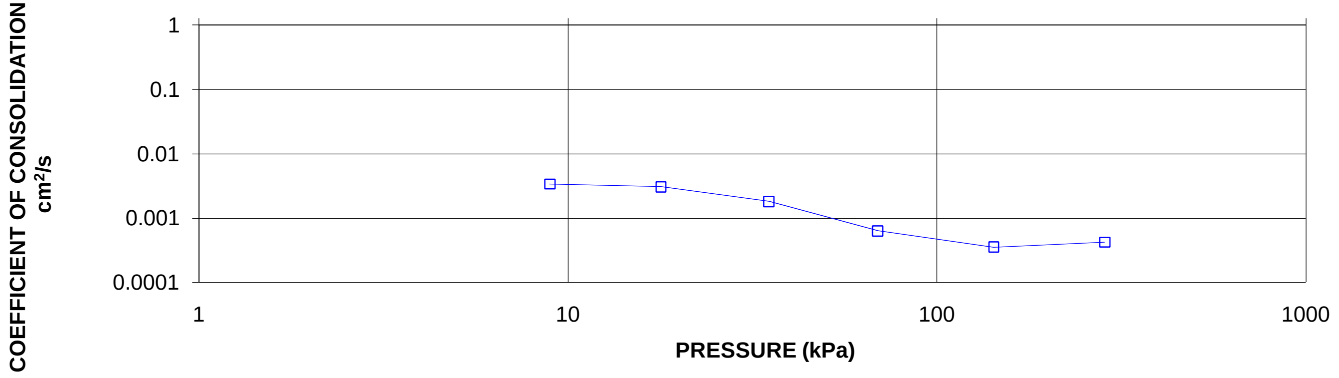
Golder Associates

Checked By: SEMC

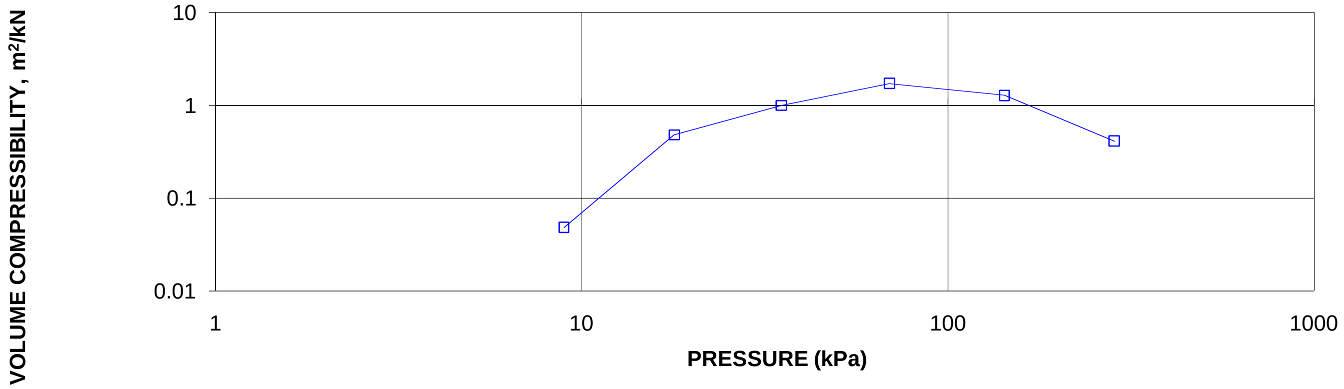
CONSOLIDATION TEST SUMMARY

FIGURE A. S101-06

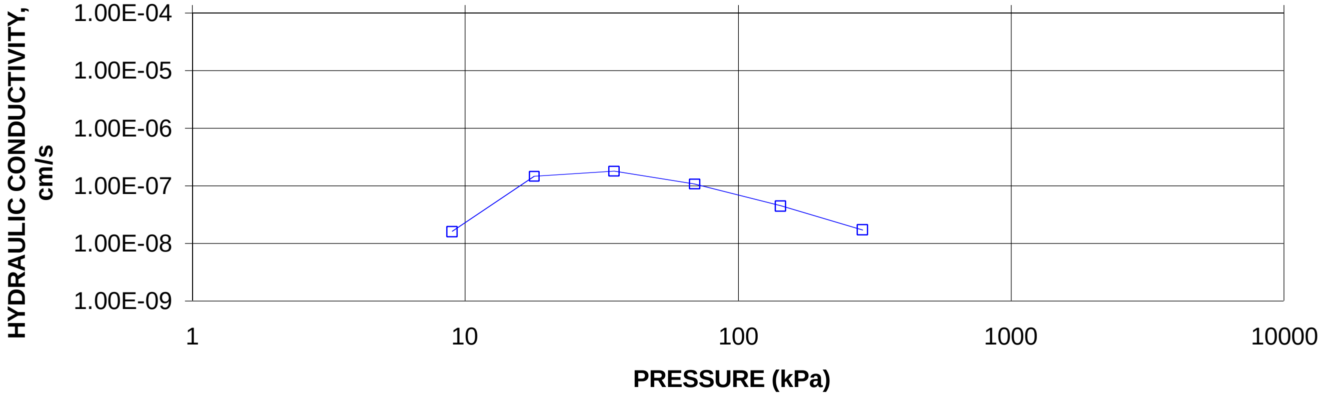
CONSOLIDATION TEST
CV cm^2/s VS PRESSURE (kPa)
BH S101-5 SA 6



CONSOLIDATION TEST
MV m^2/kN vs PRESSURE (kPa)
BH S101-05 SA 6



CONSOLIDATION TEST
HYDRAULIC CONDUCTIVITY vs PRESSURE
BH S101-05 SA 6



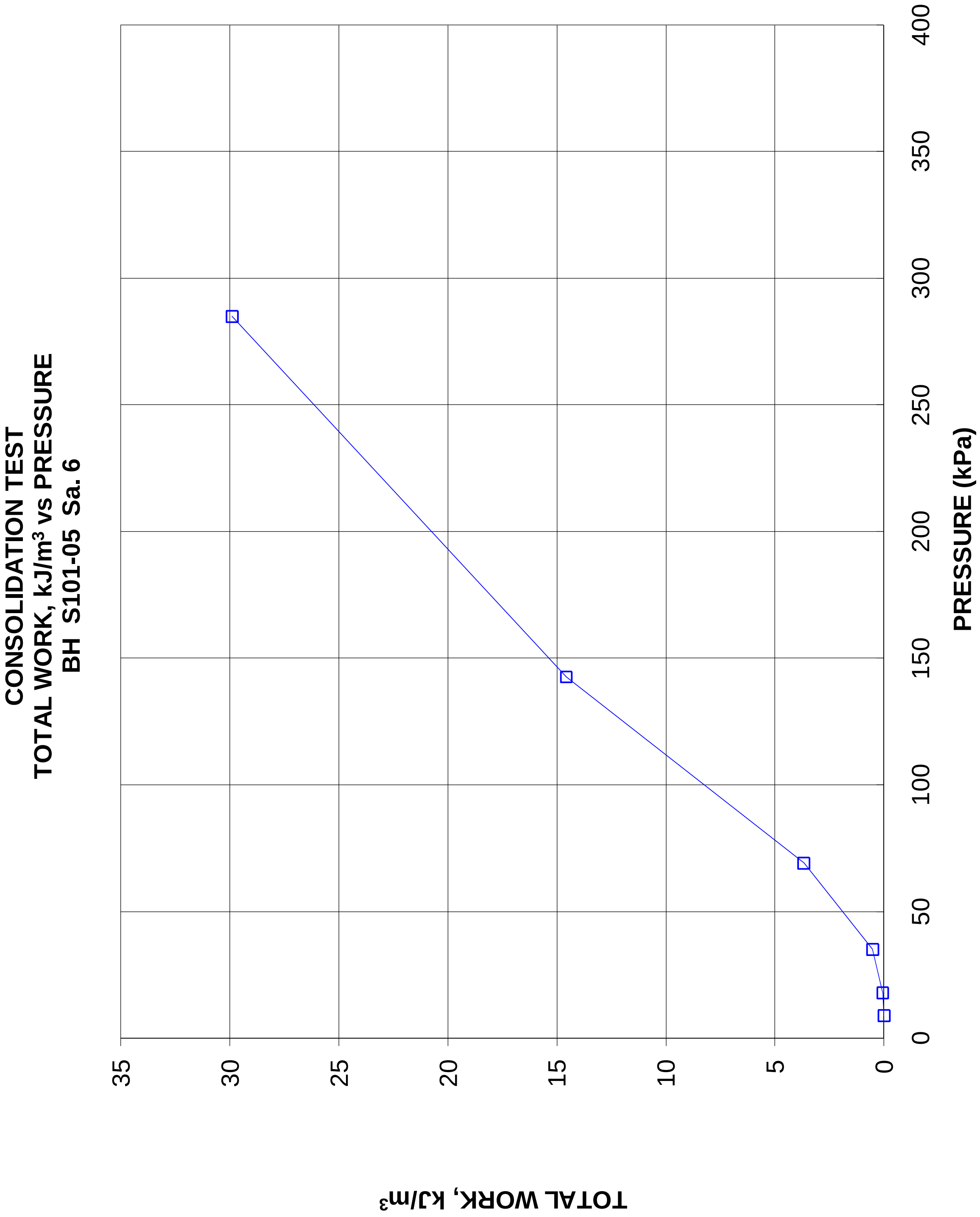
Project No. 09-1111-6014-1520
Prepared By: TG

Golder Associates

Checked By: SEMC

CONSOLIDATION TEST
TOTAL WORK VS PRESSURE

FIGURE A.S101-06
Page 4 of 4



Project No. 09-1111-6014-1520

Golder Associates

Prepared By: TG

Checked By: SEMC

CONSOLIDATION TEST SUMMARY

FIGURE A.S101-07

Page 1 of 4

SAMPLE IDENTIFICATION

Project Number	09-1111-6014-1520	Sample Number	5
Borehole Number	S101-06	Sample Depth (m)	3.4

TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	1		
Date Started	March 5/10		
Date Completed	March 18/10		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	2.538	Unit Weight, kN/m^3	14.73
Sample Diameter, cm	6.342	Dry Unit Weight, kN/m^3	7.53
Area, cm^2	31.59	Specific Gravity, assumed	2.70
Volume, cm^3	80.17	Solids Height, cm	0.722
Water Content, %	95.63	Volume of Solids, cm^3	22.79
Wet Mass, g	120.39	Volume of Voids, cm^3	57.38
Dry Mass, g	61.54	Degree of Saturation, %	102.6

TEST COMPUTATIONS

Pressure kPa	Primary Consolidation	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv. cm^2/s	mv m^2/MN	k cm/s	Total Work kJ/m3
0	0	2.538	2.518	2.538					
8.9	0.15	2.523	2.497	2.531	625	0.00217	0.661	1.41E-07	0.026
17.9	0.06	2.517	2.488	2.520	400	0.00337	0.265	8.73E-08	0.058
35.1	0.31	2.486	2.445	2.502	900	0.00147	0.710	1.03E-07	0.384
69.2	0.32	2.454	2.401	2.470	841	0.00154	0.370	5.58E-08	1.055
142.6	5.10	1.944	1.694	2.199	2601	0.00039	2.735	1.06E-07	23.062
284.9	1.50	1.794	1.486	1.869	2401	0.00031	0.415	1.26E-08	39.556
142.6	-0.07	1.801	1.496	1.798					
69.2	-0.13	1.814	1.514	1.808					
35.1	-0.16	1.830	1.536	1.822					
8.9	-0.31	1.861	1.579	1.846					

Note:

k calculated using cv based on t_{90} values.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	1.861	Unit Weight, kN/m^3	15.68
Sample Diameter, cm	6.34	Dry Unit Weight, kN/m^3	10.27
Area, cm^2	31.59	Specific Gravity, assumed	2.70
Volume, cm^3	58.79	Solids Height, cm	0.722
Water Content, %	52.76	Volume of Solids, cm^3	22.79
Wet Mass, g	94.01	Volume of Voids, cm^3	36.00
Dry Mass, g	61.54		

Prepared By: TG

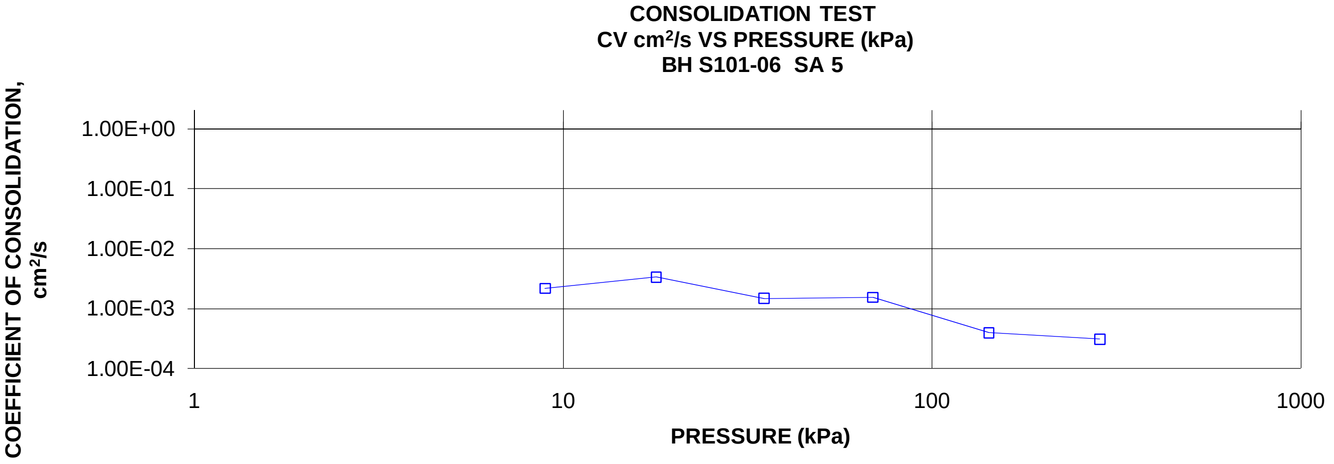
Golder Associates

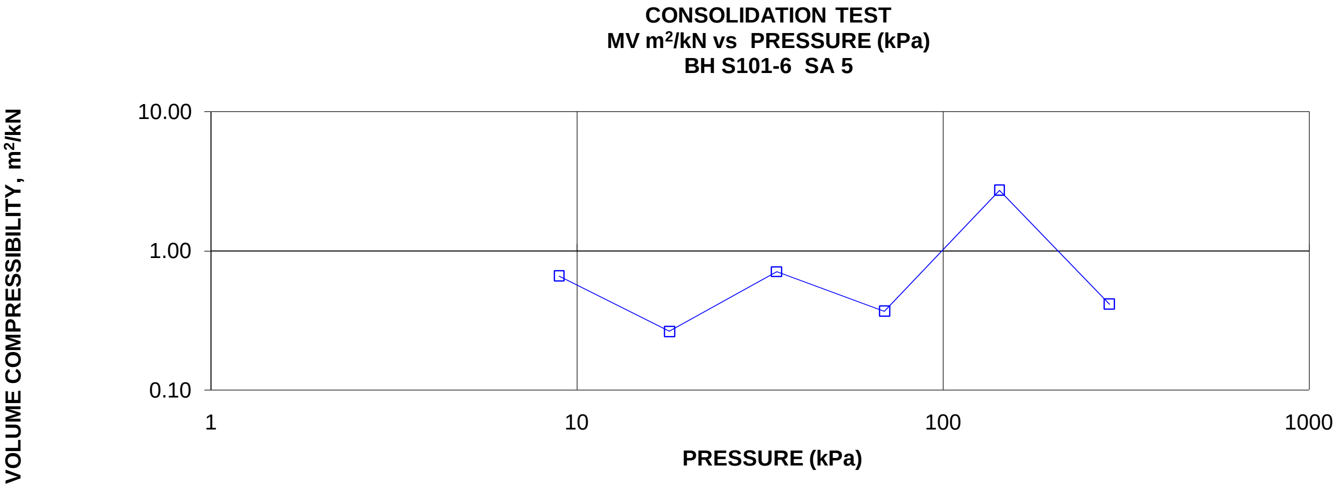
Checked By: SEMC

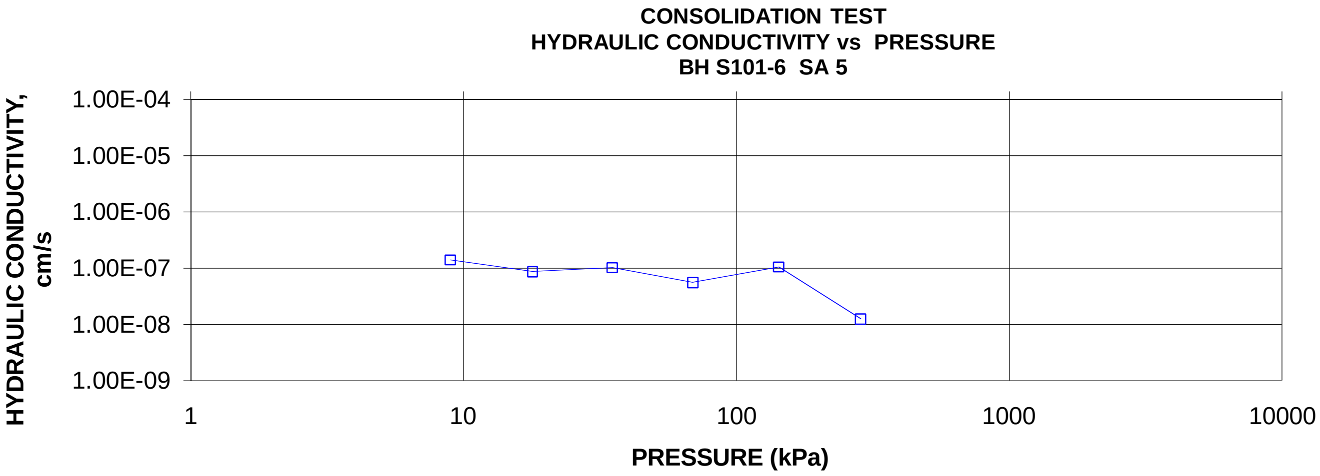
CONSOLIDATION TEST SUMMARY

FIGURE A. S101-07

Page 2 of 4







Project No. 09-1111-6014-1520

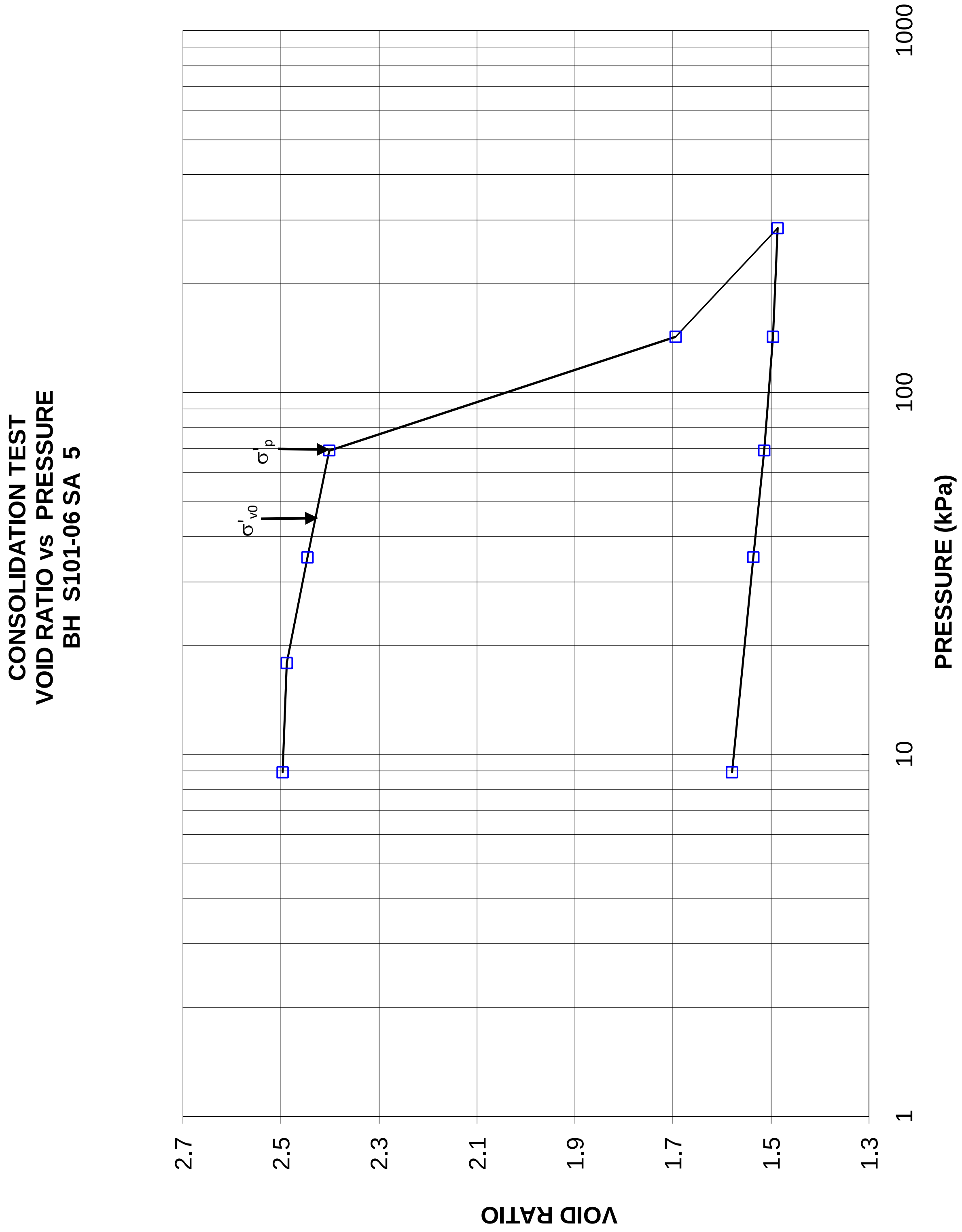
Prepared By: TG

Golder Associates

Checked By: SEMC

CONSOLIDATION TEST
VOID RATIO VS LOG PRESSURE

FIGURE A.S101-07
Page 3 of 4



Project No. 09-1111-6014-1520

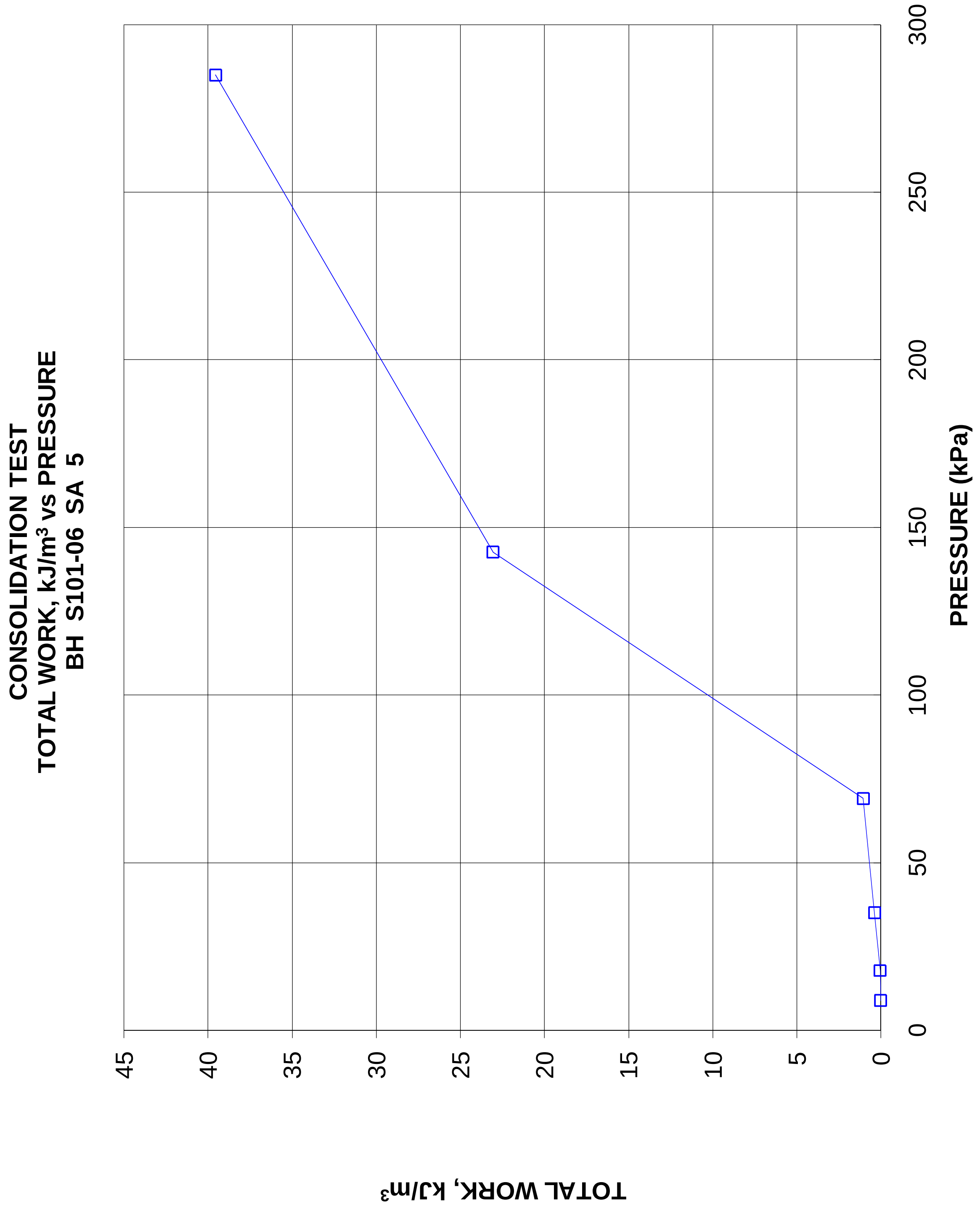
Prepared By: TG

Golder Associates

Checked By: SEMC

CONSOLIDATION TEST
TOTAL WORK VS PRESSURE

FIGURE A.S101-07
Page 4 of 4



Project No09-1111-6014-1520

Prepared By: TG

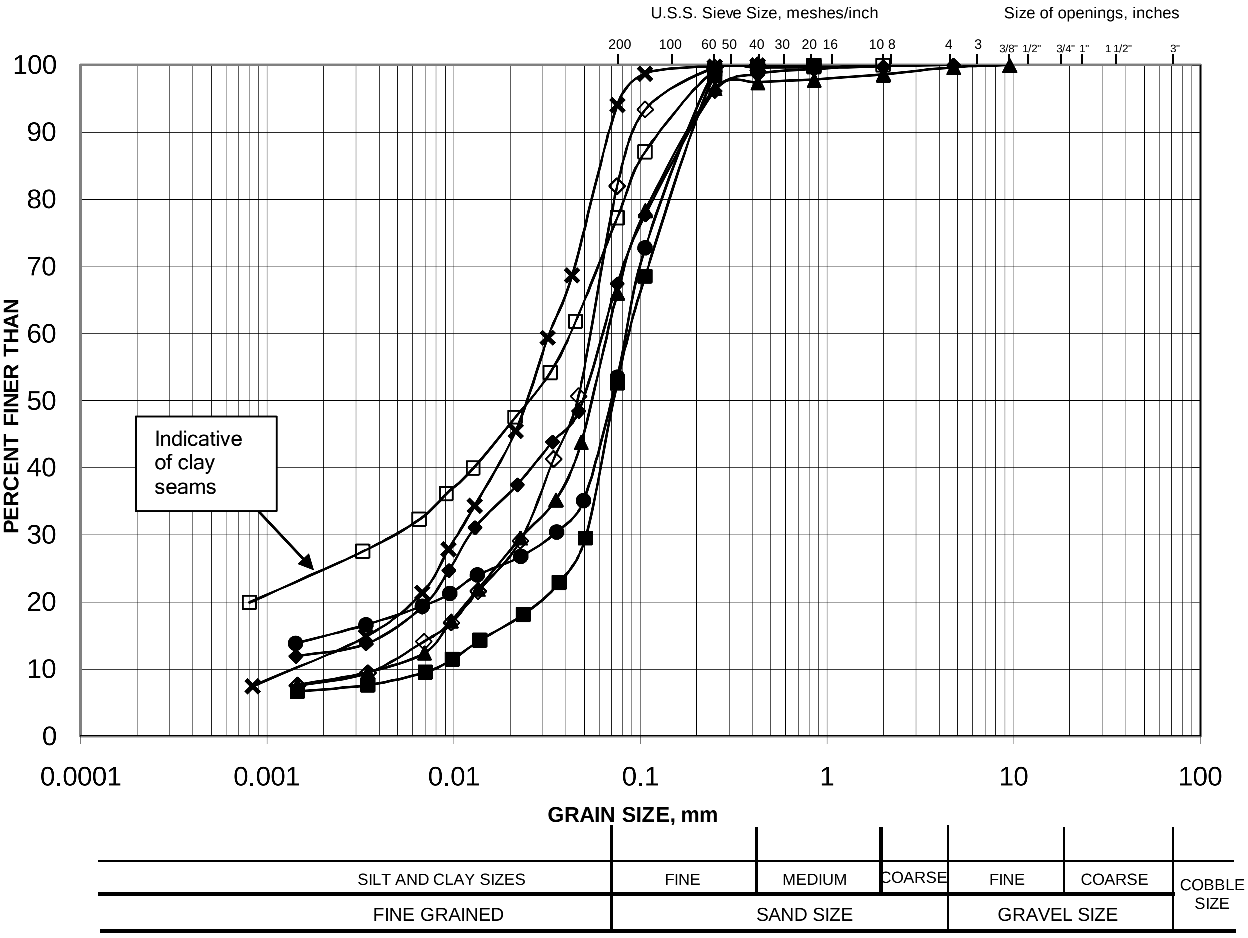
Golder Associates

Checked By: SEMC

GRAIN SIZE DISTRIBUTION

Sand and Silt to Silt
CNR - STA 328+810 to STA 328+940 (Swamp 101)

FIGURE A.S101-08



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
◆	S101-02	8	173.0
■	S101-05	9	170.9
▲	S101-06	8	172.6
●	S101-06	10	169.5
◇	S101-07	7	172.5
□	S101-07	9	169.4
✖	S101-08	9	172.0

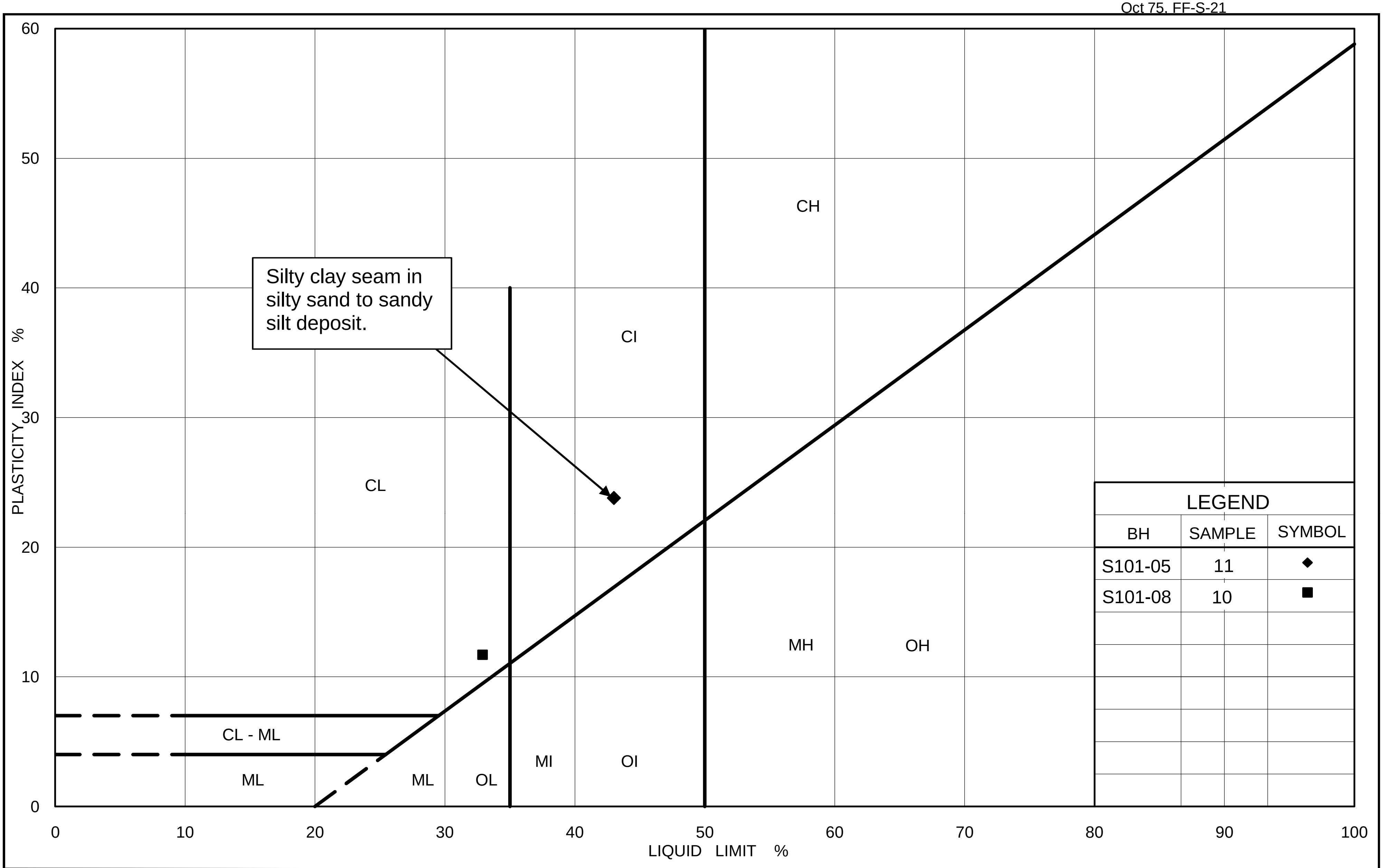
Project Number: 09-1111-6014-1520

Checked By: SEMC

Golder Associates

Date: August 2011

Oct 75, FF-S-21



Ministry of Transportation
Ontario

PLASTICITY CHART
Lower Clayey Silt
CNR - STA 328+810 to STA 328+940 (Swamp 101)

Figure A.S101-09

Project No. 09-1111-6014-1520

Checked By: SEMC

APPENDIX B

CNR - STA 329+035 to STA 329+060 (Swamp 102)

MINISTRY OF TRANSPORTATION, ONTARIO

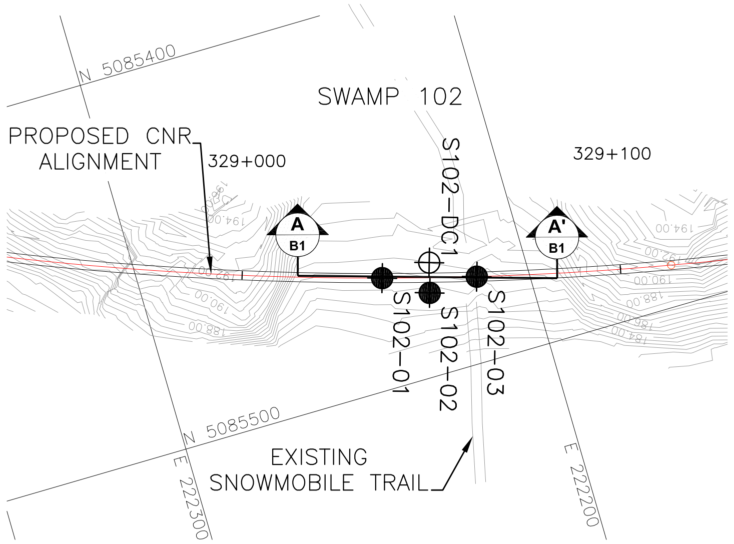
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No.5344–08–01

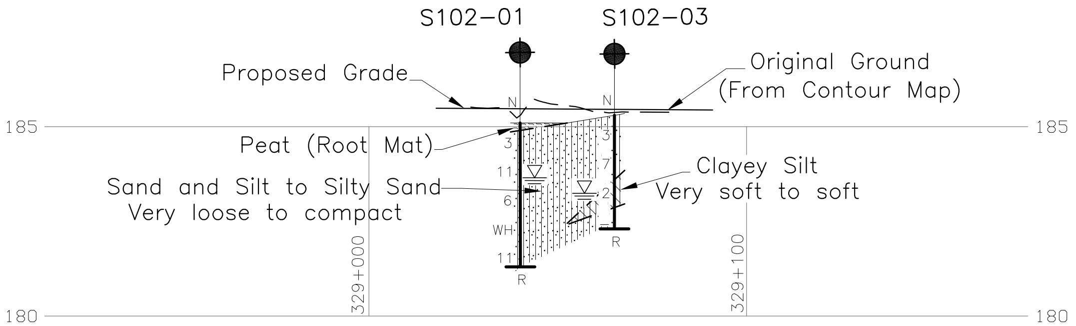
SHEET

CN RAILWAY
STA 329+035 TO STA 329+060
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

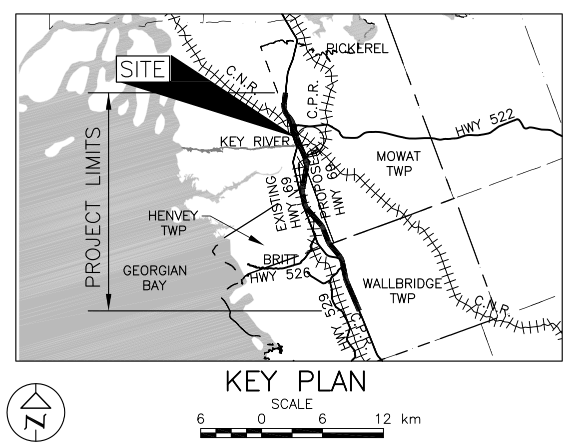


PLAN
SCALE
20 0 20 40 m



A-A'
B1
CENTRELINE PROFILE

HORIZONTAL SCALE
20 0 20 40 m
2 0 2 4 m
VERTICAL SCALE



KEY PLAN
SCALE
6 0 6 12 km

LEGEND

●	Borehole
⊕	Dynamic Cone Penetration Test
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
▽	WL upon completion of drilling
R	Refusal

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
S102–01	185.1	5085471.1	222237.6
S102–02	185.0	5085478.4	222226.6
S102–03	185.3	5085477.7	222213.5
S102–DC1	186.0	5085470.7	222224.5

NOTES

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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 URS, drawing file HWY69_plan.dwg received Feb. 17, 2010. Railroad Contours provided in digital format by URS, drawing file Railroad Contours.dwg, received Jan. 21, 2010. Key plan provided in digital format by URS, drawing file Keyplan.dwg received Apr. 16, 2010.

S.E.M. COYNE
90471921
AUG 23, 2011

J.M.A.COSTA
AUG 23, 2011

NO.	DATE	BY	REVISION

Geocres No. 41H–91

HWY. CNR		PROJECT NO. 09–1111–6014	DIST.
SUBM'D. LG	CHKD. AB	DATE: AUG 2011	SITE:
DRAWN: JJL	CHKD. SEMC	APPD. JMAC	DWG. B1

PLOT DATE: August 23, 2011
FILENAME: \\capws\sites\0911116014highway69FourLaning\Contract 1 CN Realignment\Drafting\Drawings\Swamp 102\09–1111–6014 Swamp 102.dwg

RECORD OF BOREHOLE No S102-01

1 OF 1 **METRIC**

PROJECT 09-1111-6014

W.P. 5344-08-00

DIST

HWY CNR

DATUM Geodetic

LOCATION N 5085471.1; E 222237.6

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

DATE December 16, 2009

ORIGINATED BY EHS

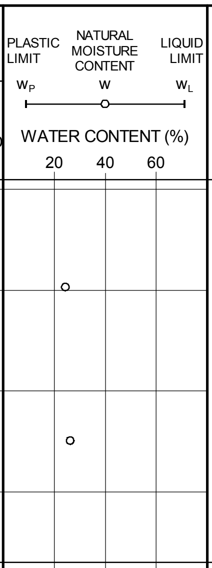
COMPILED BY JJL

CHECKED BY AB

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES			GR	SA	SI	CL
185.1	GROUND SURFACE									
0.0	PEAT (Root Mat)					185				
0.2	Brown Moist SAND and SILT to Silty SAND, trace clay Very loose to compact Brown to grey Moist to wet	1	SS	3						
		2	SS	11		184	0	45	50	5
					⊽					
		3	SS	6		183				
		4	SS	WH						
		5	SS	11		182				
181.3 3.8	END OF BOREHOLE AUGER REFUSAL Note: 1. Water level at a depth of 1.5 m below ground surface (Elev. 183.6 m) upon completion of drilling.									

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED: 20 40 60 80 100



UNIT WEIGHT γ kN/m^3

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

$\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No S102-02

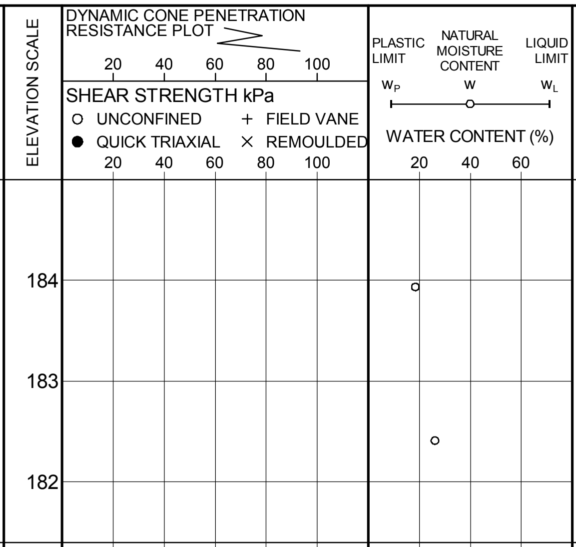
1 OF 1 **METRIC**

PROJECT 09-1111-6014			
W.P. 5344-08-00	LOCATION N 5085478.4; E 222226.6		ORIGINATED BY EHS
DIST	HWY CNR	BOREHOLE TYPE 108 mm I.D. Continuous Flight, Hollow Stem Augers	COMPILED BY JJL
DATUM Geodetic	DATE December 16, 2009		CHECKED BY AB

ELEV DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
185.0	GROUND SURFACE									
0.0	Sand and silt (FILL) Very loose Brown Moist	1	SS	2						
184.6 0.5	PEAT (Root Mat) Brown Moist	2	SS	15						
	SAND and SILT to Silty SAND, trace to some clay Very loose to compact Brown to grey Moist to wet	3	SS	8	∇					
		4	SS	WH			0	69	23	8
		5	SS	WH						
181.4 3.6	END OF BOREHOLE SPOON AND AUGER REFUSAL									

Note:

1. Water level at a depth of 1.6 m below ground surface (Elev. 183.4 m) upon completion of drilling.



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

Golder Associates

RECORD OF BOREHOLE No S102-03

1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
LOCATION N 5085477.7; E 222213.5
ORIGINATED BY EHS
DIST
HWY CNR
BOREHOLE TYPE 108 mm I.D. Continuous Flight, Hollow Stem Augers
COMPILED BY JJL
DATUM Geodetic
DATE December 16, 2009
CHECKED BY AB

SOIL PROFILE

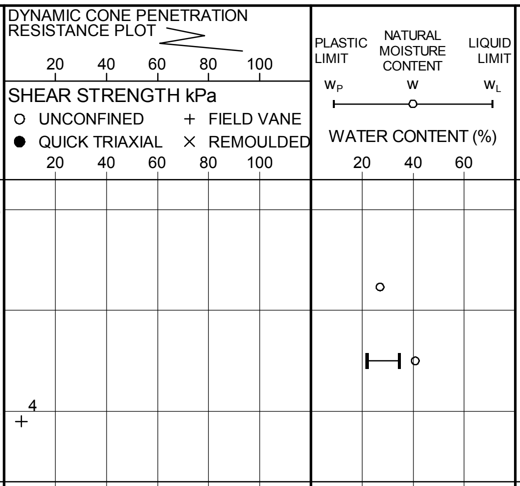
ELEV DEPTH	DESCRIPTION
185.3	GROUND SURFACE
0.0	SAND and SILT to Silty SAND, trace to some clay Very loose to loose Brown to grey Moist to wet
183.6 1.7	CLAYEY SILT Very soft to soft Grey Wet
182.8 2.5	Silty SAND, trace to some clay Grey Wet
182.3 3.0	END OF BOREHOLE AUGER REFUSAL Note: 1. Water level at a depth of 2.1 m below ground surface (Elev. 183.2 m) upon completion of drilling.

SAMPLES

NUMBER	TYPE	"N" VALUES
1	SS	3
2	SS	7
3	SS	2
4	AS	-

GROUND WATER CONDITIONS: ∇

ELEVATION SCALE: 185, 184, 183



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

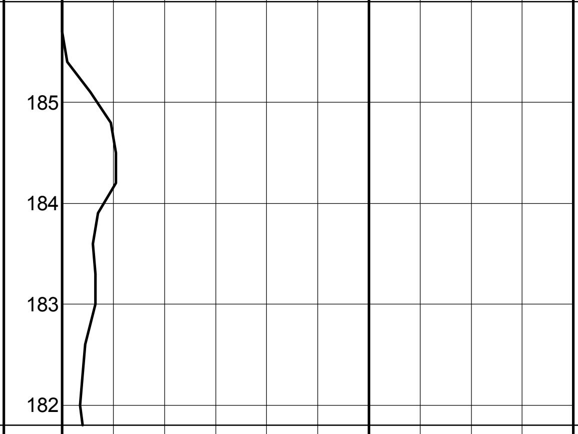
+ 3, × 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF PENETRATION TEST No S102-DC1

1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST ____ HWY CNR
DATUM Geodetic
LOCATION N 5085470.7; E 222224.5
BOREHOLE TYPE Dynamic Cone Penetration Test
DATE December 8, 2009
ORIGINATED BY EHS
COMPILED BY JJL
CHECKED BY AB

SOIL PROFILE			SAMPLES								
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 O 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
186.0 0.0	GROUND SURFACE										
181.8 4.2	END OF DCPT REFUSAL TO FURTHER PENETRATION (8 BLOWS / 0.3 m)										

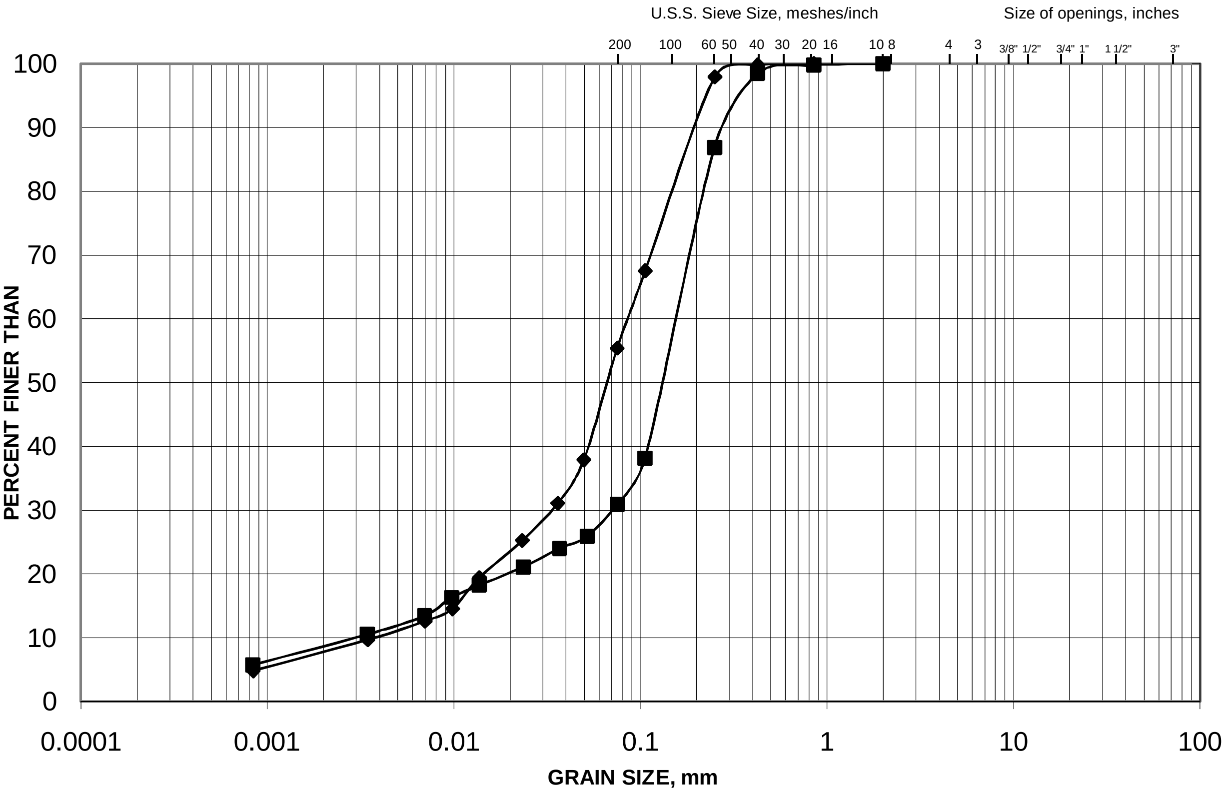


+3, ×3: Numbers refer to Sensitivity
O 3% STRAIN AT FAILURE

GRAIN SIZE DISTRIBUTION

Sand and Silt to Silty Sand
CNR - STA 329+035 to STA 329+060 (Swamp 102)

FIGURE B.S102-01



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
◆	S102-01	2	184.0
■	S102-02	4	182.4

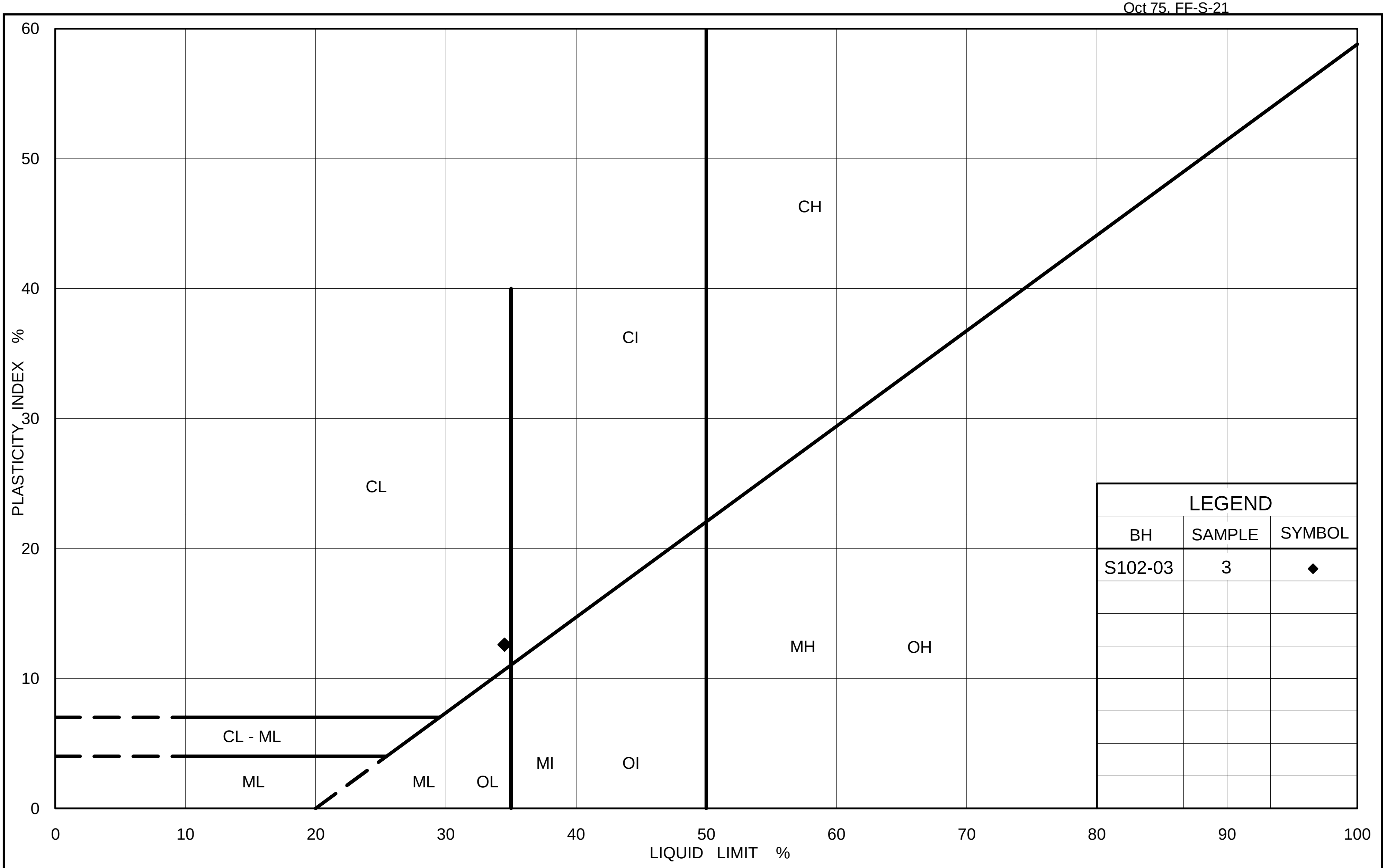
Project Number: 09-1111-6014-1520

Checked By: SEMC

Golder Associates

Date: August 2011

Oct 75, FF-S-21



Ministry of Transportation
Ontario

PLASTICITY CHART
Clayey Silt
CNR - STA 329+035 to STA 329+060 (Swamp 102)

Figure B.S102-02

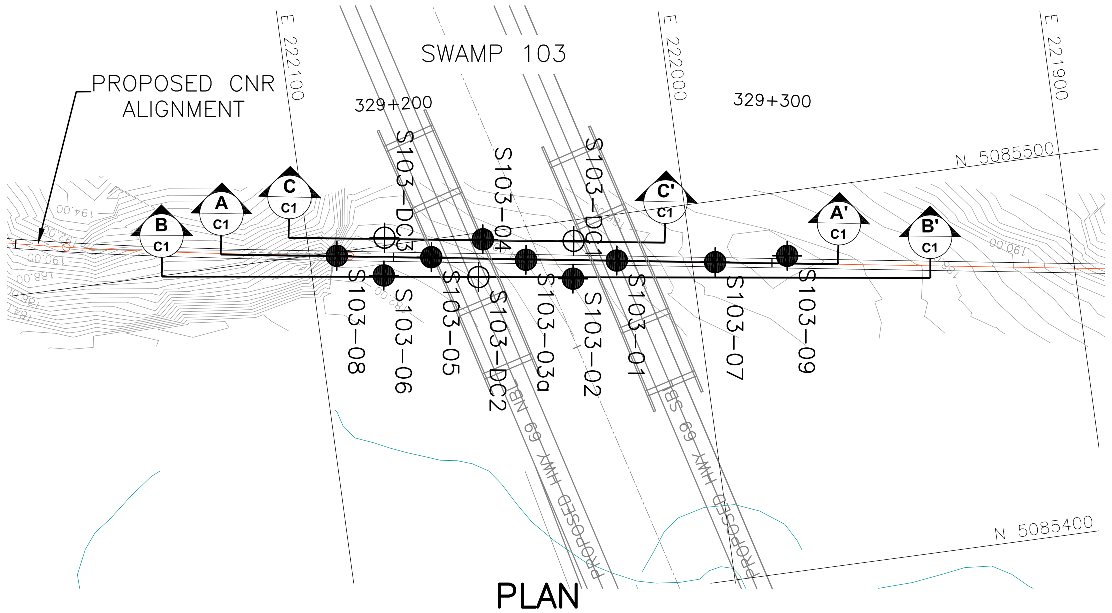
Project No. 09-1111-6014-1520

Checked By: SEMC

APPENDIX C

CNR - STA 329+185 to STA 329+305 (Swamp 103)

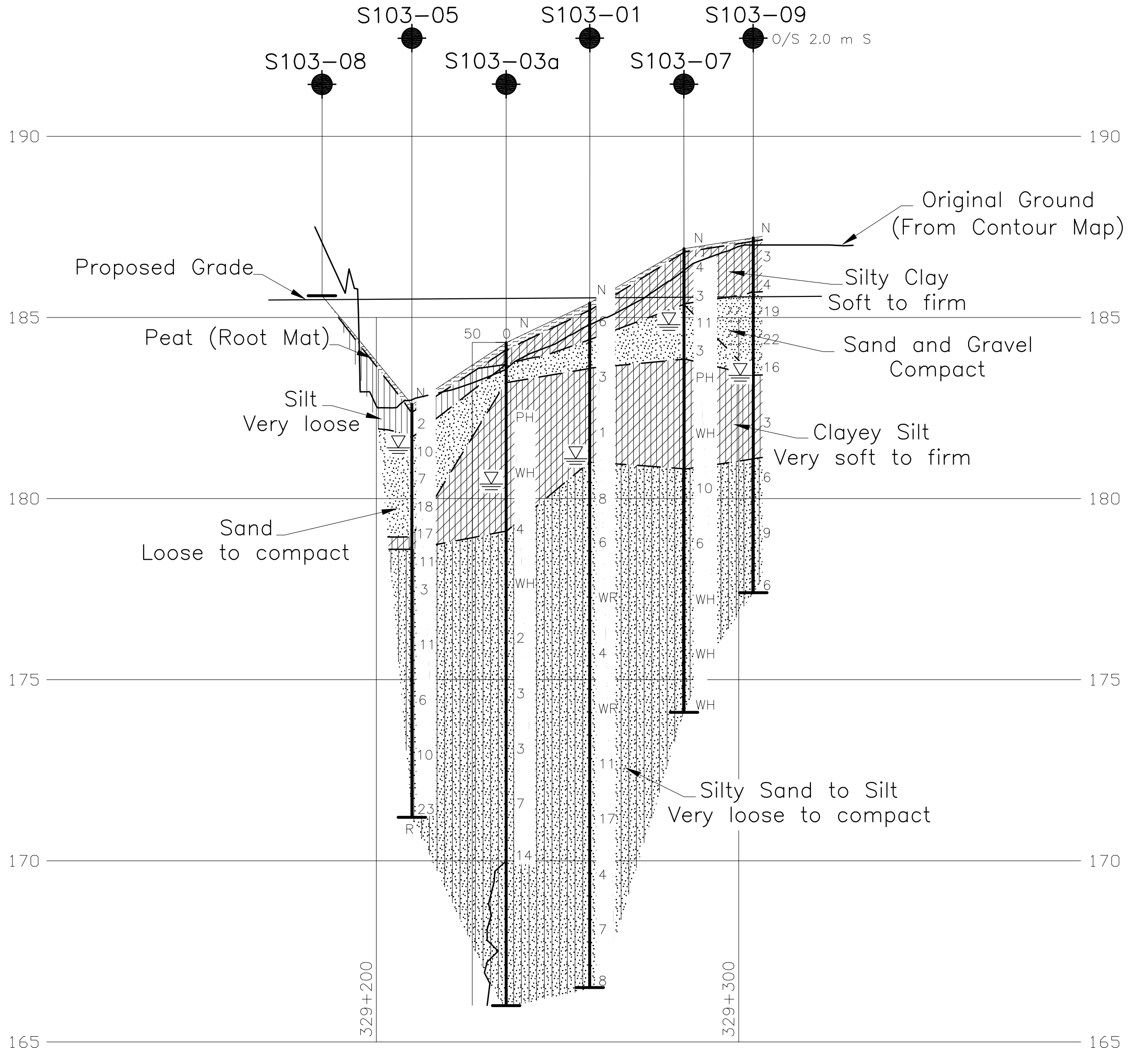
MINISTRY OF TRANSPORTATION, ONTARIO



PLAN

SCALE

20 0 20 40 m



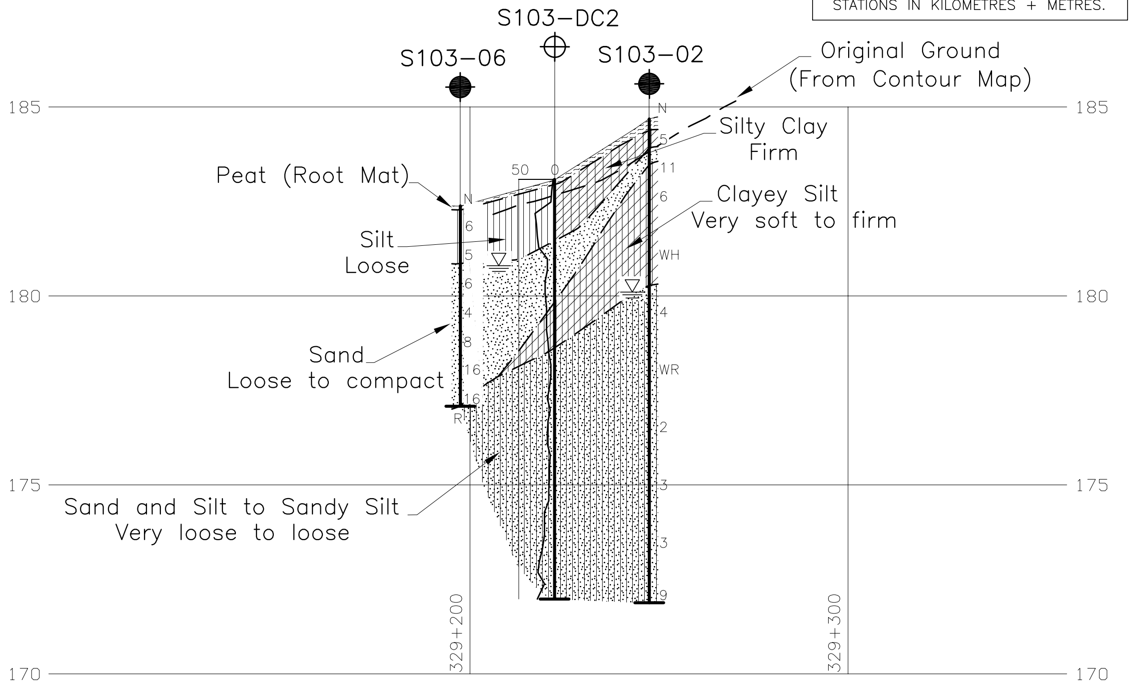
A-A' C1 CENTRELINE PROFILE

HORIZONTAL SCALE

20 0 20 40 m

2 0 2 4 m

VERTICAL SCALE



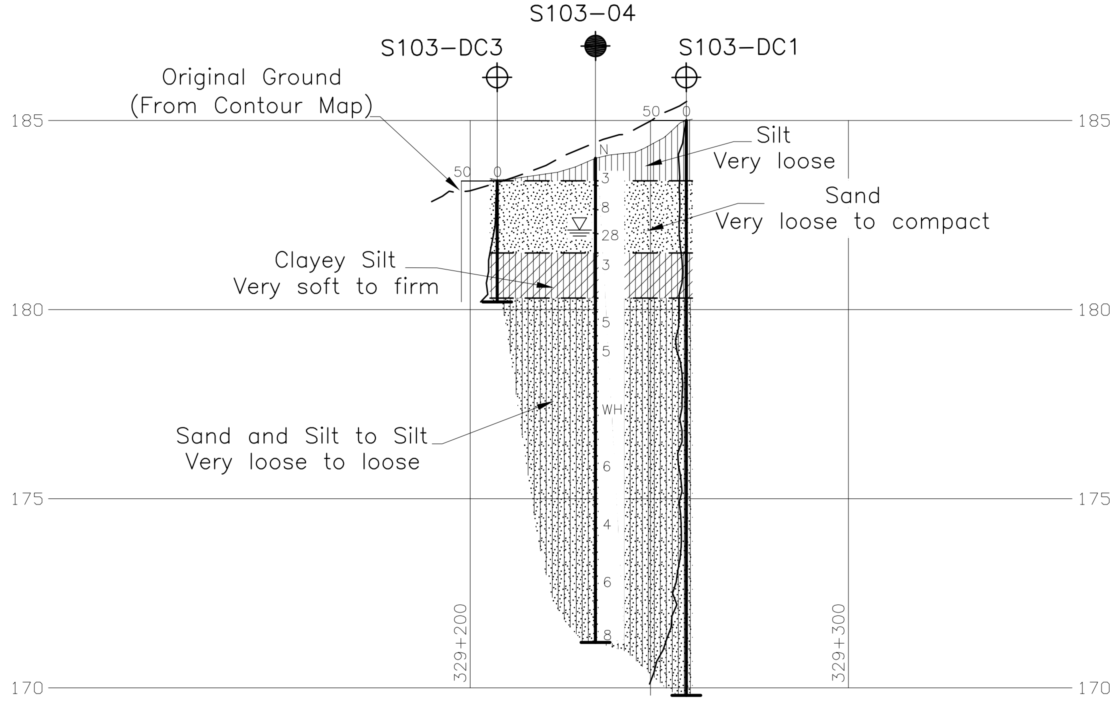
B-B' C1 EMBANKMENT TOE PROFILE

HORIZONTAL SCALE

20 0 20 40 m

2 0 2 4 m

VERTICAL SCALE



C-C' C1 EMBANKMENT TOE PROFILE

HORIZONTAL SCALE

20 0 20 40 m

2 0 2 4 m

VERTICAL SCALE

METRIC

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

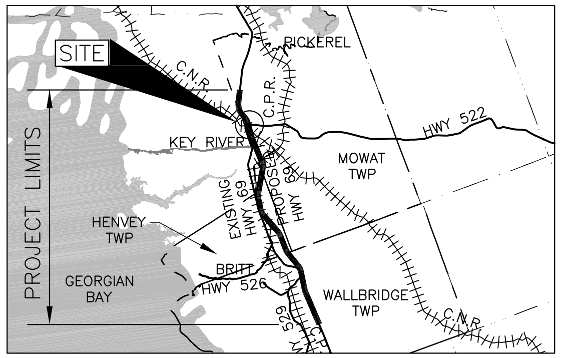
CONT No.
WP No. 5344-08-01

SHEET

CN RAILWAY
STA 329+185 TO STA 329+305
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



KEY PLAN

SCALE

6 0 6 12 km

LEGEND

- ● Borehole
- ⊕ Dynamic Cone Penetration Test
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- ▽ WL upon completion of drilling
- R Refusal

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
S103-01	185.4	5085512.1	222019.6
S103-02	184.6	5085515.3	222031.8
S103-03	184.3	5085508.5	222043.4
S103-03a	184.3	5085508.7	222042.4
S103-04	184.0	5085501.8	222054.0
S103-05	182.6	5085504.7	222068.1
S103-06	182.3	5085507.8	222081.2
S103-07	186.9	5085516.0	221993.9
S103-08	185.6	5085501.0	222092.8
S103-09	187.2	5085516.9	221974.8
S103-DC1	185.0	5085505.5	222030.3
S103-DC2	183.0	5085511.6	222056.5
S103-DC3	183.4	5085497.9	222079.7

NOTES

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S.E.M. COYNE
90471921
AUG 23, 2011

J.M.A.COSTA
AUG 23, 2011

NO.	DATE	BY	REVISION

Geocres No. 41H-91

HWY. CNR		PROJECT NO. 09-1111-6014	DIST.
SUBM'D. LG	CHKD. AB	DATE: AUG 2011	SITE:
DRAWN: JJL	CHKD. SEMC	APPD. JMAC	DWG. C1

PLOT DATE: August 23, 2011
FILENAME: \\capws\sites\09111160144highway69FourLaning\Contract 1 CN Realignment\Drafting\Drawings\Swamp 103\09-1111-6014 Swamp 103.dwg

RECORD OF BOREHOLE No S103-01

1 OF 2 **METRIC**

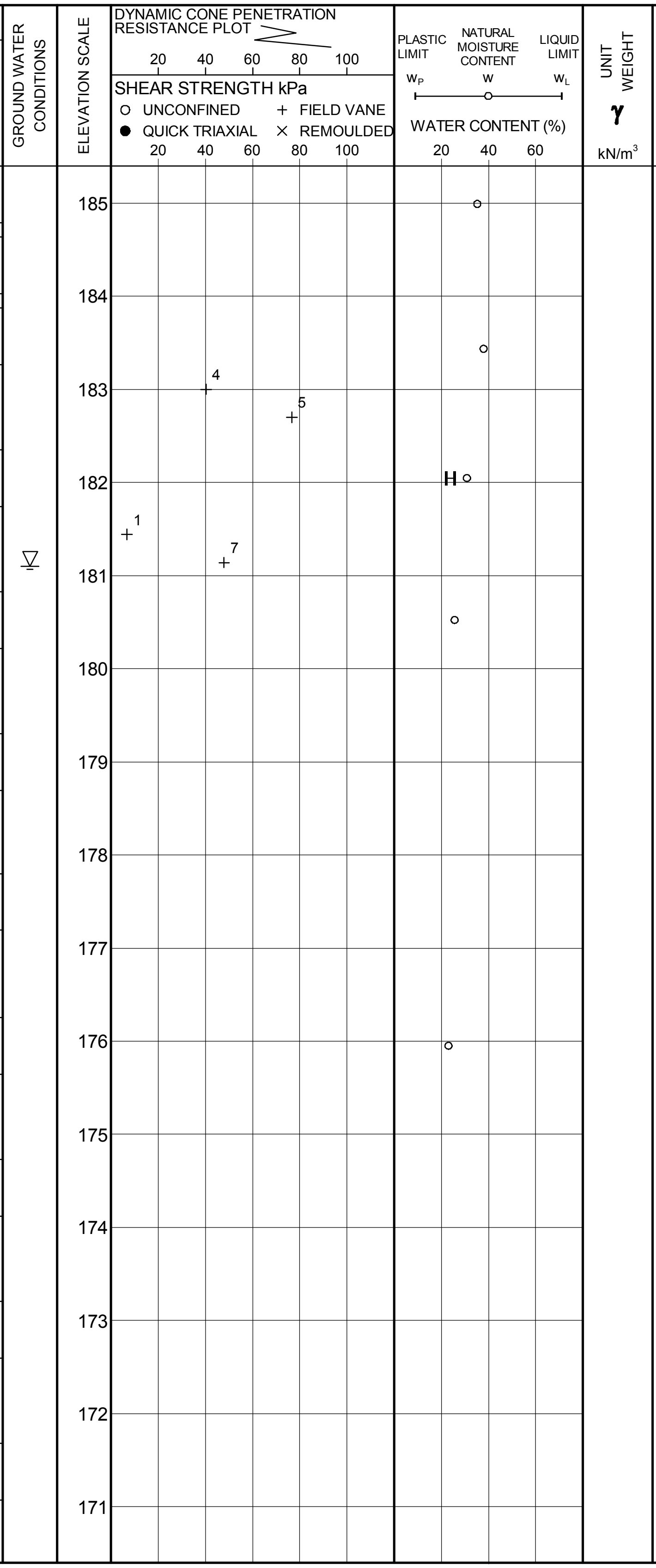
PROJECT 09-1111-6014
W.P. 5344-08-00
LOCATION N 5085512.1; E 222019.6
ORIGINATED BY EHS
DIST HWY CNR
BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers
COMPILED BY LG
DATUM Geodetic
DATE December 17, 2009
CHECKED BY AB

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
185.4	GROUND SURFACE
0.0	PEAT (Root Mat) Brown Moist
0.2	SILTY CLAY Firm Brown Moist
184.4 1.0	SAND, trace gravel Loose to compact Brown Moist
183.6 1.8	CLAYEY SILT with sand and silt layers / seams Very soft Brown to grey Moist
181.0 4.4	SAND and SILT to SILT, trace to some clay Very loose to compact Grey Wet

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	6				
2	SS	18				
3	SS	3				
4	SS	1				
5	SS	8	0	5	89	6
6	SS	6				
7	SS	WR				
8	SS	4	0	43	54	3
9	SS	WR				
10	SS	11				
11	SS	17				



Continued Next Page

+3, ×3: Numbers refer to Sensitivity

O 3% STRAIN AT FAILURE

SUD-MTO V2.0 09-1111-6014 BH SWAMP LOGS METRIC.GPJ GAL-MISS.GDT 18/08/11 DATA INPUT:

Golder Associates

RECORD OF BOREHOLE No S103-01

2 OF 2 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
LOCATION N 5085512.1; E 222019.6
ORIGINATED BY EHS
DIST HWY CNR
BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers
COMPILED BY LG
DATUM Geodetic
DATE December 17, 2009
CHECKED BY AB

SOIL PROFILE			SAMPLES			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 (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR	SA	SI	CL
	--- CONTINUED FROM PREVIOUS PAGE ---													
	SAND and SILT to SILT, trace to some clay Very loose to compact Grey Wet		12	SS	4		170							
							169							
			13	SS	7				○ (20)		2	61	34	3
							168							
							167							
166.5			14	SS	8									
18.9	END OF BOREHOLE Note: 1. Water level at a depth of 4.3 m below ground surface (Elev. 181.1 m) upon completion of drilling.													

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

RECORD OF BOREHOLE No S103-02

1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST
HWY CNR
DATUM Geodetic
LOCATION N 5085515.3; E 222031.8
BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers
DATE December 17 and 18, 2009
ORIGINATED BY EHS
COMPILED BY LG
CHECKED BY AB

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
184.6	GROUND SURFACE
0.0	PEAT (Root Mat) Brown Moist
184.3 / 0.3	SILTY CLAY, trace organics Firm Brown to grey Moist
183.8 / 0.8	SAND, trace gravel Compact Brown Moist
183.4 / 1.2	CLAYEY SILT with sand and silt layers / seams Very soft to firm Brown to grey Moist to wet
180.2 / 4.4	SAND and SILT to Sandy SILT, trace clay Very loose to loose Grey Wet
171.8 / 12.8	END OF BOREHOLE

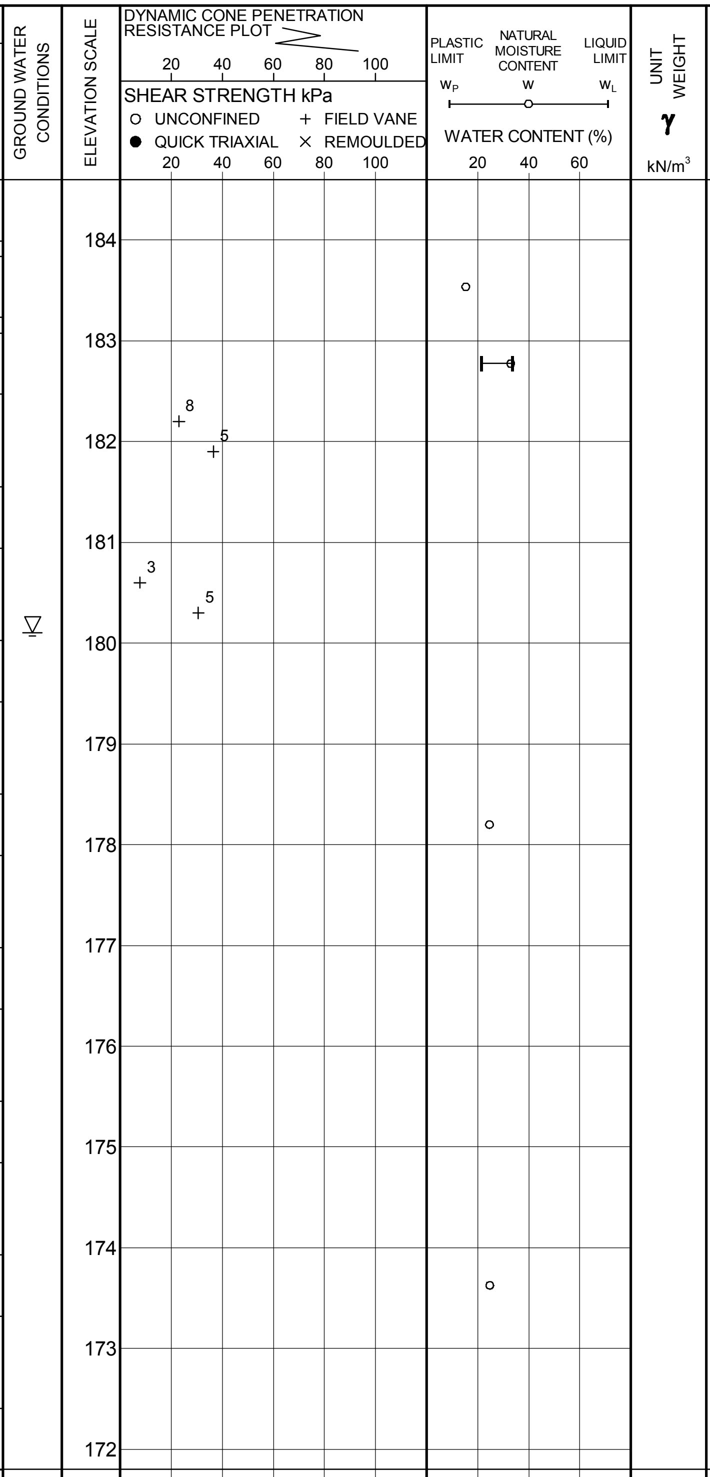
Note:

1. Water level at a depth of 4.5 m below ground surface (Elev. 180.1 m) upon completion of drilling.

SAMPLES

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1	SS	5				
2	SS	11				
3	SS	6				
4	SS	WH				
5	SS	4				
6	SS	WR	0	28	69	3
7	SS	2				
8	SS	3				
9	SS	3	0	40	58	2
10	SS	9				

REMARKS & GRAIN SIZE DISTRIBUTION (%)



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

Golder Associates

Foundation Design

RECORD OF BOREHOLE No S103-03

1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
LOCATION N 5085508.5; E 222043.4
ORIGINATED BY EHS
DIST
HWY CNR
BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers
COMPILED BY LG
DATUM Geodetic
DATE December 20, 2009
CHECKED BY AB

ELEV DEPTH	SOIL PROFILE – DESCRIPTION
184.3	GROUND SURFACE
0.0	PEAT (Root Mat) Brown Moist
183.7 0.6	SILTY CLAY, trace sand, trace organics Firm Brown Moist
183.2 1.1	SAND, some gravel, trace silt Loose Brown Moist
	CLAYEY SILT with sand and silt layers / seams Very soft Brown to grey Wet
180.8 3.5	END OF BOREHOLE

Note:

1. No recovery in Shelby tube for samples 4 and 5, relocated 1 m west for another attempt and to continue borehole. Refer to Record of Borehole S103-03a.

SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE
1	SS	4		184
2	SS	7		
				183
3	SS	WH		
				182
4	TO	PM		
5	TO	PM		181

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/m^3

REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

SUD-MTO V2.0 09-1111-6014 BH SWAMP LOGS METRIC.GPJ GAL-MISS.GDT 18/08/11 DATA INPUT:

Golder Associates

RECORD OF BOREHOLE No S103-03a

1 OF 2 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST HWY CNR
DATUM Geodetic
LOCATION N 5085508.7; E 222042.4
BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers
DATE December 20 and 21, 2009
ORIGINATED BY ID
COMPILED BY LG
CHECKED BY AB

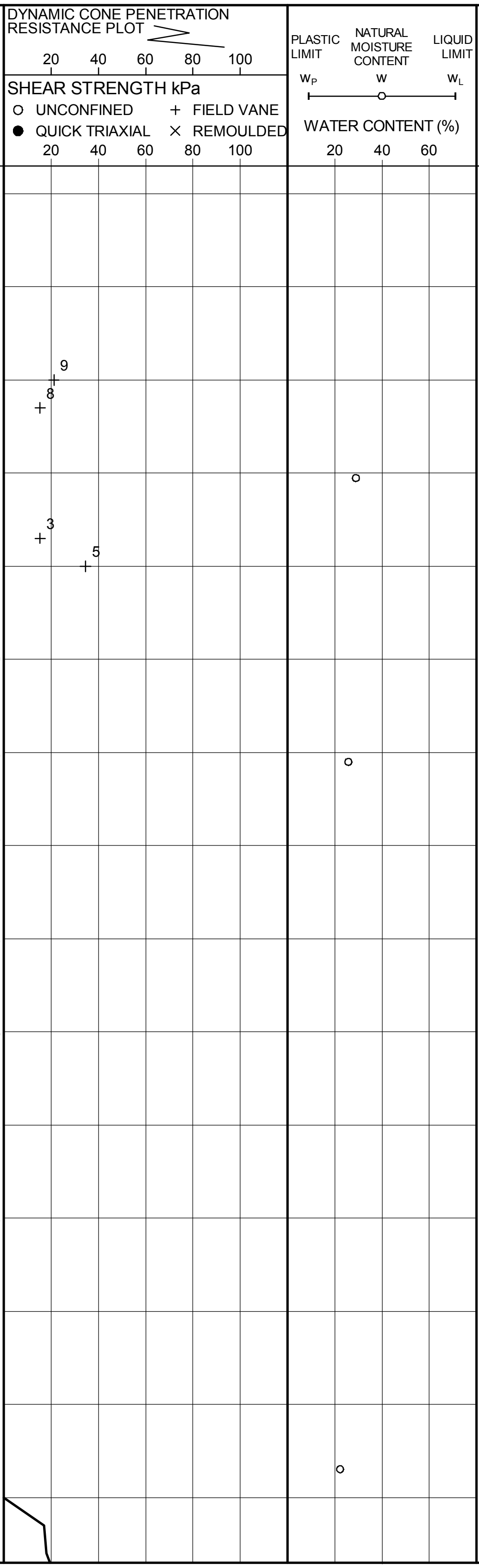
SOIL PROFILE

ELEV DEPTH	DESCRIPTION
184.3	GROUND SURFACE
0.0	PEAT (Root Mat) Brown Moist
183.7 0.6	SILTY CLAY, trace sand, trace organics Brown Moist
183.2 1.1	SAND some gravel, trace silt Brown Moist
	CLAYEY SILT with sand and silt layers / seams Very soft to firm Brown to grey Moist to wet
179.1 5.2	Sandy SILT to Silty SAND, trace clay Very loose to compact Grey Wet
170.0 14.3	Start of DCPT

SAMPLES

NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
1	TO	PH					
2	SS	WH	NP				
3	SS	4					
4	SS	WH		0	28	69	3
5	SS	2					
6	SS	3					
7	SS	3					
8	SS	7					
9	SS	14		0	72	26	2

GROUND WATER CONDITIONS: ∇ (at approx. elevation 180.5)



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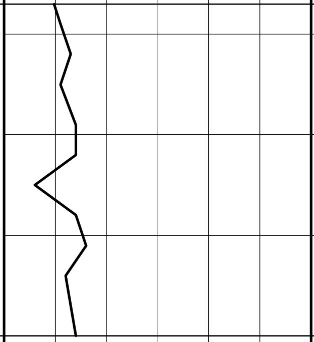
+³, ×³: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No S103-03a

2 OF 2 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST HWY CNR
DATUM Geodetic
LOCATION N 5085508.7; E 222042.4
BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers
DATE December 20 and 21, 2009
ORIGINATED BY ID
COMPILED BY LG
CHECKED BY AB

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O 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
ELEV DEPTH	DESCRIPTION --- CONTINUED FROM PREVIOUS PAGE ---	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
							169 168 167				
166.0 18.3	END OF DCPT END OF BOREHOLE Note: 1. Water level at a depth of 3.9 m below ground surface (Elev. 180.4 m) upon completion of drilling.						166				

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

RECORD OF BOREHOLE No S103-04

1 OF 1 **METRIC**

PROJECT 09-1111-6014			
W.P. 5344-08-00	LOCATION N 5085501.8; E 222054.0		ORIGINATED BY ID
DIST	HWY CNR	BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers	COMPILED BY LG
DATUM Geodetic		DATE December 21, 2009	CHECKED BY AB

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
184.0	GROUND SURFACE
0.0	SILT, some clay, some sand, trace organics Very loose Brown Moist
183.4 0.6	SAND, trace to some silt, trace clay Very loose to compact Brown Moist to wet
181.5 2.5	CLAYEY SILT with sand and silt layers / seams Very soft to firm Grey Wet
180.3 3.7	SAND and SILT to SILT, some sand, trace clay Very loose to loose Grey Wet
171.2 12.8	END OF BOREHOLE

Note:

1. Water level at a depth of 1.9 m below ground surface (Elev. 182.1 m) upon completion of drilling.

SAMPLES

NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	3					
2	SS	8		0	90	6	4
3	SS	28	⊻				
4	SS	3					
5	SS	5		0	16	80	4
6	SS	5					
7	SS	WH					
8	SS	6					
9	SS	4					
10	SS	6					
11	SS	8					

ELEVATION SCALE: 183, 182, 181, 180, 179, 178, 177, 176, 175, 174, 173, 172

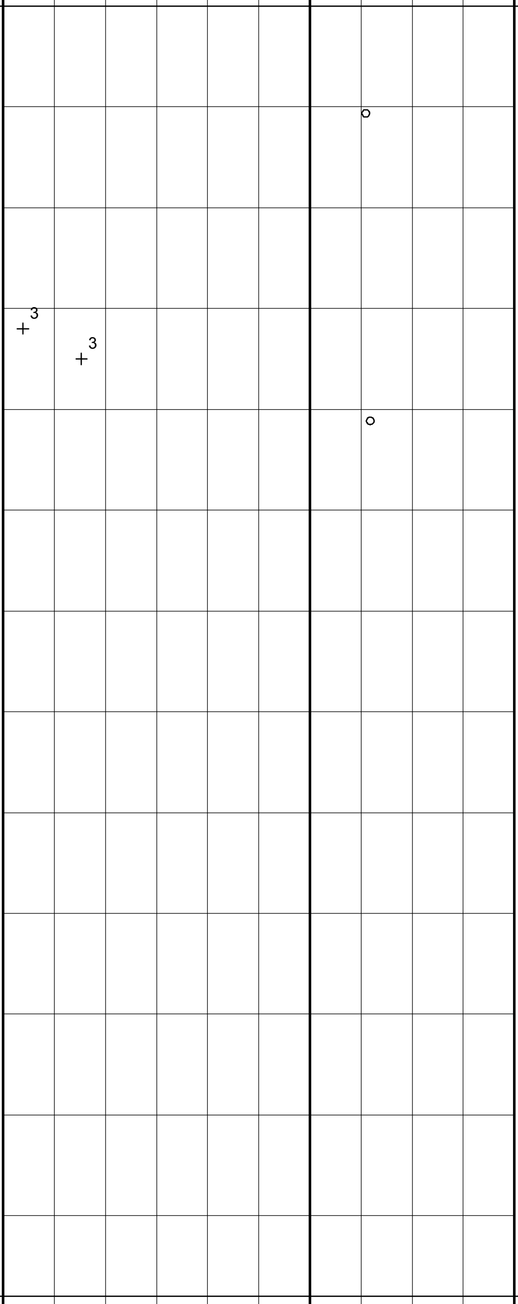
DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

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



$+^3$, $\times^3$: Numbers refer to Sensitivity $\text{O}^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No S103-05

1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST
HWY CNR
DATUM Geodetic
LOCATION N 5085504.7; E 222068.1
BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers
DATE December 22, 2009
ORIGINATED BY ID
COMPILED BY LG
CHECKED BY AB

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
182.6	GROUND SURFACE
0.0	PEAT (Root Mat)
182.4 0.2	SILT, some clay, trace sand, trace organics Very loose Brown to grey Moist (Brown, Moist)
181.7 0.9	SAND trace to some gravel, trace silt, trace clay Loose to compact Brown Wet
178.9	CLAYEY SILT with sand and silt layers / seams Grey Wet
178.6 4.0	SAND and SILT to Silty SAND, trace to some gravel, trace clay Very loose to compact Grey Wet
171.2 11.4	END OF BOREHOLE AUGER REFUSAL

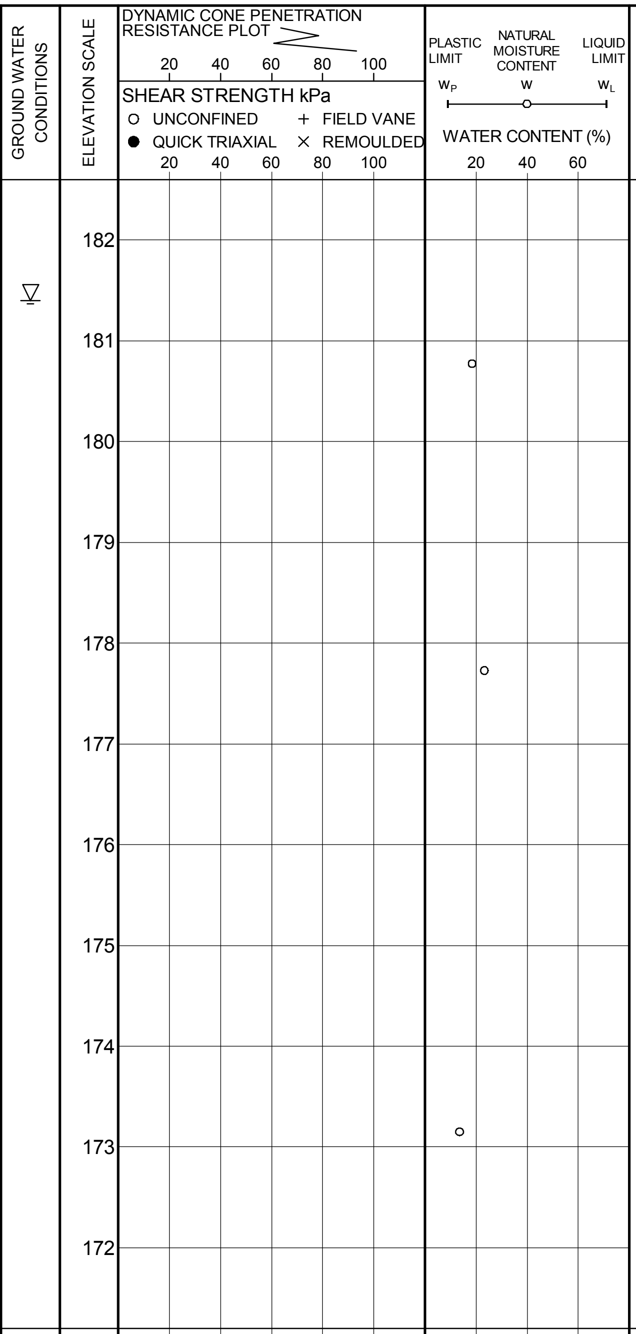
Note:

1. Water level at a depth of 1.2 m below ground surface (Elev. 181.4 m) upon completion of drilling.

SAMPLES

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1	SS	2				
2	SS	10				
3	SS	7	9	84	5	2
4	SS	18				
5	SS	17				
6	SS	11				
7	SS	3	0	76	20	4
8	SS	11				
9	SS	6				
10	SS	10	13	48	37	2
11	SS	23				

GROUND WATER CONDITIONS: ∇ at Elev. 181.4



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

$\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No S103-06

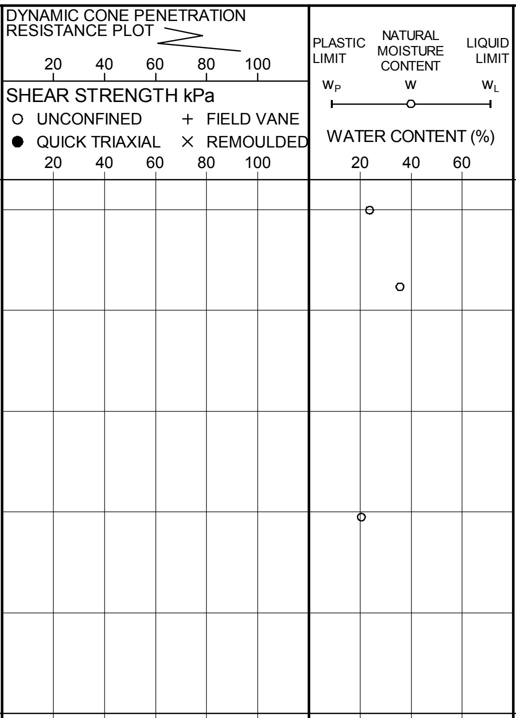
1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST
HWY CNR
DATUM Geodetic
LOCATION N 5085507.8; E 222081.2
BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers
DATE December 22, 2009
ORIGINATED BY ID
COMPILED BY LG
CHECKED BY AB

SOIL PROFILE			SAMPLES								
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
182.3	GROUND SURFACE									
0.0 0.1	PEAT (Root Mat) Brown Moist									
	SILT, trace clay, trace organics Loose Brown Moist		1	SS	6		182			
			2	SS	5				NP	
180.8 1.5	SAND, trace to some gravel, trace silt, trace clay Loose to compact Brown Wet		3	SS	6	∇	181			
			4	SS	4		180			
			5	SS	8		179			1 97 (2)
			6	SS	16		178			
			7	SS	16					
177.0 5.3	END OF BOREHOLE AUGER REFUSAL						177			

Note:

1. Water level at a depth of 1.5 m below ground surface (Elev. 180.8 m) upon completion of drilling.



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

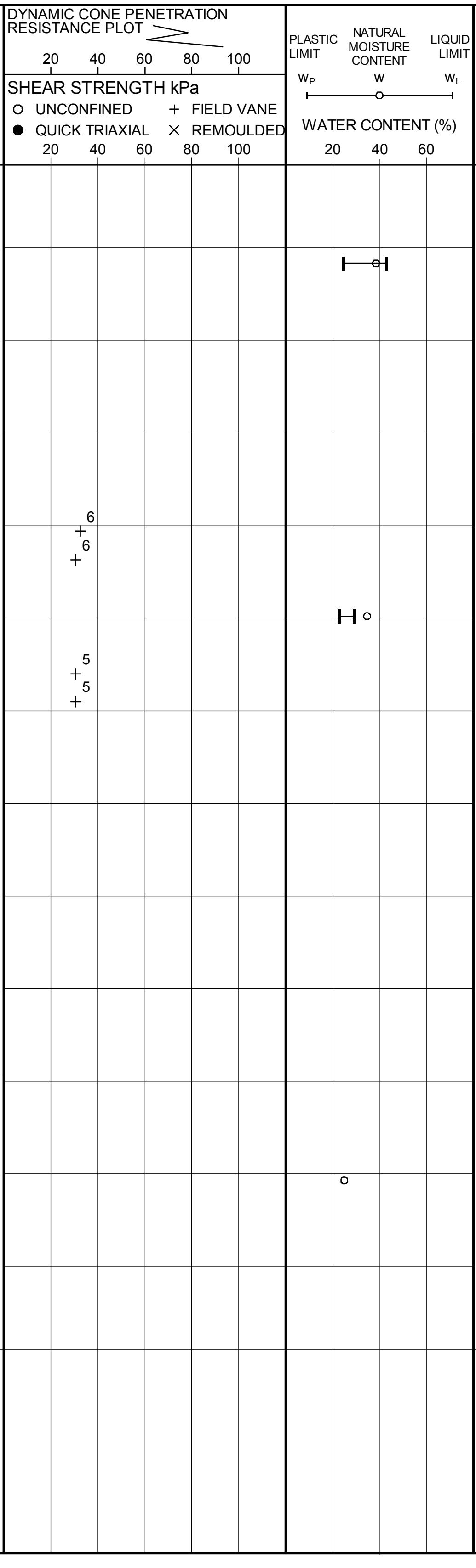
$\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No S103-07

1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST
HWY CNR
DATUM Geodetic
LOCATION N 5085516.0; E 221993.9
BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers
DATE December 21, 2009
ORIGINATED BY ID
COMPILED BY LG
CHECKED BY AB

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
186.9	GROUND SURFACE					
0.0	PEAT (Root Mat) Brown Moist	1	SS	4		
0.1	SILTY CLAY, trace organics Soft Brown Moist	2	SS	3		
185.4 1.5	SAND, trace gravel Loose to compact Brown to grey Moist to wet	3	SS	11	▽	
		4	SS	3		
183.9 3.0	CLAYEY SILT Very soft to firm Grey Wet	5	TO	PH		
		6	SS	WH		
180.8 6.1	Sandy SILT to SILT Very loose to loose Grey Wet	7	SS	10		
		8	SS	6		
		9	SS	WH		
		10	SS	WH		0 25 72 3
		11	SS	WH		
174.1 12.8	END OF BOREHOLE Note: 1. Water level at a depth of 2.1 m below ground surface (Elev. 184.8 m) upon completion of drilling.					



UNIT WEIGHT γ kN/m³

+3, ×3: Numbers refer to Sensitivity

○3% STRAIN AT FAILURE

RECORD OF BOREHOLE No S103-08

1 OF 1 **METRIC**

PROJECT 09-1111-6014

W.P. 5344-08-00

LOCATION N 5085501.0; E 222092.8

ORIGINATED BY ID

DIST

HWY CNR

BOREHOLE TYPE Hand Shovel

COMPILED BY LG

DATUM Geodetic

DATE December 21, 2009

CHECKED BY AB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O 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
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
185.6	GROUND SURFACE										
0.0	EXPOSED BEDROCK										

+ 3, × 3: Numbers refer to Sensitivity

O 3% STRAIN AT FAILURE

Foundation Design

RECORD OF BOREHOLE No S103-09

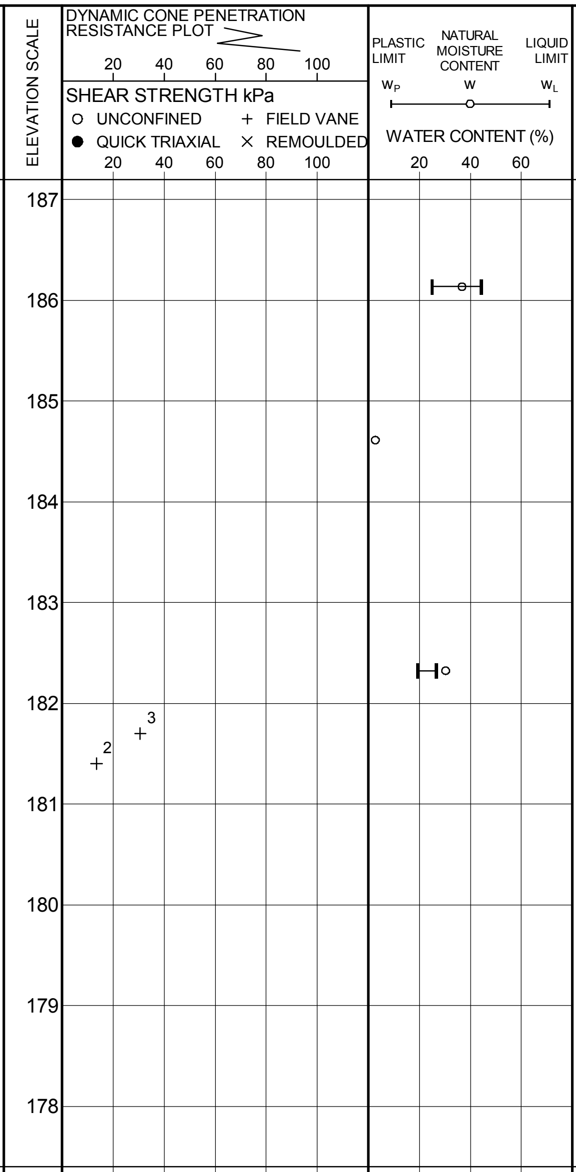
1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST
HWY CNR
DATUM Geodetic

LOCATION N 5085516.9; E 221974.8
BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers
DATE December 22, 2009

ORIGINATED BY ID
COMPILED BY LG
CHECKED BY AB

SOIL PROFILE: ELEV DEPTH	SOIL PROFILE: DESCRIPTION	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
187.2 0.0	GROUND SURFACE PEAT (Root Mat) Brown Moist	1	SS	3						
0.1	SILTY CLAY, trace organics Soft Brown Moist	2	SS	4						
185.7 1.5	SAND and GRAVEL Compact Brown Moist	3	SS	19						
		4	SS	22			35	60		(5)
		5	SS	16	∇					
183.4 3.8	CLAYEY SILT Soft to firm Grey Wet	6	SS	3						
181.1 6.1	Sandy SILT to SILT Loose Grey Wet	7	SS	6						
		8	SS	9						
		9	SS	6						
177.4 9.8	END OF BOREHOLE Note: 1. Water level at a depth of 3.8 m below ground surface (Elev. 183.4 m) upon completion of drilling.									



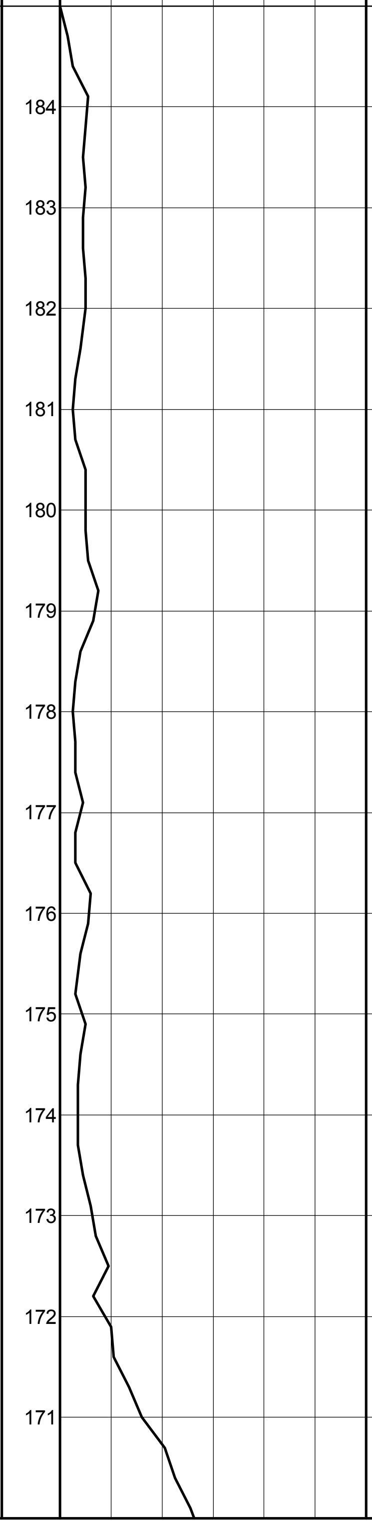
+3, ×3: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

RECORD OF PENETRATION TEST No S103-DC1

1 OF 2 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST HWY CNR
DATUM Geodetic
LOCATION N 5085505.5; E 222030.3
BOREHOLE TYPE Dynamic Cone Penetration Test
DATE December 18, 2009
ORIGINATED BY ID
COMPILED BY LG
CHECKED BY AB

SOIL PROFILE			SAMPLES			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
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
185.0	GROUND SURFACE										
0.0											



Continued Next Page

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

PROJECT 09-1111-6014

RECORD OF PENETRATION TEST No S103-DC1

2 OF 2 **METRIC**

W.P. 5344-08-00

LOCATION N 5085505.5; E 222030.3

ORIGINATED BY ID

DIST

HWY CNR

BOREHOLE TYPE Dynamic Cone Penetration Test

COMPILED BY LG

DATUM Geodetic

DATE December 18, 2009

CHECKED BY AB

SOIL PROFILE			SAMPLES			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
ELEV DEPTH	DESCRIPTION --- CONTINUED FROM PREVIOUS PAGE ---	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
169.8 15.2	END OF DCPT										

+ 3, × 3: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

SUD-MTO V2.0 09-1111-6014 BH SWAMP LOGS METRIC.GPJ GAL-MISS.GDT 18/08/11 DATA INPUT:

PROJECT 09-1111-6014

RECORD OF PENETRATION TEST No S103-DC2

1 OF 1 **METRIC**

W.P. 5344-08-00

LOCATION N 5085511.6; E 222056.5

ORIGINATED BY ID

DIST

HWY CNR

BOREHOLE TYPE Dynamic Cone Penetration Test

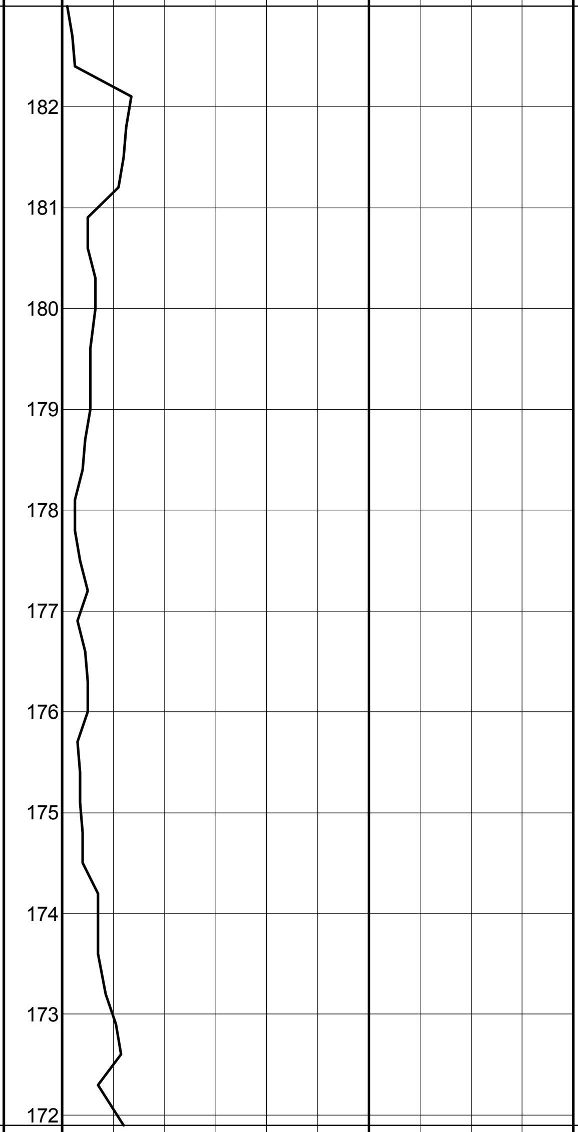
COMPILED BY LG

DATUM Geodetic

DATE December 21, 2009

CHECKED BY AB

SOIL PROFILE			SAMPLES					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
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
183.0	GROUND SURFACE										
0.0											
171.9 11.1	END OF DCPT										



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

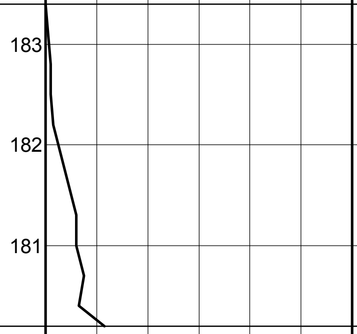
○ $^{3\%}$ STRAIN AT FAILURE

RECORD OF PENETRATION TEST No S103-DC3

1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST
HWY CNR
DATUM Geodetic
LOCATION N 5085497.9; E 222079.7
BOREHOLE TYPE Dynamic Cone Penetration Test
DATE December 22, 2009
ORIGINATED BY ID
COMPILED BY LG
CHECKED BY AB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O 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
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
183.4	GROUND SURFACE										
0.0							183 182 181				
180.2 3.2	END OF DCPT										



SUD-MTO V2.0 09-1111-6014 BH SWAMP LOGS METRIC.GPJ GAL-MISS.GDT 18/08/11 DATA INPUT:

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

O $^{3\%}$ STRAIN AT FAILURE

Table C1

Evaluation of Stability/Settlement Mitigation Options
CNR – STA 329+185 to 329+305 (Swamp 103)

Stability/Settlement Mitigation Option	Rank	Advantages	Disadvantages	Relative Costs	Risks/Consequences
Preloading (6 months with instrumentation and monitoring) (12 months without instrumentation and monitoring)	1	■ Standard construction operation. ■ May be preferred due to construction staging with Highway 69 NBL/SBL bridges. ■ Minimized post-construction settlement. ■ Smaller volume of excavation, disposal of spoil and replacement backfill.	■ Delay in construction to allow for at least 90% primary consolidation to be completed. ■ Re-grading is required to account for settlement prior to railway ballast construction.	■ Extra costs for instrumentation and monitoring program.	■ Some secondary consolidation (creep) may occur. ■ Preload duration could be better determined by instrumenting embankment and monitoring actual rate of settlement. ■ Some risk with respect to maintaining stability of fill on weak/soft foundation soils.
Full Sub-Excavation (up to 5.2 m deep)	2	■ Improved stability. ■ Reduced total settlement. ■ No delay in construction. ■ Toe berms are not required.	■ Additional effort required for sub-excavation and replacement. ■ Additional post-construction settlement of rock fill itself. ■ Generation of large volume of excess excavation spoil (could be used for slope flattening). ■ Greater quantity of rock fill required.	■ Additional costs associated with sub-excavation, disposal and replacement of weak/ soft, compressible deposits.	■ Six months preloading may be required to reduce post-construction settlement of rock fill.

Table C1
Evaluation of Stability/Settlement Mitigation Options
CNR – STA 329+185 to 329+305 (Swamp 103)

Stability/Settlement Mitigation Option	Rank	Advantages	Disadvantages	Relative Costs	Risks/Consequences
Surcharging (no instrumentation or monitoring)	3	■ Standard construction operation. ■ Reduced secondary (creep) consolidation settlement. ■ Reduced time to reach 90% primary consolidation as compared with preloading only.	■ Increased handling of fill to remove surcharge. ■ No net-gain reduction in post-construction settlement compared to preloading only.	■ Increased costs associated with construction and materials for 2 m high surcharge.	■ Some risk with respect to maintaining stability of higher (surcharged) fills on weak/soft foundation soils.
Wick Drains (with or without surcharge)	4	■ Reduce time to reach 90% primary consolidation compared with preloading and/or surcharging; aided by silt layers/seams within cohesive deposit	■ Increased time for installation of wick drains. ■ Instrumentation and monitoring program required to monitor staged construction and to assess when end of primary consolidation is reached. ■ Wick drain design required. ■ Limited extent/variable thickness of cohesive deposit not appropriate for wick drain foundation mitigation.	■ Additional costs associated wick drain design, installation and instrumentation and monitoring program.	■ Increased secondary consolidation (creep) may occur if surcharge is not applied.

Table C1
Evaluation of Stability/Settlement Mitigation Options
CNR – STA 329+185 to 329+305 (Swamp 103)

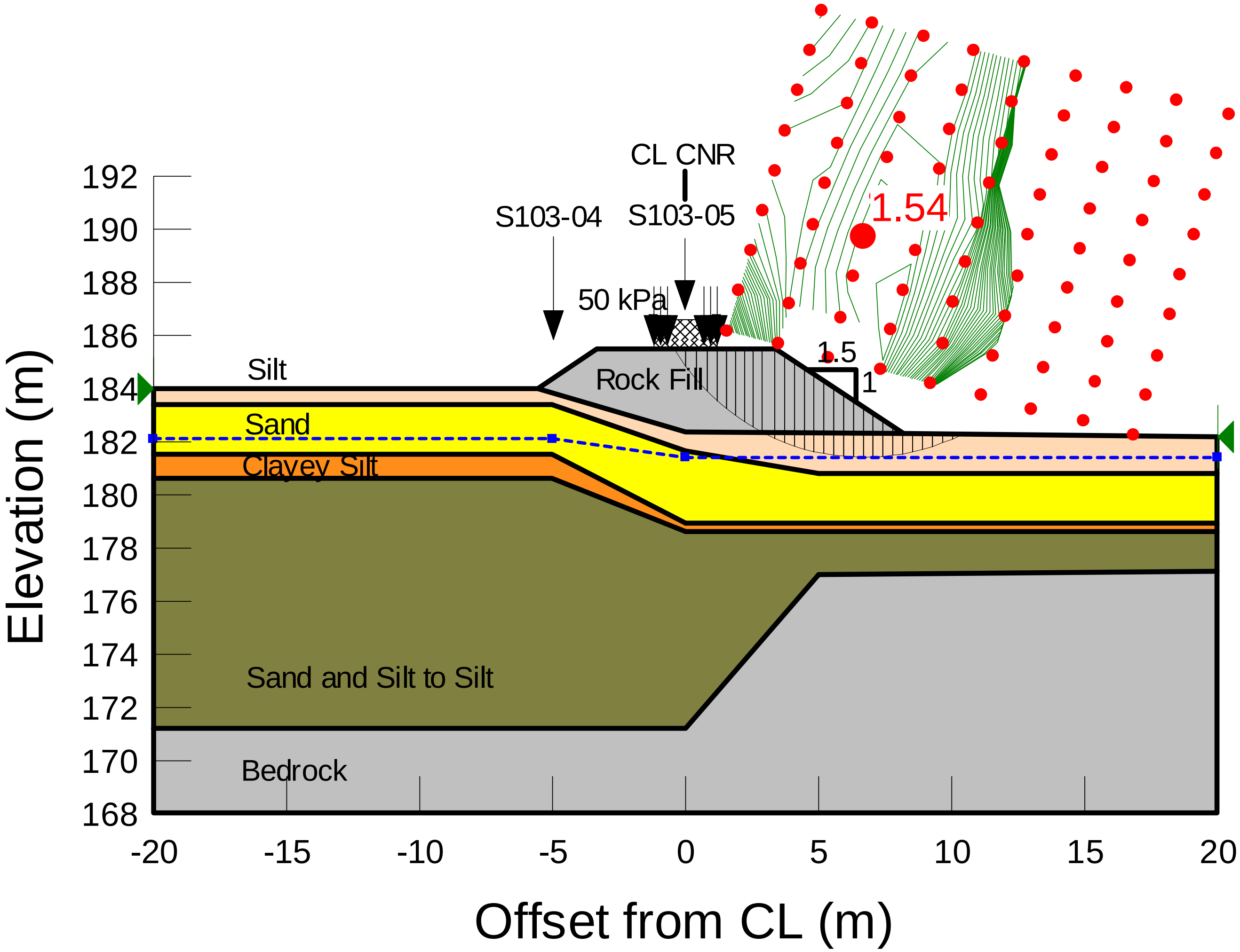
Stability/Settlement Mitigation Option	Rank	Advantages	Disadvantages	Relative Costs	Risks/Consequences
Lightweight Fill (EPS)	NF	■ Improved stability. ■ Reduced post-construction settlement. ■ No delay in construction. ■ Toe berms are not required.	■ High cost of construction materials. ■ Additional design required to assess extent of EPS practical for the embankment configuration and compressibility from train loadings.	■ Reduced costs for disposal/management of excavation spoil as compared with full sub-excavation option. ■ Relative cost of EPS fill is at least an order of magnitude higher than fill required for the other options.	■ Very low risk with respect to stability and long-term settlement of foundation soils. ■ Risk of using this technology in railway situations (may not be approved by CNR)

NF indicates that alternative has been considered but is not feasible.

Slope Stability Analysis
CNR- STA 329+210 (Swamp 103) – No Mitigation

FIGURE C1

Rock Fill	Silt	Sand	Clayey Silt	Sand and Silt to Silt
Unit Weight: 19 kN/m^3	Unit Weight: 18 kN/m^3	Unit Weight: 19 kN/m^3	Unit Weight: 15 kN/m^3	Unit Weight: 19 kN/m^3
Phi: 40˚	Phi: 28˚	Phi: 30˚	Su: 8 kPa	Phi: 28˚



DATE: August 2011

PROJECT: 09-1111-6014-1520

Golder Associates

Drawn by: LG Checked by: SEMC

Slope Stability Analysis
CNR- STA 329+235 (Swamp 103) – No Mitigation

FIGURE C2

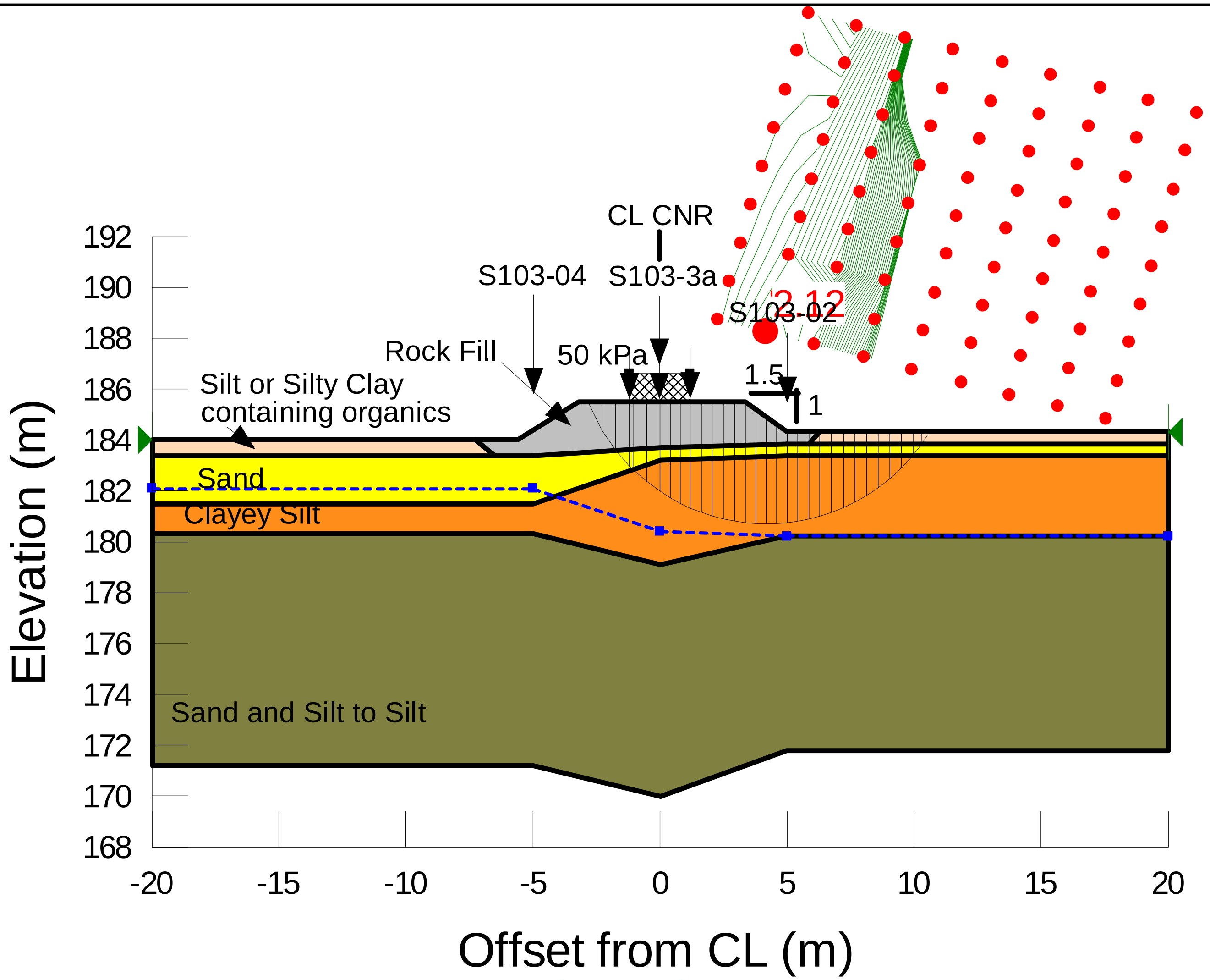
Rock Fill
Unit Weight: 19 kN/m³
Phi: 40˚

Silt or Silty Clay cont. organics
Unit Weight: 18 kN/m³
Phi: 28˚

Sand
Unit Weight: 19 kN/m³
Phi: 30˚

Clayey Silt
Unit Weight: 15 kN/m³
su(Top): 30 kPa
su(Bottom): 8 kPa

Sand and Silt to Silt
Unit Weight: 19 kN/m³
Phi: 28˚



DATE: August 2011

PROJECT: 09-1111-6014-1520

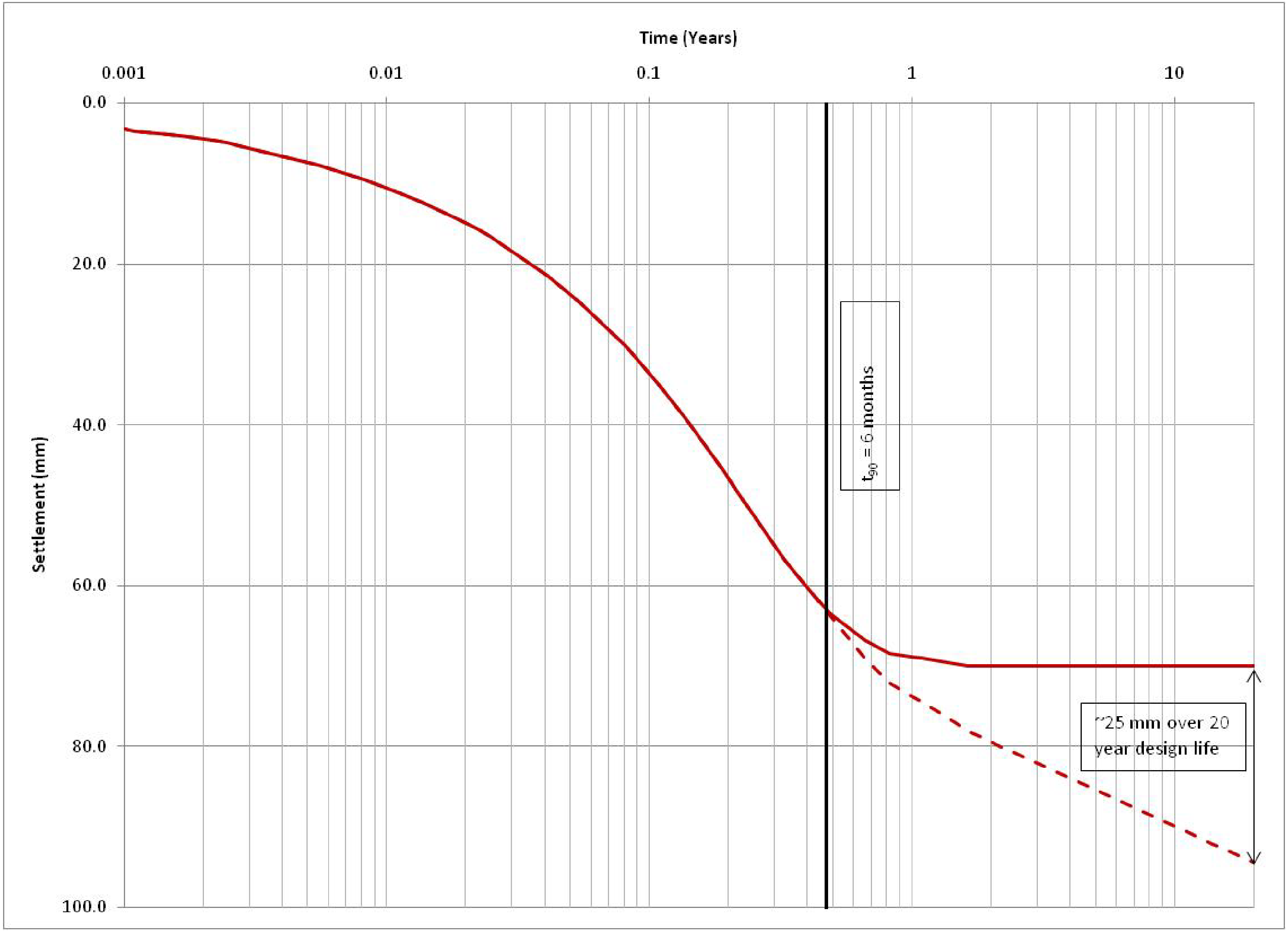
Golder Associates

Drawn by: LG

Checked by: SEMC

Estimated Consolidation Settlement vs. Log Time
Swamp 103 (STA 329+235) – No Mitigation

FIGURE C3

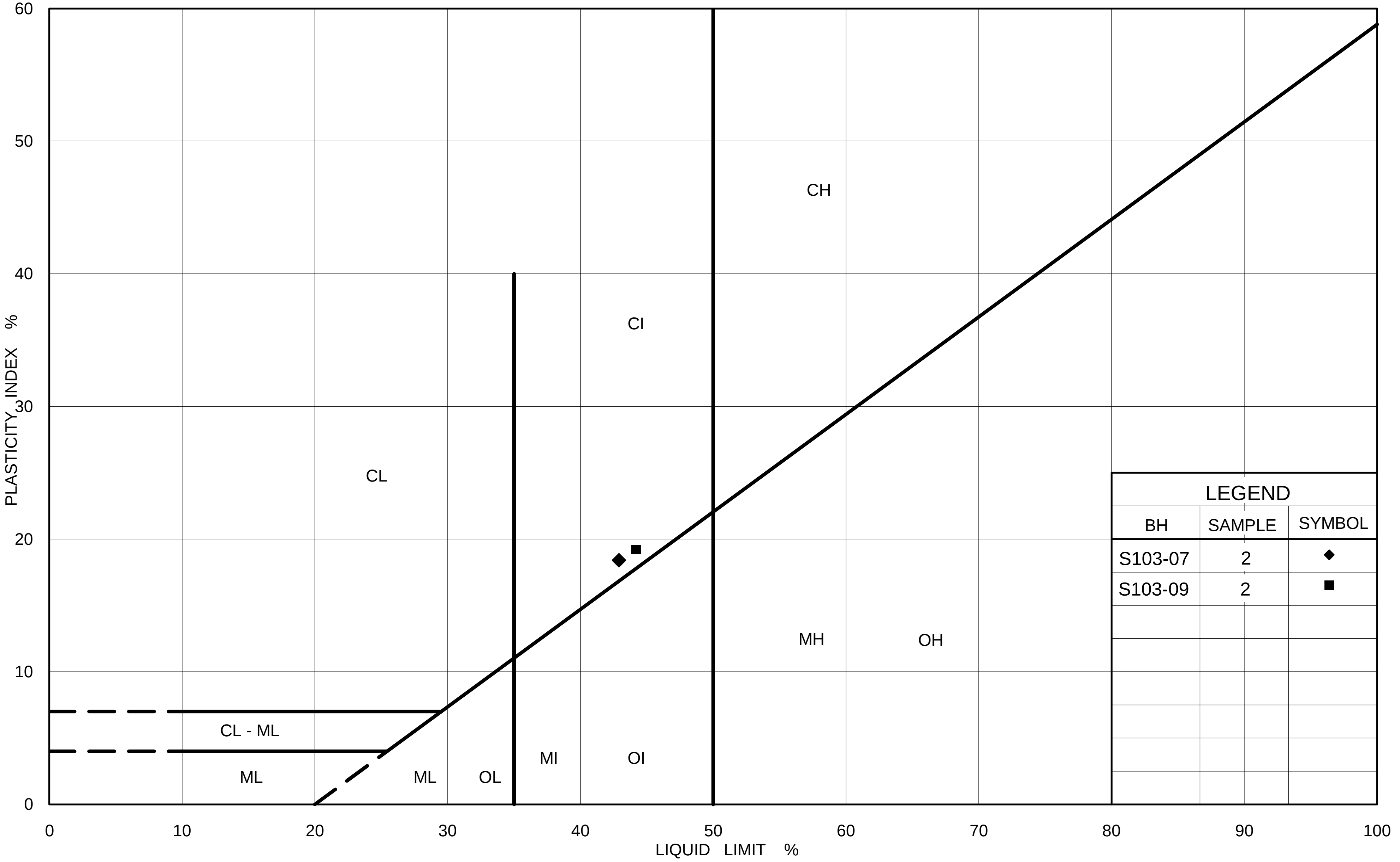


DATE: August 2011

PROJECT: 09-1111-6014-1520

Drawn by: SEMC Checked by: AB

Oct 75. FF-S-21



Ministry of Transportation
Ontario

PLASTICITY CHART
Silty Clay
CNR - STA 329+185 to STA 329+305 (Swamp 103)

Figure C.S103-01

Project No. 09-1111-6014-1520

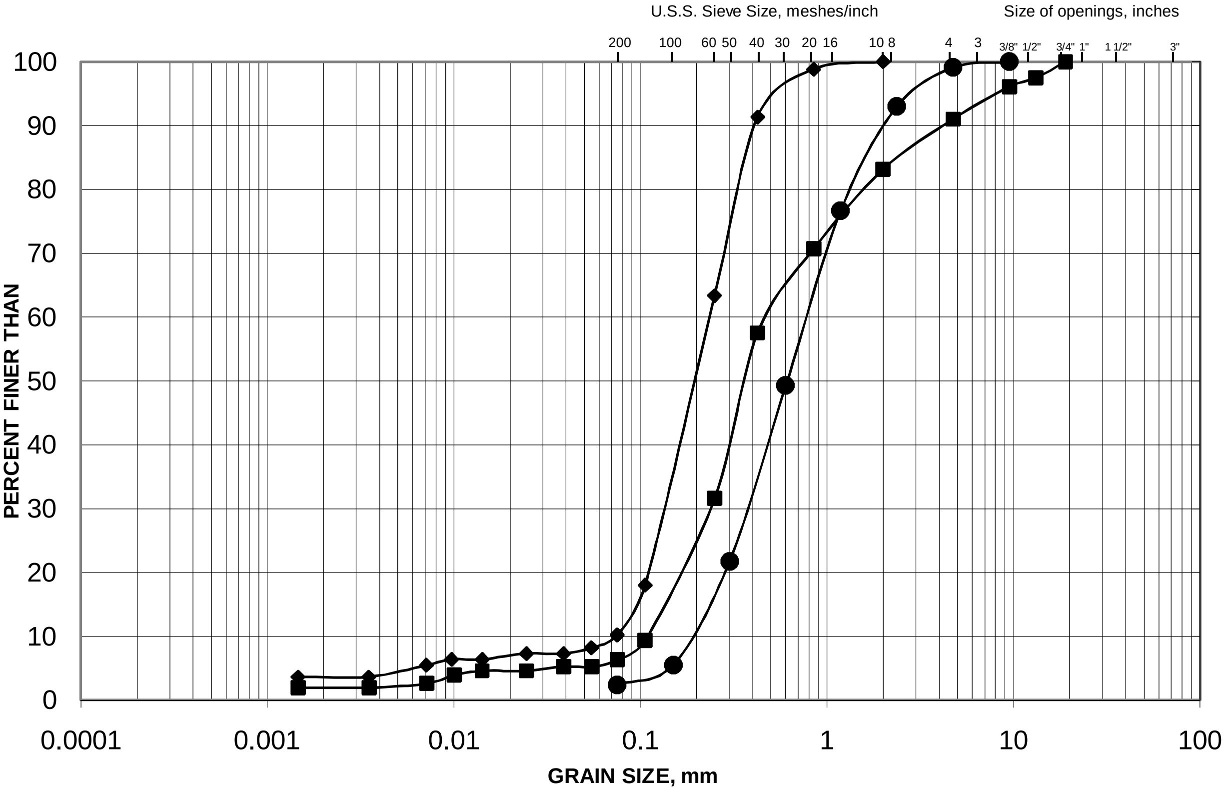
Checked By: SEMC

GRAIN SIZE DISTRIBUTION

Sand

CNR - STA 329+185 to STA 329+305 (Swamp 103)

FIGURE C.S103-02a



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
◆	S103-04	2	182.9
■	S103-05	3	180.8
●	S103-06	5	178.9

Project Number: 09-1111-6014-1520

Checked By: SEMC

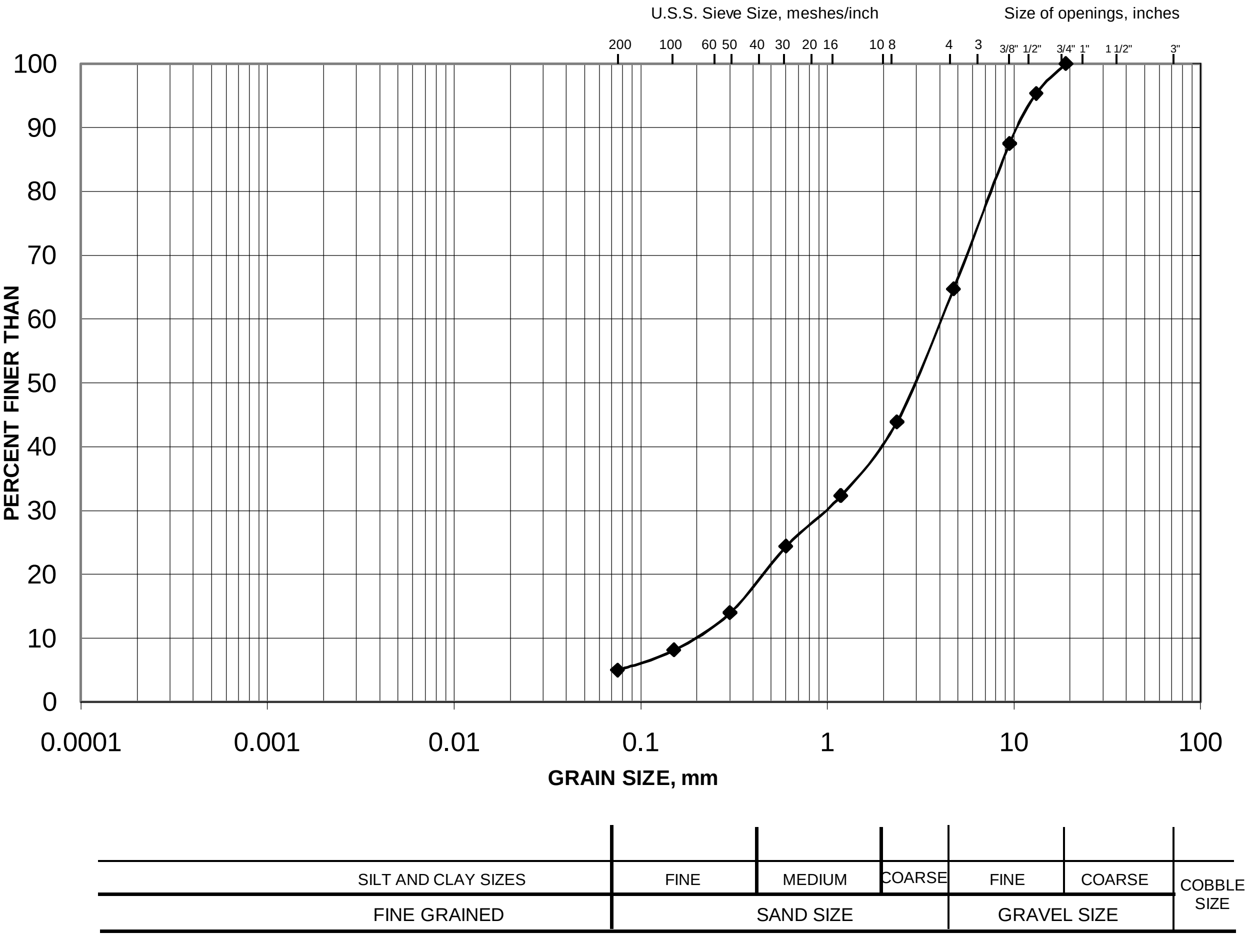
Golder Associates

Date: August 2011

GRAIN SIZE DISTRIBUTION

Sand and Gravel
CNR - STA 329+185 to STA 329+305 (Swamp 103)

FIGURE
C.S103-02b



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
—◆—	S103-09	4	184.6

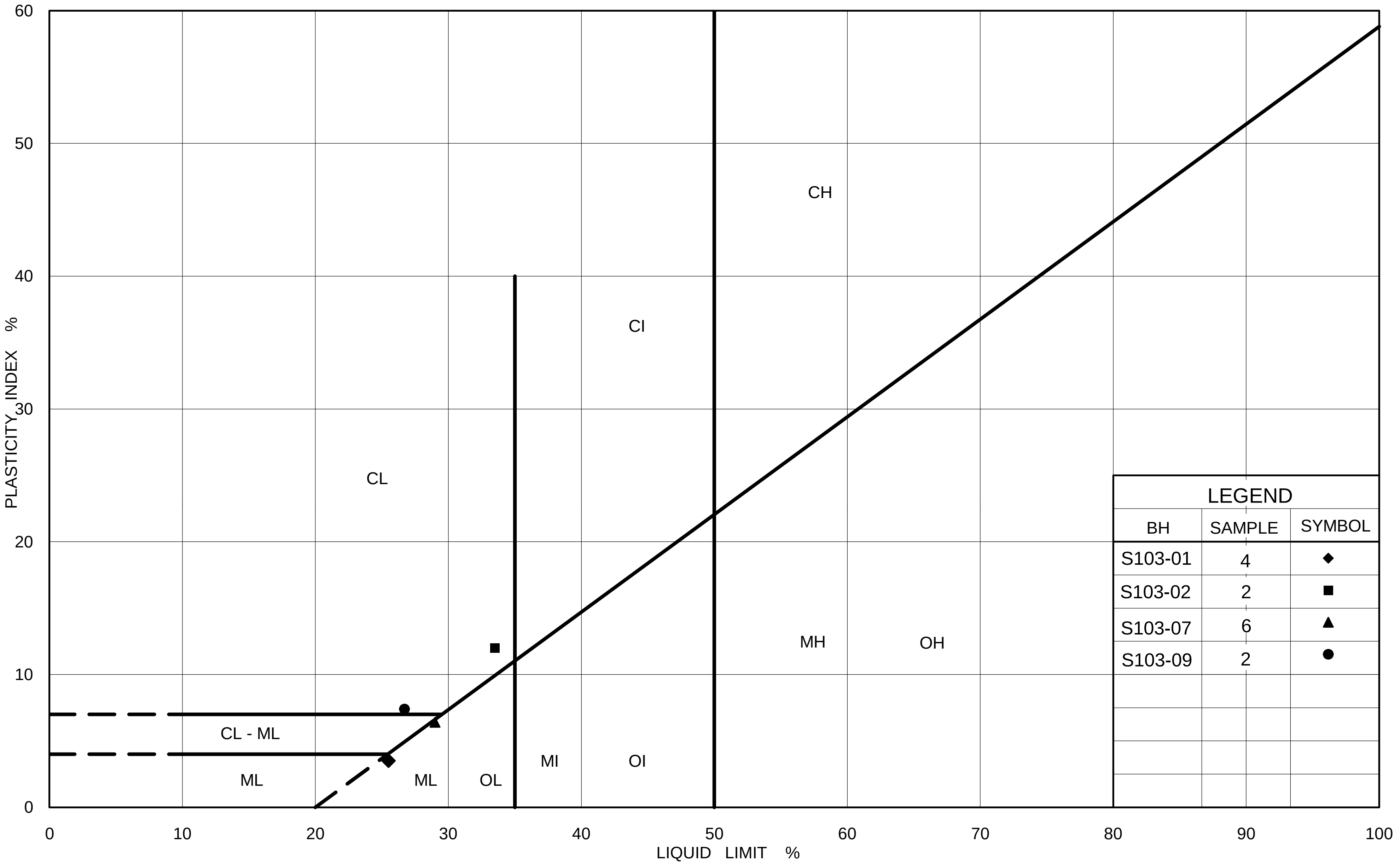
Project Number: 09-1111-6014-1520

Checked By: SEMC

Golder Associates

Date: August 2011

Oct 75, FF-S-21



BH	SAMPLE	SYMBOL
S103-01	4	◆
S103-02	2	■
S103-07	6	▲
S103-09	2	●

Ministry of Transportation
Ontario

PLASTICITY CHART
Clayey Silt
CNR - STA 329+185 to STA 329+305 (Swamp 103)

Figure C.S103-03

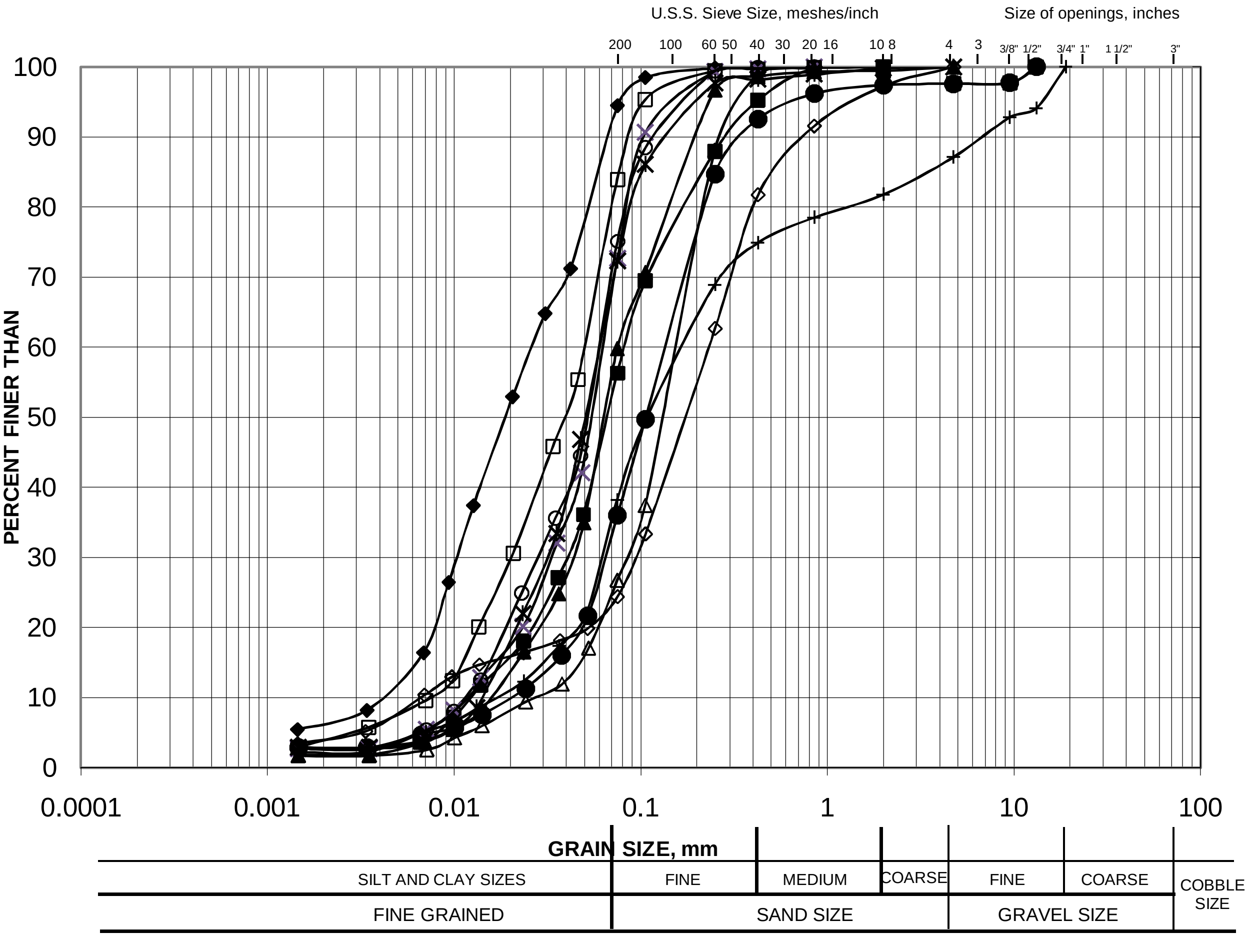
Project No. 09-1111-6014-1520

Checked By: SEMC

GRAIN SIZE DISTRIBUTION

Silty Sand to Silt
CNR - STA 329+185 to STA 329+305 (Swamp 103)

FIGURE C.S103-04



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
◆	S103-01	5	180.5
■	S103-01	8	175.9
●	S103-01	13	168.3
×	S103-02	6	178.2
▲	S103-02	9	173.6
✱	S103-03a	4	177.9
△	S103-03a	9	170.3
□	S103-04	5	179.9
◇	S103-05	7	177.7
+	S103-05	10	173.2
○	S103-07	10	175.9

Project Number: 09-1111-6014-1520

Checked By: SEMC

Golder Associates

Date: August 2011

APPENDIX D

CNR - STA 329+680 to STA 329+780 (Swamp 104)

MINISTRY OF TRANSPORTATION, ONTARIO

METRIC

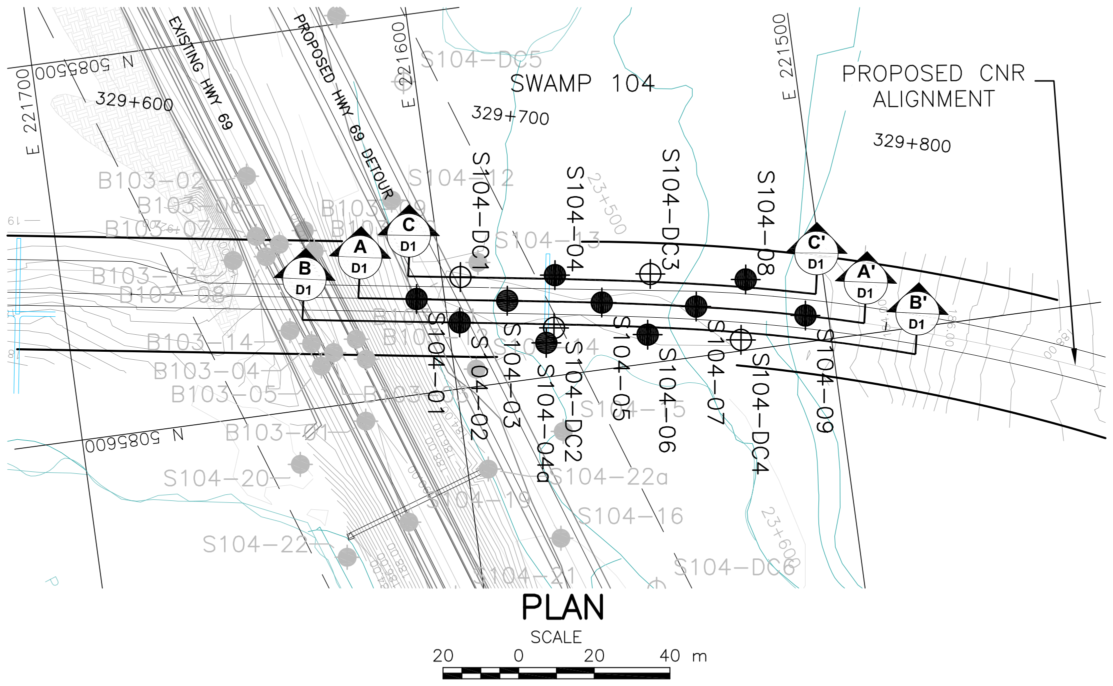
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5344-08-01

SHEET

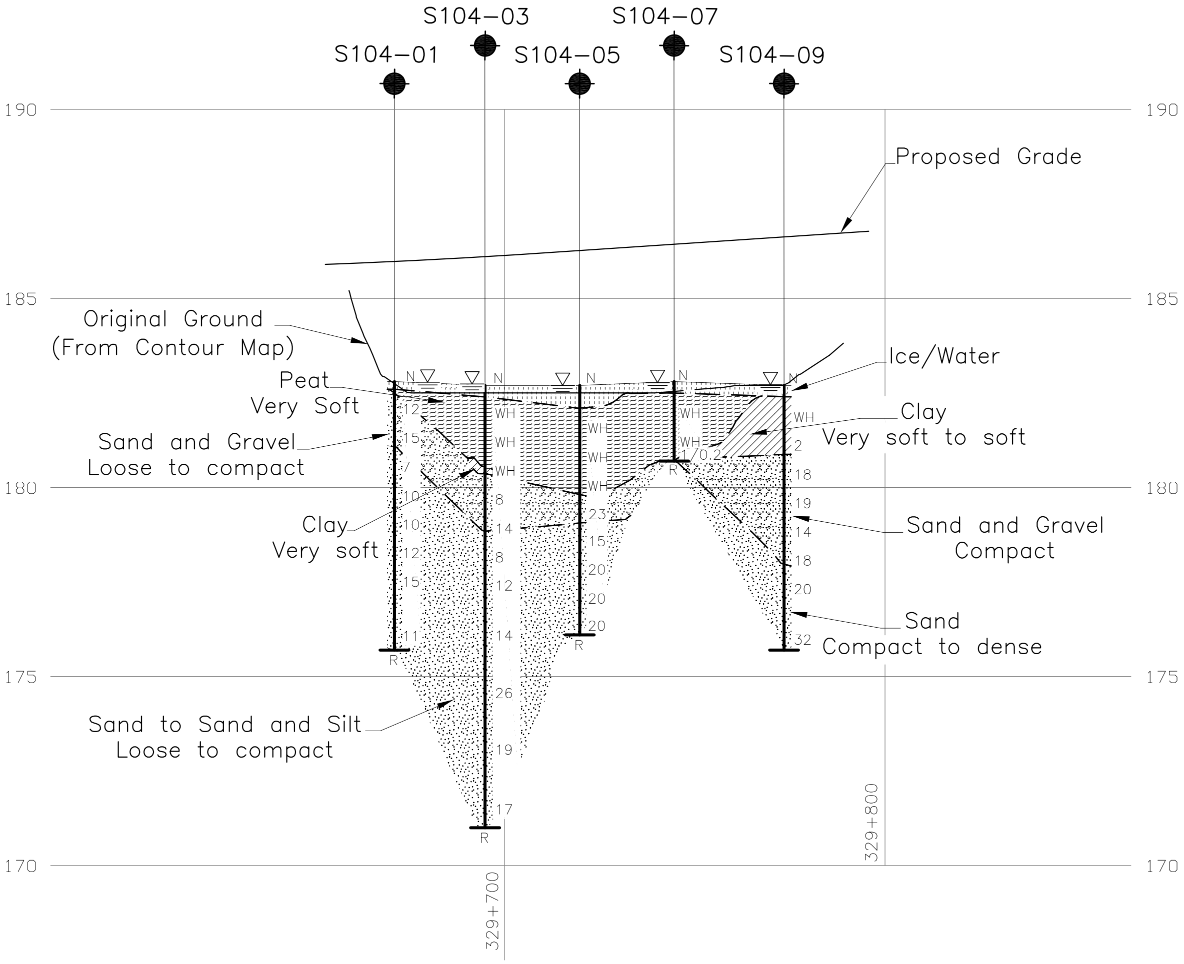
CN RAILWAY
STA 329+680 TO STA 329+780
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



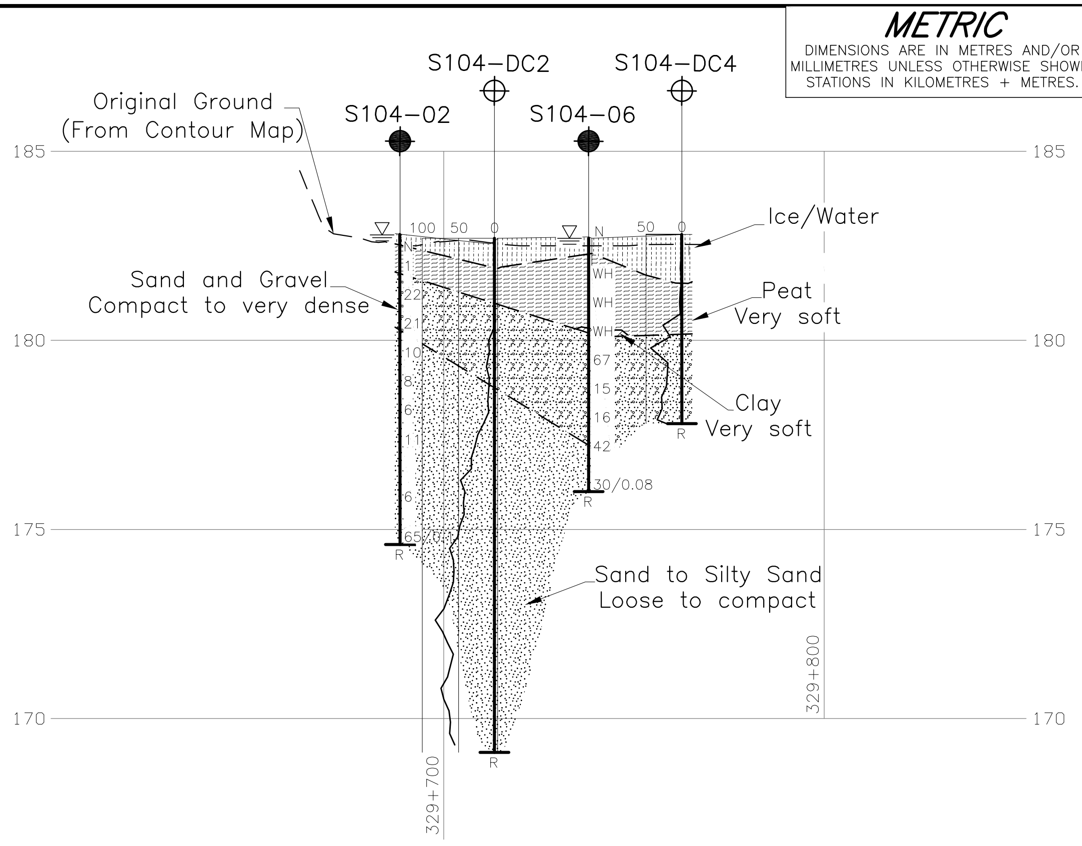
PLAN

SCALE
20 0 20 40 m



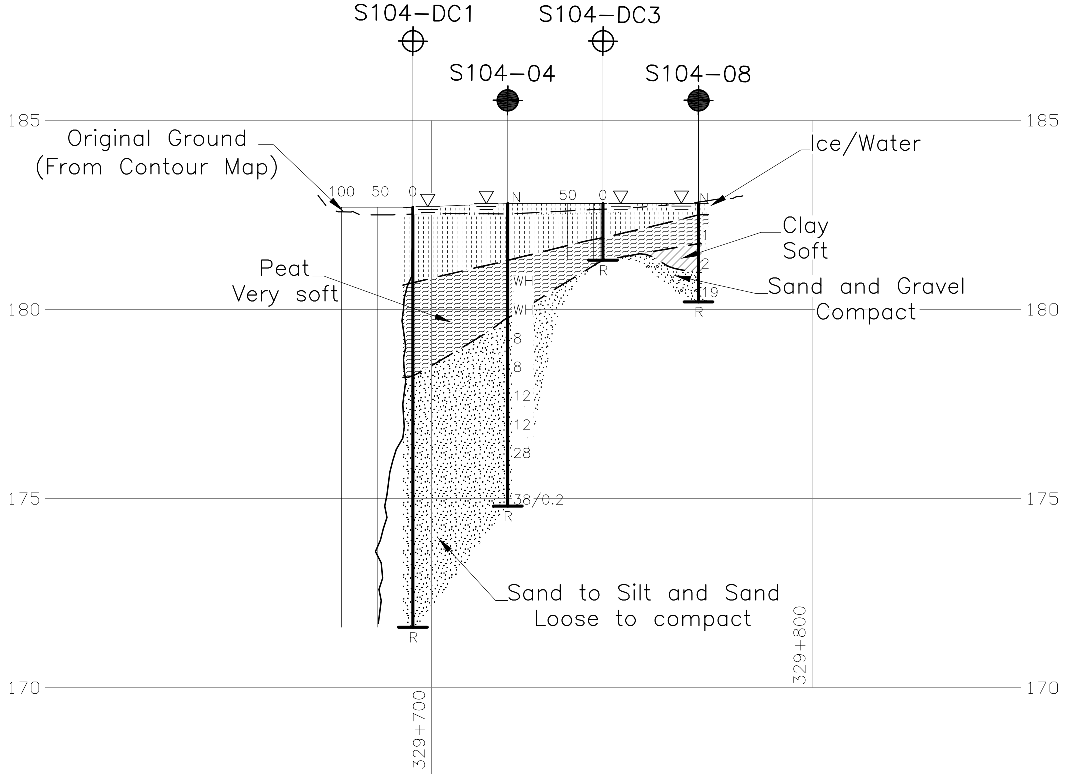
A-A' D1 CENTRELINE PROFILE

HORIZONTAL SCALE
20 0 20 40 m
2 0 2 4 m
VERTICAL SCALE



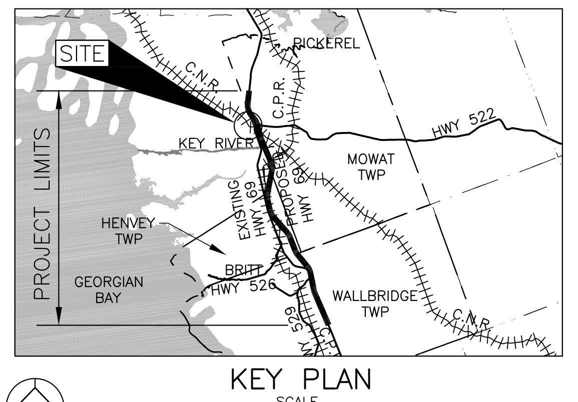
B-B' D1 EMBANKMENT TOE PROFILE

HORIZONTAL SCALE
20 0 20 40 m
2 0 2 4 m
VERTICAL SCALE



C-C' D1 EMBANKMENT TOE PROFILE

HORIZONTAL SCALE
20 0 20 40 m
2 0 2 4 m
VERTICAL SCALE



KEY PLAN

SCALE
6 0 6 12 km

LEGEND

●	Borehole
⊕	Dynamic Cone Penetration Test
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
▽	WL upon completion of drilling
R	Refusal

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
S104-01	182.8	5085575.0	221607.4
S104-02	182.8	5085582.6	221596.9
S104-03	182.7	5085578.6	221583.7
S104-04	182.8	5085573.6	221570.2
S104-04a	182.5	5085573.6	221574.9
S104-05	182.7	5085582.5	221559.0
S104-06	182.7	5085592.4	221548.0
S104-07	182.8	5085586.8	221534.4
S104-08	182.8	5085581.5	221520.4
S104-09	182.7	5085593.0	221506.0
S104-DC1	182.7	5085570.8	221595.1
S104-DC2	182.7	5085587.4	221572.4
S104-DC3	182.8	5085576.7	221545.2
S104-DC4	182.8	5085597.2	221523.8

NOTES

This drawing is for subsurface information only. The proposed site 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 URS, drawing file HWY69_plan.dwg received Feb. 17, 2010. Railroad Contours provided in digital format by URS, drawing file Railroad Contours.dwg, received Jan. 21, 2010. Key plan provided in digital format by URS, drawing file Keyplan.dwg received Apr. 16, 2010.

S.E.M. COYNE
90471921
AUG 23, 2011

J.M.A.COSTA
AUG 23, 2011

NO.	DATE	BY	REVISION

Geocres No. 41H-91

HWY. CNR		PROJECT NO. 09-1111-6014	DIST.
SUBM'D. LG	CHKD. AB	DATE: AUG 2011	SITE:
DRAWN: JJL	CHKD. SEMC	APPD. JMAC	DWG. D1

PLOT DATE: August 23, 2011
FILENAME: \\capws\sites\0911116014highway69FourLaning\Contract 1 CN Realignment\Drafting\Drawings\Swamp 104\09-1111-6014 Swamp 104.dwg

RECORD OF BOREHOLE No S104-01

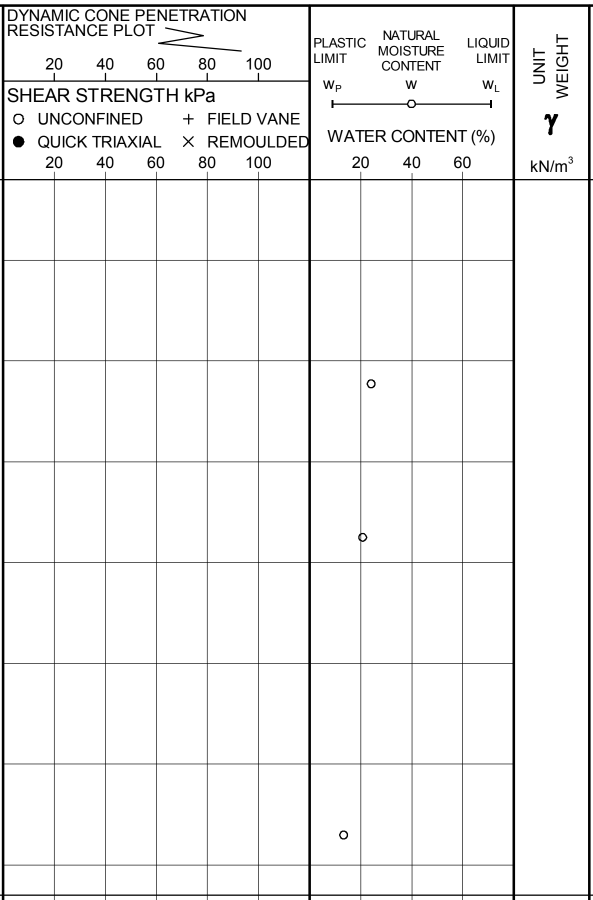
1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST ____ HWY CNR
DATUM Geodetic
LOCATION N 5085575.0; E 221607.4
BOREHOLE TYPE Portable Equipment, NW Casing, Wash Boring
DATE January 12, 2010
ORIGINATED BY ID
COMPILED BY LG
CHECKED BY AB

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	SAMPLES TYPE	"N" VALUES	GROUND WATER CONDITIONS ▽	ELEVATION SCALE	GR	SA	SI	CL
182.8	ICE SURFACE									
0.0	ICE									
	WATER									
0.3	PEAT (Fibrous) Brown Wet	1	SS	12						
	SAND and GRAVEL Compact Grey Wet					182				
		2	SS	15						
181.1 1.7	SAND to SAND and SILT Loose to compact Grey Wet					181				
		3	SS	7			0	85	(15)	
		4	SS	10		180				
		5	SS	10		179	17	63	(20)	
		6	SS	12						
		7	SS	15		178				
						177				
		8	SS	11		176	11	45	(44)	
175.7 7.1	END OF BOREHOLE CASING REFUSAL									

Note:

1. Water level at ice surface (Elev. 182.8 m) upon completion of drilling.



REMARKS & GRAIN SIZE DISTRIBUTION (%)

+³, ×³: Numbers refer to Sensitivity

○³% STRAIN AT FAILURE

RECORD OF BOREHOLE No S104-02

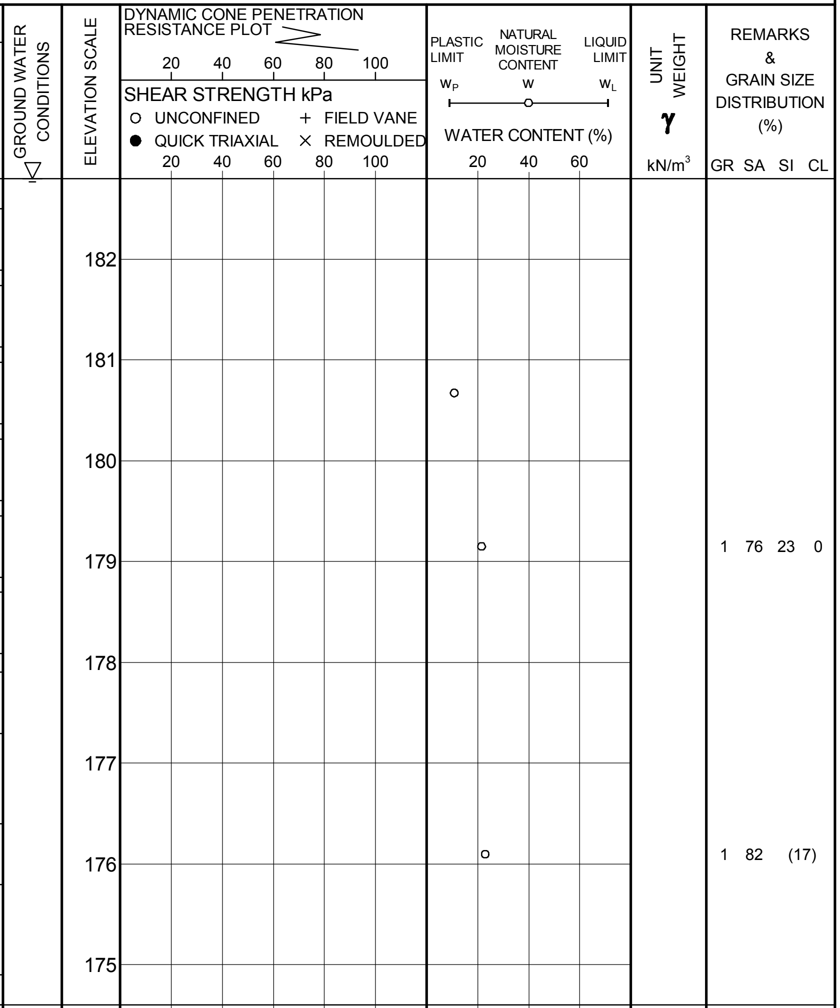
1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST ______ HWY CNR
DATUM Geodetic
LOCATION N 5085582.6; E 221596.9
BOREHOLE TYPE Portable Equipment, NW Casing, Wash Boring
DATE January 12, 2010
ORIGINATED BY ID
COMPILED BY LG
CHECKED BY AB

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
182.8	ICE SURFACE							
0.0	ICE							
	WATER							
0.3	PEAT (Fibrous) Very soft Brown Wet	1	SS	1				
181.7 1.1	SAND and GRAVEL Compact Grey Wet	2	SS	22				
		3	SS	21				
180.2 2.6	SAND to Silty SAND, trace gravel Loose to compact Grey Wet	4	SS	10				
		5	SS	8	1	76	23	0
		6	SS	6				
		7	SS	11				
		8	SS	6	1	82	(17)	
174.6		9	SS	65/0.1				
8.2	END OF BOREHOLE SPOON AND CASING REFUSAL							

Note:

1. Water level at ice surface (Elev. 182.8 m) upon completion of drilling.



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

RECORD OF BOREHOLE No S104-03

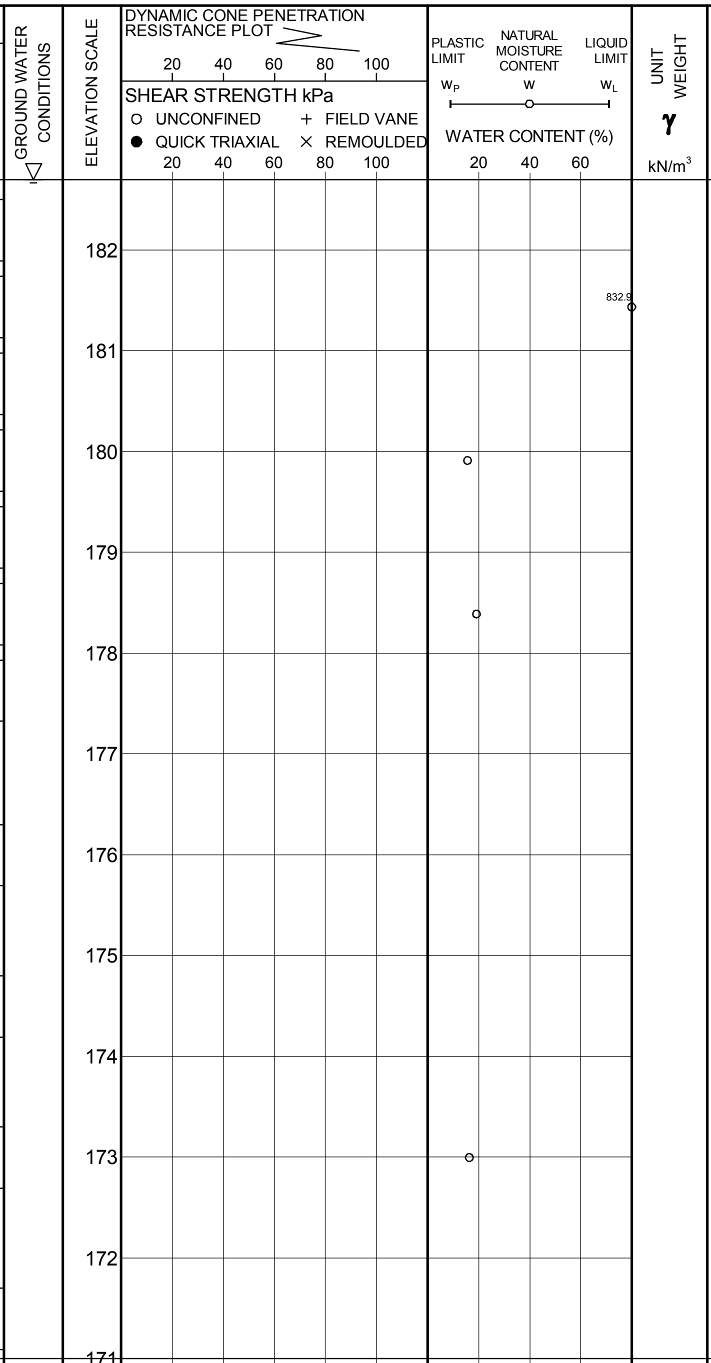
1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST
HWY CNR
DATUM Geodetic
LOCATION N 5085578.6; E 221583.7
BOREHOLE TYPE Portable Equipment, NW Casing, Wash Boring
DATE January 13, 2010
ORIGINATED BY ID
COMPILED BY LG
CHECKED BY AB

ELEV DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLES – NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
182.7	ICE SURFACE							
0.0	ICE							
	WATER							
0.3	PEAT (Amorphous) Very soft Brown Wet	1	SS	WH				
		2	SS	WH				
		3	SS	WH				
180.5	CLAY Grey Wet							
2.3	SAND and GRAVEL Loose to compact Grey Wet	4	SS	8	34	58	(8)	
		5	SS	14				
178.8 3.9	SAND, trace to some gravel, trace silt Loose to compact Grey Wet	6	SS	8	4	93	(3)	
		7	SS	12				
		8	SS	14				
		9	SS	26				
		10	SS	19	9	88	(3)	
		11	SS	17				
171.0 11.7	END OF BOREHOLE CASING REFUSAL							

Note:

1. Water level at ice surface (Elev. 182.7 m) upon completion of drilling.



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

RECORD OF BOREHOLE No S104-04

1 OF 1 **METRIC**

PROJECT 09-1111-6014

W.P. 5344-08-00

DIST

HWY CNR

DATUM Geodetic

LOCATION N 5085573.6; E 221570.2

BOREHOLE TYPE Portable Equipment, NW Casing, Wash Boring

DATE January 14, 2010

ORIGINATED BY ID

COMPILED BY LG

CHECKED BY AB

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
182.8	ICE SURFACE
0.0	ICE
182.5 0.3	WATER
181.3 1.5	PEAT (Fibrous) Very soft Brown Wet
179.8 3.0	SAND to SAND and SILT, trace gravel, trace clay Loose to compact Grey Wet Sand and Gravel layer 200 mm thick at 3.8 m depth.
174.8 8.0	END OF BOREHOLE SPOON AND CASING REFUSAL Note: 1. Water level at ice surface (Elev. 182.8 m) upon completion of drilling.

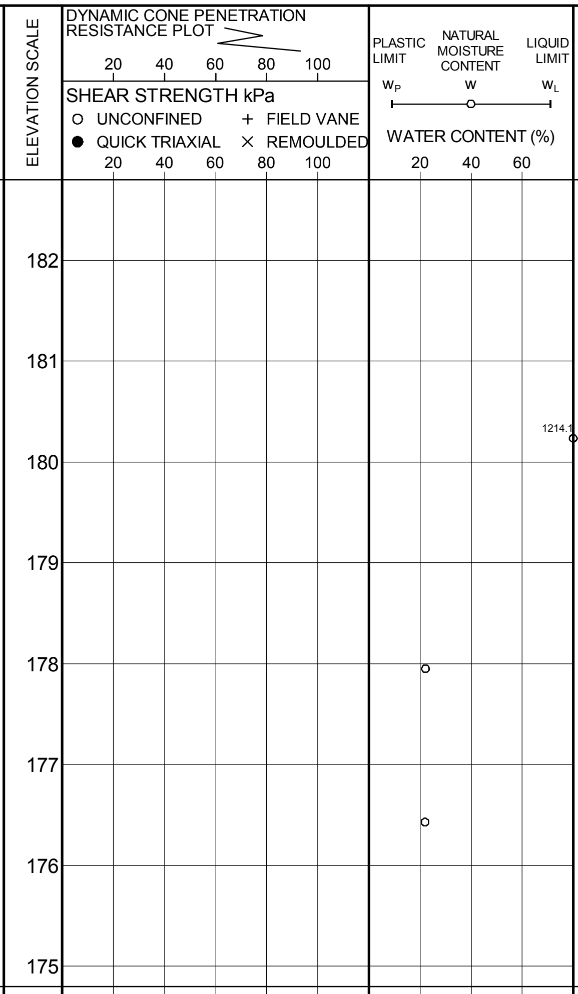
SAMPLES

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1	SS	WH				
2	SS	WH				
3	SS	8				
4	SS	8				
5	SS	12	1	50	47	2
6	SS	12				
7	SS	28	0	87	(13)	
8	SS	38/0.2				

GROUND WATER CONDITIONS ▽

UNIT WEIGHT γ kN/m^3

REMARKS & GRAIN SIZE DISTRIBUTION (%)



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

$\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No S104-04a

1 OF 1 **METRIC**

PROJECT 09-1111-6014			
W.P. 5344-08-00	LOCATION N 5085591.0; E 221574.9		ORIGINATED BY ID
DIST	HWY CNR	BOREHOLE TYPE Portable Equipment, BW Casing, Wash Boring	COMPILED BY LG
DATUM Geodetic		DATE August 20, 2010	CHECKED BY AB

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
182.5	WATER SURFACE
182.2 0.0	WATER
0.3	PEAT (Fibrous) Very soft Brown Wet
180.5 2.2	PEAT (Amorphous), some clay Very soft Grey Wet
	SAND and GRAVEL Compact to dense Grey Wet
177.9 4.6	SAND, trace to some silt, trace gravel Compact Grey Wet
172.3 10.2	END OF BOREHOLE CASING REFUSAL

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	WH				
2	SS	WH				
3	SS	WH				
4	SS	21				
5	SS	32				
6	SS	29				
7	SS	14	1	79	(20)	
8	SS	14				
9	SS	16				
10	SS	26	0	93	(7)	

STRAT PLOT

GROUND WATER CONDITIONS

ELEVATION SCALE

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

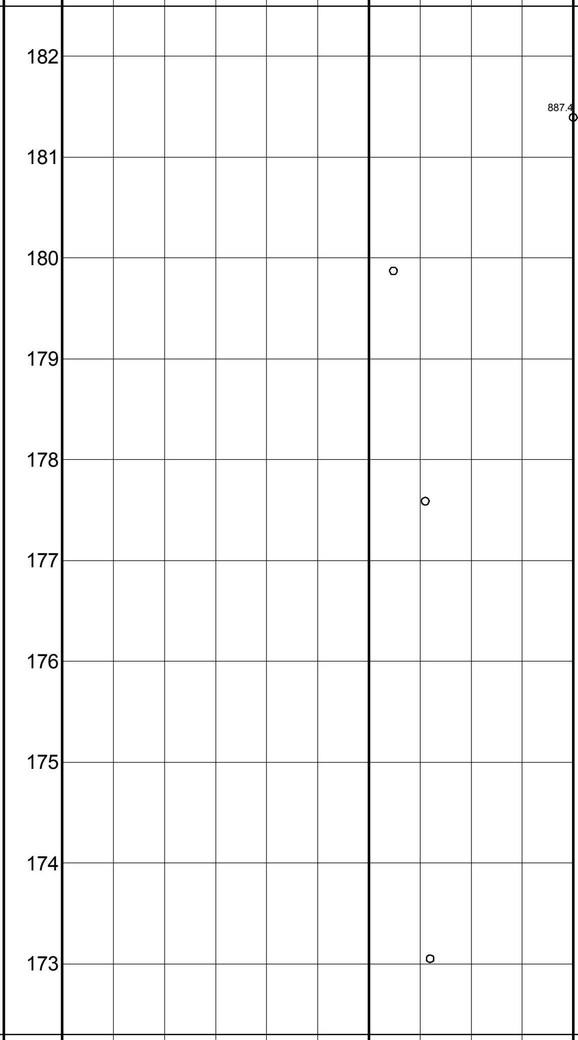
SHEAR STRENGTH kPa
- ○ UNCONFINED
- + FIELD VANE
- ● QUICK TRIAXIAL
- × REMOULDED

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

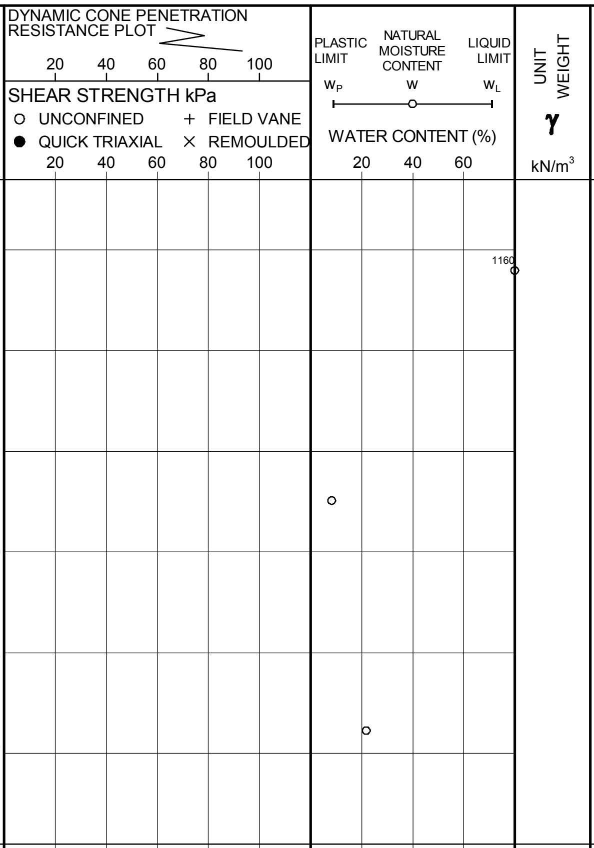
Golder Associates

RECORD OF BOREHOLE No S104-05

1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
LOCATION N 5085582.5; E 221559.0
ORIGINATED BY ID
DIST
HWY CNR
BOREHOLE TYPE Portable Equipment, NW Casing, Wash Boring
COMPILED BY LG
DATUM Geodetic
DATE January 14, 2010
CHECKED BY AB

SOIL PROFILE			SAMPLES					REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	GR	SA	SI	CL
182.7	ICE SURFACE					∇					
0.0	ICE										
	WATER										
182.1 0.6	PEAT (Fibrous) Very soft Brown Wet		1	SS	WH		182				
			2	SS	WH		181				
180.6 2.1	PEAT (Amorphous) Very soft Brown Wet		3	SS	WH		180				
179.8 2.9	SAND and GRAVEL Compact Grey Wet		4	SS	23						
179.1 3.6	SAND, trace gravel, trace silt Compact Grey Wet		5	SS	15		179				
			6	SS	20		178				
			7	SS	20		177	2	94	(4)	
			8	SS	20						
176.1 6.6	END OF BOREHOLE CASING REFUSAL Note: 1. Water level at ice surface (Elev. 182.7 m) upon completion of drilling.										



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

RECORD OF BOREHOLE No S104-06

1 OF 1 **METRIC**

PROJECT 09-1111-6014

W.P. 5344-08-00

DIST HWY CNR

DATUM Geodetic

LOCATION N 5085592.4; E 221548.0

BOREHOLE TYPE Portable Equipment, NW Casing, Wash Boring

DATE January 15, 2010

ORIGINATED BY ID

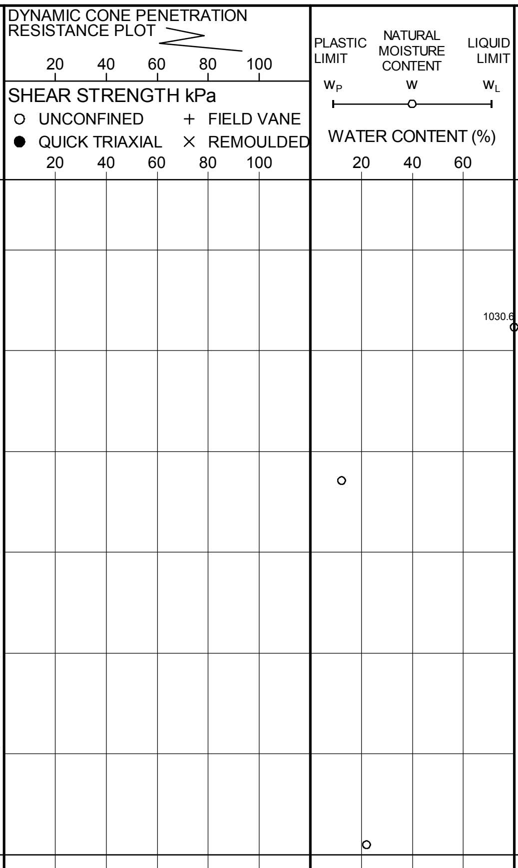
COMPILED BY LG

CHECKED BY AB

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
182.7	ICE SURFACE									
0.0	ICE									
	WATER									
0.4	PEAT (Fibrous) Very soft Brown Wet	1	SS	WH	182					
		2	SS	WH	181	1030.6				
180.8 1.9	PEAT (Amorphous) Very soft Brown Wet	3	SS	WH						
180.3 2.5	CLAY Brown Wet				180					
	SAND and GRAVEL, trace silt Compact to very dense Grey Wet	4	SS	67			45	52	(3)	
		5	SS	15	179					
		6	SS	16	178					
		7	SS	42						
177.2 5.5	SAND, trace gravel, trace silt Compact Grey Wet				177					
176.0		8	SS	30/0.08	176		3	94	(3)	
6.7	END OF BOREHOLE SPOON AND CASING REFUSAL									

Note:

1. Water level at ice surface (Elev. 182.7 m) upon completion of drilling.



GROUND WATER CONDITIONS ▽

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

+³, ×³: Numbers refer to Sensitivity

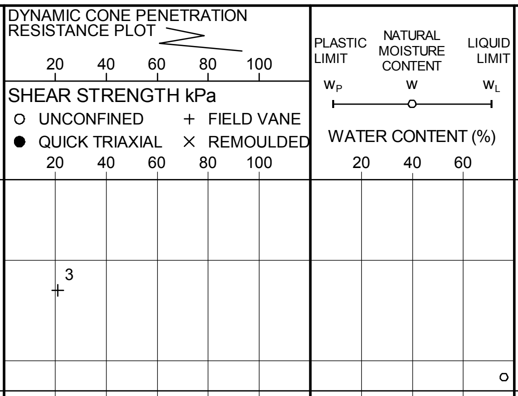
○³% STRAIN AT FAILURE

RECORD OF BOREHOLE No S104-07

1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST
HWY CNR
DATUM Geodetic
LOCATION N 5085586.8; E 221534.4
BOREHOLE TYPE Portable Equipment, NW Casing, Wash Boring
DATE January 18, 2010
ORIGINATED BY ID
COMPILED BY LG
CHECKED BY AB

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
182.8	ICE SURFACE					▽			
0.0	ICE								
	WATER								
0.3	PEAT (Fibrous) Very soft Brown Wet		1	SS	WH		182		
			2	SS	WH				
181.0							181		
180.7 2.1	PEAT (Amorphous), some silt, some clay Very soft Grey to brown Wet		3	SS	1/0.2				
	END OF BOREHOLE SPOON REFUSAL (HAMMER BOUNCING)								



Note:

1. Water level at ice surface (Elev. 182.8 m) upon completion of drilling.

2. Moved 1 m south, refusal at 2.1 m depth, moved 1 m west, refusal at 2.1 m depth.

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

$\bigcirc^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No S104-08

1 OF 1 **METRIC**

PROJECT 09-1111-6014

W.P. 5344-08-00

DIST

HWY CNR

DATUM Geodetic

LOCATION N 5085581.5; E 221520.4

BOREHOLE TYPE Portable Equipment, NW Casing, Wash Boring

DATE January 18, 2010

ORIGINATED BY ID

COMPILED BY LG

CHECKED BY AB

SOIL PROFILE			SAMPLES			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/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
182.8	ICE SURFACE					∇					
0.0	ICE										
	WATER										
0.3	PEAT (Fibrous) Very soft Brown Wet		1	SS	1		182				
181.7 1.1	CLAY, some organics Soft Grey Wet		2	SS	2			+ 3			
181.0 1.8	SAND and GRAVEL, trace silt Compact Grey Wet		3	SS	19		181		○		37 55 (8)
180.2 2.6	END OF BOREHOLE CASING REFUSAL										

Note:

1. Water level at ice surface (Elev. 182.8 m) upon completion of drilling.

2. Moved 1 m southeast to advance one field vane as recorded above.

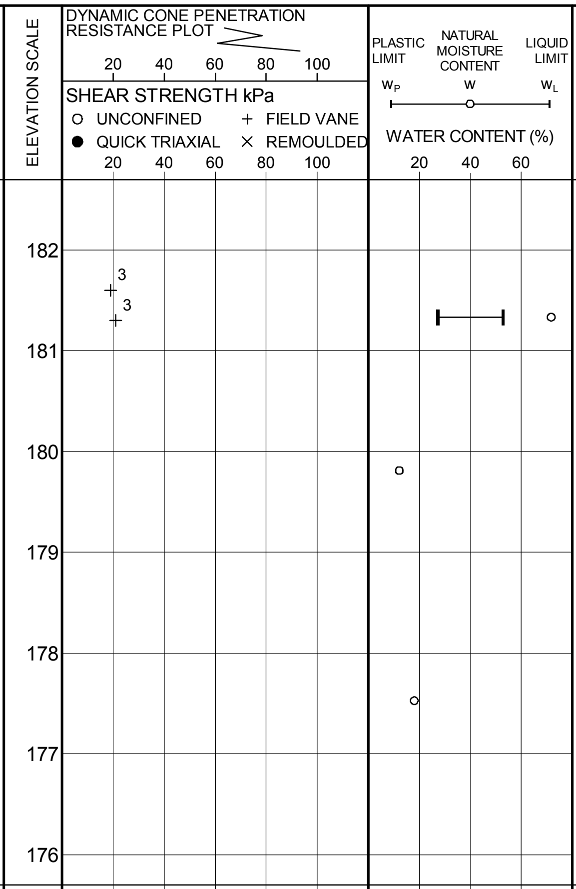
$+^3$, $\times^3$: Numbers refer to Sensitivity ○ $^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No S104-09

1 OF 1 **METRIC**

PROJECT	09-1111-6014				
W.P.	5344-08-00	LOCATION	N 5085593.0; E 221506.0	ORIGINATED BY	ID
DIST	HWY CNR	BOREHOLE TYPE	Portable Equipment, NW Casing, Wash Boring	COMPILED BY	LG
DATUM	Geodetic	DATE	January 19, 2010	CHECKED BY	AB

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	SAMPLES TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
182.7	ICE SURFACE				▽					
0.0	ICE									
	WATER									
0.3	CLAY, trace organics Soft Grey Wet	1	SS	WH						
		2	SS	2						
180.9 1.8	SAND and GRAVEL, trace silt Compact Grey Wet	3	SS	18						
		4	SS	19			39	57	(4)	
		5	SS	14						
		6	SS	18						
178.0 4.7	SAND, trace gravel, trace silt Compact to dense Brown Wet	7	SS	20			4	94	(2)	
		8	SS	32						
175.7 7.0	END OF BOREHOLE									



Note:

1. Water level at ice surface (Elev. 182.7 m) upon completion of drilling.

2. Moved 1 m northeast to advance two vanes as recorded above.

+3, ×3: Numbers refer to Sensitivity

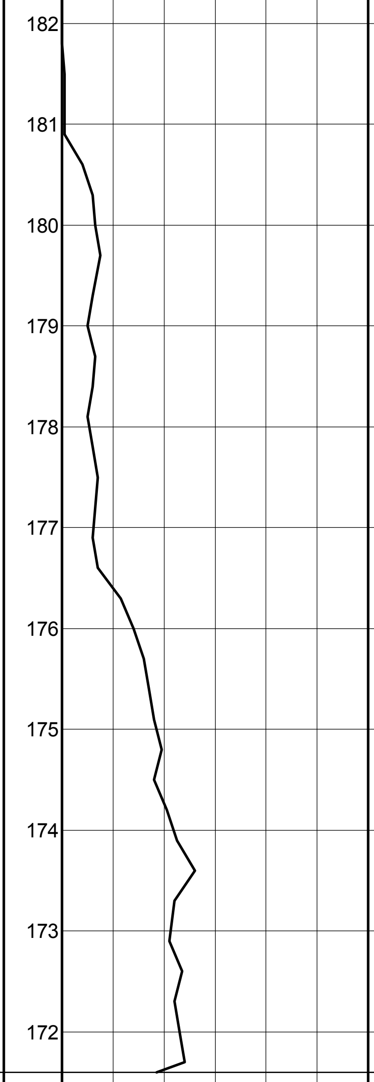
○3% STRAIN AT FAILURE

RECORD OF PENETRATION TEST No S104-DC1

1 OF 1 **METRIC**

PROJECT	09-1111-6014		
W.P.	5344-08-00	LOCATION	N 5085570.8; E 221595.1
DIST		HWY	CNR
BOREHOLE TYPE	Dynamic Cone Penetration Test		
DATUM	Geodetic	DATE	January 11, 2010
ORIGINATED BY	ID	COMPILED BY	LG
CHECKED BY	AB		

SOIL PROFILE			SAMPLES								
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 O 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
182.7	ICE SURFACE										
0.0	ICE										
182.1 0.6	WATER										
171.6 11.1	END OF DCPT REFUSAL TO FURTHER PENETRATION (HAMMER BOUNCING)										



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

RECORD OF PENETRATION TEST No S104-DC2

1 OF 1 **METRIC**

PROJECT 09-1111-6014

W.P. 5344-08-00

DIST

HWY CNR

DATUM Geodetic

LOCATION N 5085587.4; E 221572.4

BOREHOLE TYPE Dynamic Cone Penetration Test

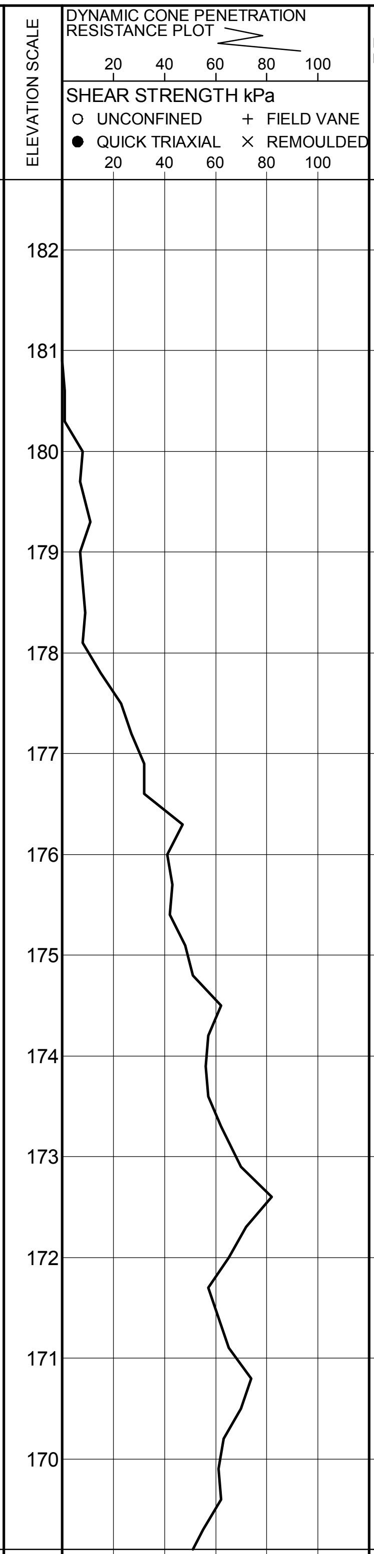
DATE January 11, 2010

ORIGINATED BY ID

COMPILED BY LG

CHECKED BY AB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
182.7	ICE SURFACE										
0.0	ICE										
0.2	WATER										
182.0 0.7											
169.1 13.6	END OF DCPT REFUSAL TO FURTHER PENETRATION (HAMMER BOUNCING)										



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

$O^{3\%}$ STRAIN AT FAILURE

Golder Associates

Foundation Design

RECORD OF PENETRATION TEST No S104-DC3

1 OF 1 **METRIC**

PROJECT 09-1111-6014

W.P. 5344-08-00

DIST ______ HWY CNR

DATUM Geodetic

LOCATION N 5085576.7; E 221545.2

BOREHOLE TYPE Dynamic Cone Penetration Test

DATE January 18, 2010

ORIGINATED BY ID

COMPILED BY LG

CHECKED BY AB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O 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
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
182.8	ICE SURFACE										
0.0 0.3	WATER										
							182				
181.3 1.5	END OF DCPT REFUSAL TO FURTHER PENETRATION (HAMMER BOUNCING)										

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

O $^{3\%}$ STRAIN AT FAILURE

SUD-MTO V2.0 09-1111-6014 BH SWAMP LOGS METRIC.GPJ GAL-MISS.GDT 18/08/11 DATA INPUT:

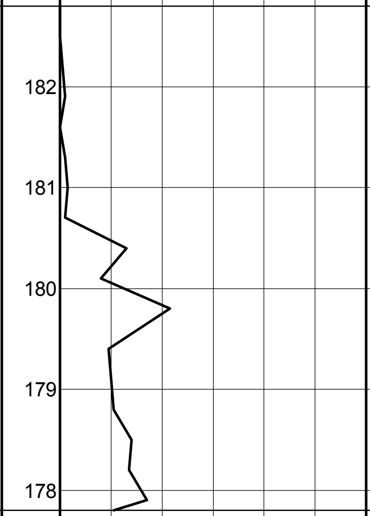
PROJECT 09-1111-6014

RECORD OF PENETRATION TEST No S104-DC4

1 OF 1 **METRIC**

W.P. 5344-08-00
LOCATION N 5085597.2; E 221523.8
ORIGINATED BY ID
DIST
HWY CNR
BOREHOLE TYPE Dynamic Cone Penetration Test
COMPILED BY LG
DATUM Geodetic
DATE January 15, 2010
CHECKED BY AB

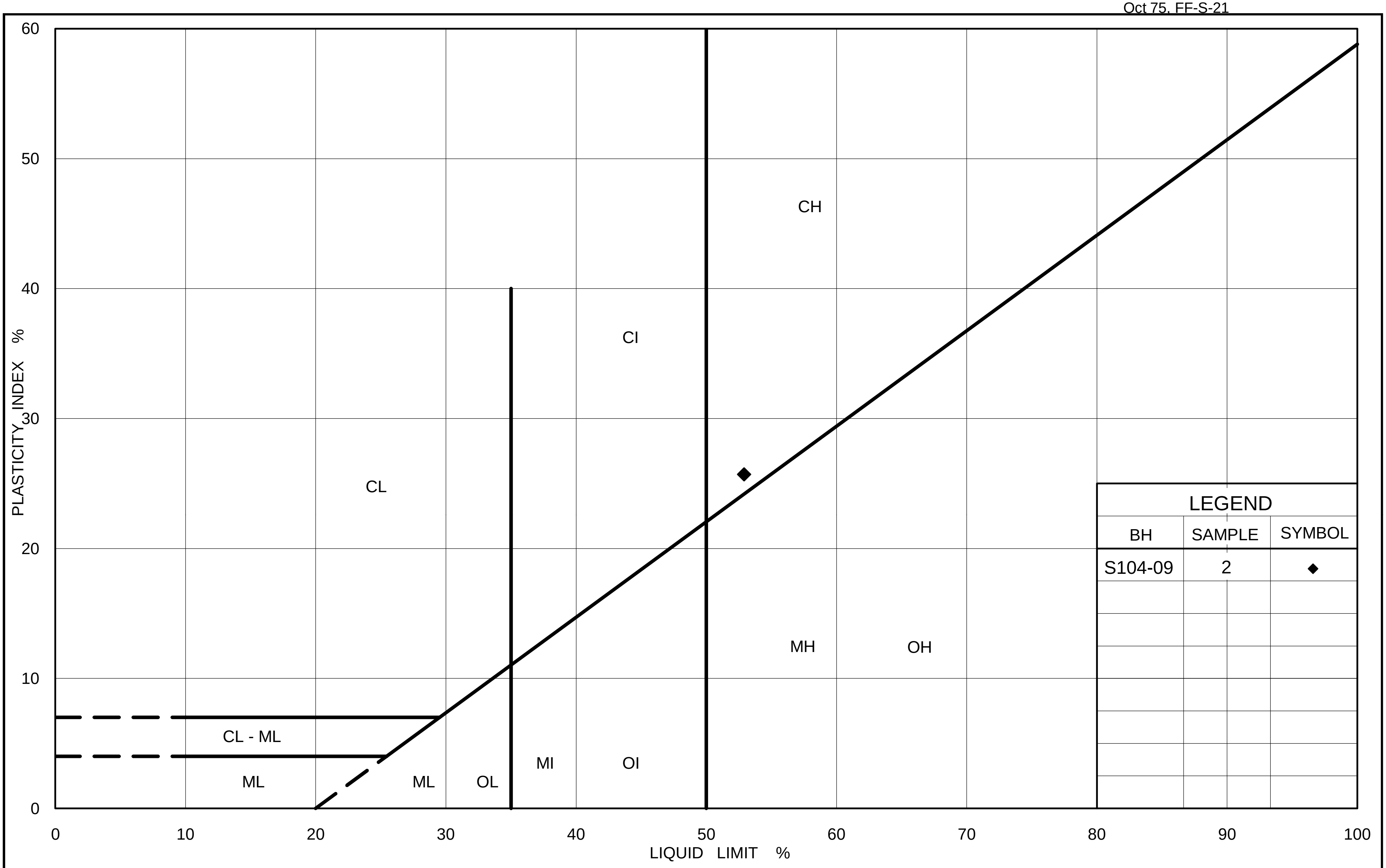
SOIL PROFILE			SAMPLES								
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100	PLASTIC LIMIT W_P NATURAL 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
182.8	ICE SURFACE										
0.0	ICE										
182.5 0.3											
177.8 5.0	END OF DCPT REFUSAL TO FURTHER PENETRATION (HAMMER BOUNCING)										



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

$\circ^{3\%}$ STRAIN AT FAILURE

Oct 75, FF-S-21



Ministry of Transportation

Ontario

PLASTICITY CHART
Clay
CNR - STA 329+680 to STA 329+780 (Swamp 104)

Figure D.S104-01

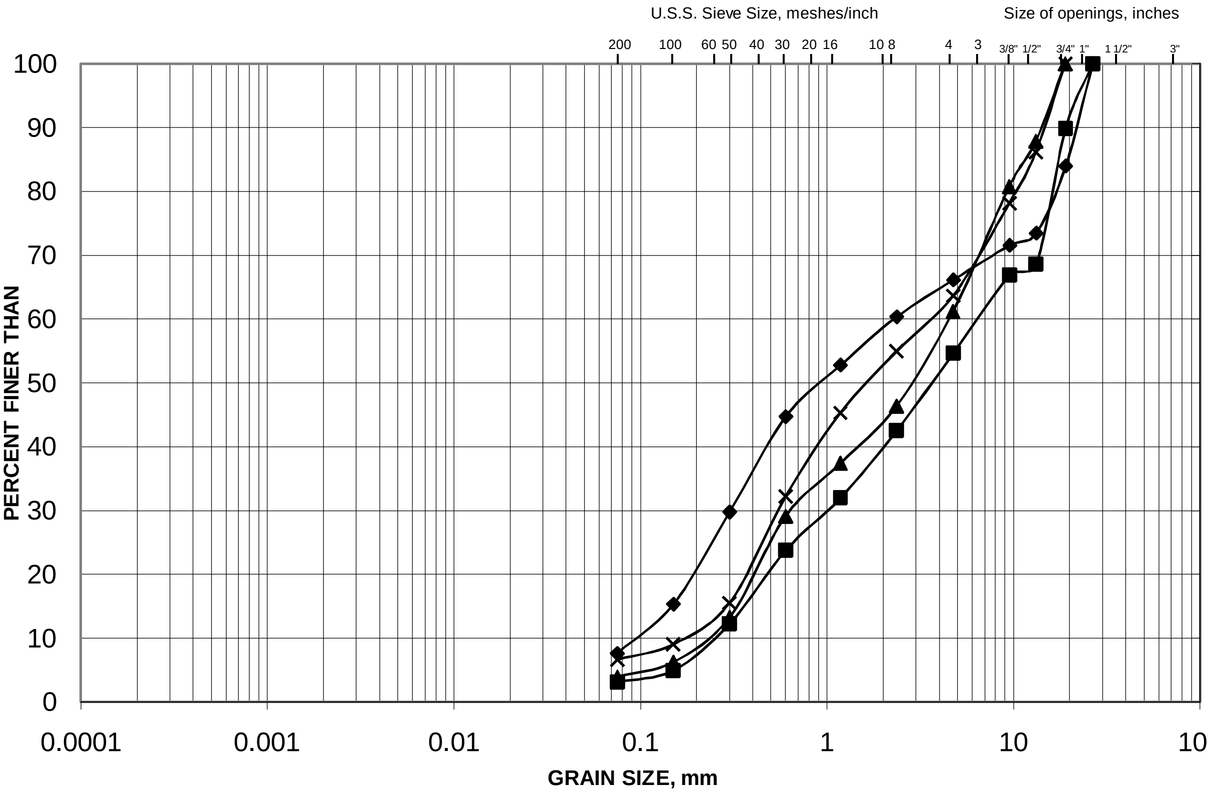
Project No. 09-1111-6014-1520

Checked By: SEMC

GRAIN SIZE DISTRIBUTION

Sand and Gravel
CNR - STA 329+680 to STA 329+780 (Swamp 104)

FIGURE D.S104-02



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
◆	S104-03	4	179.8
■	S104-06	4	179.7
×	S104-08	3	180.7
▲	S104-09	4	179.8

Project Number: 09-1111-6014-1520

Checked By: SEMC

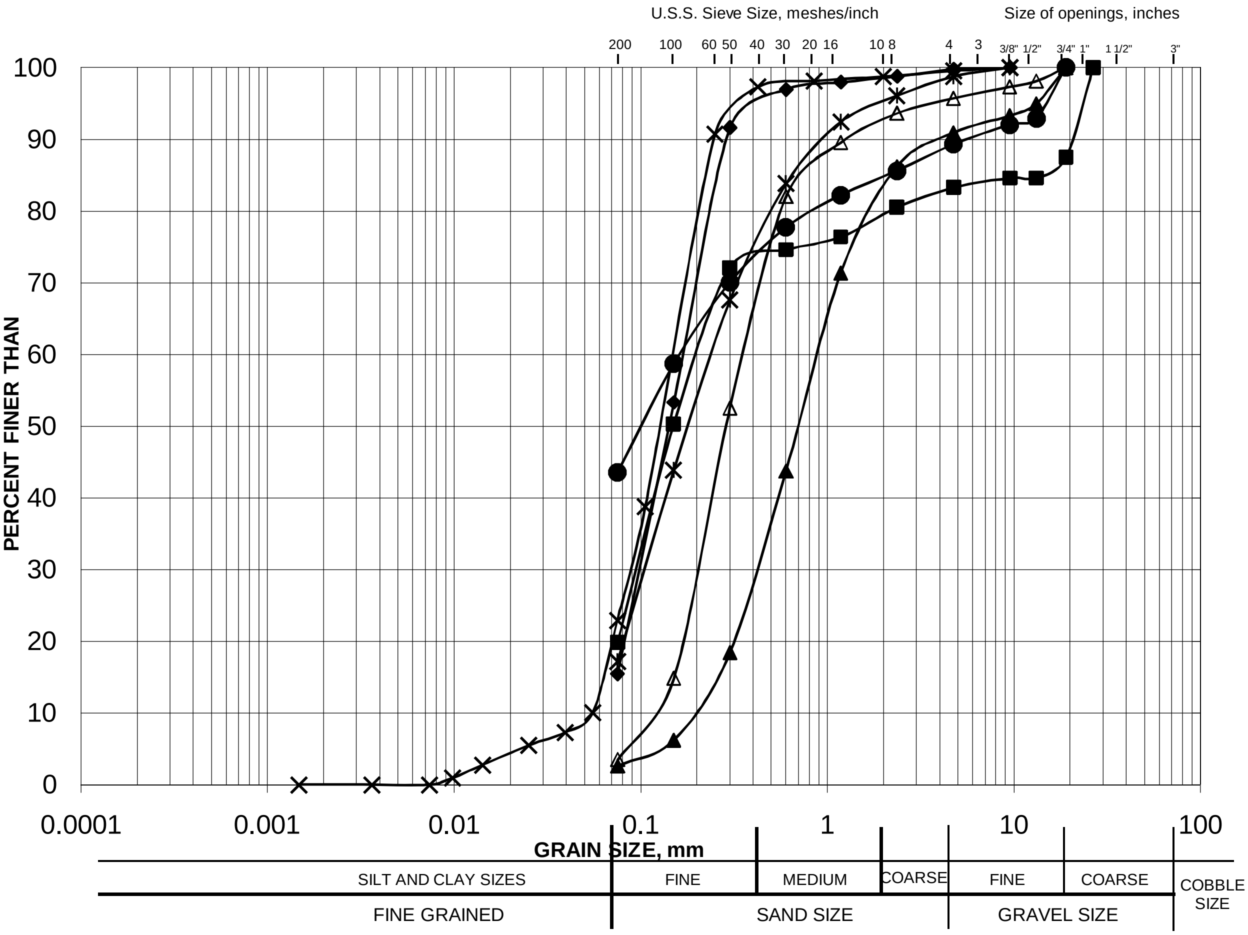
Golder Associates

Date: August 2011

GRAIN SIZE DISTRIBUTION

Sand to Sand and Silt
CNR - STA 329+680 to STA 329+780 (Swamp 104)

FIGURE D.S104-03a



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
◆	S104-01	3	180.8
■	S104-01	5	179.2
●	S104-01	8	176.3
×	S104-02	5	179.1
✳	S104-02	8	176.1
△	S104-03	6	178.4
▲	S104-03	10	173.0

Project Number: 09-1111-6014-1520

Checked By: SEMC

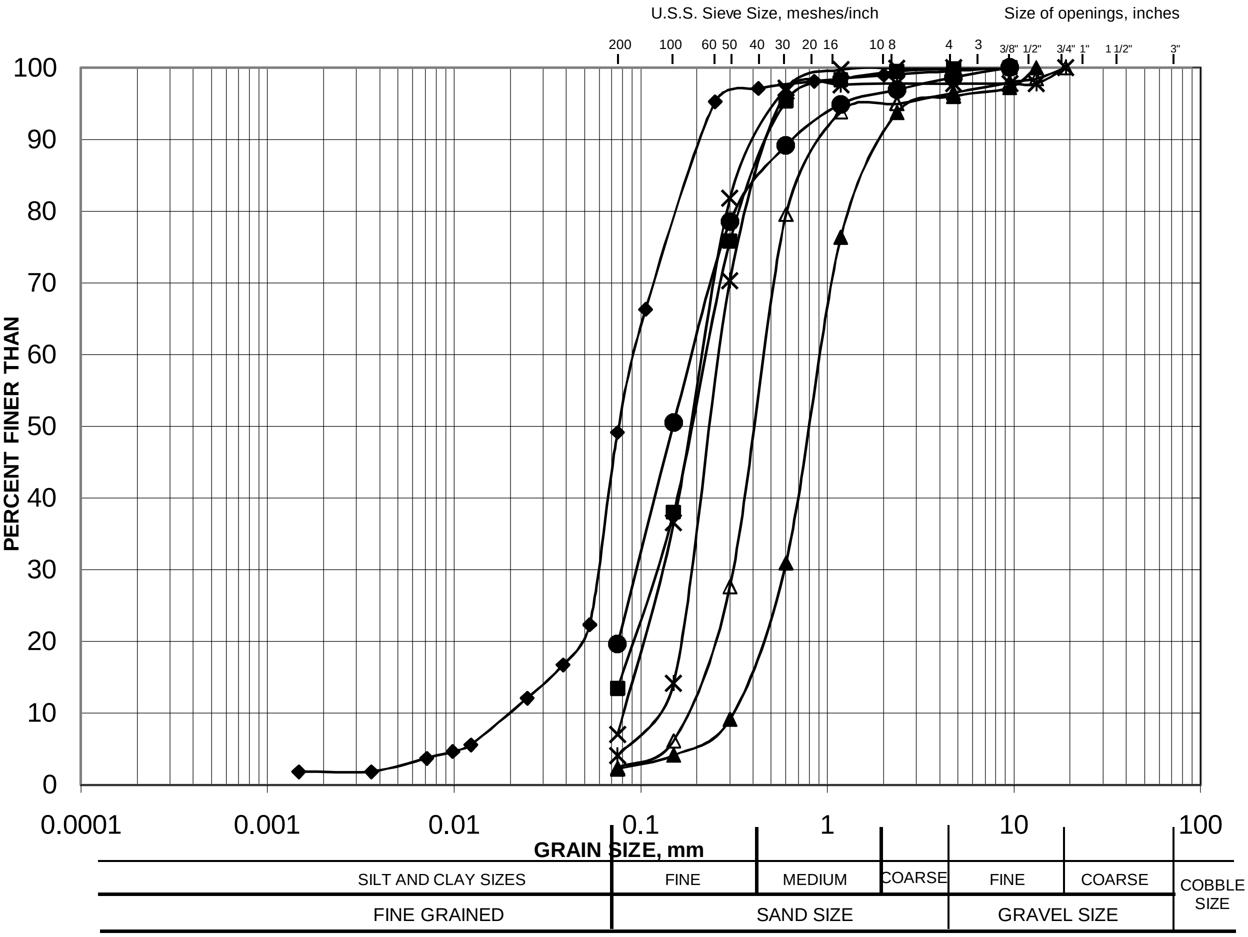
Golder Associates

Date: August 2011

GRAIN SIZE DISTRIBUTION

Sand to Sand and Silt
CNR - STA 329+680 to STA 329+780 (Swamp 104)

**FIGURE
D.S104-03b**



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
◆	S104-04	5	177.9
■	S104-04	7	176.5
●	S104-04a	7	177.6
×	S104-04a	10	173.0
✱	S104-05	7	177.2
△	S104-06	8	176.1
▲	S104-09	7	177.5

Project Number: 09-1111-6014-1520

Checked By: SEMC

Golder Associates

Date: August 2011

APPENDIX E

Highway 69 Detour - STA 23+400 to STA 23+650 (Swamp 104)

MINISTRY OF TRANSPORTATION, ONTARIO

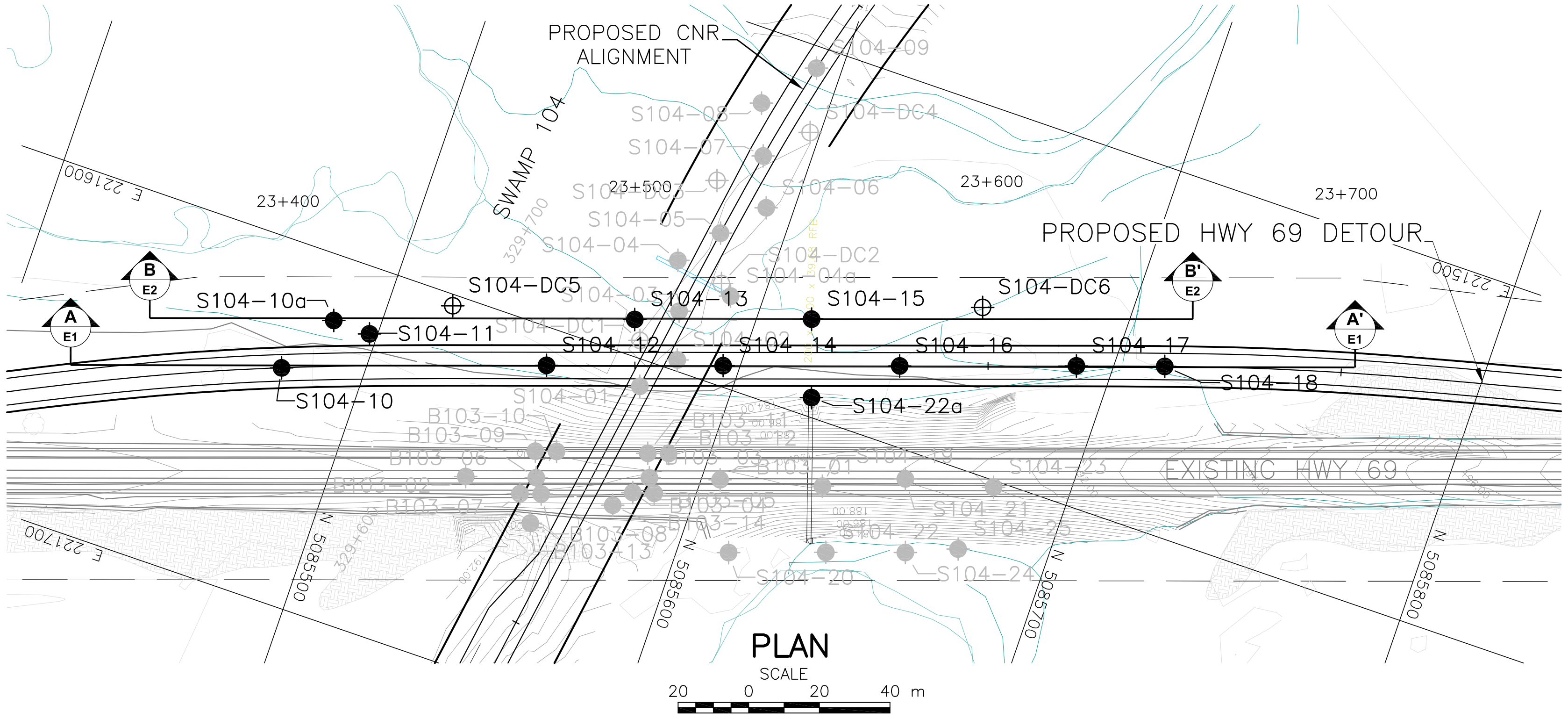
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 5344-08-01

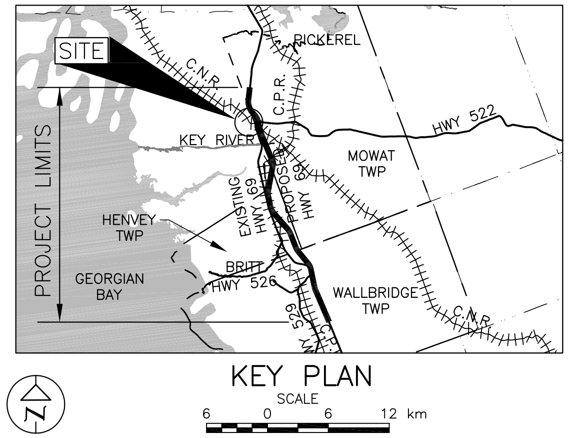
SHEET

CN RAILWAY
HIGHWAY 69 DETOUR
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



PLAN
SCALE

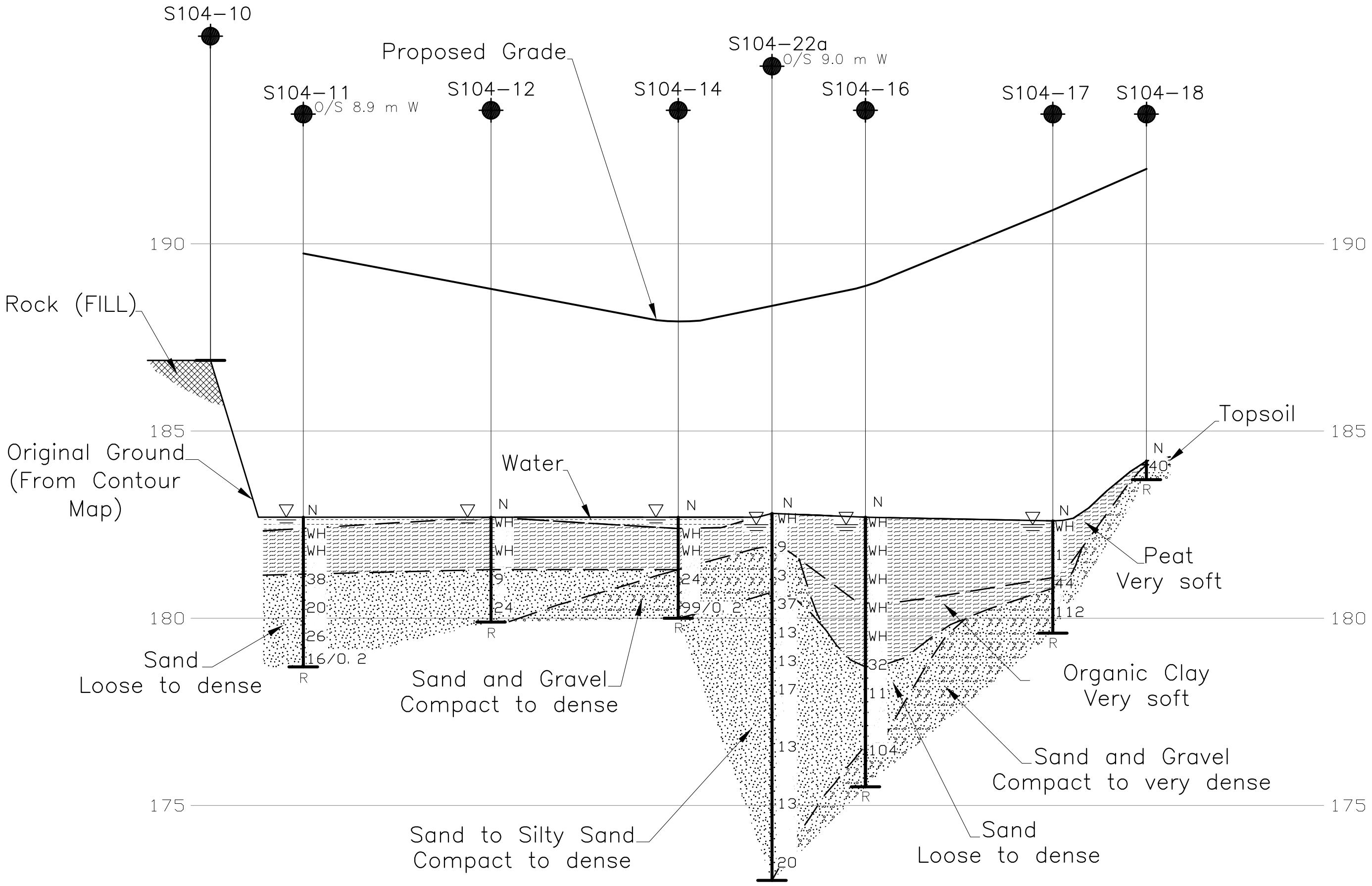


KEY PLAN
SCALE

LEGEND

●	Borehole
⊕	Dynamic Cone Penetration Test
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
▽	WL upon completion of drilling
R	Refusal

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
S104-10	187.5	5085477.4	221635.5
S104-10a	182.7	5085487.0	221618.0
S104-11	182.7	5085497.8	221618.3
S104-12	182.7	5085548.1	221610.4
S104-13	182.7	5085567.5	221590.0
S104-14	182.7	5085595.4	221594.2
S104-15	182.8	5085614.8	221573.6
S104-16	182.7	5085642.7	221578.0
S104-17	182.8	5085690.0	221561.7
S104-18	184.2	5085713.7	221553.7
S104-22a	182.8	5085622.0	221594.6
S104-DC5	182.7	5085517.5	221603.1
S104-DC6	182.5	5085659.5	221554.7



A-A' E1 CENTRELINE PROFILE

HORIZONTAL SCALE
20 0 20 40 m
2 0 2 4 m
VERTICAL SCALE

NOTES

This drawing is for subsurface information only. The proposed site 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 URS, drawing file HWY69_Plan_CNR.dwg received Sept. 09, 2010. Railroad Contours provided in digital format by URS, drawing file Railroad Contours.dwg, received Jan. 21, 2010. Key plan provided in digital format by URS, drawing file Keyplan.dwg received Apr. 16, 2010.

S.E.M. COYNE 90471921 AUG 23, 2011

J.M.A.COSTA AUG 23, 2011

NO.	DATE	BY	REVISION

Geocres No. 41H-91

HWY. 69		PROJECT NO. 09-1111-6014	DIST.
SUBM'D. LG	CHKD. AB	DATE: AUG 2011	SITE:
DRAWN: JJL	CHKD. SEMC	APPD. JMAC	DWG. E1

PLOT DATE: August 23, 2011
FILENAME: \\capws\sites\0911116014highway69FourLaning\Contract 1 CN Realignment\Drafting\Drawings\Swamp 104\Detour\09-1111-6014 Swamp 104 Detour.dwg

MINISTRY OF TRANSPORTATION, ONTARIO

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

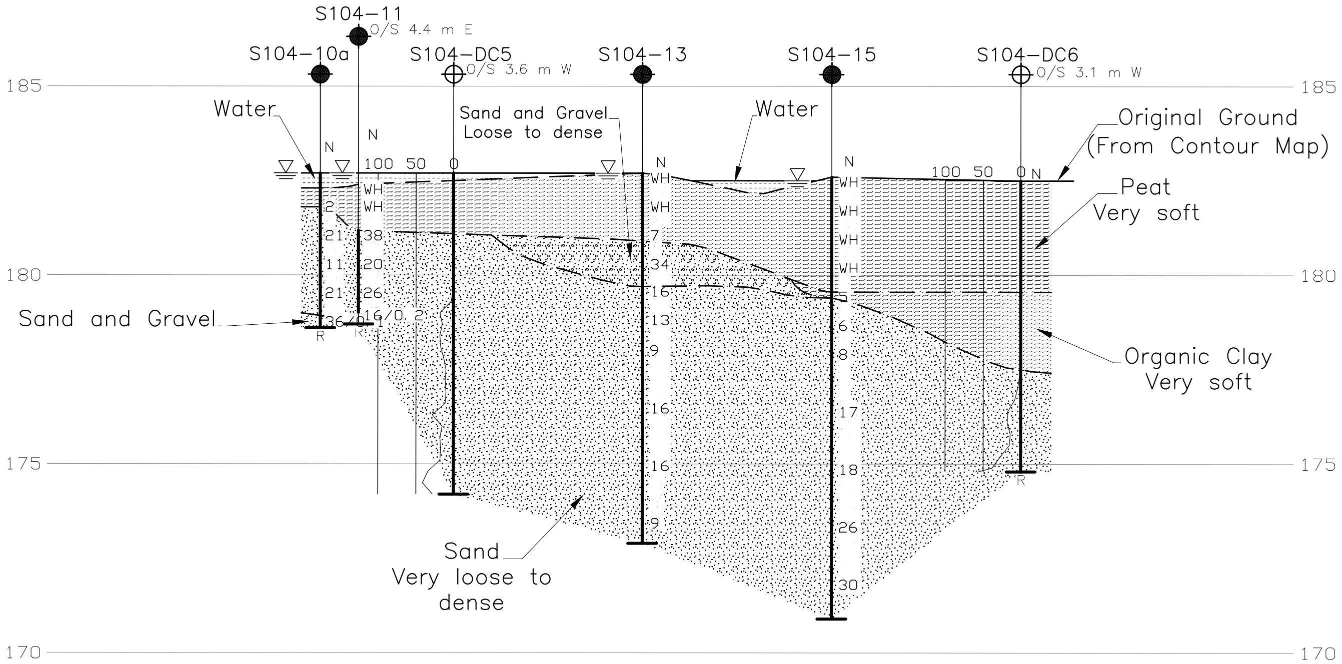
CONT No.
WP No. 5344-08-01

CN RAILWAY
HIGHWAY 69 DETOUR

SOIL STRATA

SHEET

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



B-B'
E2
EMBANKMENT TOE PROFILE

HORIZONTAL SCALE
20 0 20 40 m
2 0 2 4 m
VERTICAL SCALE

LEGEND

●	Borehole
⊕	Dynamic Cone Penetration Test
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
▽	WL upon completion of drilling
R	Refusal

No.	ELEVATION	CO-ORDINATES	
		NORTHING	EASTING
S104-10	187.5	5085477.4	221635.5
S104-10a	182.7	5085487.0	221618.0
S104-11	182.7	5085497.8	221618.3
S104-12	182.7	5085548.1	221610.4
S104-13	182.7	5085567.5	221590.0
S104-14	182.7	5085595.4	221594.2
S104-15	182.8	5085614.8	221573.6
S104-16	182.7	5085642.7	221578.0
S104-17	182.8	5085690.0	221561.7
S104-18	184.2	5085713.7	221553.7
S104-22a	182.8	5085622.0	221594.6
S104-DC5	182.7	5085517.5	221603.1
S104-DC6	182.5	5085659.5	221554.7

NOTES

This drawing is for subsurface information only. The proposed site 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 URS, drawing file HWY69_Plan_CNR.dwg received Sept. 09, 2010. Railroad Contours provided in digital format by URS, drawing file Railroad Contours.dwg, received Jan. 21, 2010. Key plan provided in digital format by URS, drawing file Keyplan.dwg received Apr. 16, 2010.

S.E.M. COYNE
90471921
AUG 23, 2011

J.M.A.COSTA
AUG 23, 2011

NO.	DATE	BY	REVISION

Geocres No. 41H-91

HWY. 69		PROJECT NO. 09-1111-6014	DIST.
SUBM'D. LG	CHKD. AB	DATE: AUG 2011	SITE:
DRAWN: JJL	CHKD. SEMC	APPD. JMAC	DWG. E2

PLOT DATE: August 23, 2011
FILENAME: \\capws\sites\0911116014highway69FourLaning\Contract 1 CN Realignment\Drafting\Drawings\Swamp 104\Detour\09-1111-6014 Swamp 104 Detour.dwg

Golder Associates

RECORD OF BOREHOLE No S104-10

1 OF 1 **METRIC**

PROJECT 09-1111-6014

W.P. 5344-08-00

LOCATION N 5085477.4; E 221635.5

ORIGINATED BY EHS

DIST

HWY CNR

BOREHOLE TYPE N/A

COMPILED BY LG

DATUM Geodetic

DATE August 25, 2010

CHECKED BY AB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa O 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/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
187.5	GROUND SURFACE										
0.0	END OF BOREHOLE Notes: 1. Borehole located on rock fill embankment (unable to set up the equipment on the slope to assess for rockfill thickness.) 2. Exposed rock noted 5.0 m to the south.										

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

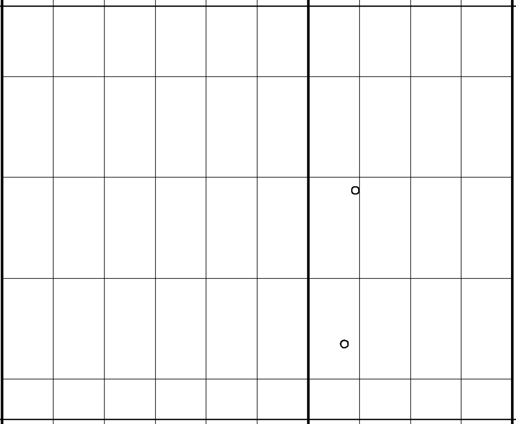
O $^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No S104-10a

1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST
HWY CNR
DATUM Geodetic
LOCATION N 5085487.0; E 221618.0
BOREHOLE TYPE Portable Equipment, BW Casing, Wash Boring
DATE August 25, 2010
ORIGINATED BY EHS
COMPILED BY LG
CHECKED BY AB

SOIL PROFILE			SAMPLES			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 (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR	SA	SI	CL
182.7	WATER SURFACE													
0.0	WATER													
182.3 0.4	PEAT (Fibrous) Brown Wet						182							
181.8 0.9	SAND, some gravel, trace to some silt Very loose to compact Grey Wet		1	SS	2									
			2	SS	21		181							
			3	SS	11		180							
			4	SS	21						19	64	(17)	
178.9							179							
178.6 4.1	SAND and GRAVEL Grey Wet		5	SS	36/0.1									
	END OF BOREHOLE SPOON AND CASING REFUSAL													



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

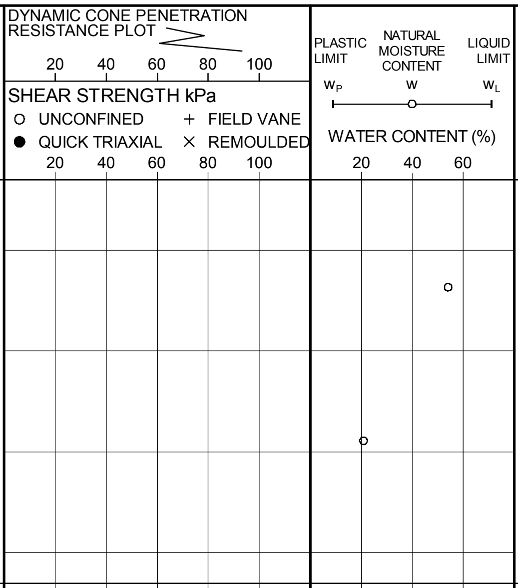
$\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No S104-11

1 OF 1 **METRIC**

PROJECT 09-1111-6014			
W.P. 5344-08-00	LOCATION N 5085497.8; E 221618.3	ORIGINATED BY EHS	
DIST	HWY CNR	BOREHOLE TYPE Portable Equipment, BW Casing, Wash Boring	COMPILED BY LG
DATUM Geodetic	DATE August 25, 2010	CHECKED BY AB	

ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%): GR	SA	SI	CL
182.7	WATER SURFACE					▽						
0.0 182.4	WATER											
0.3	PEAT (Fibrous) Very soft Brown Wet		1	SS	WH		182					
181.7 1.0	PEAT (Amorphous), trace sand, trace clay Very soft Brown Wet		2	SS	WH							
181.2 1.5	Cobbles encountered at 1.5 m depth. SAND, trace to some silt, trace gravel Compact to dense Grey Wet		3	SS	38		181					
			4	SS	20		180		3	85	(12)	
			5	SS	26		179					
178.7			6	SS	16/0.2							
4.0	END OF BOREHOLE SPOON AND CASING REFUSAL											



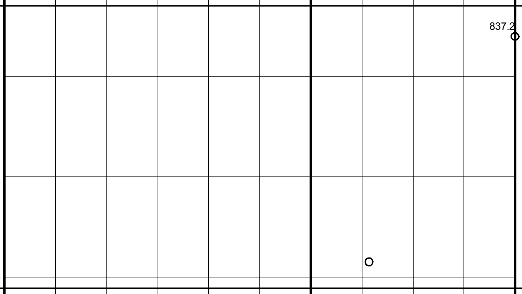
+3, ×3: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No S104-12

1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST
HWY CNR
DATUM Geodetic
LOCATION N 5085548.1; E 221610.4
BOREHOLE TYPE Portable Equipment, BW Casing, Wash Boring
DATE August 24, 2010
ORIGINATED BY EHS
COMPILED BY LG
CHECKED BY AB

SOIL PROFILE			SAMPLES					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 (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				GR	SA	SI	CL
182.7	GROUND SURFACE					∇								
0.0	PEAT (Fibrous) Very soft Brown Wet		1	SS	WH				837.2					
							182							
			2	SS	WH									
181.3 1.4	SAND, trace to some silt, trace gravel Loose to compact Grey Wet		3	SS	9		181							
			4	SS	24						1	89	(10)	
179.9 2.8	END OF BOREHOLE SPOON AND CASING REFUSAL Note: 1. Water level at ground surface (Elev. 182.7 m) upon completion of drilling.						180							



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

$\circ^{3\%}$ STRAIN AT FAILURE

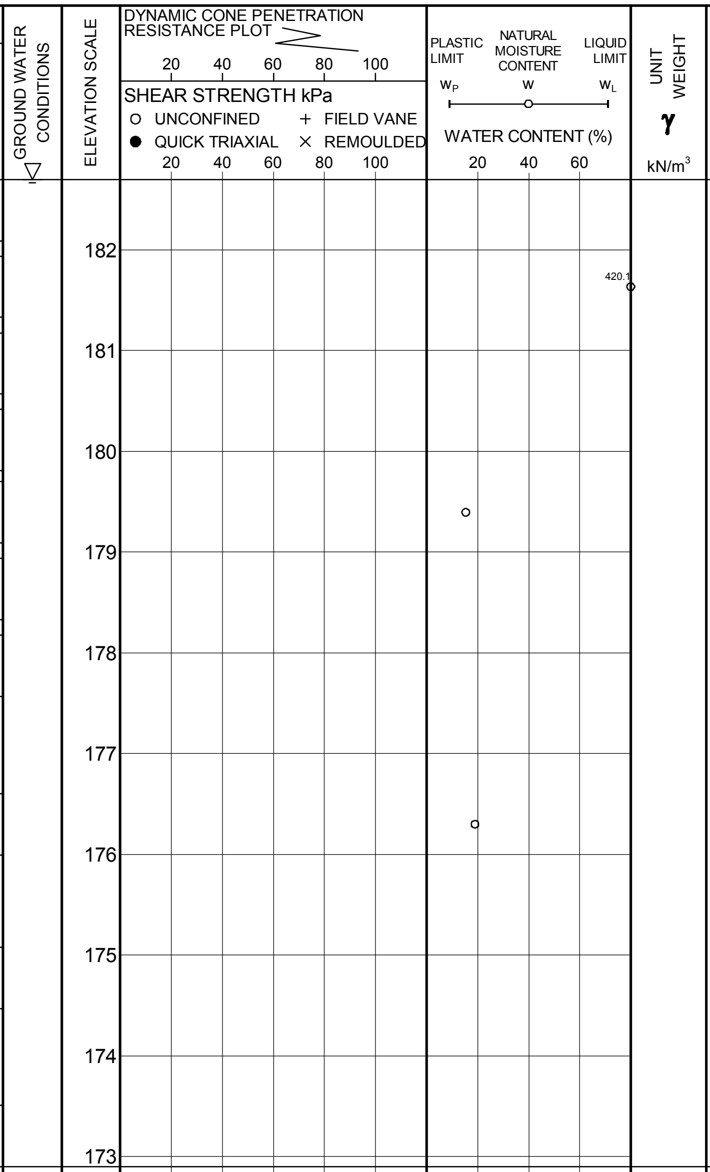
SUD-MTO V2.0 09-1111-6014 BH SWAMP LOGS METRIC.GPJ GAL-MISS.GDT 18/08/11 DATA INPUT:

RECORD OF BOREHOLE No S104-13

1 OF 1 **METRIC**

PROJECT 09-1111-6014			
W.P. 5344-08-00	LOCATION N 5085567.5; E 221590.0		ORIGINATED BY EHS
DIST	HWY CNR	BOREHOLE TYPE Portable Equipment, BW Casing, Wash Boring	COMPILED BY LG
DATUM Geodetic		DATE August 23 and 24, 2010	CHECKED BY AB

SOIL PROFILE ELEV DEPTH	DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
182.7	GROUND SURFACE							
0.0	PEAT (Fibrous) Very soft Brown Wet	1	SS	WH				
182.1 0.6	PEAT (Amorphous), trace sand Very soft Black Wet	2	SS	WH				
180.9 1.8	SAND and GRAVEL, trace to some silt Loose to dense Grey Wet	3	SS	7				
		4	SS	34				
179.7 3.0	SAND, trace to some gravel, trace to some silt Loose to compact Grey Wet	5	SS	16	20	64	(16)	
		6	SS	13				
		7	SS	9				
		8	SS	16	5	76	(19)	
		9	SS	16				
		10	SS	9				
172.9 9.8	END OF BOREHOLE Note: 1. Water level at ground surface (Elev. 182.7 m) upon completion of drilling.							



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

$\bigcirc^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No S104-14

1 OF 1 **METRIC**

PROJECT 09-1111-6014

W.P. 5344-08-00

DIST HWY CNR

DATUM Geodetic

LOCATION N 5085595.4; E 221594.2

BOREHOLE TYPE Portable Equipment, BW Casing, Wash Boring

DATE August 23, 2010

ORIGINATED BY EHS

COMPILED BY LG

CHECKED BY AB

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

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)
182.7	WATER SURFACE				▽		
0.0 182.4	WATER						
0.3	PEAT (Fibrous) Very soft Brown Wet	1	SS	WH		182	908.3
181.9 0.8	PEAT (Amorphous), trace sand Very soft Black Wet	2	SS	WH			122.5
181.3 1.4	SAND and GRAVEL, trace to some silt Compact to dense Grey Wet	3	SS	24		181	
		4	SS	99/0.2			
180.0 2.7	END OF BOREHOLE SPOON AND CASING REFUSAL					180	

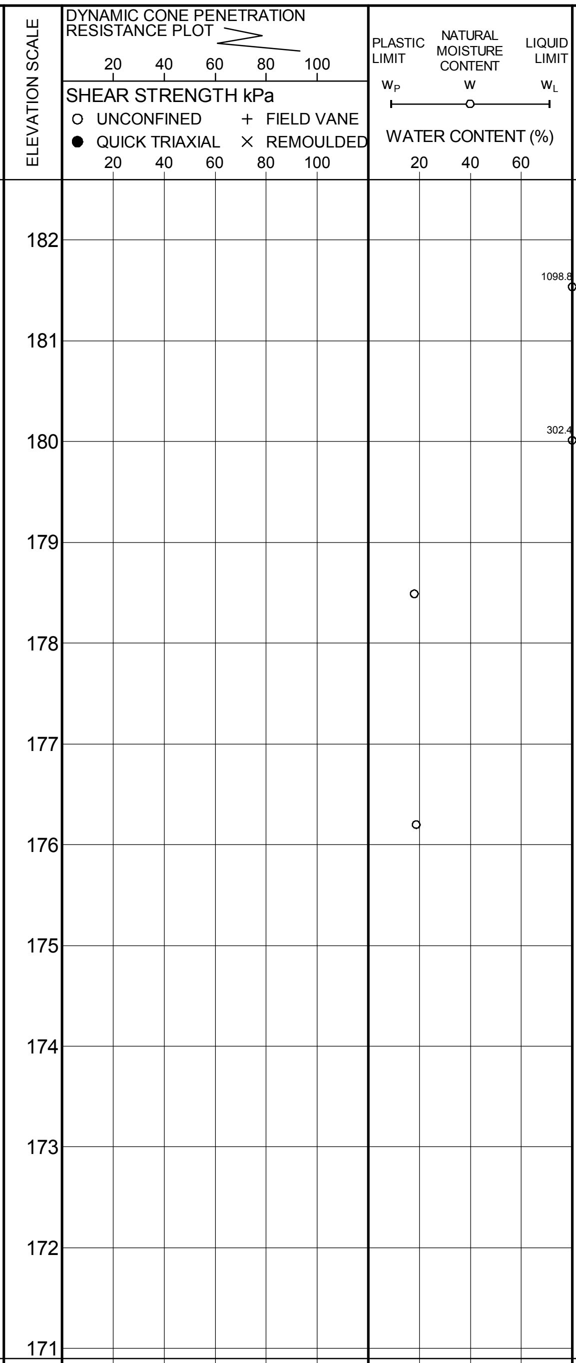
+³, ×³: Numbers refer to Sensitivity ○ ³% STRAIN AT FAILURE

RECORD OF BOREHOLE No S104-15

1 OF 1 **METRIC**

PROJECT 09-1111-6014			
W.P. 5344-08-00	LOCATION N 5085614.8; E 221573.6	ORIGINATED BY ID	
DIST	HWY CNR	BOREHOLE TYPE Portable Equipment, BW Casing, Wash Boring	COMPILED BY LG
DATUM Geodetic	DATE August 18 and 19. 2010	CHECKED BY AB	

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
182.6	GROUND SURFACE					
0.0	PEAT (Fibrous) Very soft Brown Wet	1	SS	WH	∇	
		2	SS	WH		
		3	SS	WH		
180.3 2.3	PEAT (Amorphous) Very soft Brown Wet	4	SS	WH		
179.6 3.2	CLAY, organic Very soft Grey and brown Wet	5	SS	5		
	SAND, trace gravel, trace silt Loose to compact Grey Wet	6	SS	6		3 93 (4)
		7	SS	8		
		8	SS	17		
		9	SS	18		
		10	SS	26		
		11	SS	30		
170.9 11.7	END OF BOREHOLE					



UNIT WEIGHT γ kN/m^3

Note:

1. Water level at a depth of 0.1 m below ground surface (Elev. 182.5 m) upon completion of drilling.

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

O$^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No S104-16

1 OF 1 **METRIC**

PROJECT 09-1111-6014

W.P. 5344-08-00

DIST

HWY CNR

DATUM Geodetic

LOCATION N 5085642.7; E 221578.0

BOREHOLE TYPE Portable Equipment, BW Casing, Wash Boring

DATE August 18, 2010

ORIGINATED BY ID

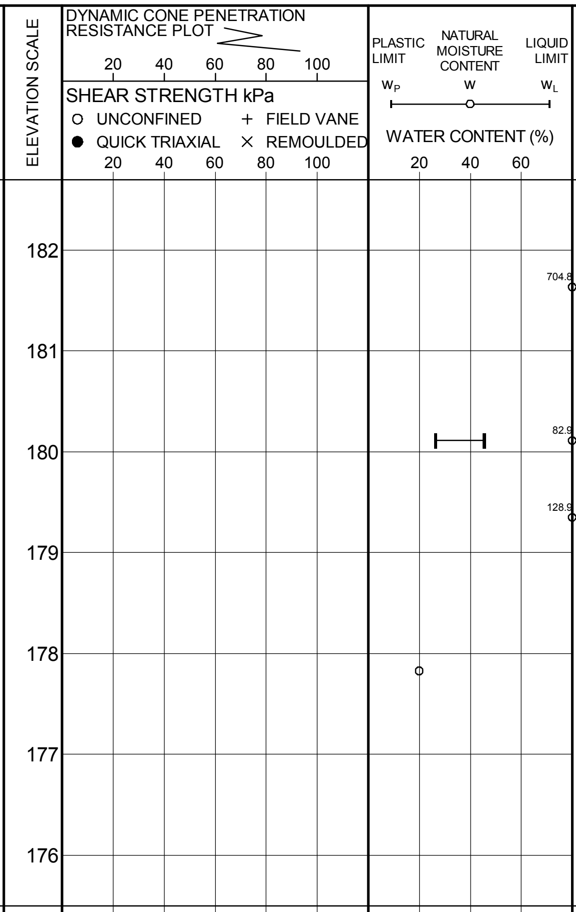
COMPILED BY LG

CHECKED BY AB

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
182.7	GROUND SURFACE									
0.0	PEAT (Fibrous) Very soft Brown Wet	1	SS	WH	∇					
		2	SS	WH						
		3	SS	WH						
180.4 2.3	CLAY, organic Very soft Grey and brown Wet	4	SS	WH		OC = 5%				
		5	SS	WH		OC = 7%				
178.7 4.0	SAND, trace gravel, trace silt Compact to dense Grey Wet	6	SS	32						
		7	SS	11			4	94	(2)	
176.6 6.1	SAND and GRAVEL, containing cobbles Very dense Grey Wet	8	SS	104						
175.5 7.2	END OF BOREHOLE CASING REFUSAL									

Note:

1. Water level at a depth of 0.2 m below ground surface (Elev. 182.5 m) upon completion of drilling.



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

$O^{3\%}$ STRAIN AT FAILURE

SUD-MTO V2.0 09-1111-6014 BH SWAMP LOGS METRIC.GPJ GAL-MISS.GDT 18/08/11 DATA INPUT:

RECORD OF BOREHOLE No S104-17

1 OF 1 **METRIC**

PROJECT	09-1111-6014		
W.P.	5344-08-00	LOCATION	N 5085690.0; E 221561.7
ORIGINATED BY	ID		
DIST		HWY	CNR
BOREHOLE TYPE	Portable Equipment, BW Casing, Wash Boring	COMPILED BY	LG
DATUM	Geodetic	DATE	August 17, 2010
CHECKED BY	AB		

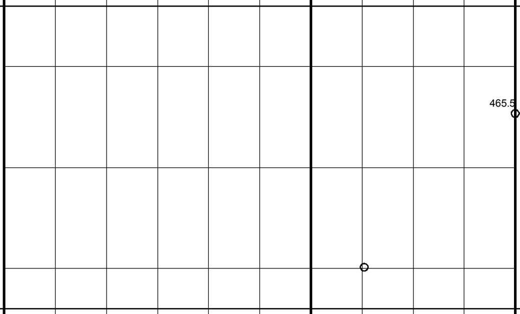
SOIL PROFILE			SAMPLES							REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³		GR	SA	SI	CL
182.6	GROUND SURFACE												
0.0	PEAT (Fibrous) Very soft Brown Wet		1	SS	WH	▽	182						
			2	SS	1								
181.1	CLAY, organic Very soft Grey and brown Wet		3	SS	44		181						
180.8 1.8	SAND and GRAVEL, trace silt Dense to very dense Grey Wet		4	SS	112		180			34	61		(5)
179.6 3.0	END OF BOREHOLE CASING REFUSAL Note: 1. Water level at a depth of 0.1 m below ground surface (Elev. 182.5 m) upon completion of drilling.												

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



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

RECORD OF BOREHOLE No S104-18

1 OF 1 **METRIC**

PROJECT 09-1111-6014

W.P. 5344-08-00

LOCATION N 5085713.7; E 221553.7

ORIGINATED BY ID

DIST

HWY CNR

BOREHOLE TYPE Hand Sampling

COMPILED BY LG

DATUM Geodetic

DATE August 17, 2010

CHECKED BY AB

SOIL PROFILE			SAMPLES			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
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
184.2	GROUND SURFACE										
0.0	TOPSOIL Brown Moist		1	SS	40		184				
183.7 0.5	SAND and GRAVEL Dense Brown Wet										
	END OF BOREHOLE SPOON REFUSAL										

Notes:

1. Borehole dry upon completion of drilling.

2. Split spoon samples obtained by driving with a 1/2 weight hammer; SPT 'N' value has been adjusted to the inferred value that would be obtained using a standard weight hammer.

SUD-MTO V2.0 09-1111-6014 BH SWAMP LOGS METRIC.GPJ GAL-MISS.GDT 18/08/11 DATA INPUT:

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

$\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No S104-22a

1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST ____ HWY CNR
DATUM Geodetic
LOCATION N 5085622.0; E 221594.6
BOREHOLE TYPE Portable Equipment, BW Casing, Wash Boring
DATE August 16 and 17, 2010
ORIGINATED BY ID
COMPILED BY LG
CHECKED BY AB

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT (%)	GR	SA	SI	CL
182.8	GROUND SURFACE									
0.0	PEAT (Amorphous), some sand Very soft Brown Wet	1	SS	WH	∇	101.8				
181.9 0.9	SAND and GRAVEL Very loose to loose Grey Wet	2	SS	9						
		3	SS	3						
180.7 2.1	SAND to Silty SAND, trace gravel Compact to dense Grey Wet	4	SS	37						
		5	SS	13			1	67	(32)	
		6	SS	13						
		7	SS	17						
		8	SS	13						
		9	SS	13			2	98	(0)	
		10	SS	20						
173.0 9.8	END OF BOREHOLE									

Note:

1. Water level at a depth of 0.3 m below ground surface (Elev. 182.5 m) upon completion of drilling.

Elevation scale: 182, 181, 180, 179, 178, 177, 176, 175, 174, 173

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

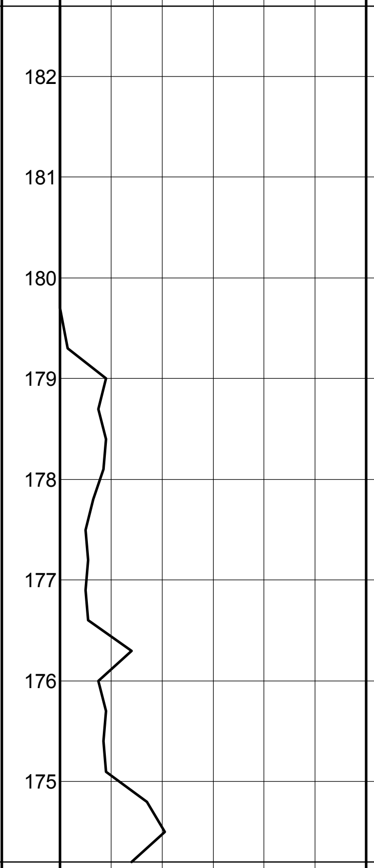
Foundation Design

RECORD OF PENETRATION TEST No S104-DC5

1 OF 1 **METRIC**

PROJECT 09-1111-6014
W.P. 5344-08-00
DIST
HWY CNR
DATUM Geodetic
LOCATION N 5085517.5; E 221603.1
BOREHOLE TYPE Dynamic Cone Penetration Test
DATE August 24, 2010
ORIGINATED BY EHS
COMPILED BY LG
CHECKED BY AB

SOIL PROFILE			SAMPLES								
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 O 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/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
182.7	GROUND SURFACE										
0.0											
174.2 8.5	END OF DCPT										



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

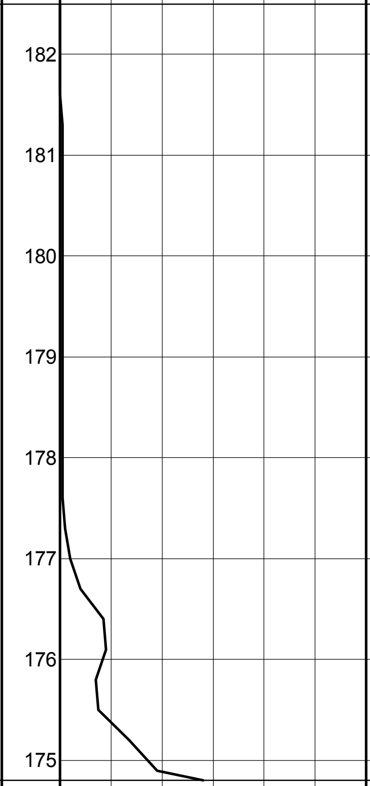
O $^{3\%}$ STRAIN AT FAILURE

RECORD OF PENETRATION TEST No S104-DC6

1 OF 1 **METRIC**

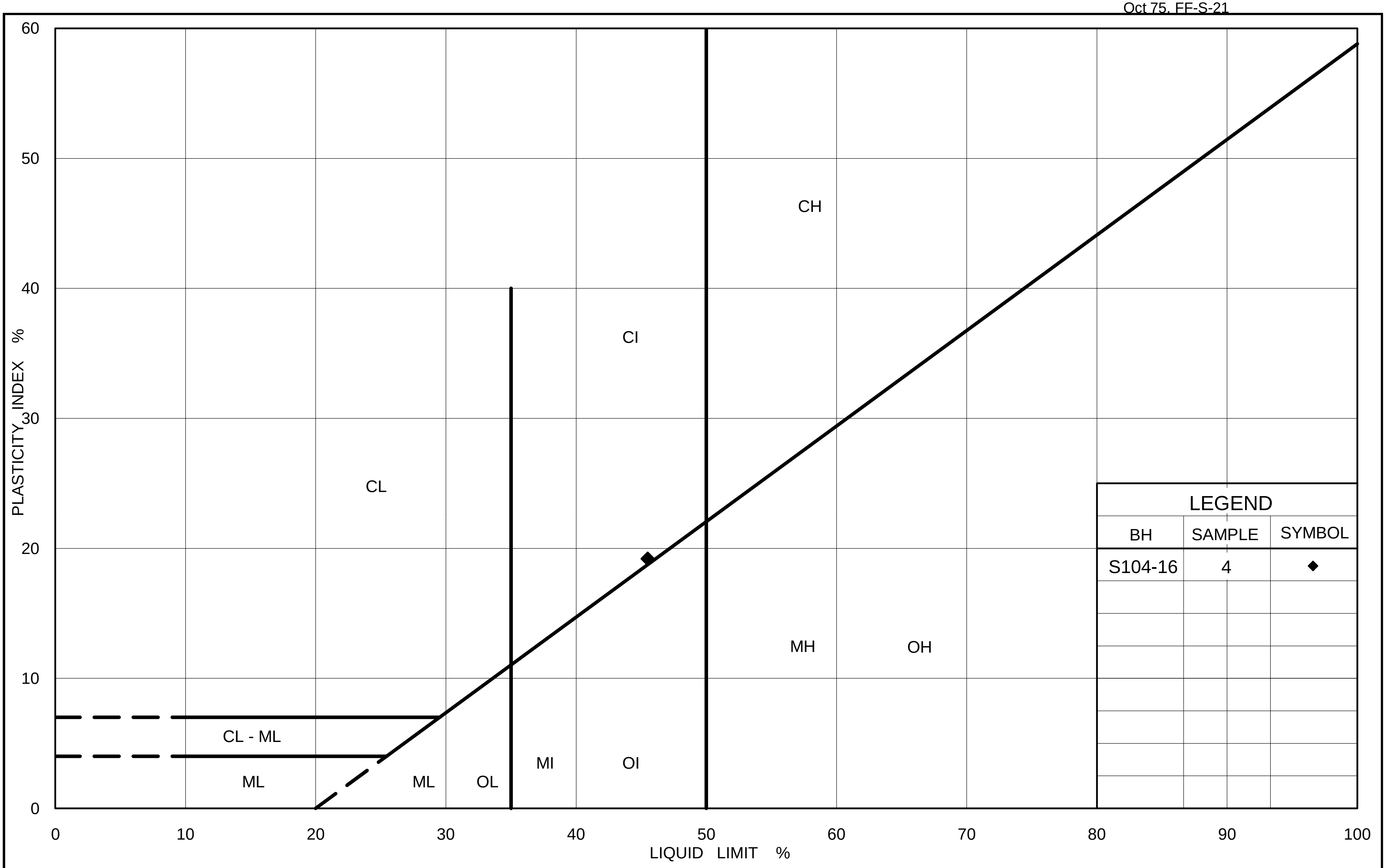
PROJECT 09-1111-6014
W.P. 5344-08-00
DIST
HWY CNR
DATUM Geodetic
LOCATION N 5085659.5; E 221554.7
BOREHOLE TYPE Dynamic Cone Penetration Test
DATE August 18, 2010
ORIGINATED BY ID
COMPILED BY LG
CHECKED BY AB

SOIL PROFILE		SAMPLES										
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
182.5	GROUND SURFACE										
0.0											
174.8 7.7	END OF DCPT REFUSAL TO FURTHER PENETRATION (HAMMER BOUNCING)										



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

Oct 75, FF-S-21



BH	SAMPLE	SYMBOL
S104-16	4	◆

Ministry of Transportation
Ontario

PLASTICITY CHART
Clay, Organic
Hwy 69 Detour - STA 23+400 to STA 23+650

Figure E.S104-01

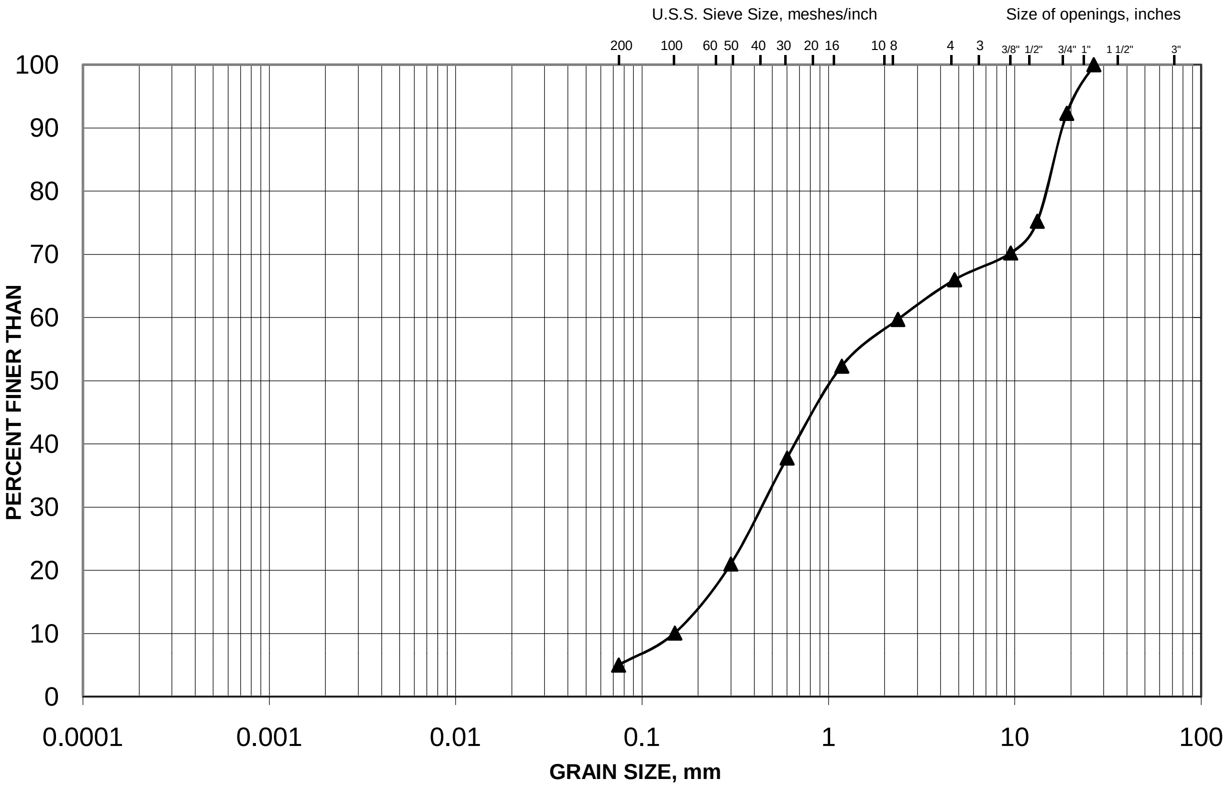
Project No. 09-1111-6014-1520

Checked By: SEMC

GRAIN SIZE DISTRIBUTION

Sand and Gravel
Hwy 69 Detour - STA 23+400 to STA 23+650 (Swamp 104)

**FIGURE
E.S104-02**



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
—▲—	S104-17	4	180.0

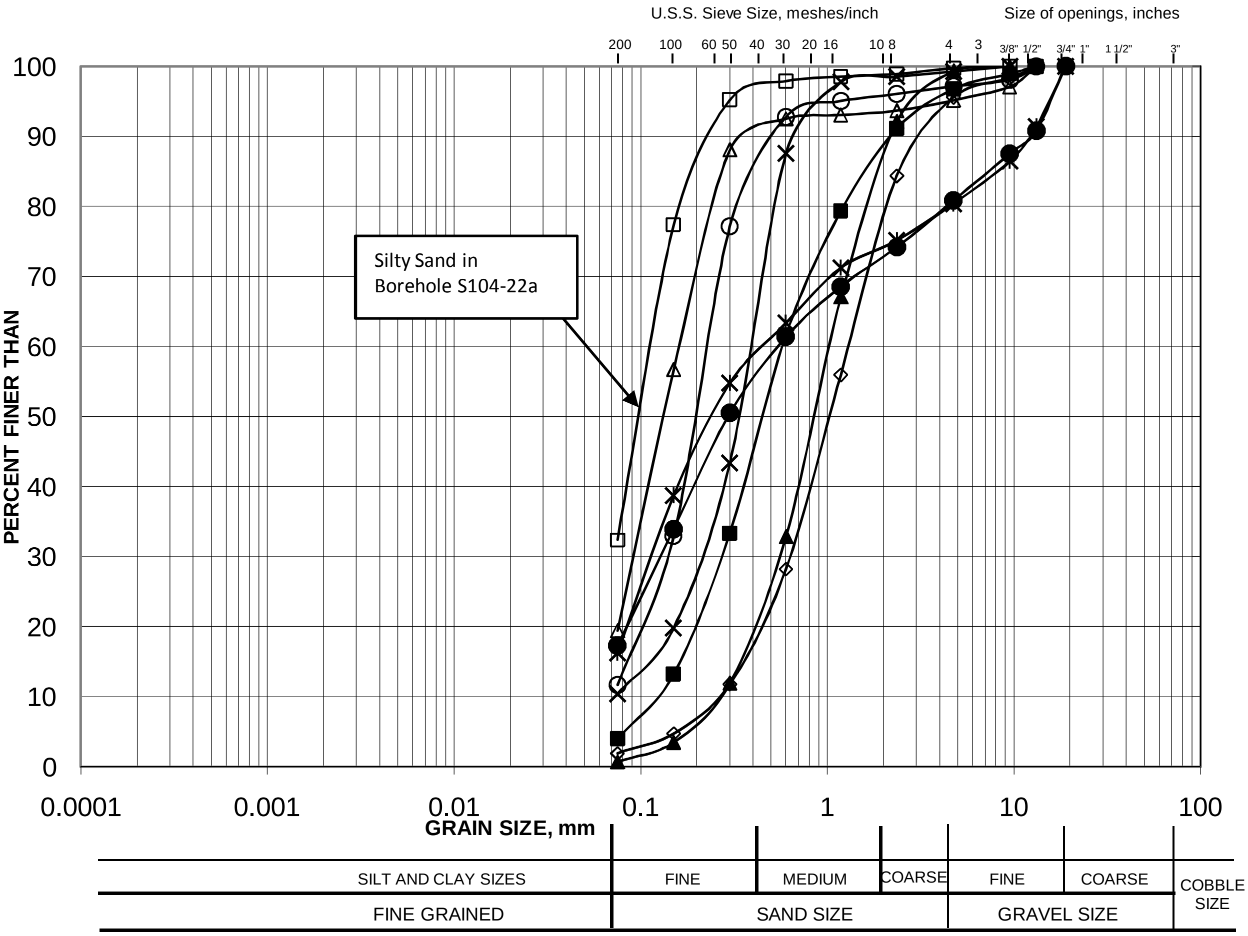
Project Number: 09-1111-6014-1520

Checked By: SEMC

Golder Associates

Date: August 2011

GRAIN SIZE DISTRIBUTION **Sand** **Hwy 69 Detour - STA 23+400 to STA 23+650 (Swamp 104)**	**FIGURE** **E.S104-03**



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	S104-10a	4	179.4
○	S104-11	4	180.1
×	S104-12	4	180.1
✱	S104-13	5	179.4
△	S104-13	8	176.3
■	S104-15	6	178.5
◇	S104-16	7	177.8
▲	S104-22a	5	179.5
□	S104-22a	9	174.9

Project Number: 09-1111-6014-1520

Checked By: SEMC

Golder Associates

Date: August 2011

APPENDIX F

Non-Standard Special Provisions

Item No.

Non-Standard Special Provision

This Non-Standard Special Provision outlines the procedure for sub-excavation of the organic deposits for the Highway 69 Detour between STA 23+400 to STA 23+650 (Swamp 104). Staged excavation of limited extent shall be employed to maintain stability and to protect the existing Highway 69 embankment during sub-excavation and replacement operations. The staged excavation procedures to be followed are:

- Removal of the organic deposits within the proposed embankment footprint and backfilling of the excavation shall be carried out simultaneously in accordance with OPSS 209.

- Excavation side slopes should be in accordance with OPSD 203.020.

- Excavation shall be carried out in sections of limited width (3 m) perpendicular to the proposed embankment.

- Provisions for traffic control measures shall be available on site to maintain the safe operation of Highway 69 during the excavation and backfilling operations in the event that distress to the existing roadway occurs during the staged excavation.

At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

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