Golder Associates Ltd.

1010 Lorne Street
Sudbury, Ontario, Canada P3C 4R9
Telephone: (705) 524-6861
Fax: (705) 524-1984

# PRELIMINARY FOUNDATION INVESTIGATION AND DESIGN REPORT
# HIGHWAY 17 (NEW) FROM BLACK ROAD TO GRFN WEST BOUNDARY
# TRUNK ROAD ACCESS AND HIGHWAY 17 SNOWMOBILE CROSSING
# SAULT STE MARIE, ONTARIO
# G.W.P 357-94-00
# AGREEMENT NO. 6005-A-000209

Submitted to:

McCormick Rankin Corporation
2655 North Sheridan Way, Suite 300
Mississauga, Ontario
L5K 2P8

GEOCRES No. 41K-81

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October 12, 2007 07-1191-0014

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## PRELIMINARY FOUNDATION INVESTIGATION REPORT
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## 1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by McCormick Rankin Corporation (MRC) on behalf of the Ministry of Transportation, Ontario (MTO) to provide preliminary foundation engineering services for the proposed Trunk Road Access and Black Road/Second Line Interchange structures as well as potential snowmobile crossings and interchange locations along the new Highway 17 alignment through the Batchewana First Nation (BFN) in Sault Ste. Marie, Ontario.

The terms of reference for the scope of work are outlined in Golder's proposal P7-1191-0014, dated April 2, 2007, and addendum dated June 8, 2007, that forms part of the Consultant's Agreement (Agreement Number 6005-A-000209) for this project.

The following document was referenced when completing this report:

- Foundation Investigation Report, Proposed Highway 17 Trunk Access Road Bridges over the Black Creek, Sault Ste. Marie, Ontario, G.W.P. 406-01-00, Geocres No. 41K-66, April 12, 2005, by Shaheen & Peaker Limited.

## 2.0 SITE DESCRIPTION

The site is situated on the east limit of the City of Sault Ste Marie, extending from the Black Road/Second Line East intersection easterly to the newly constructed Highway 17 four-laning at the east limit of the City of Sault Ste. Marie. The total length of the alignment is approximately 4.5 km. Starting from Station 12+000 easterly, the alignment splits into two proposed alternatives, rejoining just east of the proposed Trunk Access Road Interchange. Drawing 1 shows the location of the proposed alignments.

From the west end of the site at Station 10+000, the Highway 17 (new) alignment follows a man made ditch and snowmobile trail. The proposed highway crosses Black Creek at about Station 12+450. The Root River runs roughly parallel to and north of the proposed alignments. There is a ± 4 m high stockpile of fill located in the area of the proposed Trunk Road Access Interchange extending west to approximately Station 14+450. This fill was likely placed as part of the four-laning construction to the east.

The existing ground surface at the borehole locations ranges from about Elevation 194.7 m at the west end of the site to about Elevation 188.0 m at the east end of the site. The water level in Black Creek was measured at approximately Elevation 187.4 m in May 2007.

The locations of the potential sites are presented below.

| Approximate Station | Proposed Works |
|---|---|
| 10+045 | Black Road/Second Line Interchange |
| 10+525 | Potential Snowmobile Crossing |
| 11+125 | Potential Interchange |
| 12+025 | Potential Interchange |
| 12+500 | Black Creek Crossing |
| 14+500 | Trunk Access Road Interchange |

# 3.0 INVESTIGATION PROCEDURES

## 3.1 Foundation Investigation

The field investigation was carried out in two stages: between May 23 and 31, 2007 during which period five boreholes (BH07-1 to BH07-5) were advanced at proposed structure locations; and between July 9 and 11, 2007 during which period one borehole (BH07-6) was advanced at the west end of the site at the proposed location of an interchange. The borehole locations are shown on Drawing 1. The results of the drilling are presented in the Record of Borehole sheets that follow the text of this report, including a single Dynamic Cone Penetration Test (DCPT) advanced from the bottom of BH07-5.

The field investigation was carried out using a track-mounted CME-55 Bombardier drill rig supplied and operated by Marathon Drilling Ltd. (Marathon) of Ottawa, Ontario. The boreholes were advanced using 108 mm inside diameter (I.D.) continuous flight hollow stem augers in combination with wash boring methods using ‘NW’ casing. Tri-cone methods were used to advance the boreholes at some locations. Soil samples were obtained at intervals ranging from 0.75 m to 3.0 m in depth, using a 50 mm outer diameter (O.D.) split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures with an automatic sampling hammer. In situ vane (‘N’ vane) tests were taken in cohesive deposits in all boreholes and Shelby tube samples were obtained in four of the boreholes.

The boreholes were advanced to depths between 31.1 m and 49.2 m below the existing ground surface. The groundwater conditions in the open boreholes were observed during the drilling operations and summarized on the Record of Borehole sheets. A piezometer was installed in BH07-5, to permit monitoring of the groundwater level at this location. The piezometer consisted of a 50 mm outside diameter rigid PVC tubing with a 1.5 m long slotted screen, sealed within the clayey silt to clay deposit. The boreholes and piezometer (after the last water level was obtained) were backfilled with bentonite and/or cement-bentonite grout as per Ontario Reg. 128 (amendment to O. Reg. 903). The piezometer installation details and water level readings are presented on the Record of Borehole sheets.

In Boreholes BH07-1 and BH07-6, artesian water conditions were encountered with a static head of approximately 0.5 m above ground surface. In these boreholes, an impermeable seal consisting of granular bentonite (i.e. holeplug) was placed from the bottom of the boreholes up to about 3.0 m and to 6.0 m above the base of the hole, respectively. Above this seal, cement bentonite grout was pumped down the holes, and the holes were backfilled to approximately 1.0 m below ground surface. A bentonite seal was placed to ground surface to complete the abandonment of the boreholes.

The fieldwork was supervised throughout by members of our engineering and technical staff, who located the boreholes, arranged for the clearance of underground services at the borehole locations, supervised the drilling and sampling 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. Two one-dimensional consolidation (oedometer) tests were carried out on Shelby tube samples from Boreholes BH07-2 and BH07-6.

The locations of the proposed boreholes were laid out in the field by Golder staff relative to the alignment staked by surveyors retained by MRC. The as-drilled locations of the boreholes were estimated relative to the alignment stakes and the northings and eastings were determined based on the digital terrain mapping supplied by MRC. The elevation of the boreholes was determined based on interpolation of contours on the terrain map at the actual borehole locations.

Members from Batchewana First Nations accompanied Golder during the first phase of the drilling operations and provided assistance with tree clearing.

# 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

## 4.1 Regional Geology

Sault Ste. Marie is located on the north bank of the St. Mary's River, which drains Lake Superior into Lake Huron[1]. The city area is underlain by lowland Proterozoic red sandstone of the Jacobsville Formation, with Quarternary sediments dominated by glaciolacustrine clays and shoreline deltaic and beach sand and gravel deposit. The city area also contains glacial deposits laid during the Wisconsinan stage of glaciation. The glacial deposits of the area have the form of a ground moraine or till plain, covering bedrock in varying thicknesses.

The rocks of the city area may be divided in three major groups: The Precambrian (Archean) formation, which forms the basement rock in the area, consists mostly of highly metamorphosed and steeply tilted metavolcanic and metasedimentary rock, intruded and replaced by extensive granitic rocks; the Precambrian (Proterozoic) sedimentary and volcanic rocks which are made up of mostly unmetamorphosed and slightly tilted rocks; and the Palaeozoic Cambrian Sandstone of the Jacobsville Formation, nearly flat lying and unmetamorphosed sedimentary rocks.

There are major groundwater aquifers in the vicinity of the city, which include the granular sections of the glacial till and the underlying sandstone bedrock of the Jacobsville Formation. Most of the aquifers are confined by overlying clay deposits; however, potentially artesian conditions existing in the sand belt region. Where shallow bedrock is encountered theses aquifers are unconfined. A high water table is expected within the area of the subsurface investigation for this section of New Highway 17 alignment.

## 4.2 Subsoil Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced during this investigation, together with the results of the laboratory tests carried out on selected soil samples, are given on the attached Record of Borehole sheets following the text of this report. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling and observations of drilling progress and cuttings. 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 inferred soil stratigraphy based on the results of the boreholes is shown on Drawing 1.

[1] Urban Geology of Canadian Cities, GAC Special Paper 42, P.F. Karrow and O.L. White Editors, Geological Association of Canada, 1998.

In general, the subsoils at the locations investigated consist of an upper deposit of silt with interlayers of sand and clay underlain by a silty clay to clay deposit, underlain at some locations by a lower deposit of silt some clay. All boreholes but one were terminated within the silty clay to clay deposit or within the underlying lower silt deposit. Borehole BH07-6 was terminated on possible bedrock. Three of the six locations encountered fill at the ground surface. The groundwater level was typically encountered within the upper 6 m of the overburden, and artesian conditions were encountered at the west end of the site. A detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

### 4.2.1 Topsoil/Fill

Fill was encountered at the ground surface in BH-07-1, BH07-5 and BH07-6 ranging in thickness between 0.6 m and 3.7 m. The fill in Borehole BH07-1 ranged in consistency from dark brown, moist, silty organics to silty sand. In Boreholes BH07-5 and BH07-6, the fill consisted of brown and grey, moist, sandy silt to silty sand.

Standard Penetration Test (SPT) ‘N’ values measured within the fill ranged between 2 and 8 blows per 0.3 m of penetration, indicating a very loose to loose relative density.

The natural water content measured on samples of the fill ranged between 26 percent and 48 percent.

A 25 mm to 75 mm thick layer of topsoil was encountered at the ground surface in Boreholes BH07-2 to BH07-4. In Borehole BH07-5, a 50 mm layer of topsoil was encountered underlying the fill, at Elevation 184.3 m.

### 4.2.2 Upper Clay

A 1.7 m thick deposit of moist, grey, clay containing some silt was encountered below the fill and topsoil in Borehole BH07-5. The surface of this deposit was encountered at Elevation 184.2 m.

SPT ‘N’ values measured within this deposit ranged between 0 blows (weight of hammer) and 3 blows per 0.3 m of penetration indicating a very soft to soft consistency.

One Atterberg limits test was carried out on a sample of the clay deposit. The result yielded a liquid limit of 72 percent and a plastic limit of 32 percent, corresponding to a plasticity index of about 39 percent. The results of the Atterberg limits test are shown on the plasticity chart on Figure 1 and classify the deposit as a clay of high plasticity.

### 4.2.3 Upper Silt

A deposit of grey, wet silt containing trace to some sand and clay was encountered below the fill, topsoil, or clay in Boreholes BH07-1 to BH07-6. The thickness of this deposit ranged from 1.2 m to 17.1 m, including interlayers of clayey silt and sand. Towards the east end of the new alignment in Boreholes BH07-4 and BH07-5, the silt deposit is divided into an upper and lower portion and the material grades into a sandy silt to sand and silt: the upper portion ranged in thickness between 1.6 m and 3.5 m; and the lower portion ranged in thickness between 6.1 m and 8.4 m. The surface of the silt deposit was encountered between Elevation 182.5 m and 194.1 m, increasing towards the west. The surface of the lower portion of the deposit was encountered at Elevation 177.8 m and 176.4 m in Boreholes BH07-4 and BH07-5, respectively.

In Borehole BH07-3, the upper 0.7 m of the deposit was described as brown to black, moist sand containing some silt; interlayers of clayey silt and sand were encountered within the silt deposit in Boreholes BH07-4; and, in Borehole BH07-5, the upper portion of the silt deposit is described as consisting of a sandy silt containing some clay to a sand and silt containing trace clay.

Measured SPT 'N' values in the upper portion of the silt deposit ranged from 0 blows (weight of hammer) to 61 blows per 0.3 m of penetration indicating a very loose to very dense relative density. In general, the 'N' values were less than 14 blows per 0.3 m of penetration indicating a very loose to compact relative density; the higher 'N' values were encountered in BH07-2. In the lower portion of the silt deposit, the SPT 'N' values ranged from 0 blows to 28 blows per 0.3 m of penetration indicating a very loose to compact relative density.

Grain size distribution analyses were performed on several samples of the silt deposit and are shown on Figure 2A. The grain size distribution results from BH07-5, carried out on the sandy silt to sand and silt samples, are shown on Figure 2B.

The natural water content measured on samples of the silt deposit ranged between 18 percent and 33 percent.

In Borehole BH07-4, a 2.1 m thick interlayer of grey, wet, clayey silt containing some sand and silt seams was encountered at Elevation 185.3 m. The SPT 'N' values measured within the clayey silt interlayer were 0 blows (weight of hammer) indicating a very soft consistency. One Atterberg limits test was carried out and yielded a liquid limit of 26 percent and a plastic limit of 16 percent, corresponding to a plasticity index of 10 percent. This result is shown on the plasticity chart on Figure 3 and classifies the deposit as a clayey silt of low plasticity. A grain size distribution test was performed on a sample of clayey silt and the test result is shown on Figure 4. The natural water content measured on samples of the clayey silt were 32 percent and 35 percent.

In Boreholes BH07-4 and BH07-5, an interlayer of reddish brown to reddish grey, wet, sand containing trace to some silt and trace clay was encountered between Elevation 183.2 m and 180.9 m, ranging in thickness between 4.5 m and 5.4 m. The SPT 'N' values measured within the sand interlayer ranged from 0 blows (weight of hammer) to 8 blows per 0.3 m of penetration indicating a very loose to loose relative density. Two grain size distribution tests were performed on samples within the sand interlayer and the test results are shown on Figure 5. The natural water content measured on samples of the sand ranged from 25 percent to 28 percent.

#### 4.2.4 Silty Clay to Clay

A deposit of reddish brown, wet, silty clay to clay, some silt was encountered below the silt layer in all boreholes. In Borehole BH07-5, the upper approximately 6 m of the deposit is described as clayey silt containing trace sand. The surface of the deposit was encountered between Elevation 168.0 m and Elevation 191.0 m, being lower towards the east end of the alignment. The thickness of the deposit ranged from 14.5 m to 23.7 m in Boreholes BH07-1 to BH07-3 and BH07-6, where it was fully penetrated. Boreholes BH07-4 and BH07-5 were terminated within this deposit.

Measured SPT 'N' values within the silty clay to clay deposit ranged from 0 blows (weight of hammer or rods) to 10 blows per 0.3 m of penetration. In situ field vane measurements completed within the silty clay to clay deposit ranged between 9 kPa and 71 kPa, typically between about 20 kPa and 50 kPa. The SPT values in conjunction with the field vanes indicate the deposit has a very soft to stiff consistency.

A Dynamic Cone Penetration Test (DCPT) was advanced from the bottom of BH07-5 to a depth of 36.6 m and the blow counts ranged from 0 blows (weight of hammer) to 19 blows per 0.3 m of penetration; refusal was not recorded at the depth that the DCPT was terminated.

The clay deposit contains zones of silty clay to clayey silt, particularly at Borehole BH07-5. Atterberg limits tests were carried out on selected samples of the clay deposit and yielded liquid limits ranging from 51 percent and 76 percent and plastic limits between 20 percent and 31 percent with resulting plasticity indices between 29 percent and 47 percent, as shown on the plasticity chart on Figure 6A, which classify the deposit as a clay of high plasticity. In the upper portion of Borehole BH07-5 and in zones of Boreholes BH07-3 and BH07-4, the results of Atterberg limits tests yielded liquid limits ranging from 26 percent to 43 percent, plastic limits ranging from 19 percent to 28 percent and resulting in plasticity indices ranging from 8 percent to 22 percent. The results of these tests are shown on Figure 6B and indicated that these materials are classified as silty clay to clayey silt of intermediate to low plasticity. Grain size distributions of the clay deposit are shown on Figures 7A and 7B for the silty clay to clay and clayey silt portions of the deposit, respectively.

Two laboratory consolidation (oedometer) tests were carried out on samples of the clay obtained from Boreholes BH07-2 and BH07-6, at a depth of 12.5 m and 4.9 m, respectively, and the test results are shown on Figures 8A and 8B. The pre-consolidation pressures were estimated from the voids ratio versus logarithmic pressure plots using the Casagrande method. The relevant oedometer test results are summarized below:

| Borehole / Sample Number | Elevation (m) | $\sigma_{vo}'$ (kPa) | $\sigma_p'$ (kPa) | OCR | $e_o$ | $C_c$ | $C_r$ | $c_v^*$ ($cm^2/s$) |
|---|---|---|---|---|---|---|---|---|
| BH07-2 SA 12 | 178.0 | 154 | 150 | ~1.0 | 1.943 | 0.724 | 0.128 | $4.71 \times 10^{-3}$ |
| BH07-6 SA 8 | 189.8 | 54 | 55 | ~1.0 | 1.940 | 0.646 | 0.133 | $3.03 \times 10^{-4}$ |

Note: *For stress range of $20 \leq \sigma_v' \leq 300$ kPa

where:
- $\sigma_{vo}'$ effective overburden pressure in kPa
- $\sigma_p'$ 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

Measured water contents of the samples of silty clay to clay deposit ranged between 28 percent and 89 percent, with the lowest values being associated with the clayey silt portion. In general, the water contents were at or higher than the liquid limits for the corresponding sample.

### 4.2.5 Lower Silt

A deposit of grey, wet, silt containing some clay and trace sand was encountered below the silty clay to clay deposit in Boreholes BH07-1 to BH07-3 and BH07-6. The surface of the deposit was encountered between Elevation 171.8 m and 161.2 m. The deposit was a minimum of 1.8 m thick; however, the deposit was not fully penetrated in these boreholes except at Borehole BH07-6, where the thickness of the lower silt deposit was 25.1 m.

Measured SPT 'N' values in the lower silt deposit ranged from 0 blows (weight of rods) to 27 blows per 0.3 m of penetration, indicating a very loose to compact relative density.

The test results from grain size distributions performed on samples of the silt are shown on Figure 9 and indicate that the deposit contains zones of clayey silt/silty clay material.

The natural water content measured on samples of the lower silt deposit ranged from 25 percent to 38 percent.

### 4.2.6 Sand and Silt Till

At the location of Borehole BH07-6, the lower silt deposit is underlain by a 1.0 m thick layer of very dense brownish red till comprised primarily of sand and silt containing some clay and trace gravel. Refusal of the split spoon advanced was recorded at the base of this deposit, possibly on bedrock at Elevation 145.5 m.

Measured SPT 'N' value in the till deposit was 64 blows per 0.3 m of penetration, indicating a very dense relative density.

The test result of a grain size distribution performed on a sample of the till is shown on Figure 10.

The natural water content measured on a sample of the till deposit was measured at about 16 percent.

### 4.2.7 Groundwater Conditions

The water levels in the boreholes were noted during the drilling operations. A piezometer was installed in Borehole BH07-5 with the screened zone sealed within the clayey silt portion of the clay deposit. Details of the piezometer installation are shown in the Record of Borehole sheet. The water levels in the open holes upon completion of drilling and in the piezometer are summarized below.

| Borehole | Installation | Groundwater Level Depth (m) | Groundwater Level Elevation (m) | Date |
|---|---|---|---|---|
| BH07-1 | Open Borehole | 0.5 AGS* | 194.0 | Upon Completion of Drilling |
| BH07-2 | Open Borehole | 4.9 | 185.6 | Upon Completion of Drilling |
| BH07-3 | Open Borehole | 5.2 | 183.0 | Upon Completion of Drilling |
| BH07-4 | Open Borehole | 5.5 | 183.3 | Upon Completion of Drilling |
| BH07-5 | Piezometer | 6.1 | 182.0 | May 30, 2007 |
| | | 5.1 | 183.0 | July 10, 2007 |
| BH07-6 | Open Borehole | 0.5 AGS * | 195.2 | Upon Completion of Drilling |

* AGS indicates above ground surface.

In general, the soil samples taken in the boreholes were noted to be moist to wet with free water evident within most of the non-cohesive materials from greater depths. In Borehole BH07-1 and Borehole BH07-6, artesian groundwater conditions were encountered with a static head of about 0.5 m. In Borehole BH07-5, sand was noted to flow into the hollow-stem augers at a depth of approximately 9 m and a constant head of water was then required to prevent further heave during drilling. The groundwater level is expected to fluctuate seasonally, being lower during extended dry periods and higher during wet periods. The water level in Black Creek as measured in May 2007 was at Elevation 187.4 m.

## 4.3 Closure

The field technicians who supervised the drilling program were Mr. Ed Savard and Mr. Tim Rancourt from Golder's Sudbury office. This report was prepared by Mr. Tim Rancourt, a geotechnical program student; the technical aspects were reviewed by Sarah E. M. Coyne, P.Eng. A quality control review of the report was provided by Mr. Jorge Costa, P.Eng., a Designated MTO Contact for Golder.

**GOLDER ASSOCIATES LTD.**

LICENSED PROFESSIONAL ENGINEER
S.E.M. COYNE
90471921
PROVINCE OF ONTARIO

Sarah E. M. Coyne, P.Eng.
Geotechnical Engineer/Associate

LICENSED PROFESSIONAL ENGINEER
J. M. A. COSTA
PROVINCE OF ONTARIO

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

TRR/SEP/JMAC/lb
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# PART B

# PRELIMINARY FOUNDATION DESIGN REPORT
# HIGHWAY 17 (NEW) FROM BLACK ROAD TO GRFN WEST BOUNDARY
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# 5.0 PRELIMINARY DESIGN ENGINEERING RECOMMENDATIONS

## 5.1 General

This section of the report provides foundation design recommendations for the preliminary design of potential snowmobile crossings and interchange locations along Highway 17 (New) between Black Road and the newly constructed highway at the western boundary of the Garden River First Nation. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the preliminary subsurface investigation at this site. The interpretation and recommendations presented are intended to provide the designers with sufficient information to assess the preferred structure locations based on stability and settlement of the proposed embankments as well as preliminary structure foundation design. Where comments are made on construction, they are provided in order to highlight those aspects which could affect the preliminary design of the project.

Additional borehole drilling will be required during the detail design phase of the project, when the preferred sites for interchanges, crossings and bridges are established and the locations of the structures and geometry of the embankments are known. At such time, further testing of the silty clay to clay deposit will be required to confirm the magnitude and time rate of settlement under the proposed embankment loading, the stability of the embankments, the requirement for deep foundations and to develop the necessary operational constraints and/or special provisions for the contract(s).

One borehole was drilled at each potential interchange/bridge site as follows:

| Approximate Station | Proposed Works | Borehole Number |
|---|---|---|
| 10+045 | Proposed Black Road/Second Line Interchange | BH07-6 |
| 10+525 | Potential Snowmobile Crossing | BH07-1 |
| 11+125 | Potential Interchange | BH07-2 |
| 12+025 | Potential Interchange | BH07-3 |
| 12+500 (Alignment 2) | Potential Black Creek Crossing | BH07-4 |
| 14+500 (Alignment 1) | Proposed Trunk Road Access Interchange | BH07-5 |

We understand that the pavement engineers have undertaken a separate geotechnical investigation and that it is desirable to set the profile grade of the proposed highway/sideroads 2 m above the original ground. Consequently, this will result in embankments as high as 9 m. The exception is the proposed crossing of Black Creek, where embankments are likely to be less than about 4 m.

The results of the embankment stability and settlement analyses provided herein may be used to assist the designer in determining the profile grade and to assess if one site is preferable over another. Further, preliminary recommendations are given for both shallow and deep foundations, where applicable at each potential site.

In general, the subsoils consist of an upper deposit of very loose to compact silt containing clayey silt and sand interlayers underlain by a very soft to stiff silty clay to clay deposit, underlain by a deposit of loose to compact silt in the west portion of the site. The boreholes were terminated at depths between 31 m and 49 m (between Elevation 162.4 m and Elevation 145.5 m) within the silty clay to clay deposit or within the underlying silt deposit; refusal to split spoon advance was recorded at the base of a thin layer of till-bedrock interface in the borehole at the west end of the site. The groundwater level was typically encountered within 6 m below the ground surface, and artesian conditions were encountered at the potential crossing interchange locations at Stations 10+045 and 10+525.

## 5.2 Approach Embankment Design and Construction

Based on the subsurface information gathered, analyses were carried out to determine the maximum stable embankment height and the magnitude of settlement under the maximum proposed embankment height was also estimated. In general, a range of embankment heights was considered in the analyses to assess the stability and settlement of the proposed embankments. Table 1 summarizes the values of engineering parameters used in the stability and settlement analyses and Table 2 presents a summary of the results of the analyses. Further discussion is given in the sections below.

The analyses assumed that embankments are to be constructed using earth fill material with side slopes no steeper than 2 horizontal to 1 vertical (2H:1V). Further, the analyses assumes that fill for embankment construction will be properly placed and compacted in accordance with SP206S03. We understand that all fill for this project will be imported to the site (i.e. earth borrow).

### 5.2.1 Approach Embankment Stability

Limit equilibrium slope stability analyses were performed using the commercially available program GeoStudio 2004 (Version 6.20), 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 to establish the minimum factor of safety. The factor of safety is defined as the ratio of the forces tending to resist failure to the driving forces tending to cause failure. A target minimum factor of safety of 1.3 is normally adopted for the design of embankment slopes under static conditions for the various embankment heights. In general, circular slip surfaces were analyzed in the design.

For granular soils, effective stress parameters were employed in the analyses assuming drained conditions for the soils. The effective stress parameters (effective friction angle and cohesion) for the granular soils were estimated from empirical correlations using the results of in situ Standard Penetration Tests (SPT) (Bowles, 1984; Kulhawy and Mayne, 1990), in conjunction with engineering judgement considering experience in similar soil conditions.

For cohesive deposits, total-stress parameters were employed in the analyses assuming undrained (i.e. short-term or during construction) conditions. The total stress parameters (i.e. average mobilized undrained shear strength – $s_u$) for the cohesive soils were derived based on the results of field vane shear tests (where applicable) and estimated from correlations with the SPT results and other laboratory test data (natural water content and Atterberg limits) (Mesri, 1975). Consolidation test data was used where appropriate.

Table 2 presents the results of the stability analysis and provides the maximum stable embankment height (i.e. for a FoS >1.3) for each location without implementation of mitigation measures.

Should embankment heights in excess of the heights noted in Table 2 be required, suitable mitigation measures will need to be employed; a brief discussion of the potential mitigation alternatives is given in Section 5.2.3.

It is noted that the stability analysis results given in Table 2 are for preliminary design purposes only, and further investigation will be required at the detailed design stage.

### 5.2.2 Approach Embankment Settlement

Settlement analyses were performed for various embankment heights. The settlement analysis was performed using standard equations from published literature. Embankment settlement will occur due to primary time-dependent consolidation and secondary creep settlement (where applicable) of the cohesive deposits; immediate settlement of the native granular soils and existing fill material; and self-weight compression of the earth embankment fill materials.

The settlement of the founding soils has been estimated using the consolidation parameters and elastic deformation moduli presented in Table 1, based on correlations with the undrained shear strength, Atterberg limits, consolidation testing and SPT 'N' values.

The estimated magnitude and time rate of settlement are presented in Table 2. Additional discussion regarding the time rate of settlement is given below. The settlement estimates given in Table 2 are for preliminary design purposes only, and further investigation will be required at the detailed design stage.

In general, underpasses may be preferred to overpasses for the sites towards the east end of the alignment where the surface of the clay deposit was encountered at depth. In this regard, the magnitude of settlement may be less than shown in Table 2 since the embankment footprint (i.e. width) for an underpass is less than for an overpass and the zone of influence of settlement may not extend down through the full thickness of the compressible clay. Detailed analysis will be required to determine if underpasses are preferred to overpasses at the eastern sites.

Provided that the embankment material consists of select subgrade material or clean earth fill (i.e. granular fill containing less than 50 percent passing 75 μm sieve and having a plasticity index less than 5 percent), the settlement of the fill will occur during construction. However, if fill containing more than 50 percent fines or having a plasticity index greater than 5% is used, the settlement of the fill may occur over the long term.

When the embankment loading exceeds the preconsolidation pressure of clay deposits, consolidation settlement of these deposits will occur. Due to the highly plastic nature of the clay deposit at this site, the primary settlement is expected to take place over a period of years following construction as detailed in Table 2, unless mitigation measures are carried out during the construction period.

Secondary consolidation (i.e. creep) of the cohesive will also occur after the primary consolidation is complete. Creep settlement occurs over the long term (i.e. decades) for the normally consolidated clays at this site and has been included in the analyses.

Compression of the silt and sand deposits will also occur, but with the majority of this compression occurring during or immediately following construction of the embankments.

### 5.2.3 Mitigation of Stability and Settlement

Table 3 summarizes the advantages, disadvantages, relative costs, post-construction settlement and risks/consequences of the various stability and settlement mitigation alternatives. Discussion on the alternatives is given in the sections below.

The preferred alternative for each site will depend on the thickness and properties of the clay deposit, the embankment height and the length of time available in the construction schedule.

The preferred mitigation alternative for each site for 2-year and 5-year proposed construction schedules is presented in Table 4. In general, the preferred alternative to mitigate potential stability issues and post-construction settlement is a combination of wick drains with preloading, surcharging and staged construction. Lightweight fill options, while potentially more expensive than other options or combination of options, may have a positive effect in reducing overall length of a bridge structure, height of embankment and reduced post-construction settlement as well as improving stability.

### Sub-excavation (Partial or Full)

Full sub-excavation of the soft, compressible clay deposit is likely not feasible at the six sites since the deposit is deep and thick to make this alternative practical. Partial sub-excavation could be considered where the clay deposit is closest to the ground surface (i.e. proposed Black Road/Second Line Interchange or the potential snowmobile crossing); however, due to the thickness of the deposit, it is unlikely that sufficient soft material could be readily removed and, therefore, post-construction settlement would still occur. Depending on the site, embankment stability could still be an issue with only partial removal of the soft clay material.

### Preloading

Preloading involves constructing the embankment and allowing it to consolidate the subsurface soils below the embankment for a specified period of time - the preload period - prior to final roadway granular base construction, paving or bridge construction. The actual preload period required will depend on the compressibility parameters of the subsoils. Typically, the preload period continues until 90 percent to 95 percent of the estimated primary settlement is completed; however, the preload period could be extended depending on the results of settlement monitoring (see Section 5.2.4). It should be noted that some long-term post-construction settlement due to secondary consolidation (i.e. creep) of the cohesive layer should also be expected with this option. An estimation of the magnitude of the creep settlement is given in Table 2. For the soils at this site, it could take several years (see Table 4) to achieve 90 percent to 95 percent of primary settlement by preloading alone.

In order to construct the preload, depending on the embankment height, other mitigation alternatives will be required to maintain stability during embankment construction, such as stability (toe) berms along the embankment or flattening the side slopes to perhaps a 4H:1V configuration.

### Surcharging

Surcharging an embankment involves placement of additional load onto the embankment above the final grade. The surcharge material has to be removed after the end of the surcharge period and prior to construction of the pavement structure. Since this process temporarily increases the embankment height, other mitigation measures will be necessary to maintain stability of the embankments constructed to the top-of-surcharge grade.

The advantage of adding a surcharge is that it reduces the preload period to reach 95 percent consolidation settlement, based on the final embankment height; the long-term post-construction settlements due to secondary consolidation (i.e. creep) of the cohesive layer would be reduced if surcharging is carried out. Due to the nature of the clay soils at this site, preloading with surcharging could still take years (see Table 4) to achieve the expected magnitude of consolidation settlement.

### Toe Berms/Slope Flattening

Depending on the final or temporary embankment height, toe berms along the embankment or overall slope flattening may be required to maintain stability of the embankment. Toe berms typically have a cross-section with a relatively flat slope near the new embankment and will be on the order of one third to one half of the main embankment height. The lateral extent of toe berms varies depending on the strength of the subsoils and is defined on the basis of stability analyses, but the width of the berms can range from about equal to the embankment height up to about twice this value. Thus, the use of toe berms results in a stepped embankment cross-section geometry and requires additional fill materials. This stepped configuration produces a similar effect on stability as using a flatter overall embankment slope, but often requires less fill materials. Depending on the results of analyses and subsoil conditions, the toe berms may be removed after sufficient time has passed if their necessity is for temporary stability only.

### Staged Construction

As cohesive soils consolidate (or settle) beneath imposed loads such as an embankment, the additional stress on the ground causes the ground strength to increase over time. Initially, when new loads are imposed on soft cohesive soils, the water pressure within the soil increases to match the new loads. As the pressures dissipate, the soils then consolidate. The time required for strength gain is dependent upon the time required for the induced pore water pressures to partially or fully dissipate. Constructing the embankment in stages often allows the subsoils to gain strength between filling stages, thereby improving stability and limiting the requirement for toe berms. Each stage of embankment construction must be left to rest for an adequate period of time to allow for sufficient strength gain before construction of the next stage can begin. Typically, staged construction is used in conjunction with preloading and surcharging methods, where the preloading and surcharging are used to reduce long-term settlement and staged construction is used to maintain stability.

It should be noted that monitoring of the settlement and dissipation of the excess pore water pressures would be required to check that adequate consolidation had occurred prior to proceeding with the subsequent construction stages as is the case with surcharge construction (see Section 5.2.4). It should also be noted that some additional long-term settlements due to secondary consolidation (i.e. creep) of the cohesive layer should be expected with this option.

### Wick Drains

In combination with the preloading/surcharging/staged construction alternatives discussed above, wick drains may be installed to reduce the preload/surcharge period required to reduce primary settlement to an acceptable level. Wick drains are prefabricated geotextile strips installed through the clay deposit at a 1.0 m to 1.5 m (typical) triangular grid spacing across the embankment area. The installation of these strips increases the drainage area through the clay deposit and allows for faster dissipation of pore water pressures thus speeding up the consolidation process. The advantage of wick drains, in addition to the reduction of the preload period, is that the number of construction stages (if required) could also be reduced. Monitoring of the settlement and dissipation of the excess porewater pressures would be required to check that adequate consolidation had occurred prior to proceeding with the subsequent construction stages (see Section 5.2.4). Long-term post-construction settlements due to secondary consolidation (i.e. creep) of the cohesive layer should still be expected with this option, as the magnitude of creep occurs per log-cycle of time after completion of primary consolidation. Since wick drains decreases the time required for completion of primary consolidation, the number of log-cycles of creep within the design life may be increased.

Typically, wick drains are considered feasible where the total length of the drainage path can be reduced significantly in order to reduce the time required for consolidation. Due to the thickness of the clay deposits at this site, the use of wick drains should have a significant positive impact on the preload period, potentially reducing it from many years to possibly months. The length of time to complete preloading will be dictated based on the final embankment height, surcharge loading, etc., and should be assessed at the detailed design stage of the project.

At two of the sites (10+045 and 10+525), artesian groundwater conditions were observed. If wick drains are considered for these sites, then the length of drain penetration into the clay deposit and the surface drainage will have to be carefully considered in the detailed design, to avoid unacceptable reduction in efficiency of the wick drain foundation.

Lightweight Fill

An alternative for reducing the magnitude of long-term settlement of the subsoils and improving stability in the areas of the soft clay deposits would be to use lightweight fill in a portion of, or all of, the embankment. Lightweight fill could consist of either blast furnace slag fill or expanded polystyrene (EPS) fill. We understand, however, that environmental concerns may eliminate the use of slag fill in highway embankments.

Lightweight fill materials are typically an order of magnitude costlier than rock or earth fill. Part of the reason for the high cost is that lightweight fill materials are not locally available and will have to be shipped to the site; given that borrow materials will be required for this project, the cost of lightweight fill materials may not be significantly higher than the borrow material. Because of high cost, lightweight fill is typically not considered an economically suitable option; however, its use could be considered if other options such as sub-excavation or wick drains are not considered practical or if the schedule does not allow sufficient time for preloading (see Table 4).

### 5.2.4 Instrumentation and Monitoring

If preloading/surcharging and/or wick drains are chosen as a preferred alternative, a full-scale monitoring program would be required. The monitoring program should consist of a series of settlement plates and settlement cells within the embankment and settlement rods set deeper in the subgrade soils, which would be surveyed at regular intervals during and after construction, for the duration of the preloading and/or surcharge period. In addition, vibrating wire piezometers should be installed at specified locations along the embankments to monitor the dissipation of excess pore pressures during staged construction or where wick drains are used. Standpipe piezometers to measure water levels are required to calibrate the vibrating wire piezometers.

### 5.2.5 Seismic Analysis and Liquefaction

It should be noted that Sault Ste. Marie lies within Seismic Zone 0 and has a zonal acceleration value of 0.00 (Table A3.1.7 of the CHBDC, 2000). Table C4.4.4.1 of the CHBDC indicates that the peak horizontal ground acceleration (PHA) for Seismic Zone 0 ranges from 0.00 to 0.04g. Although the granular subsoils are considered potentially liquefiable, with the extremely low zonal acceleration and PHA, liquefaction is not anticipated. However, additional analysis will be required during the detail design stage once final embankment heights are known.

### 5.3 Structure Foundation Options

Table 5 summarizes the advantages, disadvantages, relative costs and risks/consequences of foundation alternatives for the structures to be constructed at this site. Discussion on the alternatives and preliminary recommendations for the preferred alternative are given in the sections below. Shallow foundations are not recommended for support of structures at any of the five potential structure sites because the bearing resistance of the soils is considered inadequate for the anticipated structure loads and expected excessive settlements. Deep foundations, such as piles or caissons would be the feasible alternatives for support of structures. The preferred alternative at this site is to use driven steel H-piles terminating within the clay or lower silt deposits and derive load carrying capacity from shaft resistance. Due to the significant depth to bedrock at these sites (i.e. greater than 49 m), end-bearing piles may not be feasible.

### 5.4 Steel H-Pile Foundations

Bridge structures may be supported on steel H-piles driven to found within the clay deposit or underlying silt deposit. In any case, the piles will be considered friction piles, with no end-bearing. The length of the pile will determine the resistance of the pile, which will vary from location to location. Once details of the structures are known, further borehole investigation will be required within the limits of the proposed foundation elements to confirm the pile lengths and pile tip elevations. Although the actual geotechnical resistance of the piles will vary from location to location, in general, conservative values of resistance are given below. A more rigorous pile design will have to be carried out at each structure location to determine more accurate values of resistance.

Steel HP310x110 piles should be used for design; however, during the detailed design, consideration could be given to using a lighter pile section (such as HP310x79) or tube piles. Presented below are the factored axial geotechnical resistance at Ultimate Limit States (ULS) and the axial geotechnical resistance at Serviceability Limit States (SLS) for 25 mm of settlement for various lengths of HP310 x 110 piles, as estimated from CFEM 2006; these preliminary values apply to the potential structure locations investigated at this site.

| Estimated Pile Length | Factored Axial Geotechnical Resistance (ULS) (KN) | Axial Geotechnical Resistance (SLS) (KN) |
|---|---|---|
| 15 m | 250 | 200 |
| 20 m | 450 | 350 |
| 30 m | 600 | 500 |
| 40 m | 750 | 600 |

It should be noted that the boreholes advanced for this preliminary design did not extend below about 31 m, except at two locations. However, generally a higher design value for shaft resistance would be expected for piles that extend deeper than about 30 m. Consideration should be given to advancing boreholes to greater depths during the detail design phase of this project.

As noted in Section 5.2, settlement of the approach embankments resulting from large post-construction consolidation settlement within the silty clay deposit is a key concern. This settlement will result in negative skin friction loads on the abutment piles. For preliminary design, based on piles in similar soil conditions and of similar length and loading, an unfactored downdrag load acting on a single pile of between 450 kN and 750 kN will need to be taken into account in the design of the abutment piles; the structural capacity of the piles must be checked for the factored dead and downdrag loads, in accordance with Section 6.8.4 of the CHBDC. The lower downdrag loads are applicable to locations east of Station 12+000 where the clay deposits are deeper. Also, these values depend on the length of pile that extends through the clay deposit subject to consolidation settlement. These values should be refined after details of the structure sites are known.

Due to the large settlements anticipated at these sites, the approach embankments should be constructed in advance of pile installation for bridge abutment construction to allow the majority of the consolidation settlement to occur. If the relative movement between the soil and pile can be reduced to less than about 15 mm, downdrag loads on the piles can be eliminated. The preloading time period required depends on the settlement mitigation option adopted, as discussed in Section 5.2.

## 5.5 Conclusions

Based on the subsurface conditions encountered at this site and the assessment of stability and settlement and mitigation of alternatives, the following conclusions can be drawn:

- Stability of the approach proposed 9 m high embankments at Stations 10+045, 10+525 and 11+125 will have to be constructed by staged construction and/or use of lightweight fill to reduce the loadings on the clay deposit.
- Long-term primary consolidation settlement is estimated to be on the order of 1 m to 3 m depending on the structure location. The magnitude of post-construction settlement will depend on the length of time in the schedule available for preloading/surcharging and other mitigation alternatives chosen. The most feasible alternatives to mitigate post-construction settlement, and to optimize the overall length of the structures, include wick drains in combination with preloading/surcharging and staged construction, and lightweight fills.
- For support of foundation elements, deep foundations will be required. These could consist of steel H-Piles deriving the load carrying capacity from shaft friction, but this load capacity is limited. Additional subsurface information will be required to refine shaft friction values. Further, piles should be driven after primary consolidation settlement is complete, to minimize the effects of downdrag loads on the piles.

### 5.6 Closure

This Preliminary Foundation Design Report was prepared by Ms. Sarah Coyne, P.Eng., an Associate and geotechnical engineer with Golder. Mr. Jorge Costa, a Principal and Golder's Designated MTO Contact for this project, conducted an independent quality control review of the report.

**GOLDER ASSOCIATES LTD.**

LICENSED PROFESSIONAL ENGINEER
S.E.M. COYNE
90471921
PROVINCE OF ONTARIO

Sarah E. M. Coyne, P.Eng.
Geotechnical Engineer/Associate

LICENSED PROFESSIONAL ENGINEER
J. M. A. COSTA
PROVINCE OF ONTARIO

Jorge M.A. Costa, P.Eng.
Principal/Designated MTO Contact
SEMC/JMAC/lb

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## TABLE 1
## SUMMARY OF ENGINEERING PARAMETERS
## HIGHWAY 17 (NEW) FROM BLACK ROAD TO GRFN WEST BOUNDARY
## TRUNK ROAD ACCESS AND HIGHWAY 17 SNOWMOBILE CROSSING
## SAULT STE MARIE, ONTARIO
## G.W.P. 357-94-00

| Proposed Structure | Borehole (Station) | Soil Deposit | Depth (m) | Elevation (m) | Ground-water Elev.(m) | Bulk Unit Weight ($kN/m^3$) | $s_u$ (kPa) | $e_o$ | Cc | Cr | $c_v$ ($cm^2/s$) | E' (MPa) | Φ' (°) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Black Road / Second Line Interchange | BH07-6 (10+045) | Loose Fill | 0-0.6 | 194.7-194.1 | 195.2 Artesian | 20 | - | - | - | - | - | 5 | 28 |
| | | Compact to loose Silt | 0.6-3.7 | 194.1-191.0 | | 20 | - | - | - | - | - | 5 | 28 |
| | | Soft to firm Clay | 3.7-22.9 | 191.0-171.8 | | 16 | 10-20 | 1.940 | 0.646 | 0.133 | 0.0003 | 5 | 25 |
| | | Very loose to loose Silt, some clay | 22.9-48.2 | 171.8-146.5 | | 20 | - | - | - | - | - | 10 | 28 |
| | | Very Dense Till | 48.2-49.2* | 146.5-145.5 | | 22 | - | - | - | - | - | 35 | 32 |
| Snowmobile Crossing | BH07-1 (10+525) | Loose Fill | 0-1.8 | 193.5–191.7 | 194.0 Artesian | 20 | - | - | - | - | - | 5 | 27 |
| | | Loose Silt | 1.8-3.0 | 191.7-190.5 | | 20 | - | - | - | - | - | 5 | 28 |
| | | Very soft to firm Clay | 3.0-22.9 | 190.5-170.6 | | 16 | 10-50 | 1.863 | 0.729 | 0.130 | 0.0006 | 5-15 | 25 |
| | | Very loose to Compact Silt, some clay | 22.9-31.1* | 170.6-162.4 | | 20 | - | - | - | - | - | 10 | 30 |
| Interchange | BH07-2 (11+125) | Very loose to very dense Silt | 0-5.6 | 190.5-184.9 | 185.6 | 20 | - | - | - | - | - | 25 | 30 |
| | | Very soft to stiff Silty Clay to Clay | 5.6-29.3 | 184.9-161.2 | | 16 | 20-60 | 1.943 | 0.724 | 0.128 | 0.0047 | 5-15 | 25-27 |
| | | Compact Silt, some clay | 29.3-31.1* | 161.2-159.4 | | 20 | - | - | - | - | - | 10 | 30 |
| Interchange | BH07-3 (12+025) | Very loose to compact Sand/Silt | 0-8.7 | 188.2-179.5 | 183.0 | 20 | - | - | - | - | - | 5 | 27 |
| | | Very soft to stiff Silty Clay to Clay | 8.7-23.2 | 179.5-165.0 | | 16 | 40 | 1.512 | 0.534 | 0.096 | 0.0018 | 15 | 26 |
| | | Loose to compact Silt, some clay | 23.2-31.1* | 165.0-157.1 | | 20 | - | - | - | - | - | 10 | 30 |
| Black Creek Crossing | BH07-4 (12+500) | Very loose to loose Silt | 0-3.5 | 188.8-185.3 | 183.3 | 20 | - | - | - | - | - | 5 | 28 |
| | | Very soft Clayey Silt | 3.5-5.6 | 185.3-183.2 | | 16 | 10 | 0.905 | 0.194 | 0.032 | 0.0057 | 10 | 26 |
| | | Very loose to loose Sand | 5.6-11.0 | 183.2-177.8 | | 20 | - | - | - | - | - | 5 | 27 |
| | | Loose to compact Silt | 11.0-17.1 | 177.8-171.7 | | 20 | - | - | - | - | - | 10 | 30 |
| | | Soft to stiff Silty Clay to Clay | 17.1-31.1* | 171.7-157.7 | | 16 | 40 | 1.229 | 0.448 | 0.084 | 0.0088 | 15 | 26 |

## TABLE 1 (CONTINUED)

| Proposed Structure | Borehole (Station) | Soil Deposit | Depth (m) | Elevation (m) | Ground-water Elev.(m) | Bulk Unit Weight (kN/m$^3$) | $s_u$ (kPa) | $e_o$ | Cc | Cr | $c_v$ (cm$^2$/s) | E' (MPa) | Φ' ($^o$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Trunk Road Access Interchange | BH07-5 (14+500) | Very loose to loose Fill (Topsoil lense) | 0-3.9 | 188.1-184.2 | 183.0 | 20 | - | - | - | - | - | 5 | 27 |
| | | Very soft to soft Clay | 3.9-5.6 | 184.2-182.5 | | 16 | 10-25 | 2.012 | 0.740 | 0.125 | 0.0006 | 5 | 25 |
| | | Very loose Sandy Silt | 5.6-7.2 | 182.5-180.9 | | 20 | - | - | - | - | - | 5 | 28 |
| | | Very loose Sand | 7.2-11.7 | 180.9-176.4 | | 20 | - | - | - | - | - | 5 | 27 |
| | | Very loose to compact Sand & Silt | 11.7-20.1 | 176.4-168.0 | | 20 | - | - | - | - | - | 10 | 30 |
| | | Very soft to stiff Clayey Silt to Clay | 20.1-31.4 | 168.0-156.7 | | 16 | 30-60 | 1.512 | 0.464 | 0.077 | 0.0033 | 10 | 26 |
| | | | 31.4-36.6** | 156.7-151.5 | | - | - | - | - | - | - | - | - |

**NOTES:**

* Depth at which borehole was terminated.

** Dynamic Cone Penetration Test

This table should be read in conjunction with Section 5.2 of the Preliminary Foundation Investigation and Design Report.

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# TABLE 2
## SUMMARY OF STABILITY AND SETTLEMENT ANALYSIS
## HIGHWAY 17 (NEW) FROM BLACK ROAD TO GRFN WEST BOUNDARY
## TRUNK ROAD ACCESS AND HIGHWAY 17 SNOWMOBILE CROSSING
## SAULT STE MARIE, ONTARIO
## G.W.P. 357-94-00

| Borehole (Station) | Maximum Embankment Height (m) for FoS >1.3 (Short-term)[1] | Maximum Proposed Embankment Height (m) | Estimated Settlement Under Maximum Proposed Embankment Height (mm) | | | Time for 95% Consolidation (Years)[2] |
|---|---|---|---|---|---|---|
| | | | Immediate | Primary | Secondary (one log cycle) | |
| BH07-6 (10+045) Black Road/Second Line | 3.5 | 9 | 50-100 | 2100 - 2300 | ~150 | >10 |
| BH07-1 (10+525) Snowmobile Crossing | 4.5 | 9 | 25-75 | 2600 – 2800 | ~150 | >10 |
| BH07-2 (11+125) Potential Interchange | 6.5 | 9 | 50-100 | 1900 – 2100 | ~125 | ~10 |
| BH07-3 (12+025) Potential Interchange | 9.0 | 9 | 75-125 | 1000 – 1200 | ~75 | ~10 |
| BH07-4 (12+500) Black Creek Crossing | 7.0 | 4 | 125-175 | 150 – 200 | ~75 | ~7 |
| BH07-5 (14+500) Trunk Road Access | 10.0 | 9 | 150-200 | 700 - 900 | ~75 | ~4 |

**NOTES:**

1. Without implementation of mitigation measures.
2. Primary settlement only.
3. This table should be read in conjunction with Section 5.2 of the Preliminary Foundation Investigation and Design Report.
4. Earth fill embankments require a mid-height bench for fills in excess of 8 m.

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# TABLE 3
# EVALUATION OF STABILITY AND SETTLEMENT MITIGATION ALTERNATIVES
# HIGHWAY 17 (NEW) FROM BLACK ROAD TO GRFN WEST BOUNDARY
# TRUNK ROAD ACCESS AND HIGHWAY 17 SNOWMOBILE CROSSING
# SAULT STE MARIE, ONTARIO
# G.W.P. 357-94-00

| Stability/Settlement Mitigation Option | Advantages | Disadvantages | Relative Costs | Post-Construction Settlement | Risks/Consequences |
|---|---|---|---|---|---|
| **Sub-excavation of weak, soft and compressible material** | • Long-term settlement of clay minimized.<br>• Stability not a concern.<br>• Limited construction period. | • High groundwater table.<br>• Cut slopes at 3H:1V required.<br>• Disposal of excavated soil to be considered.<br>• Deep excavation required (23 m). | • Cost of sub-excavation and backfill material. | • Less than 25 mm. | • Not practical due to the depths and thicknesses of the soft stratum |
| **Preloading** | • Eliminates sub-excavation below the water table.<br>• Reduces long term settlement. | • Preloading alone could take years; should be used in conjunction with another mitigation method, such as surcharging and wick drains.<br>• May not address stability concerns.<br>• Monitoring program for settlements and pore-pressures required to confirm duration of settlement. | • Typically less expensive than sub-excavation. | • Depends on embankment height and site location | • Settlement of clay will occur during preload period.<br>• Some post-construction settlement will occur after the preload period.<br>• Construction duration dependant on the results of the monitoring program. |
| **Surcharging** | • Reduces time for consolidation settlement. | • May not address stability concerns.<br>• More material required that may not be re-usable.<br>• Monitoring program for settlements and pore-pressures required to confirm duration of settlement.<br>• Monitoring program for settlements and pore-pressures required to confirm duration of settlement. | • Extra cost of surcharge material | • Depends on embankment height and site location | • Settlement of clay will occur during preload and surcharge period.<br>• Some post-construction settlement will occur after the surcharge period.<br>• Construction duration dependant on the results of the monitoring program. |
| **Toe Berms/ Slope Flattening** | • May be required for stability depending on final embankment height. | • More material required for the berms.<br>• Additional property required. | • Extra cost of toe berm material | • Depends on embankment height and site location | • Settlement of clay will occur during preload period.<br>• Some post-construction settlement will occur after the preload period. |

## TABLE 3 (CONTINUED)

| Stability/Settlement Mitigation Option | Advantages | Disadvantages | Relative Costs | Post-Construction Settlement | Risks/Consequences |
|---|---|---|---|---|---|
| **Staged Construction** | • May be required for stability depending on final embankment height. | • Wait times required between stages will increase overall preload duration.<br>• Monitoring program for settlements and pore-pressures required to confirm duration of settlement. | n/a | • Depends on embankment height and site location | • Settlement of clay will occur during backfilling and preload period.<br>• Construction duration dependant on the results of the monitoring program. |
| **Wick Drains (with preloading/ surcharging/staged construction)** | • Typically significant reduction in preload time.<br>• Reduced long-term settlement. | • Monitoring program for settlements and pore-pressures required to confirm duration of settlement. | • Cost of installation of wick drains and drainage blanket | • Depends on embankment height and site location | • Settlement of clay will occur during preload period.<br>• Construction duration dependant on the results of the monitoring program. |
| **Lightweight Fill (EPS/slag)** | • Can be used when not sufficient time for preloading.<br>• May be a local source of lightweight slag in Sault Ste. Marie.<br>• Reduced long-term settlement.<br>• Enhanced embankment stability. | • May be too expensive to be practical for long embankment stretches; typically only practical near bridge abutments.<br>• Not appropriate in high groundwater conditions if proposed to be used at/near ground surface. | • EPS = $140/m^3$<br>• Slag = $35/t - $60/t | • Depends on embankment height, site location, type and quantity of lightweight fill used. | • May not be practical due to the cost and extent of embankments requiring the fill |

**NOTES:**

**1.** This table should be read in conjunction with Section 5.2 of the Preliminary Foundation Investigation and Design Report.

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Checked by: **JMAC**

# TABLE 4
## SUMMARY OF PREFERRED MITIGATION ALTERNATIVE
## HIGHWAY 17 (NEW) FROM BLACK ROAD TO GRFN WEST BOUNDARY
## TRUNK ROAD ACCESS AND HIGHWAY 17 SNOWMOBILE CROSSING
## SAULT STE MARIE, ONTARIO - G.W.P. 357-94-00

| Borehole (Station) | Maximum Proposed Embankment Height (m) | Maximum Stable Embankment Height (m) [1] (FoS > 1.3) | Estimated Settlement (mm)[2] | Time for 95% Consolidation (Years)[3] | Preferred Mitigation Alternative[4] | |
|---|---|---|---|---|---|---|
| | | | | | 2 Year Construction Schedule | 5 Year Construction Schedule |
| BH07-6 (10+045) | 9 | 3.5 | ~2,300 | >10 | Preloading with surcharging and wick drains to reduce time for settlement. Staged construction required for stability.<br>Lightweight (EPS) fill required to reduce magnitude of loading. | Preloading with surcharging and wick drains to reduce time for settlement. Staged construction required for stability. |
| BH07-1 (10+525) | 9 | 4.5 | ~2,800 | >10 | Preloading with surcharging and wick drains to reduce time for settlement. Staged construction required for stability.<br>Lightweight (EPS) fill may be required to reduce magnitude of loading. | Preloading with surcharging and wick drains to reduce time for settlement. Staged construction required for stability. |
| BH07-2 (11+125) | 9 | 6.5 | ~2,100 | ~10 | Preloading with surcharging and wick drains to reduce time for settlement. Staged construction required for stability. | Preloading with surcharging and wick drains to reduce time for settlement. Staged construction required for stability. |
| BH07-3 (12+025) | 9 | 9.0 | ~1,200 | ~10 | Preloading with surcharging and wick drains to reduce time for settlement. | Preloading with surcharging and wick drains to reduce time for settlement. |
| BH07-4 (12+500) | 4 | 7.0 | ~250 | ~7 | Preloading with surcharging and wick drains to reduce time for settlement. | Preloading with surcharging to reduce time for settlement. |
| BH07-5 (14+500) | 9 | 10.0 | ~900 | ~4 | Preloading with surcharging and wick drains to reduce time for settlement. | Preloading with surcharging to reduce time for settlement. |

**NOTES:**

1. Without implementation of mitigation measures.
2. Includes primary and secondary consolidation settlement. Excludes immediate settlement.
3. Primary settlement only.
4. Alternatives outlined in Table 3. Preferred alternative from a foundations perspective (i.e. reduction of post-construction settlement).
5. This table should be read in conjunction with Section 5.2 of the Preliminary Foundation Investigation and Design Report.

Compiled by: **SEMC**

Checked by: **JMAC**

# TABLE 5
## STRUCTURE FOUNDATION ALTERNATIVES
## HIGHWAY 17 (NEW) FROM BLACK ROAD TO GRFN WEST BOUNDARY
## TRUNK ROAD ACCESS AND HIGHWAY 17 SNOWMOBILE CROSSING
## SAULT STE MARIE, ONTARIO - G.W.P. 357-94-00

| Options | Advantages | Disadvantages | Relative Costs | Risks/Consequences |
|---|---|---|---|---|
| Spread Footings on Native Soil | • Ease of construction; not a feasible alternative due to excessive long-term settlements | • Preloading or other mitigation alternative would be required prior to constructing footings<br>• Extremely low bearing resistance, even with preloading - will likely not be feasible | n/a | • Not a feasible alternative due to potential for large long-term settlement |
| Steel H-piles (friction piles) | • Feasible alternative | • Will likely have to preload first to reduce downdrag loads on piles<br>• Low shaft resistance unless piles are very long or many piles are used; may preclude the use of integral abutments | • Typical pile cost = $200/m (plus mobilization) | • May have to drive piles to refusal layer (refusal encountered at Black Road at 49 m depth) |
| Caissons | • Feasible alternative | • Will likely have to preload first to reduce downdrag loads on piles<br>• Temporary liners would be required for groundwater control.<br>• Low shaft resistance unless caissons are very deep | • Typical caisson cost = $5,000/m (plus mobilization) | • May have to found caissons on refusal layer (refusal encountered at Black Road at 45 m depth) |

**NOTES:**

1. This table should be read in conjunction with Section 5.3 of the Preliminary Foundation Investigation and Design Report.

Compiled by: **SEMC**

Checked by: **JMAC**

# LIST OF ABBREVIATIONS

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

## 1. SAMPLE TYPE

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

## II. PENETRATION RESISTANCE

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

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

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

**Piezocone Penetration Test (CPT)**
An 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) |
| $\gamma$ | unit weight |

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

# LIST OF SYMBOLS

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

## 1. GENERAL

| | |
|---|---|
| $\pi$ | 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 |
| F | factor of safety |
| V | volume |
| W | weight |

## II. STRESS AND STRAIN

| | |
|---|---|
| $\gamma$ | shear strain |
| $\Delta$ | change in, e.g. stress: $\Delta\sigma$ |
| $\varepsilon$ | linear strain |
| $\varepsilon_v$ | volumetric strain |
| $\eta$ | coefficient of viscosity |
| $\nu$ | Poisson's ratio |
| $\sigma$ | total stress |
| $\sigma'$ | effective stress ($\sigma' = \sigma\text{-}u$) |
| $\sigma_{vo}$ | initial effective overburden stress |
| $\sigma_1, \sigma_2, \sigma_3$ | principal stress (major, intermediate, minor) |
| $\sigma_{oct}$ | mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$ |
| $\tau$ | 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 |
| $\gamma'$ | 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 $\rho$. Unit weight symbol is $\gamma$ where $\gamma = \rho g$ (i.e. mass density x 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 |
| $\sigma'_p$ | pre-consolidation pressure |
| OCR | over-consolidation ratio $= \sigma'_p / \sigma'_{vo}$ |

### (d) Shear Strength

| | |
|---|---|
| $\tau_p, \tau_r$ | peak and residual shear strength |
| $\phi'$ | effective angle of internal friction |
| $\delta$ | angle of interface friction |
| $\mu$ | 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 $\tau = c' + \sigma' \tan\phi'$

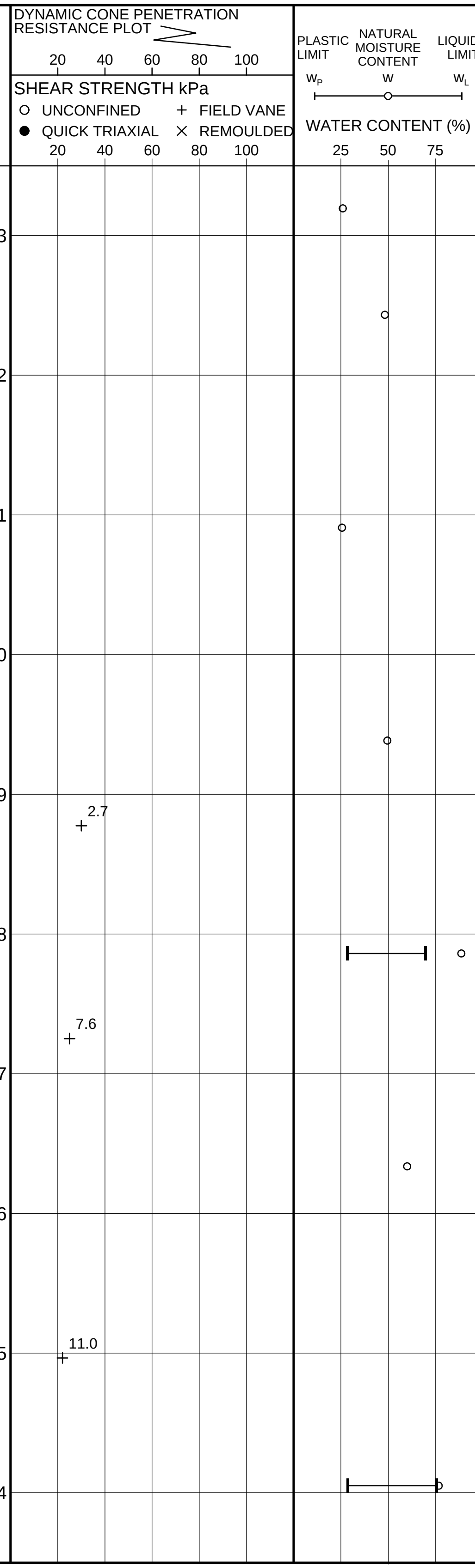
2 Shear strength = (Compressive strength)/2

# RECORD OF BOREHOLE No BH07-1

 **METRIC**

PROJECT 07-1191-0014
W.P. 357-94-00
LOCATION N 5155572.3 ;E 283282.3
ORIGINATED BY EHS
DIST
HWY 17
BOREHOLE TYPE 108mm I.D. Hollow Stem Augers/NW Wash Boring
COMPILED BY BB
DATUM Geodetic
DATE 2007/05/23
CHECKED BY SEMC

| ELEV / DEPTH | SOIL PROFILE: DESCRIPTION | SAMPLE NUMBER | SAMPLE TYPE | "N" VALUES | ELEVATION SCALE | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|
| 193.5 | GROUND SURFACE | | | | | |
| 0.0 | Silty Organics to silty sand (FILL)<br>Loose<br>Dark brown<br>Moist to wet | 1 | AS | - | 193 | |
| | | 2 | SS | 6 | 192 | |
| 191.7 / 1.8 | SILT, trace sand, trace clay<br>Loose<br>Grey<br>Wet | 3 | SS | 3 | | |
| | | 4 | SS | 6 | 191 | 0 2 89 9 |
| 190.5 / 3.0 | CLAY, some silt<br>Very soft to firm<br>Reddish brown<br>Wet | 5 | SS | 3 | 190 | |
| | | 6 | SS | 1 | 189 | |
| | | 7 | SS | WH | 188 | |
| | | | | | 187 | |
| | | 8 | SS | WH | 186 | |
| | | 9 | SS | WH | 185 | |
| | | 10 | SS | WH | 184 | |




UNIT WEIGHT γ kN/m³

Continued Next Page

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

Golder Associates



# RECORD OF BOREHOLE No BH07-1

 **METRIC**

PROJECT 07-1191-0014
W.P. 357-94-00
LOCATION N 5155572.3 ;E 283282.3
ORIGINATED BY EHS
DIST HWY 17
BOREHOLE TYPE 108mm I.D. Hollow Stem Augers/NW Wash Boring
COMPILED BY BB
DATUM Geodetic
DATE 2007/05/23
CHECKED BY SEMC

--- CONTINUED FROM PREVIOUS PAGE ---

SOIL PROFILE: CLAY, some silt; Very soft to firm; Reddish brown; Wet

| SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION | WATER CONTENT (%) | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|
| 11 | TO | PH | 182.5 | | |
| 12 | SS | WH | 181.0 | w ≈ 75 | 0 0 16 84 |
| 13 | SS | WH | 179.5 | | |
| 14 | SS | WR | 178.0 | $w_P$ ≈ 25, $w_L$ ≈ 72, w ≈ 77 | |
| 15 | SS | WR | 175.0 | w ≈ 50 | |

Field vane shear strength (kPa), with sensitivity numbers:

| Elevation (approx.) | Shear strength (kPa) | Sensitivity |
|---|---|---|
| 183.4 | ~25 | 4.0 |
| 181.9 | ~10 | 10.0 |
| 180.4 | ~30 | 4.0 |
| 178.9 | ~35 | 4.3 |
| 177.4 | ~35 | 4.0 |
| 174.3 | ~40 | 3.3 |

Elevation scale: 183, 182, 181, 180, 179, 178, 177, 176, 175, 174

Continued Next Page

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

# RECORD OF BOREHOLE No BH07-1

 **METRIC**

PROJECT 07-1191-0014
W.P. 357-94-00
LOCATION N 5155572.3 ;E 283282.3
ORIGINATED BY EHS
DIST HWY 17
BOREHOLE TYPE 108mm I.D. Hollow Stem Augers/NW Wash Boring
COMPILED BY BB
DATUM Geodetic
DATE 2007/05/23
CHECKED BY SEMC

--- CONTINUED FROM PREVIOUS PAGE ---

| ELEV DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | SHEAR STRENGTH kPa | WATER CONTENT (%) | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|
| | CLAY, some silt<br>Very soft to firm<br>Reddish brown<br>Wet | | | | 173 | | | |
| | | 16 | SS | WR | 172 | Field vane + 2.9 (sensitivity) | | |
| | | | | | 171 | | | |
| 170.6<br>22.9 | SILT, some clay, trace sand<br>Very loose to compact<br>Grey<br>Wet | | | | 170 | | | |
| | | 17 | SS | WR | 169 | | o (approx. 30) | 0 1 79 20 |
| | | | | | 168 | | | |
| | | | | | 167 | | | |
| | | 18 | SS | 12 | 166 | | | |
| | | | | | 165 | | | |
| | | | | | 164 | | | |

Continued Next Page

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

Golder Associates

Foundation Design

# RECORD OF BOREHOLE No BH07-1

 **METRIC**

PROJECT 07-1191-0014
W.P. 357-94-00
LOCATION N 5155572.3 ;E 283282.3
ORIGINATED BY EHS
DIST HWY 17
BOREHOLE TYPE 108mm I.D. Hollow Stem Augers/NW Wash Boring
COMPILED BY BB
DATUM Geodetic
DATE 2007/05/23
CHECKED BY SEMC

| 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) | PLASTIC LIMIT $W_P$ / NATURAL MOISTURE CONTENT W / LIQUID LIMIT $W_L$ — WATER CONTENT (%) 25 50 75 | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | --- CONTINUED FROM PREVIOUS PAGE --- | | | | | | | | | | |
| | SILT, some clay, trace sand<br>Very loose to compact<br>Grey<br>Wet | | | | | | 163 | | | | |
| | | | 19 | SS | 2 | | | | o (~27) | | |
| 162.4<br>31.1 | End of Borehole<br><br>Note:<br><br>1. Water level measured at a depth of 0.5m (Elev. 194.0m) above ground surface upon completion of drilling. | | | | | | | | | | |

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

MIS-MTO 001 07-1191-0014.GPJ GAL-MISS.GDT 10/12/07 ACM

Foundation Design

Golder Associates

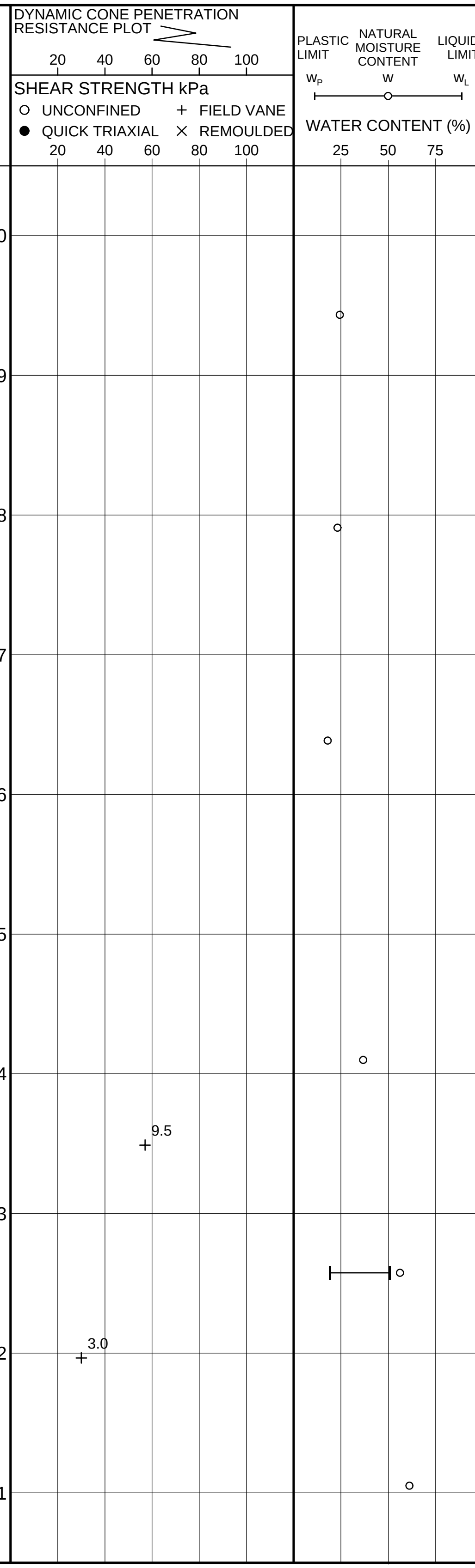
# RECORD OF BOREHOLE No BH07-2

 **METRIC**

| | | | |
|---|---|---|---|
| PROJECT | 07-1191-0014 | | |
| W.P. | 357-94-00 | LOCATION | N 5155590.1 ;E 283887.0 |
| DIST | | HWY | 17 |
| BOREHOLE TYPE | 108mm I.D. Hollow Stem Augers/NW Wash Boring | | |
| DATUM | Geodetic | DATE | 2007/05/24 |
| ORIGINATED BY | TR | COMPILED BY | BB |
| CHECKED BY | SEMC | | |

| ELEV / DEPTH | SOIL PROFILE – DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|
| 190.5 | GROUND SURFACE | | | | | |
| 0.0 | SILT, trace sand, trace clay<br>Very loose to very dense<br>Reddish brown to grey<br>Moist to wet<br><br>50mm of TOPSOIL at ground surface | 1 | AS | - | | |
| | | 2 | SS | 4 | | |
| | | 3 | SS | 3 | | |
| | | 4 | SS | 21 | | 0 8 83 9 |
| | | 5 | SS | 36 | | |
| | | 6 | SS | 61 | | |
| | | 7 | SS | 35 | ∇ | |
| 184.9<br>5.6 | CLAY, some silt<br>Very soft to stiff<br>Reddish brown<br>Wet | 8 | SS | 1 | | |
| | | 9 | SS | WH | | |
| | | 10 | SS | WH | | |

ELEVATION SCALE: 190, 189, 188, 187, 186, 185, 184, 183, 182, 181




UNIT WEIGHT γ kN/m³

Continued Next Page

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

MIS-MTO 001 07-1191-0014.GPJ GAL-MISS.GDT 10/12/07 ACM

Golder Associates



# RECORD OF BOREHOLE No BH07-2

 **METRIC**

PROJECT 07-1191-0014
W.P. 357-94-00
LOCATION N 5155590.1 ;E 283887.0
ORIGINATED BY TR
DIST HWY 17
BOREHOLE TYPE 108mm I.D. Hollow Stem Augers/NW Wash Boring
COMPILED BY BB
DATUM Geodetic
DATE 2007/05/24
CHECKED BY SEMC

--- CONTINUED FROM PREVIOUS PAGE ---

**SOIL PROFILE**

CLAY, some silt
Very soft to stiff
Reddish brown
Wet

| SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE (approx.) | WATER CONTENT (%) | UNIT WEIGHT γ (kN/m³) | GR | SA | SI | CL |
|---|---|---|---|---|---|---|---|---|---|
| 11 | SS | WH | 179.5 | | | | | | |
| 12 | TO | PH | 178 | $w_P$–w–$w_L$ plotted | 15.9 | | | | |
| 13 | SS | WR | 176.5 | $w_P$–$w_L$ and w plotted | | | | | |
| 14 | SS | WH | 175 | | | | | | |
| 15 | SS | WR | 172 | w plotted | | 0 | 0 | 18 | 82 |

Field vane shear strength (+) plotted with sensitivity values: 4.6, 3.8, 4.0, 4.2, 4.4, 3.0

Elevation scale: 180, 179, 178, 177, 176, 175, 174, 173, 172, 171

Continued Next Page

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

Golder Associates



# RECORD OF BOREHOLE No BH07-2

 **METRIC**

PROJECT 07-1191-0014
W.P. 357-94-00
DIST HWY 17
DATUM Geodetic
LOCATION N 5155590.1 ;E 283887.0
BOREHOLE TYPE 108mm I.D. Hollow Stem Augers/NW Wash Boring
DATE 2007/05/24
ORIGINATED BY TR
COMPILED BY BB
CHECKED BY SEMC

--- CONTINUED FROM PREVIOUS PAGE ---

| ELEV DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | SHEAR STRENGTH kPa / DYNAMIC CONE | WATER CONTENT (%) | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|
| | CLAY, some silt<br>Very soft to stiff<br>Reddish brown<br>Wet | | | | 170 | | | | |
| | | 16 | SS | WR | 169 | | Wp ≈ 25, w ≈ 66 | | |
| | | | | | 168 | Field vane ≈ 60, 3.2 | | | |
| | | 17 | SS | 1 | 166 | | | | |
| | | 18 | SS | WR | 163 | | w ≈ 58 | | |
| 161.2<br>29.3 | SILT, some clay, trace sand<br>Compact<br>Grey<br>Wet | | | | 161 | | | | |

Continued Next Page

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

MIS-MTO 001 07-1191-0014.GPJ GAL-MISS.GDT 10/12/07 ACM

# RECORD OF BOREHOLE No BH07-2

 **METRIC**

PROJECT 07-1191-0014
W.P. 357-94-00
LOCATION N 5155590.1 ;E 283887.0
ORIGINATED BY TR
DIST HWY 17
BOREHOLE TYPE 108mm I.D. Hollow Stem Augers/NW Wash Boring
COMPILED BY BB
DATUM Geodetic
DATE 2007/05/24
CHECKED BY SEMC

| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa | WATER CONTENT (%) | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | --- CONTINUED FROM PREVIOUS PAGE --- | | | | | | | | | | |
| | SILT, some clay, trace sand<br>Compact<br>Grey<br>Wet | | | | | | 160 | | | | |
| | | | 19 | SS | 10 | | | | o (approx. 27) | | |
| 159.4<br>31.1 | End of Borehole<br><br>Note:<br><br>1. Water level in open borehole at a depth of 4.9m (Elev. 185.6m) upon completion of drilling. | | | | | | | | | | |

Legend: 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 (%) 25 50 75.

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

Golder Associates



# RECORD OF BOREHOLE No BH07-3

 **METRIC**

PROJECT 07-1191-0014
W.P. 357-94-00
DIST ___ HWY 17
DATUM Geodetic
LOCATION N 5155621.8 ;E 284786.5
BOREHOLE TYPE 108mm I.D. Hollow Stem Augers/NW Wash Boring
DATE 2007/05/26
ORIGINATED BY TR
COMPILED BY BB
CHECKED BY SEMC

| ELEV / DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | Water content (%) | GR | SA | SI | CL |
|---|---|---|---|---|---|---|---|---|---|---|
| 188.2 | GROUND SURFACE | | | | | | | | | |
| 0.0 | SAND, some silt<br>Brown to black<br>Moist | 1 | AS | - | | o | | | | |
| 187.5 / 0.7 | 25mm of topsoil at ground surface<br>SILT, trace to some sand, trace to some clay,<br>Very loose to compact<br>Reddish brown to grey<br>Moist to wet | 2 | SS | 5 | | | | | | |
| | | 3 | SS | 8 | | o | 0 | 6 | 82 | 12 |
| | | 4 | SS | 5 | | | | | | |
| | | 5 | SS | 6 | | o | | | | |
| | | 6 | SS | 2 | | | | | | |
| | | 7 | SS | 7 | ▽ (approx. El. 183.1) | o | 0 | 14 | 78 | 8 |
| | | 8 | SS | 14 | | | | | | |
| | | 9 | SS | 8 | | o | | | | |
| 179.5 / 8.7 | SILTY CLAY to CLAY, some silt<br>Very soft to stiff<br>Reddish borwn<br>Wet | | | | | | | | | |
| | | 10 | SS | WH | | | | | | |

Elevation scale: 188, 187, 186, 185, 184, 183, 182, 181, 180, 179

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 (%) 25 50 75
UNIT WEIGHT γ kN/m³
REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

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

# RECORD OF BOREHOLE No BH07-3

 **METRIC**

| | | | |
|---|---|---|---|
| PROJECT | 07-1191-0014 | | |
| W.P. | 357-94-00 | LOCATION | N 5155621.8 ;E 284786.5 |
| DIST | | HWY | 17 |
| BOREHOLE TYPE | 108mm I.D. Hollow Stem Augers/NW Wash Boring | | |
| DATUM | Geodetic | DATE | 2007/05/26 |
| ORIGINATED BY | TR | COMPILED BY | BB |
| CHECKED BY | SEMC | | |

SOIL PROFILE: ELEV / DEPTH, DESCRIPTION, STRAT PLOT
SAMPLES: NUMBER, TYPE, "N" VALUES
GROUND WATER CONDITIONS
ELEVATION SCALE
DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED: 20 40 60 80 100
PLASTIC LIMIT $W_P$, NATURAL MOISTURE CONTENT W, LIQUID LIMIT $W_L$
WATER CONTENT (%): 25 50 75
UNIT WEIGHT γ kN/m³
REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

*--- CONTINUED FROM PREVIOUS PAGE ---*

SILTY CLAY to CLAY, some silt
Very soft to stiff
Reddish borwn
Wet

| NUMBER | TYPE | "N" VALUES |
|---|---|---|
| 11 | SS | WH |
| 12 | SS | WR |
| 13 | SS | WH |
| 14 | SS | 3 |
| 15 | SS | WR |

Elevation scale: 178, 177, 176, 175, 174, 173, 172, 171, 170, 169

Field vane sensitivity values: 4.0, 3.3, 3.1, 3.6

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

○3% STRAIN AT FAILURE

# RECORD OF BOREHOLE No BH07-3

 **METRIC**

PROJECT 07-1191-0014
W.P. 357-94-00
DIST
HWY 17
DATUM Geodetic
LOCATION N 5155621.8 ;E 284786.5
BOREHOLE TYPE 108mm I.D. Hollow Stem Augers/NW Wash Boring
DATE 2007/05/26
ORIGINATED BY TR
COMPILED BY BB
CHECKED BY SEMC

| ELEV DEPTH | DESCRIPTION | NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | WATER CONTENT (%) |
|---|---|---|---|---|---|---|
| | --- CONTINUED FROM PREVIOUS PAGE --- | | | | | |
| | SILTY CLAY to CLAY, some silt<br>Very soft to stiff<br>Reddish borwn<br>Wet | | | | 168 | |
| | | | | | 167 | |
| | | 16 | SS | WH | | $w_P$ ≈ 23, $w$ ≈ 32 |
| | | | | | 166 | |
| 165.0<br>23.2 | SILT, some clay, trace sand<br>Loose to compact<br>Reddish grey to grey<br>Wet | | | | 165 | |
| | | | | | 164 | |
| | | 17 | SS | 6 | | |
| | | | | | 163 | |
| | | | | | 162 | |
| | | | | | 161 | |
| | | 18 | SS | 20 | | $w$ ≈ 24 |
| | | | | | 160 | |
| | | | | | 159 | |

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20, 40, 60, 80, 100); PLASTIC LIMIT $W_P$, NATURAL MOISTURE CONTENT W, LIQUID LIMIT $W_L$; WATER CONTENT (%) (25, 50, 75); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) (GR SA SI CL)

Continued Next Page

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

# RECORD OF BOREHOLE No BH07-3

 **METRIC**

PROJECT 07-1191-0014

W.P. 357-94-00 LOCATION N 5155621.8 ;E 284786.5 ORIGINATED BY TR

DIST HWY 17 BOREHOLE TYPE 108mm I.D. Hollow Stem Augers/NW Wash Boring COMPILED BY BB

DATUM Geodetic DATE 2007/05/26 CHECKED BY SEMC

| 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) | PLASTIC LIMIT $W_P$ / NATURAL MOISTURE CONTENT W / LIQUID LIMIT $W_L$ — WATER CONTENT (%) 25 50 75 | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | --- *CONTINUED FROM PREVIOUS PAGE* --- | | | | | | | | | | |
| | SILT, some clay, trace sand<br>Loose to compact<br>Reddish grey to grey<br>Wet | | | | | | 158 | | | | |
| | | | 19 | SS | 27 | | | | ○ (approx. 25) | | |
| 157.1<br>31.1 | End of Borehole<br><br>Note:<br><br>1. Water level in open borehole at a depth of 5.2m (Elev. 183.0m) upon completion of borehole. | | | | | | | | | | |



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

# RECORD OF BOREHOLE No BH07-4

 **METRIC**

PROJECT 07-1191-0014
W.P. 357-94-00
DIST HWY 17
DATUM Geodetic
LOCATION N 5155703.7 ;E 285198.8
BOREHOLE TYPE 108mm I.D. Hollow Stem Augers/NW Wash Boring
DATE 2007/05/28
ORIGINATED BY TR
COMPILED BY BB
CHECKED BY SEMC

| ELEV / DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|
| 188.8 | GROUND SURFACE | | | | | | |
| 0.0 | SILT, trace to some sand, trace to some clay; Very loose to loose; Brown and grey; Moist to wet; 75mm of TOPSOIL at ground surface | 1 | AS | - | | | |
| | | 2 | SS | 4 | | 188 | |
| | | 3 | SS | WH | | 187 | 0 10 78 12 |
| | | 4 | SS | 5 | | 186 | |
| | | 5 | SS | 3 | | | |
| 185.3 / 3.5 | CLAYEY SILT, trace sand, containing silt seams; Very soft; Grey; Wet | 6 | SS | WH | | 185 | 0 1 75 24 |
| | | 7 | SS | WH | | 184 | |
| | | | | | ∇ | | |
| 183.2 / 5.6 | SAND, trace to some silt, trace clay; Very loose to loose; Reddish brown to reddish grey; Wet | | | | | 183 | |
| | | 8 | SS | 2 | | 182 | |
| | | 9 | SS | WH | | 181 | 0 86 13 1 |
| | | | | | | 180 | |
| | | 10 | SS | 4 | | 179 | |

Plot columns: 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 (%) 25 50 75; UNIT WEIGHT γ kN/m³

Continued Next Page

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

Golder Associates

# RECORD OF BOREHOLE No BH07-4

 **METRIC**

PROJECT 07-1191-0014
W.P. 357-94-00
DIST HWY 17
DATUM Geodetic
LOCATION N 5155703.7 ;E 285198.8
BOREHOLE TYPE 108mm I.D. Hollow Stem Augers/NW Wash Boring
DATE 2007/05/28
ORIGINATED BY TR
COMPILED BY BB
CHECKED BY SEMC

--- CONTINUED FROM PREVIOUS PAGE ---

| ELEV DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | WATER CONTENT (%) | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|
| | SAND, trace to some silt, trace clay<br>Very loose to loose<br>Reddish brown to reddish grey<br>Wet | | | | 178 | | |
| 177.8<br>11.0 | SILT, trace sand, trace clay<br>Loose to compact<br>Reddish brown to reddish grey<br>Wet | 11 | SS | 8 | 177 | w ≈ 24 | |
| | | 12 | SS | 9 | 176 | w ≈ 24 | |
| | | 13 | SS | 9 | 175 | w ≈ 24 | 0 7 90 3 |
| | | 14 | SS | 14 | 173 | | |
| 171.7<br>17.1 | SILTY CLAY to CLAY,<br>Soft to stiff<br>Reddish brown to reddish grey<br>Wet | | | | 172, 171 | | |
| | | 15 | SS | 3 | 170 | wP ≈ 24, w ≈ 28, wL ≈ 33 | |
| | | | | | 169 | | |

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 (%) 25 50 75
UNIT WEIGHT γ kN/m³

Continued Next Page

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

Golder Associates



# RECORD OF BOREHOLE No BH07-4

 **METRIC**

PROJECT 07-1191-0014
W.P. 357-94-00
LOCATION N 5155703.7 ;E 285198.8
ORIGINATED BY TR
DIST HWY 17
BOREHOLE TYPE 108mm I.D. Hollow Stem Augers/NW Wash Boring
COMPILED BY BB
DATUM Geodetic
DATE 2007/05/28
CHECKED BY SEMC

--- CONTINUED FROM PREVIOUS PAGE ---

| ELEV DEPTH | DESCRIPTION | NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | SHEAR STRENGTH kPa | WATER CONTENT (%) | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|
| | SILTY CLAY to CLAY, Soft to stiff Reddish brown to reddish grey Wet | | | | 168 | | | | |
| | | 16 | TO | PH | 167 | + 4.4 (field vane), × (remoulded) | | | |
| | | | | | 166 | | | | |
| | | | | | 165 | | | | |
| | | 17 | SS | 2 | 164 | | | | |
| | | | | | 163 | | | | |
| | Becoming siltier below 27m depth | | | | 162 | | | | |
| | | 18 | SS | 9 | 161 | | | | |
| | | | | | 160 | | | | |
| | | | | | 159 | | | | |

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

○3% STRAIN AT FAILURE

# RECORD OF BOREHOLE No BH07-4

 **METRIC**

PROJECT 07-1191-0014
W.P. 357-94-00
DIST
HWY 17
DATUM Geodetic
LOCATION N 5155703.7 ;E 285198.8
BOREHOLE TYPE 108mm I.D. Hollow Stem Augers/NW Wash Boring
DATE 2007/05/28
ORIGINATED BY TR
COMPILED BY BB
CHECKED BY SEMC

| 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 (%) 25 50 75 | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *--- CONTINUED FROM PREVIOUS PAGE ---* | | | | | | | | | | |
| | SILTY CLAY to CLAY, Soft to stiff Reddish brown to reddish grey Wet | | | | | | | | | | |
| | | | 19 | SS | 10 | | 158 | | | | |
| 157.7 31.1 | End of Borehole | | | | | | | | | | |

Notes:

1. Water level in open borehole at a depth of 5.5m (Elev. 183.3m) upon completion of borehole.

2. Lost 3m of augers in hole.

+ 3, × 3: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

# RECORD OF BOREHOLE No BH07-5

 **METRIC**

| | | | |
|---|---|---|---|
| PROJECT: 07-1191-0014 | | | |
| W.P.: 357-94-00 | LOCATION: N 5156906.7 ;E 286865.1 | ORIGINATED BY: TR | |
| DIST: | HWY: 17 | BOREHOLE TYPE: 108mm I.D. Hollow Stem Augers/NW Wash Boring | COMPILED BY: BB |
| DATUM: Geodetic | DATE: 2007/05/31 | CHECKED BY: SEMC | |

| ELEV / DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | WATER CONTENT (%) | GR | SA | SI | CL |
|---|---|---|---|---|---|---|---|---|---|
| 188.1 | GROUND SURFACE | | | | | | | | |
| 0.0 | Sandy silt, trace clay (FILL); Very loose to loose; Brown and grey; Moist | 1 | AS | - | | | | | |
| | | 2 | SS | 5 | ~27 | | | | |
| | | 3 | SS | 4 | | | | | |
| | | 4 | SS | 4 | ~26 | | | | |
| | | 5 | SS | 2 | | | | | |
| 184.3 / 3.9 | TOPSOIL; CLAY, some silt; Very soft to soft; Grey; Moist | 6 | SS | 3 | ~77 | | | | |
| | | 7 | SS | WH | $w_P$ ~27, w ~73 | | | | |
| 182.5 / 5.6 | Sandy SILT, some clay; Loose; Reddish brown to reddish grey; Wet | 8 | SS | 4 | ~26 | 0 | 33 | 54 | 13 |
| 180.9 / 7.2 | SAND, trace silt, trace clay; Very loose; Reddish brown to reddish grey; Wet | 9 | SS | 1 | | | | | |
| | | 10 | SS | WH | ~25 | 0 | 90 | 8 | 2 |

Ground water conditions: groundwater level at approx. elev. 183.0.

Elevation scale: 188 – 179

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 (%): 25 50 75

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

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

# RECORD OF BOREHOLE No BH07-5

 **METRIC**

PROJECT 07-1191-0014
W.P. 357-94-00
DIST ___ HWY 17
DATUM Geodetic
LOCATION N 5156906.7 ;E 286865.1
BOREHOLE TYPE 108mm I.D. Hollow Stem Augers/NW Wash Boring
DATE 2007/05/31
ORIGINATED BY TR
COMPILED BY BB
CHECKED BY SEMC

*--- CONTINUED FROM PREVIOUS PAGE ---*

| ELEV DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | WATER CONTENT (%) (approx.) | GR | SA | SI | CL |
|---|---|---|---|---|---|---|---|---|---|---|
| | SAND, trace silt, trace clay<br>Very loose<br>Reddish brown to reddish grey<br>Wet | | | | 178 | | | | | |
| | | 11 | SS | WH | 177 | | | | | |
| 176.4<br>11.7 | SAND and SILT, trace clay<br>Very loose to compact<br>Reddish Brown<br>Wet | | | | 176 | | | | | |
| | | 12 | SS | 22 | | ~24 | | | | |
| | | | | | 175 | | | | | |
| | | 13 | SS | WH | 174 | | | | | |
| | | | | | 173 | | | | | |
| | | 14 | SS | 2 | | ~26 | 0 | 44 | 50 | 6 |
| | | | | | 172 | | | | | |
| | | | | | 171 | | | | | |
| | | | | | 170 | | | | | |
| | Clayey silt layer, 0.3m thick, at a depth of 18.3m | 15 | SS | 28 | | ~25 | | | | |
| | | | | | 169 | | | | | |

Continued Next Page

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

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED (20, 40, 60, 80, 100); PLASTIC LIMIT $W_P$, NATURAL MOISTURE CONTENT W, LIQUID LIMIT $W_L$; WATER CONTENT (%) 25, 50, 75; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

# RECORD OF BOREHOLE No BH07-5

 **METRIC**

PROJECT 07-1191-0014
W.P. 357-94-00
LOCATION N 5156906.7 ;E 286865.1
ORIGINATED BY TR
DIST HWY 17
BOREHOLE TYPE 108mm I.D. Hollow Stem Augers/NW Wash Boring
COMPILED BY BB
DATUM Geodetic
DATE 2007/05/31
CHECKED BY SEMC

--- CONTINUED FROM PREVIOUS PAGE ---

| ELEV DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION | SHEAR STRENGTH kPa (FIELD VANE, sensitivity) | WATER CONTENT | GR | SA | SI | CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 168.0 / 20.1 | CLAYEY SILT to CLAY, some silt containing silt layers; Very soft to stiff; Reddish brown; Wet | | | | 168 | | | | | | |
| | | 16 | SS | WH | 166.5 | | W ≈ 27, Wp ≈ 20 | | | | |
| | | | | | 165.9 | + ≈ 29 (3.6) | | | | | |
| | | 17 | SS | WH | 163.4 | | W ≈ 27 | 0 | 3 | 72 | 25 |
| | | | | | 162.8 | + ≈ 40 (4.2) | | | | | |
| | | 18 | TO | PH | 160.4 | | | | | | |
| | | | | | 159.8 | + ≈ 62 (3.6) | | | | | |

Continued Next Page

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

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# RECORD OF BOREHOLE No BH07-5

 **METRIC**

PROJECT 07-1191-0014

W.P. 357-94-00 | LOCATION N 5156906.7 ;E 286865.1 | ORIGINATED BY TR

DIST | HWY 17 | BOREHOLE TYPE 108mm I.D. Hollow Stem Augers/NW Wash Boring | COMPILED BY BB

DATUM Geodetic | DATE 2007/05/31 | CHECKED BY SEMC

--- CONTINUED FROM PREVIOUS PAGE ---

| ELEV / DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | REMARKS |
|---|---|---|---|---|---|
| | CLAYEY SILT to CLAY, some silt containing silt layers<br>Very soft to stiff<br>Reddish brown<br>Wet | 19 | SS | WR | |
| 156.7 / 31.4 | Start of Dynamic Cone Penetration Test | | | | |
| 151.5 / 36.6 | End of Borehole<br><br>Note:<br><br>1. Water level in piezometer at 6.1m at a depth of (Elev. 182.0m) on May 30, 2007 and at a depth of 5.1m (Elev. 183.0m) on July 10, 2007 | | | | |

Elevation scale: 158, 157, 156, 155, 154, 153, 152

Field vane (+) with sensitivity: 3.3

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

# RECORD OF BOREHOLE No BH07-6

 **METRIC**

PROJECT 07-1191-0014

W.P. 357-94-00 LOCATION N 5155557.4 ;E 282807.5 ORIGINATED BY TR

DIST HWY 17 BOREHOLE TYPE 108mm I.D. Hollow Stem Augers/NW Wash Boring COMPILED BY BB

DATUM Geodetic DATE 2007/07/09 CHECKED BY SEMC

## SOIL PROFILE

| ELEV / DEPTH | DESCRIPTION |
|---|---|
| 194.7 | GROUND SURFACE |
| 0.0 | Silty sand (FILL)<br>Loose<br>Moist<br>Brown |
| 194.1 / 0.6 | SILT, some sand, some clay<br>Compact to loose<br>Moist to wet<br>Brown to Red<br><br>Turning reddish brown at a depth of 3m |
| 191.0 / 3.7 | CLAY, trace silt to some silt<br>Soft to firm<br>Wet<br>Reddish Brown |

## SAMPLES

| NUMBER | TYPE | "N" VALUES | UNIT WEIGHT γ kN/m³ | GR | SA | SI | CL |
|---|---|---|---|---|---|---|---|
| 1 | SS | 8 | | | | | |
| 2 | SS | 10 | | 0 | 18 | 67 | 15 |
| 3 | SS | 8 | | | | | |
| 4 | SS | 4 | | | | | |
| 5 | SS | 8 | | | | | |
| 6 | SS | 2 | | | | | |
| 7 | TO | PH | | | | | |
| 8 | TO | PH | 15.6 | | | | |
| 9 | SS | WH | | | | | |
| 10 | TO | PH | | | | | |

ELEVATION SCALE: 194, 193, 192, 191, 190, 189, 188, 187, 186, 185

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

Field vane sensitivity values plotted: 4.8, 3.0, 3.3

PLASTIC LIMIT $W_P$ — NATURAL MOISTURE CONTENT W — LIQUID LIMIT $W_L$

WATER CONTENT (%): 25 50 75

GROUND WATER CONDITIONS

REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

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

# RECORD OF BOREHOLE No BH07-6

 **METRIC**

PROJECT 07-1191-0014
W.P. 357-94-00 LOCATION N 5155557.4 ;E 282807.5 ORIGINATED BY TR
DIST HWY 17 BOREHOLE TYPE 108mm I.D. Hollow Stem Augers/NW Wash Boring COMPILED BY BB
DATUM Geodetic DATE 2007/07/09 CHECKED BY SEMC

--- CONTINUED FROM PREVIOUS PAGE ---

| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | SHEAR STRENGTH kPa (field vane) | WATER CONTENT | UNIT WEIGHT γ kN/m³ | GR | SA | SI | CL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CLAY, trace silt to some silt<br>Soft to firm<br>Wet<br>Reddish Brown | | | | | | | + 4.8 | | | | | | |
| | | | | | | | 184 | | | | | | | |
| | | | 11 | SS | WH | | | | Wp–W–WL | | | | | |
| | | | | | | | | + 3.7 | | | | | | |
| | | | | | | | 183 | | | | | | | |
| | | | 12 | SS | WH | | | | W | | 0 | 0 | 5 | 95 |
| | | | | | | | 182 | | | | | | | |
| | | | | | | | | + 3.6 | | | | | | |
| | | | | | | | 181 | | | | | | | |
| | | | 13 | SS | WH | | | | W | | | | | |
| | | | | | | | | + 2.8 | | | | | | |
| | | | | | | | 180 | | | | | | | |
| | | | 14 | SS | WH | | 179 | | | | | | | |
| | | | | | | | | + 1.7 | | | | | | |
| | | | | | | | 178 | | | | | | | |
| | | | | | | | 177 | | | | | | | |
| | Becoming grey at a depth of 18.3m | | 15 | SS | WH | | | | Wp–W–WL | | | | | |
| | | | | | | | 176 | | | | | | | |
| | | | | | | | | + 4.4 | | | | | | |
| | | | | | | | 175 | | | | | | | |

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED
WATER CONTENT (%): 25 50 75 — PLASTIC LIMIT $W_P$, NATURAL MOISTURE CONTENT W, LIQUID LIMIT $W_L$
REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

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

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# RECORD OF BOREHOLE No BH07-6

 **METRIC**

PROJECT 07-1191-0014
W.P. 357-94-00
DIST ___ HWY 17
DATUM Geodetic

LOCATION N 5155557.4 ;E 282807.5
BOREHOLE TYPE 108mm I.D. Hollow Stem Augers/NW Wash Boring
DATE 2007/07/09

ORIGINATED BY TR
COMPILED BY BB
CHECKED BY SEMC

--- CONTINUED FROM PREVIOUS PAGE ---

| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa | WATER CONTENT (%) | UNIT WEIGHT γ kN/m³ | GR | SA | SI | CL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CLAY, trace silt to some silt<br>Soft to firm<br>Wet<br>Reddish Brown | | | | | | 174 | | | | | | | |
| | | | 16 | SS | WH | | 173 | | | | | | | |
| | | | | | | | | Field vane + 5.7 | | | | | | |
| 171.8<br>22.9 | SILT, trace to some clay, trace sand<br>Very loose to loose<br>Wet<br>Grey | | | | | | 172 | | | | | | | |
| | | | | | | | 171 | | | | | | | |
| | | | 17 | SS | 9 | | 170 | | w ≈ 23 | | 0 | 1 | 84 | 15 |
| | | | | | | | 169 | | | | | | | |
| | | | | | | | 168 | | | | | | | |
| | | | 18 | SS | 4 | | 167 | | | | | | | |
| | | | | | | | 166 | | | | | | | |
| | | | | | | | 165 | | | | | | | |

Legend: ○ UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × REMOULDED. PLASTIC LIMIT $W_P$; NATURAL MOISTURE CONTENT W; LIQUID LIMIT $W_L$.

Continued Next Page

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

# RECORD OF BOREHOLE No BH07-6

 **METRIC**

PROJECT 07-1191-0014
W.P. 357-94-00
LOCATION N 5155557.4 ;E 282807.5
ORIGINATED BY TR
DIST ____ HWY 17
BOREHOLE TYPE 108mm I.D. Hollow Stem Augers/NW Wash Boring
COMPILED BY BB
DATUM Geodetic
DATE 2007/07/09
CHECKED BY SEMC

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20, 40, 60, 80, 100); PLASTIC LIMIT $W_P$, NATURAL MOISTURE CONTENT W, LIQUID LIMIT $W_L$; WATER CONTENT (%) (25, 50, 75); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) (GR SA SI CL)

--- *CONTINUED FROM PREVIOUS PAGE* ---

SILT, trace to some clay, trace sand
Very loose to loose
Wet
Grey

| Sample Number | Type | "N" Values | Elevation (approx.) | Water Content | GR | SA | SI | CL |
|---|---|---|---|---|---|---|---|---|
| 19 | SS | 2 | ~163.9 | | | | | |
| 20 | SS | 3 | ~160.9 | ○ (~27%) | 0 | 0 | 81 | 19 |
| 21 | SS | 2 | ~157.8 | ○ (~30%) | | | | |
| 22 | SS | 4 | ~154.8 | | | | | |

Elevation scale: 164, 163, 162, 161, 160, 159, 158, 157, 156, 155

Continued Next Page

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

# RECORD OF BOREHOLE No BH07-6

 **METRIC**

PROJECT 07-1191-0014
W.P. 357-94-00
LOCATION N 5155557.4 ;E 282807.5
ORIGINATED BY TR
DIST HWY 17
BOREHOLE TYPE 108mm I.D. Hollow Stem Augers/NW Wash Boring
COMPILED BY BB
DATUM Geodetic
DATE 2007/07/09
CHECKED BY SEMC

--- CONTINUED FROM PREVIOUS PAGE ---

| ELEV / DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | "N" VALUES | ELEVATION SCALE | WATER CONTENT (%) | GR | SA | SI | CL |
|---|---|---|---|---|---|---|---|---|---|---|
| | SILT, trace to some clay, trace sand<br>Very loose to loose<br>Wet<br>Grey | | | | 154 | | | | | |
| | | | | | 153 | | | | | |
| | | | | | 152 | | | | | |
| | | 23 | SS | 2 | | ~40 | 0 | 2 | 56 | 42 |
| | | | | | 151 | | | | | |
| | | | | | 150 | | | | | |
| | | | | | 149 | | | | | |
| | | 24 | SS | 5 | | | | | | |
| | | | | | 148 | | | | | |
| | | | | | 147 | | | | | |
| 146.5<br>48.2 | SAND and SILT, some clay, trace gravel (TILL)<br>Very dense<br>Wet<br>Brownish red | | | | 146 | | | | | |
| | | 25 | SS | 64 | | ~8 | 1 | 44 | 44 | 11 |
| 145.5<br>49.2 | | | | | | | | | | |

Continued Next Page

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

# RECORD OF BOREHOLE No BH07-6

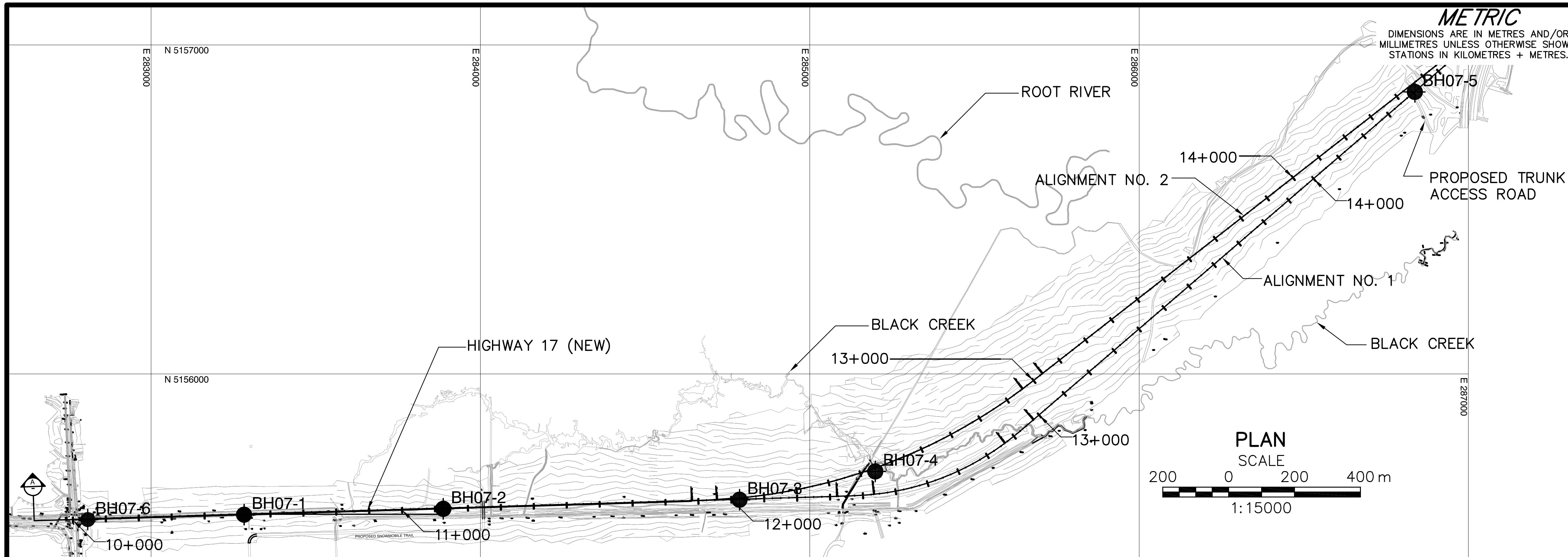
 **METRIC**

| | | | |
|---|---|---|---|
| PROJECT 07-1191-0014 | | | |
| W.P. 357-94-00 | LOCATION N 5155557.4 ;E 282807.5 | | ORIGINATED BY TR |
| DIST | HWY 17 | BOREHOLE TYPE 108mm I.D. Hollow Stem Augers/NW Wash Boring | COMPILED BY BB |
| DATUM Geodetic | DATE 2007/07/09 | | CHECKED BY SEMC |

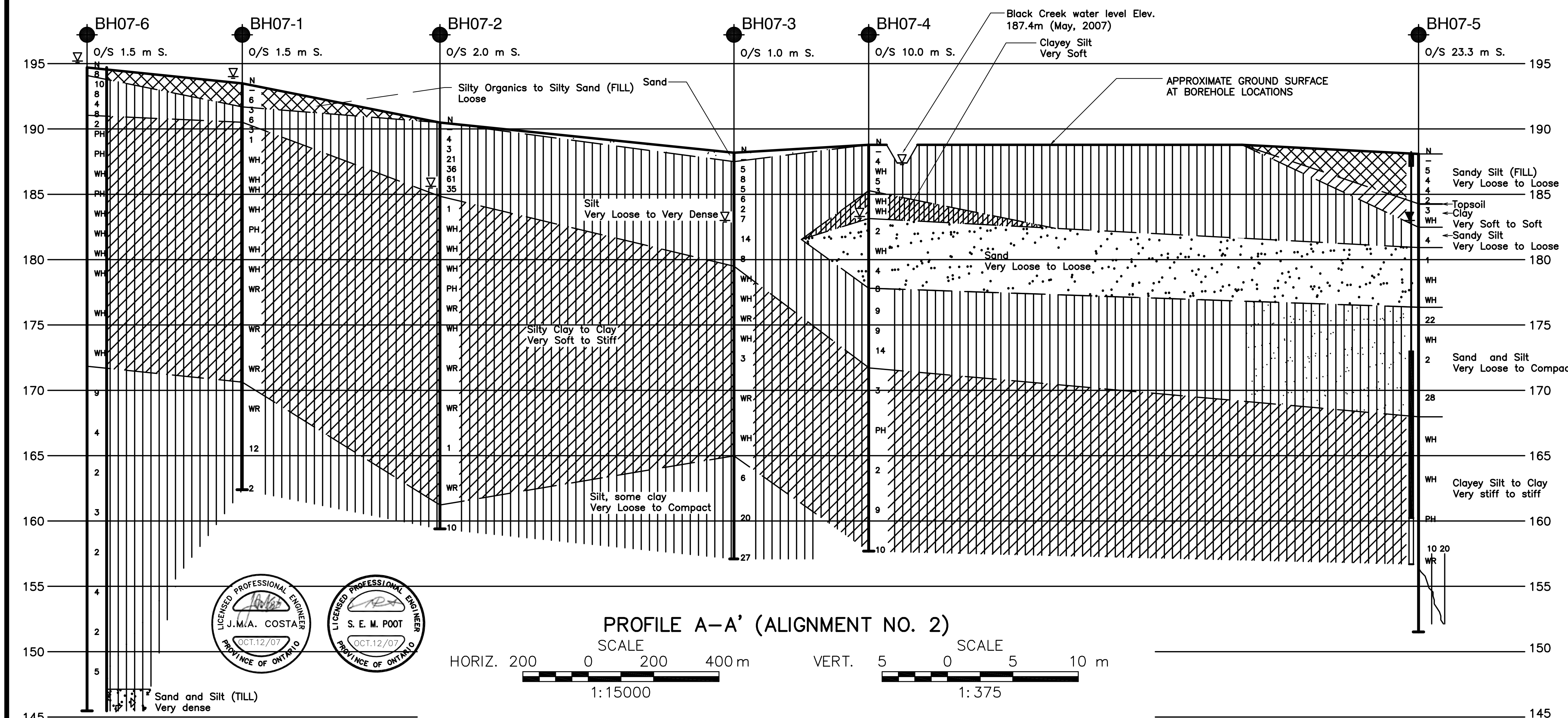
| ELEV DEPTH | SOIL PROFILE: DESCRIPTION | STRAT PLOT | SAMPLES: NUMBER | TYPE | "N" VALUES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED (20 40 60 80 100) | PLASTIC LIMIT $W_P$, NATURAL MOISTURE CONTENT W, LIQUID LIMIT $W_L$; WATER CONTENT (%) 25 50 75 | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *--- CONTINUED FROM PREVIOUS PAGE ---* | | | | | | | | | | |
| | End of Borehole<br>Refusal to Split Spoon Advance<br><br>Note:<br><br>1. Water level measured at a height of 0.5m (Elev. 195.2m) above ground surface upon completion of drilling<br><br>2. Sample 25 - spoon bouncing. | | | | | | | | | | |

+³, ×³: Numbers refer to Sensitivity    O³% STRAIN AT FAILURE

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




PLAN
SCALE
200 0 200 400 m
1:15000




PROFILE A–A' (ALIGNMENT NO. 2)

SCALE
HORIZ. 200 0 200 400 m
1:15000

SCALE
VERT. 5 0 5 10 m
1:375

LICENSED PROFESSIONAL ENGINEER J.M.A. COSTA OCT.12/07 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER S. E. M. POOT OCT.12/07 PROVINCE OF ONTARIO

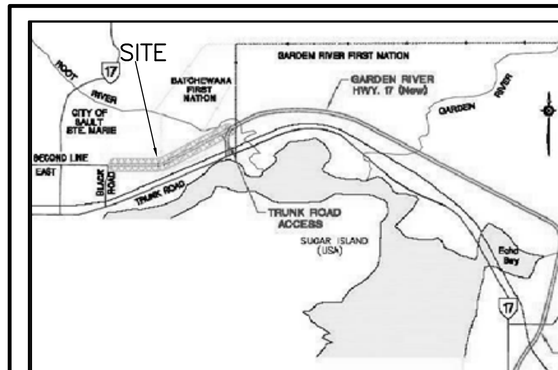
# CONT No.
# WP No. 357–94–00

SHEET

HIGHWAY 17 (NEW)
BLACK ROAD TO GRFN
BOREHOLE LOCATIONS AND
SOIL STRATA

Golder Associates

**Golder Associates Ltd.**
SUDBURY, ONTARIO, CANADA




KEY PLAN
NTS

## LEGEND

| | |
|---|---|
| ● | Borehole |
| ▮ | Seal |
| ▯ | Piezometer |
| N | Standard Penetration Test Value |
| 16 | Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow) |
| ▼ | WL in peizometer, measured on July 10, 2007 |
| ▽ | WL upon completion of drilling |

| No. | ELEVATION | CO–ORDINATES | |
|---|---|---|---|
| | | NORTHING | EASTING |
| BH07–1 | 193.5 | 5155572.3 | 283282.3 |
| BH07–2 | 190.5 | 5155590.1 | 283887.0 |
| BH07–3 | 188.2 | 5155621.8 | 284786.5 |
| BH07–4 | 188.8 | 5155703.7 | 285198.8 |
| BH07–5 | 188.1 | 5156906.7 | 286865.1 |
| BH07–6 | 194.7 | 5155557.4 | 282807.5 |

## NOTES

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

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

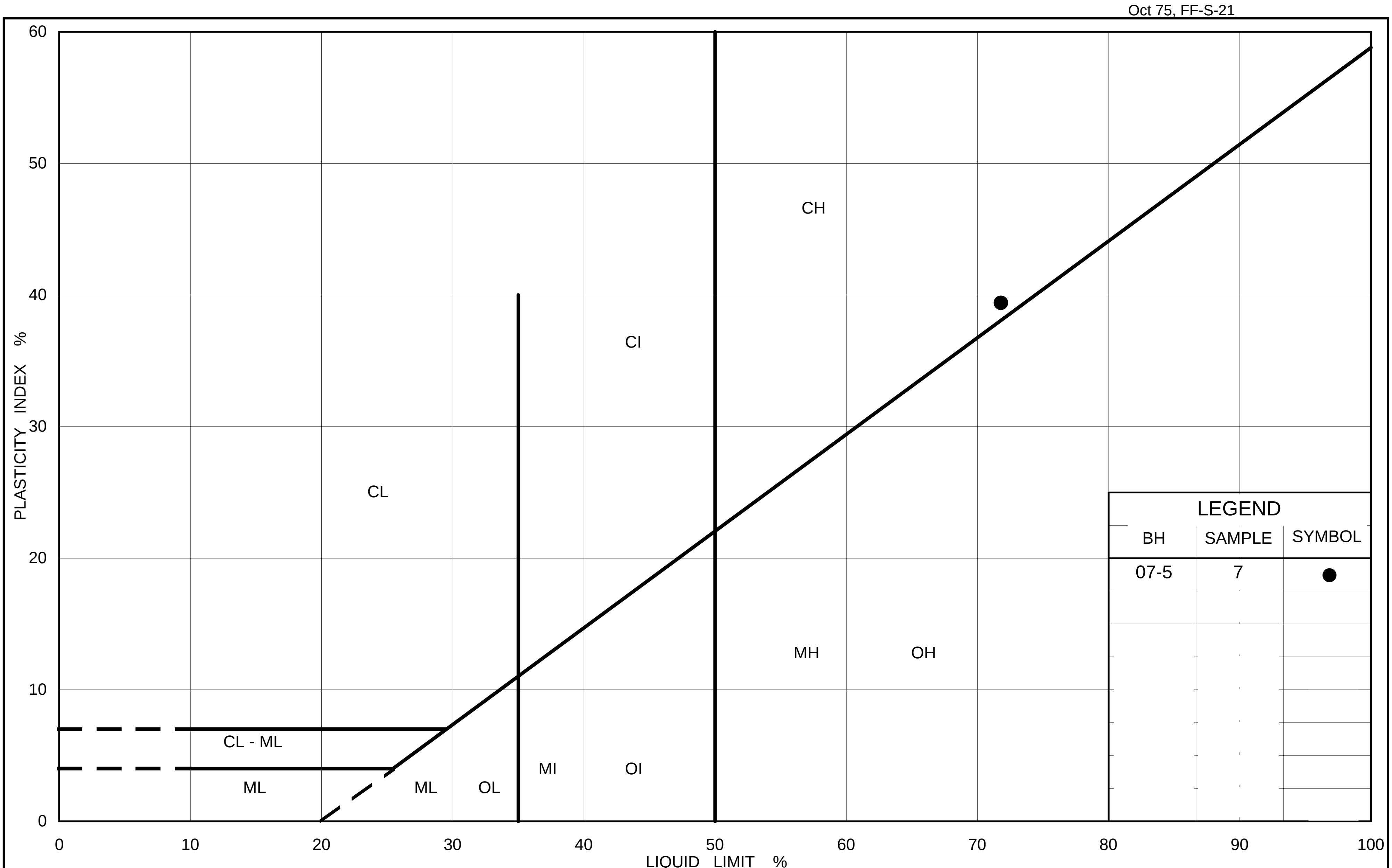
The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with section GC 2.01 of OPS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

## REFERENCE

Base plans provided in digital format by McCormick Rankin Corporation, drawing file no. 03–046.dwg and 5399kb–Alignments sent to Tulloch for Staking–Apr.23–07.dwg, recieved June 7, 2007.

| NO. | DATE | BY | REVISION |
|---|---|---|---|
| | | | |

| | | | |
|---|---|---|---|
| Geocres No.: 41K–81 | | | |
| HWY. 17(NEW) | PROJECT NO. 07–1191–0014 | | DIST. |
| SUBM'D. TR | CHKD. SEMC | DATE: OCT. 2007 | SITE: |
| DRAWN: BB | CHKD. JMAC | APPD. | DWG. 1 |




Ministry of Transportation

Ontario

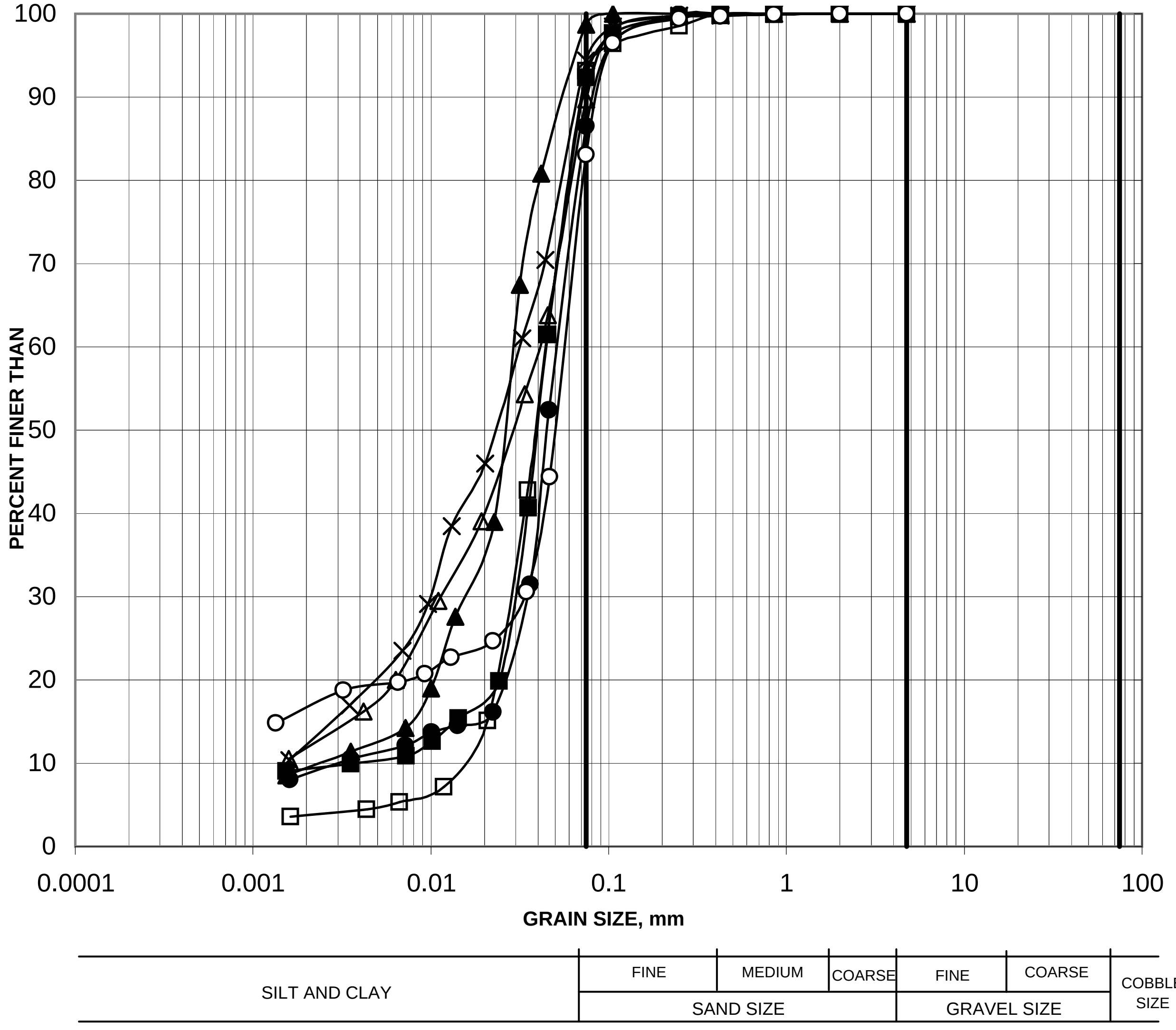
# PLASTICITY CHART
## Upper Clay

FIGURE 1

Project No. 07-1191-0014

Checked By: SEMC

| GRAIN SIZE DISTRIBUTION<br>Upper Silt | FIGURE<br>2A |
|---|---|




| Borehole | Sample | Elevation (m) |
|---|---|---|
| 07-1 (▲) | 4 | 190.9 |
| 07-2 (■) | 4 | 187.9 |
| 07-3 (×) | 3 | 186.4 |
| 07-3 (●) | 7 | 183.4 |
| 07-4 (△) | 3 | 187.0 |
| 07-4 (□) | 13 | 174.7 |
| 07-6 (○) | 2 | 193.6 |

Date: October, 2007
Project: 07-1191-0014

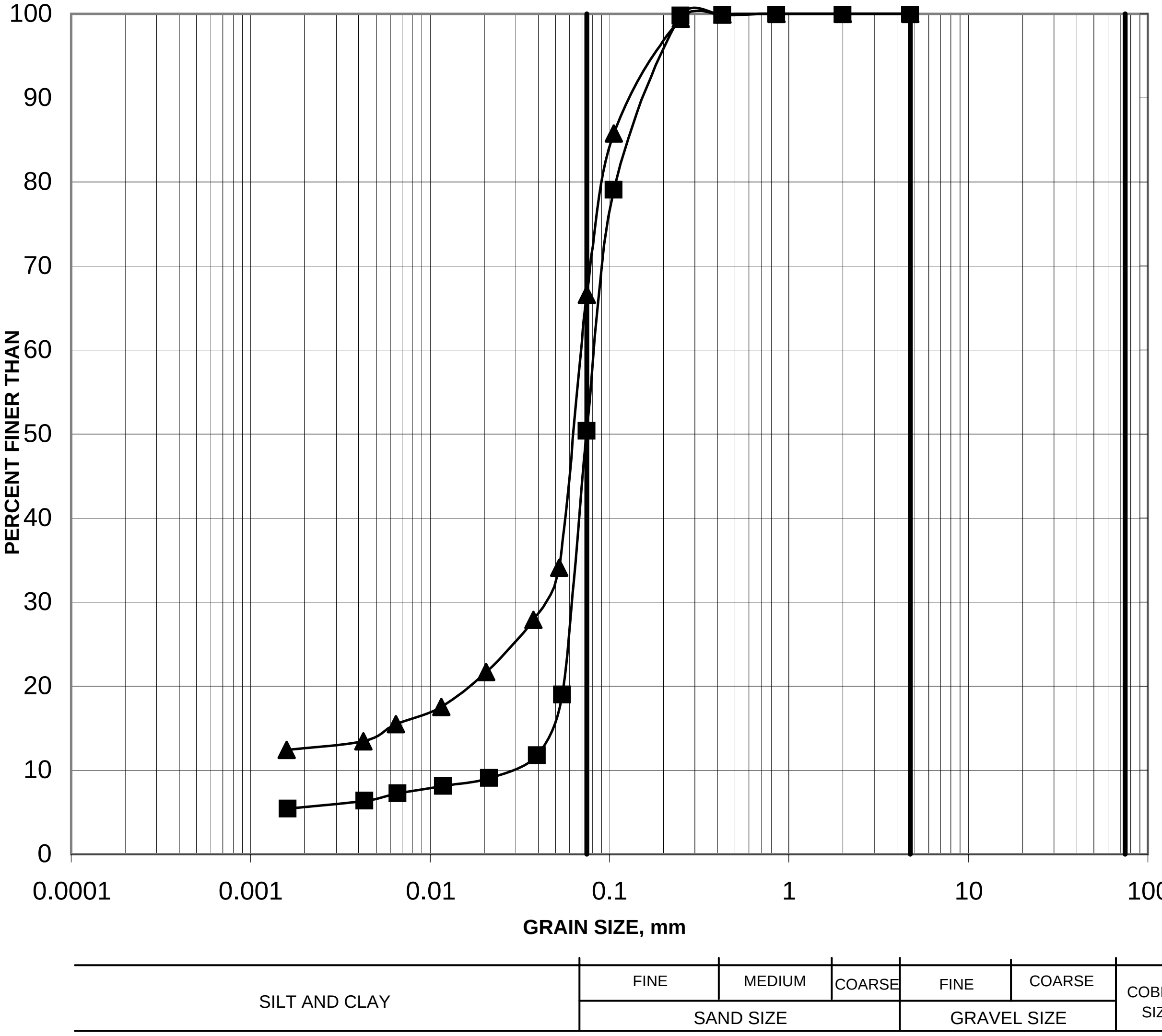
**Golder Associates**

Created by: TR
Checked by: SEMC

# GRAIN SIZE DISTRIBUTION

## Sandy Silt to Sand and Silt (Upper Silt)

**FIGURE 2B**



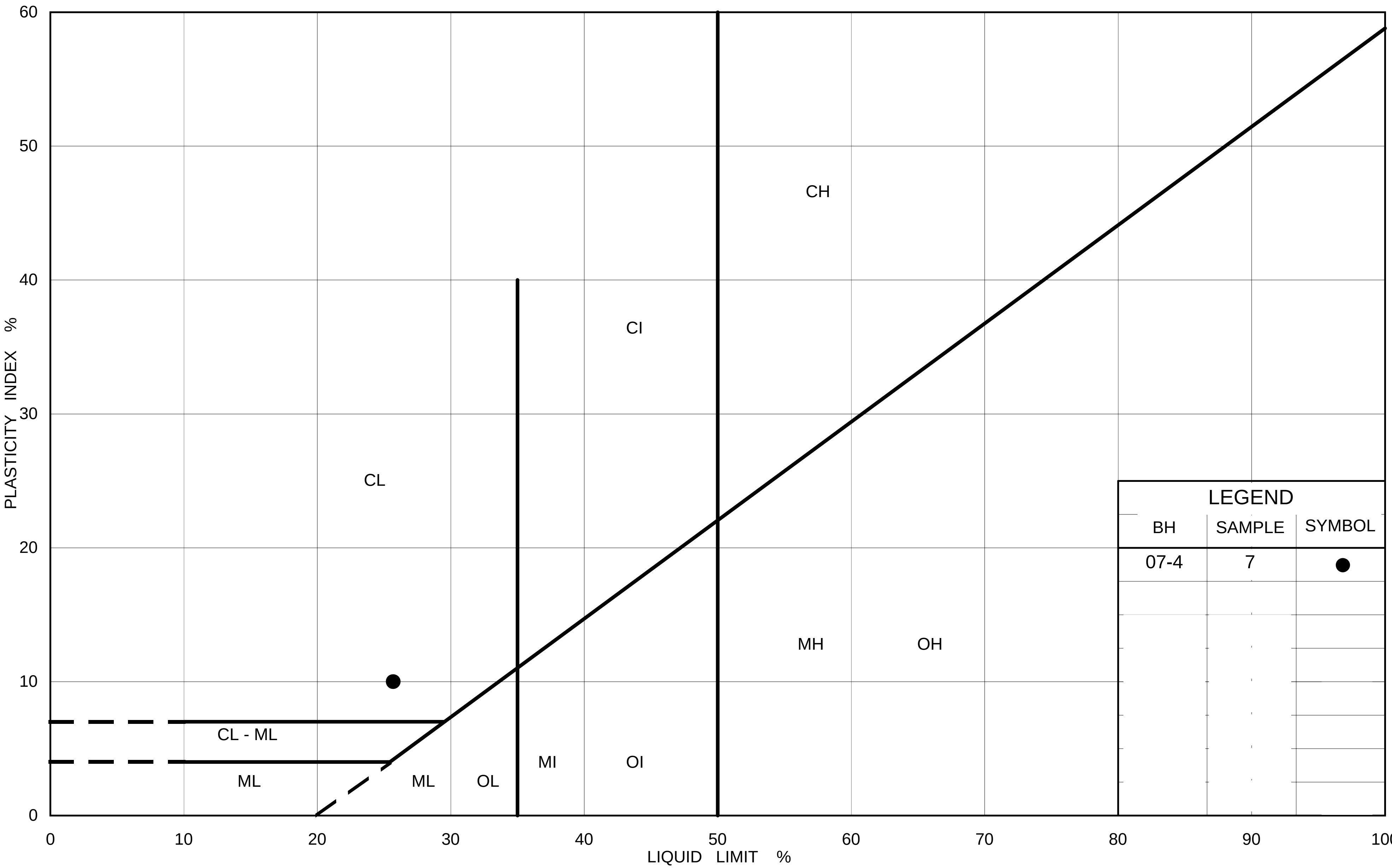

| Borehole | Sample | Elevation (m) |
|---|---|---|
| 07-5 (▲) | 8 | 181.6 |
| 07-5 (■) | 14 | 172.5 |

Date: October, 2007
Project: 07-1191-0014

**Golder Associates**

Created by: TR
Checked by: SEMC

Oct 75, FF-S-21




Ministry of Transportation

Ontario

# PLASTICITY CHART
## Clayey Silt (Interlayer)

FIGURE 3

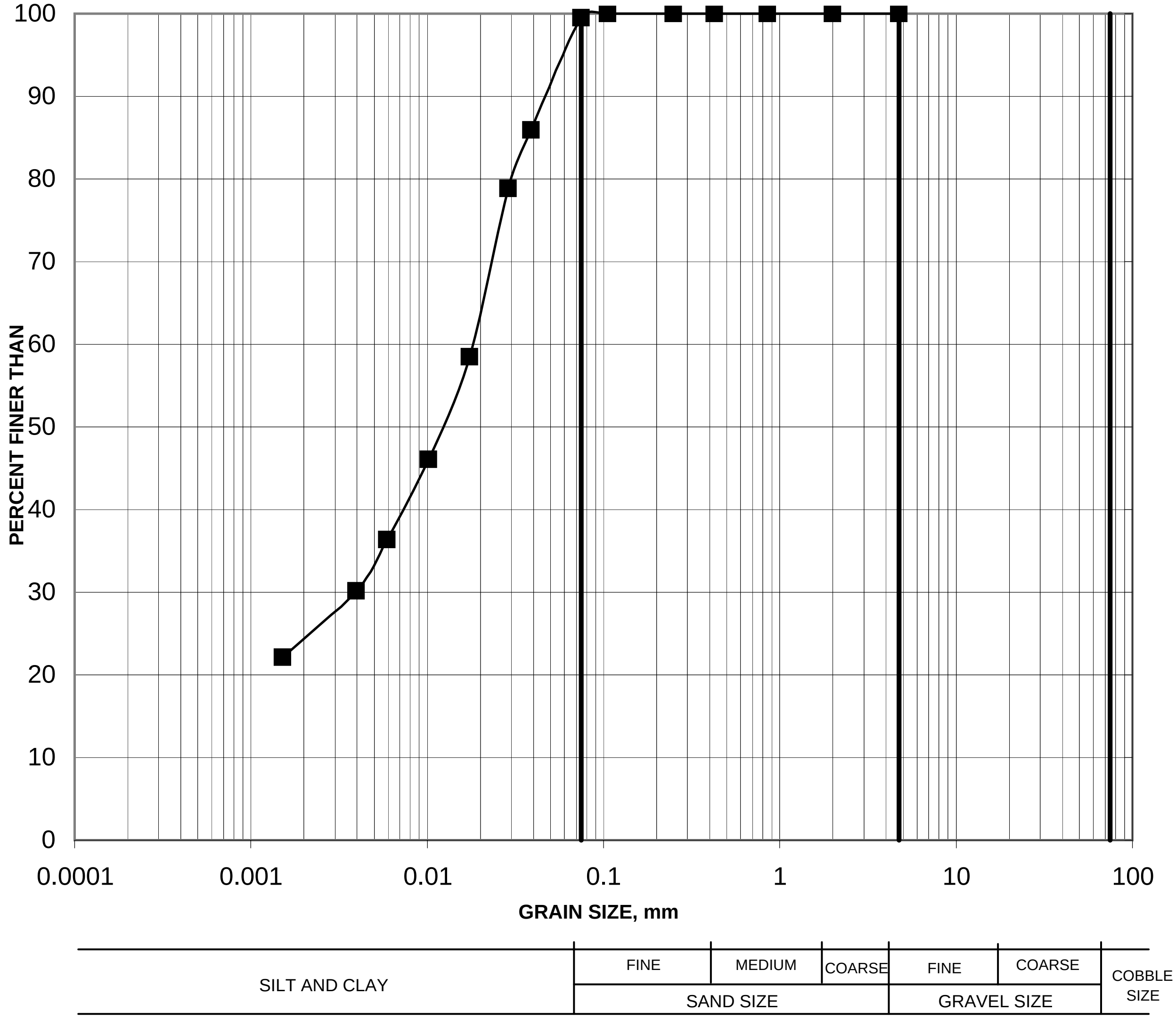
Project No. 07-1191-0014

Checked By: SEMC

# GRAIN SIZE DISTRIBUTION

## Clayey Silt (Interlayer)

**FIGURE 4**



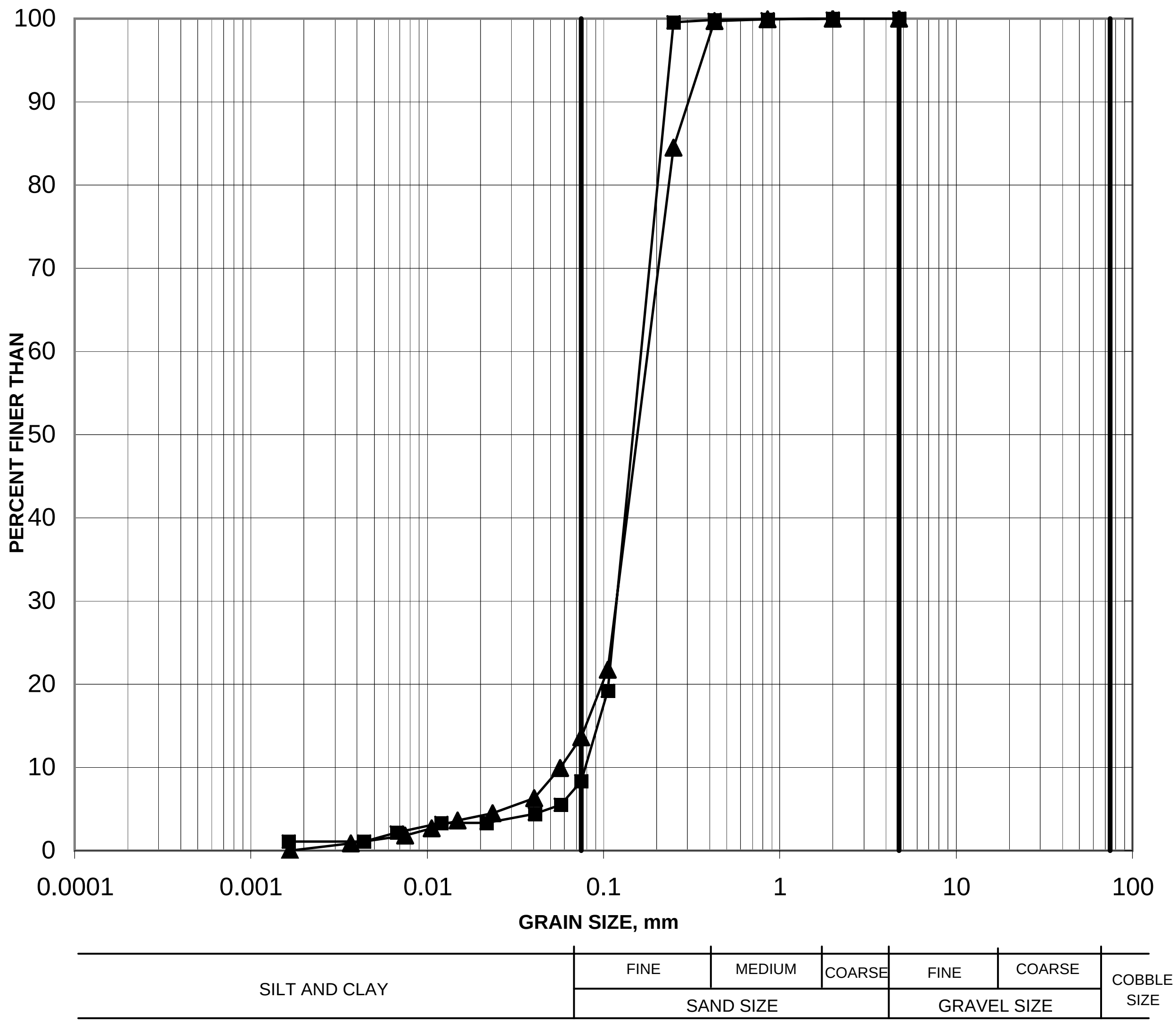

| Borehole | Sample | Elevation (m) |
|---|---|---|
| 07-4 | 6 | 184.6 |

Date: October, 2007
Project: 07-1191-0014

**Golder Associates**

Created by: TR
Checked by: SEMC

| GRAIN SIZE DISTRIBUTION<br>Sand (Interlayer) | FIGURE<br>5 |
|---|---|



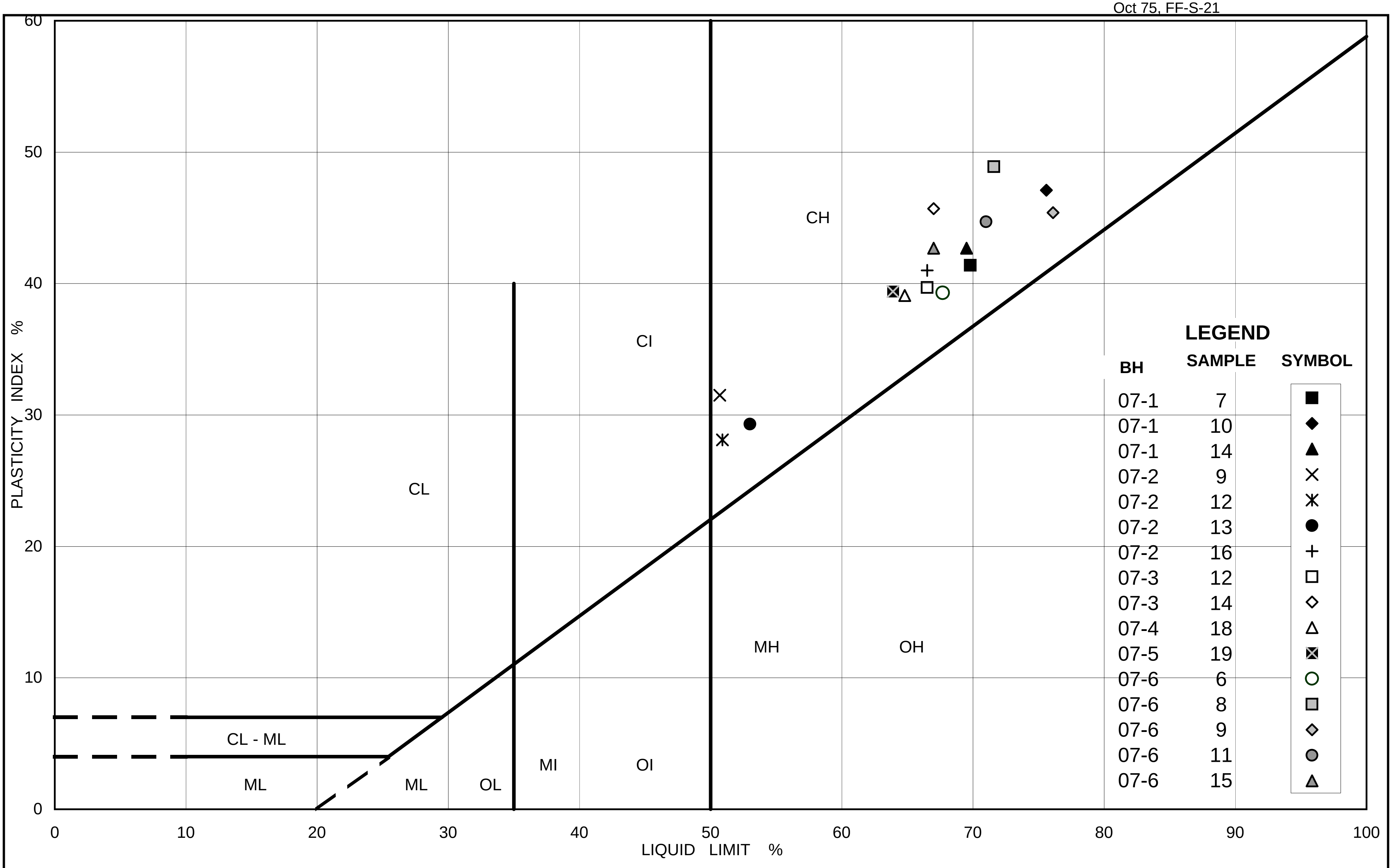

| Borehole | Sample | Elevation (m) |
|---|---|---|
| ▲ 07-4 | 9 | 180.9 |
| ■ 07-5 | 10 | 178.5 |

Date: October, 2007
Project: 07-1191-0014

**Golder Associates**

Created by: TR
Checked by: SEMC

Oct 75, FF-S-21

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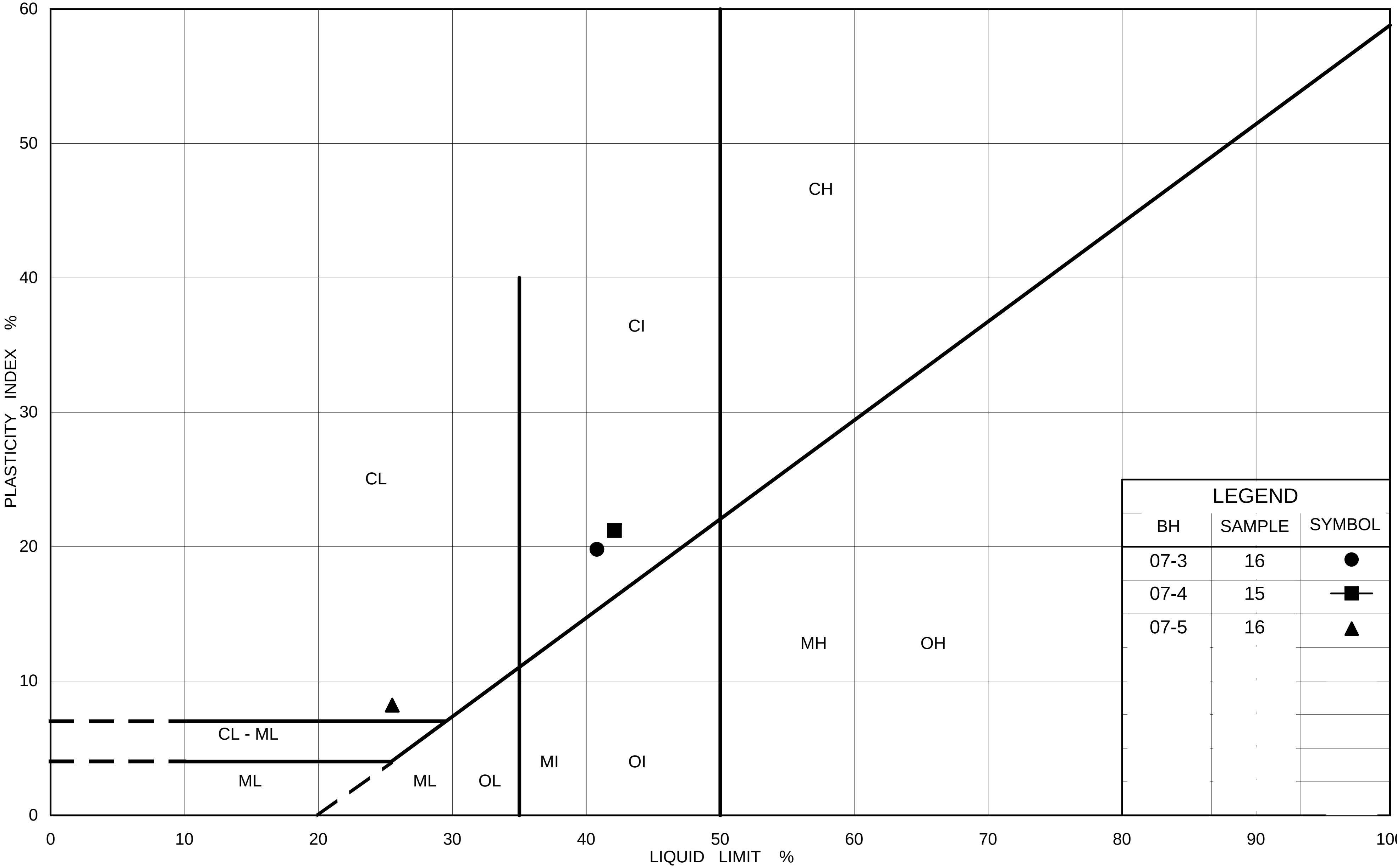
# PLASTICITY CHART
## Silty Clay to Clay

FIGURE 6A

Project No. 07-1191-0014

Checked By: SEMC

Oct 75, FF-S-21




**LEGEND**

| BH | SAMPLE | SYMBOL |
|---|---|---|
| 07-3 | 16 | ● |
| 07-4 | 15 | ■ |
| 07-5 | 16 | ▲ |

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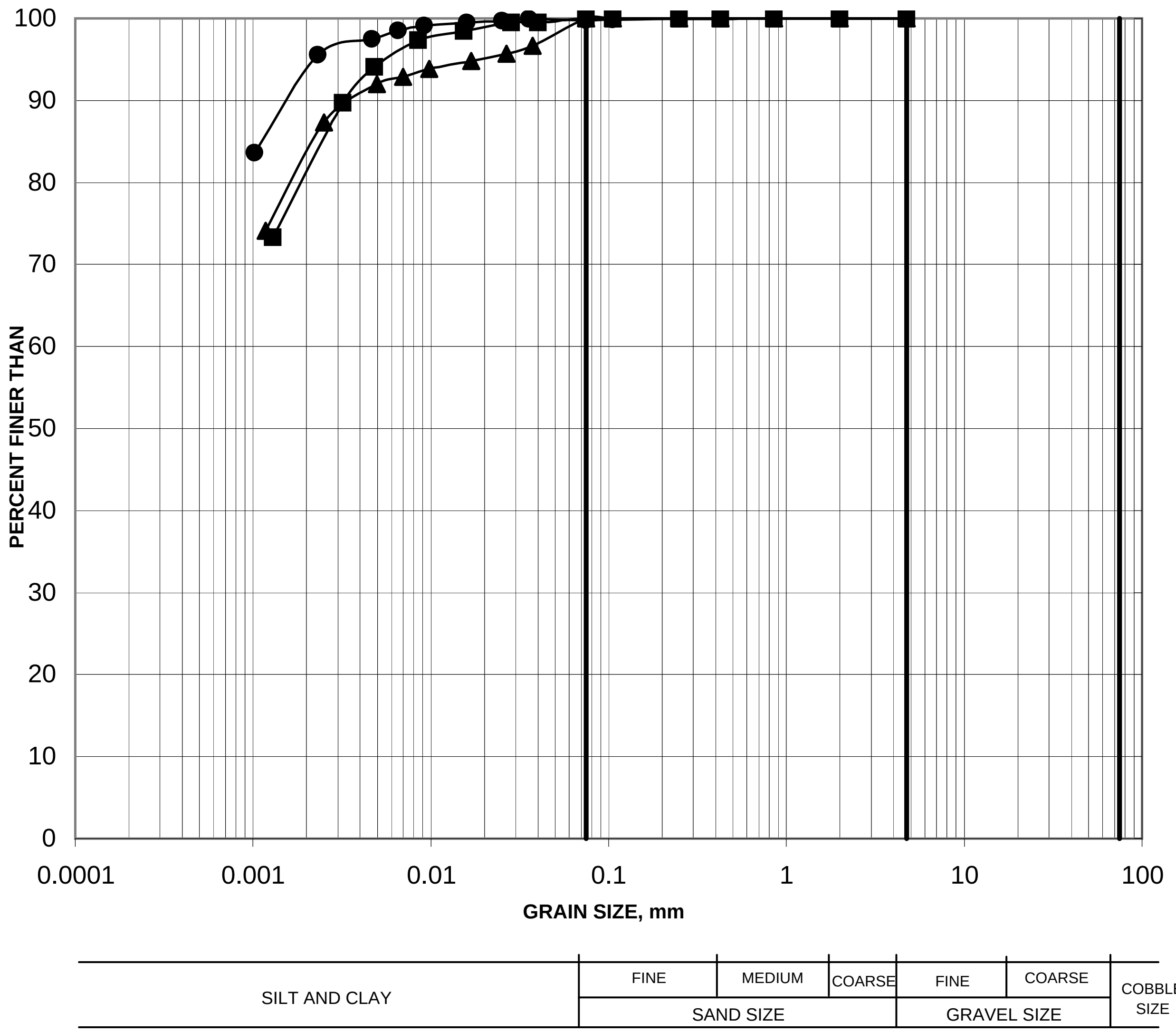
# PLASTICITY CHART
## Clayey Silt

FIGURE 6B

Project No. 07-1191-0014

Checked By: SEMC

| GRAIN SIZE DISTRIBUTION<br>Silty Clay to Clay | FIGURE<br>7A |
|---|---|



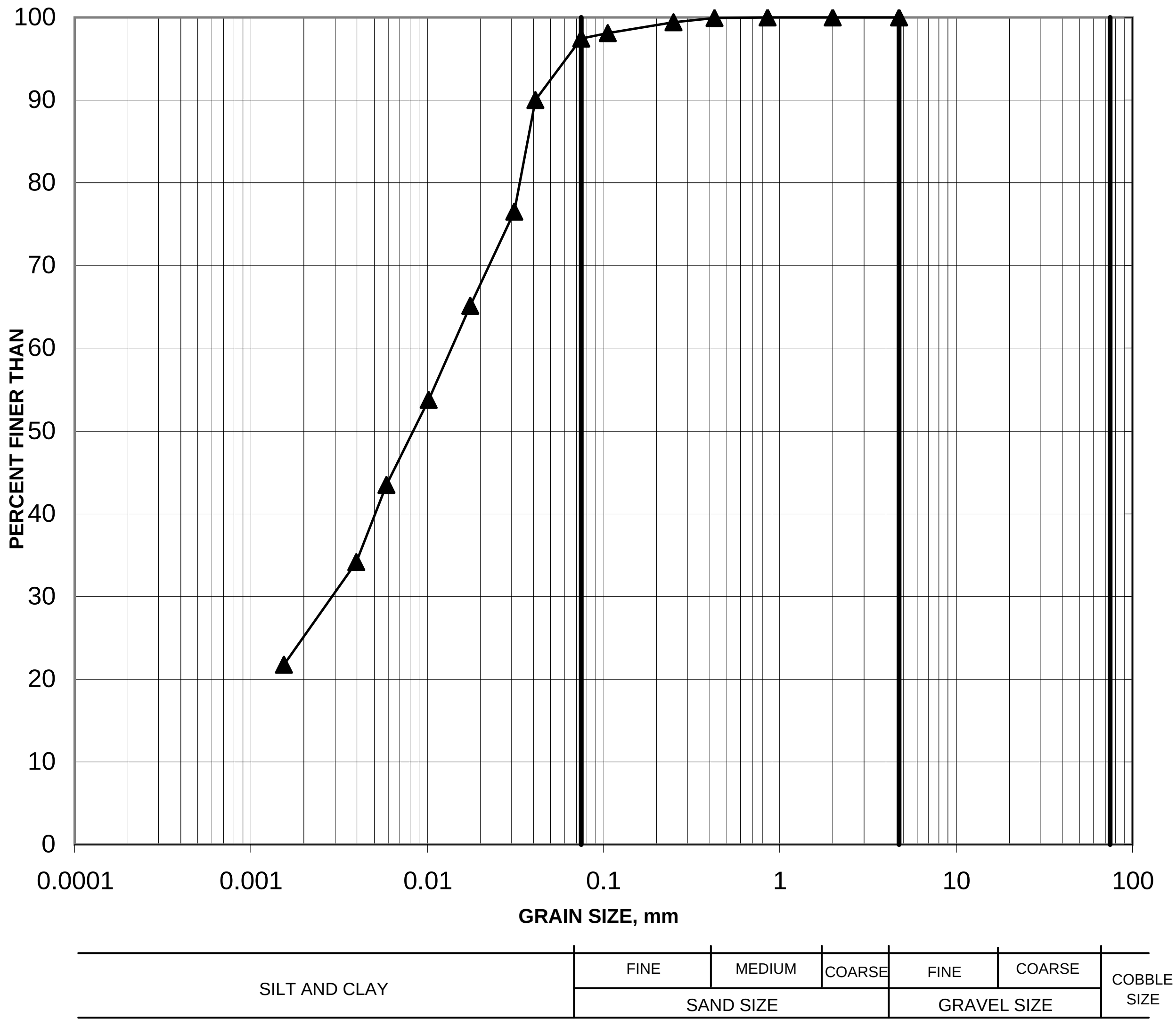

| Borehole | Sample | Elevation (m) |
|---|---|---|
| 07-1 | 12 | 181.0 |
| 07-2 | 15 | 171.9 |
| 07-6 | 12 | 182.3 |

Date: October, 2007
Project: 07-1191-0014

**Golder Associates**

Created by: TR
Checked by: SEMC

| GRAIN SIZE DISTRIBUTION<br>Clayey Silt | FIGURE<br>7B |
|---|---|




| | Borehole | Sample | Elevation (m) |
|---|---|---|---|
| —▲— | 07-5 | 17 | 163.4 |

Date: October, 2007
Project: 07-1191-0014

**Golder Associates**

Created by: TR
Checked by: SEMC

# OEDOMETER CONSOLIDATION SUMMARY

**FIGURE 8A**


## SAMPLE IDENTIFICATION

| | | | |
|---|---|---|---|
| Project Number | 07-1191-0014 | Sample Number | 12 |
| Borehole Number | 07-2 | Sample Depth, (m) | 12.2 - 12.8 |

## TEST CONDITIONS

| | | | |
|---|---|---|---|
| Test Type | Standard | Load Duration, hr | 24 |
| Oedometer Number | 1 | | |
| Date Started | June 18/07 | | |
| Date Completed | July 4/07 | | |

## SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

| | | | |
|---|---|---|---|
| Sample Height, cm | 2.539 | Unit Weight, kN/m$^3$ | 15.9 |
| Sample Diameter, cm | 6.356 | Dry Unit Weight, kN/m$^3$ | 9.0 |
| Area, cm$^2$ | 31.73 | Specific Gravity, assumed | 2.7 |
| Volume, cm$^3$ | 80.56 | Solids Height, cm | 0.863 |
| Water Content, % | 76.9 | Volume of Solids, cm$^3$ | 27.37 |
| Wet Mass, g | 130.7 | Volume of Voids, cm$^3$ | 53.19 |
| Dry Mass, g | 73.90 | Degree of Saturation, % | 106.8 |

## TEST COMPUTATIONS

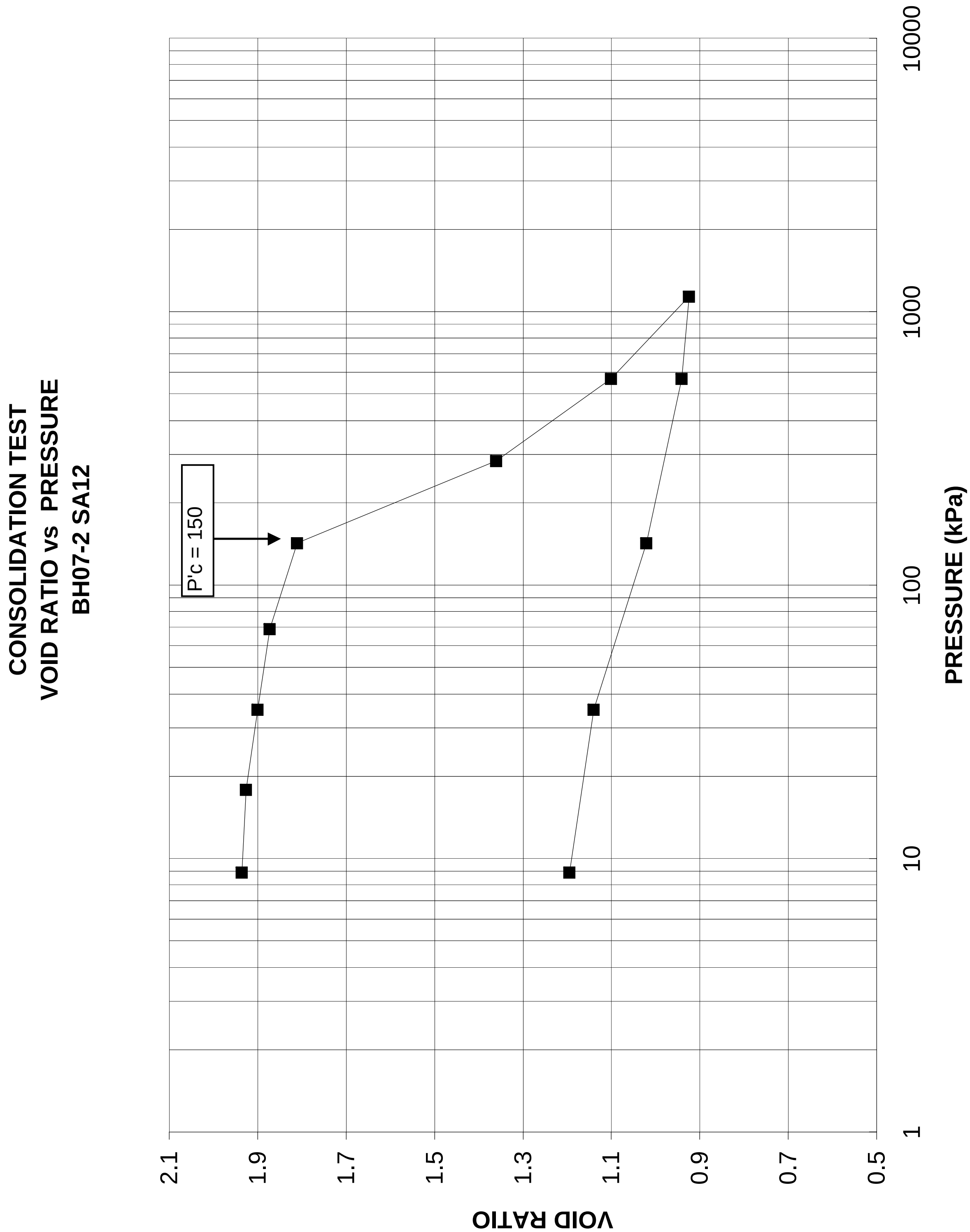
| Pressure kPa | Primary Consolidation mm | Corr. Height cm | Void Ratio | Average Height cm | $t_{50}$ s | cv. cm$^2$/s | $m_v$ m$^2$/MN | k cm/s |
|---|---|---|---|---|---|---|---|---|
| 0 | 0.00 | 2.539 | 1.943 | 2.539 | | | | |
| 8.9 | 0.07 | 2.532 | 1.935 | 2.536 | 70 | 0.01800 | 0.310 | 5.470E-07 |
| 17.9 | 0.08 | 2.524 | 1.926 | 2.528 | 180 | 0.00696 | 0.351 | 2.397E-07 |
| 35.1 | 0.23 | 2.501 | 1.899 | 2.513 | 260 | 0.00476 | 0.530 | 2.473E-07 |
| 69.2 | 0.24 | 2.478 | 1.872 | 2.489 | 255 | 0.00476 | 0.276 | 1.287E-07 |
| 142.6 | 0.53 | 2.425 | 1.811 | 2.451 | 500 | 0.00235 | 0.291 | 6.733E-08 |
| 284.9 | 3.89 | 2.036 | 1.360 | 2.230 | 2775 | 0.00035 | 1.128 | 3.885E-08 |
| 570.5 | 2.24 | 1.812 | 1.100 | 1.924 | 1300 | 0.00056 | 0.385 | 2.109E-08 |
| 1139.7 | 1.52 | 1.660 | 0.924 | 1.736 | 850 | 0.00069 | 0.147 | 1.004E-08 |
| 570.5 | -0.15 | 1.675 | 0.941 | 1.667 | | | | |
| 142.6 | -0.68 | 1.743 | 1.020 | 1.709 | | | | |
| 35.1 | -1.03 | 1.846 | 1.139 | 1.794 | | | | |
| 8.9 | -0.48 | 1.894 | 1.195 | 1.870 | | | | |

Notes:
k calculated using cv based on $t_{50}$ values.

## SAMPLE DIMENSIONS AND PROPERTIES - FINAL

| | | | |
|---|---|---|---|
| Sample Height, cm | 1.894 | Unit Weight, kN/m$^3$ | 17.4 |
| Sample Diameter, cm | 6.356 | Dry Unit Weight, kN/m$^3$ | 12.1 |
| Area, cm$^2$ | 31.73 | Specific Gravity, assumed | 2.7 |
| Volume, cm$^3$ | 60.08 | Solids Height, cm | 0.863 |
| Water Content, % | 44.2 | Volume of Solids, cm$^3$ | 27.37 |
| Wet Mass, g | 106.6 | Volume of Voids, cm$^3$ | 32.71 |
| Dry Mass, g | 73.90 | Degree of Saturation, % | 100.0 |

**Prepared By: TR** Golder Associates **Checked By: AB**

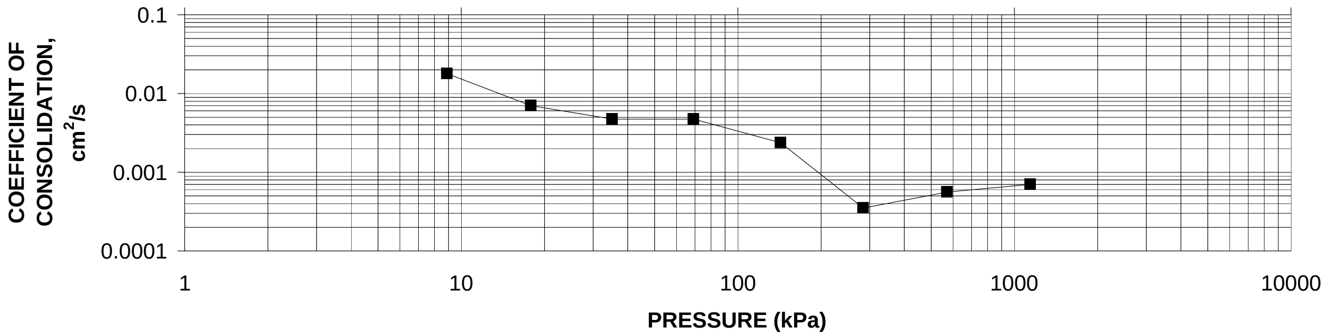


CONSOLIDATION TEST
VOID RATIO vs PRESSURE
BH07-2 SA12
P'c = 150
VOID RATIO
2.1
1.9
1.7
1.5
1.3
1.1
0.9
0.7
0.5
PRESSURE (kPa)
1
10
100
1000
10000

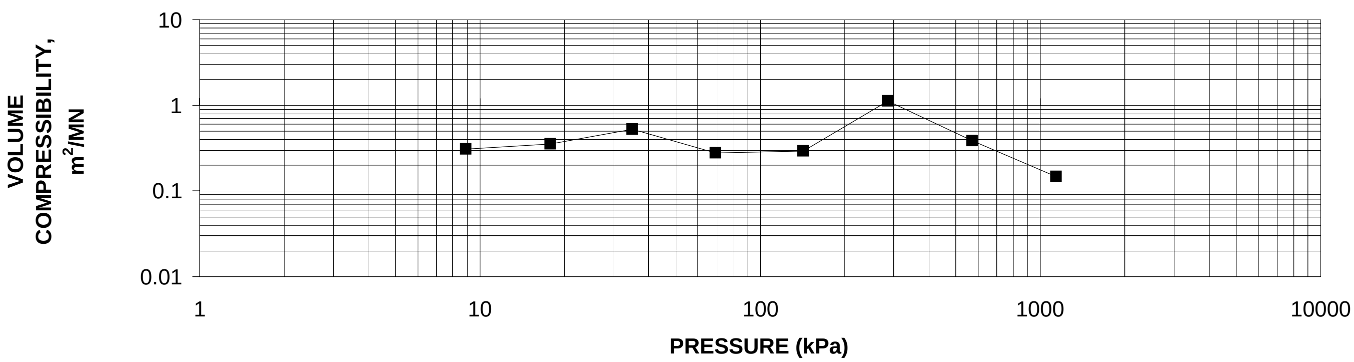
## OEDOMETER CONSOLIDATION SUMMARY



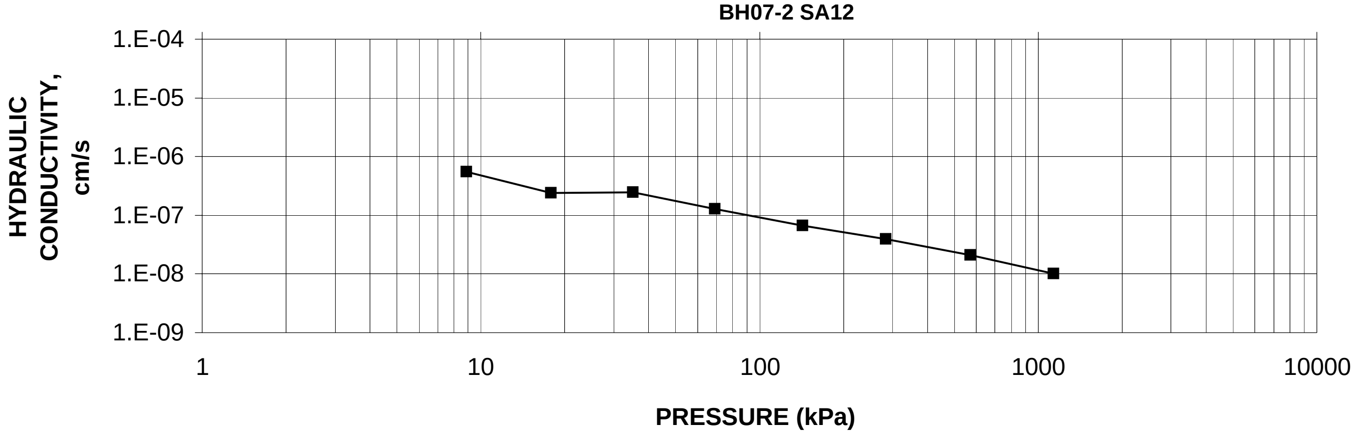
**CONSOLIDATION TEST**
**CV $cm^2/s$ VS PRESSURE (kPa)**
**BH07-2 SA12**




**CONSOLIDATION TEST**
**MV $m^2/MN$ vs PRESSURE (kPa)**
**BH07-2 SA12**

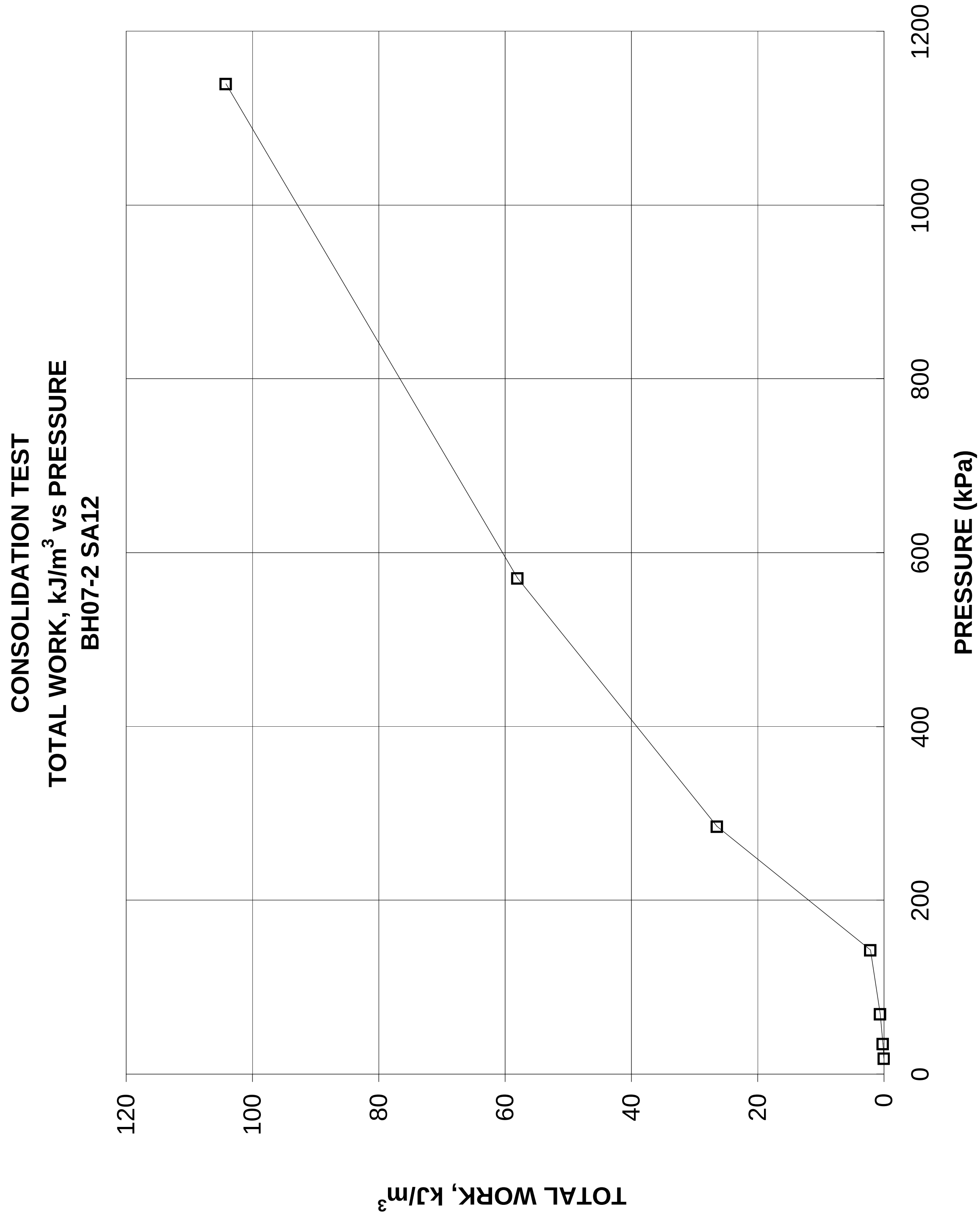



**CONSOLIDATION TEST**
**HYDRAULIC CONDUCTIVITY vs PRESSURE**
**BH07-2 SA12**



PRIMARY CONSOLIDATION TEST
TOTAL WORK VS. PRESSURE

FIGURE 8A


Project No. 07-1191-0014

Golder Associates

Prepared by: AB
Checked by: SEMC

# OEDOMETER CONSOLIDATION SUMMARY



## SAMPLE IDENTIFICATION

| | | | |
|---|---|---|---|
| Project Number | 07-1191-0014 | Sample Number | 8 |
| Borehole Number | 07-6 | Sample Depth, m | 6.1-6.7 |

## TEST CONDITIONS

| | | | |
|---|---|---|---|
| Test Type | Standard | Load Duration, hr | 24 |
| Oedometer Number | 7 | | |
| Date Started | 06/03/2007 | | |
| Date Completed | 06/13/2007 | | |

## SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

| | | | |
|---|---|---|---|
| Sample Height, cm | 1.90 | Unit Weight, kN/m$^3$ | 15.55 |
| Sample Diameter, cm | 6.32 | Dry Unit Weight, kN/m$^3$ | 9.01 |
| Area, cm$^2$ | 31.39 | Specific Gravity, measured | 2.70 |
| Volume, cm$^3$ | 59.64 | Solids Height, cm | 0.646 |
| Water Content, % | 72.72 | Volume of Solids, cm$^3$ | 20.29 |
| Wet Mass, g | 94.60 | Volume of Voids, cm$^3$ | 39.36 |
| Dry Mass, g | 54.77 | Degree of Saturation, % | 101.2 |

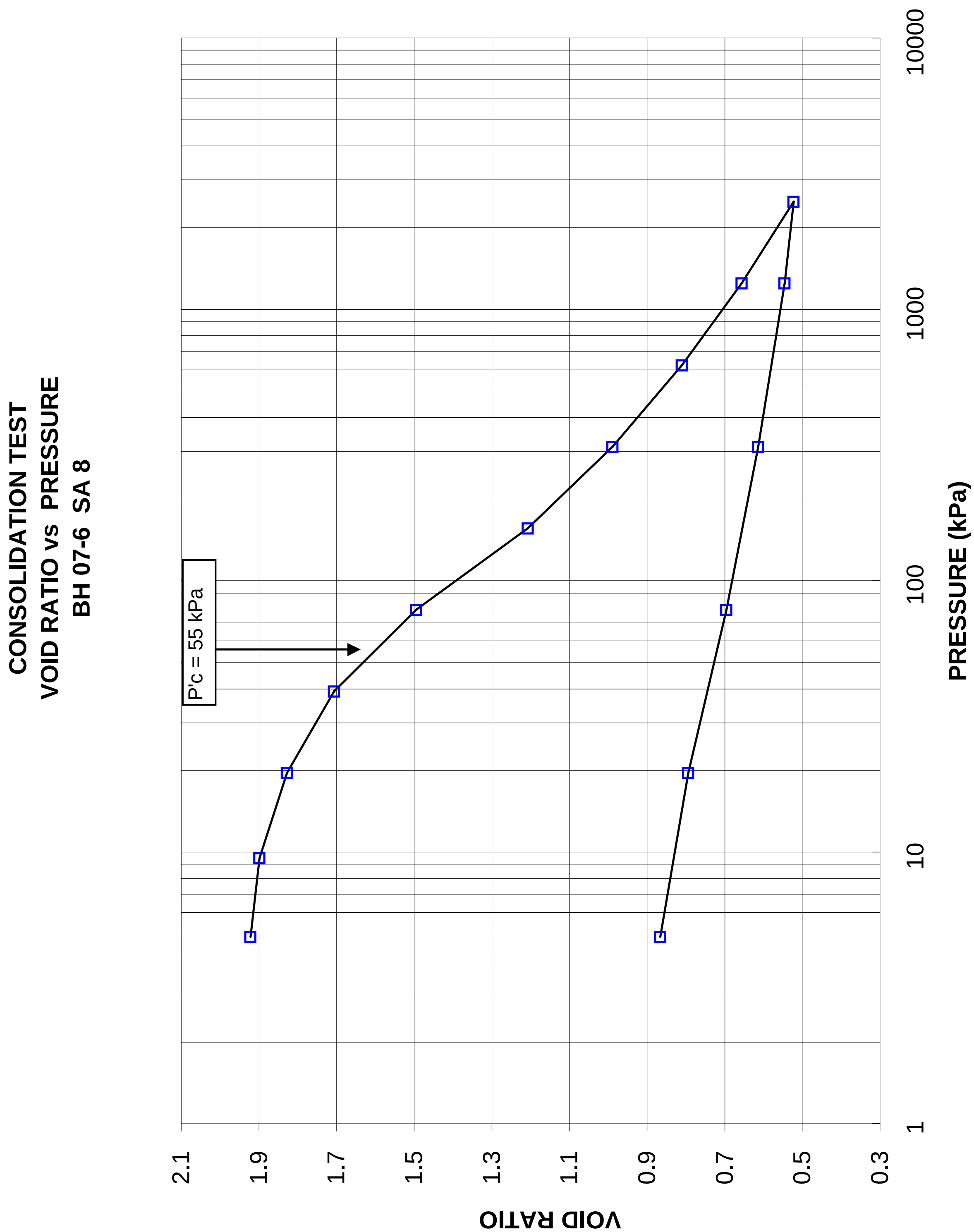
## TEST COMPUTATIONS

| Pressure kPa | Corr. Height cm | Void Ratio | Average Height cm | $t_{90}$ sec | cv. cm$^2$/s | mv m$^2$/kN | k cm/s |
|---|---|---|---|---|---|---|---|
| 0.00 | 1.900 | 1.940 | 1.900 | | | | |
| 4.87 | 1.888 | 1.922 | 1.894 | 19 | 4.00E-02 | 1.30E-03 | 5.09E-06 |
| 9.54 | 1.873 | 1.898 | 1.881 | 60 | 1.25E-02 | 1.69E-03 | 2.07E-06 |
| 19.67 | 1.827 | 1.827 | 1.850 | 960 | 7.56E-04 | 2.39E-03 | 1.77E-07 |
| 39.23 | 1.749 | 1.707 | 1.788 | 1823 | 3.72E-04 | 2.10E-03 | 7.65E-08 |
| 78.20 | 1.612 | 1.495 | 1.681 | 2339 | 2.56E-04 | 1.85E-03 | 4.64E-08 |
| 156.16 | 1.426 | 1.207 | 1.519 | 1700 | 2.88E-04 | 1.26E-03 | 3.54E-08 |
| 312.30 | 1.285 | 0.988 | 1.356 | 1316 | 2.96E-04 | 4.75E-04 | 1.38E-08 |
| 624.43 | 1.170 | 0.811 | 1.228 | 1156 | 2.76E-04 | 1.94E-04 | 5.25E-09 |
| 1247.83 | 1.070 | 0.656 | 1.120 | 540 | 4.92E-04 | 8.44E-05 | 4.07E-09 |
| 2496.50 | 0.984 | 0.523 | 1.027 | 302 | 7.40E-04 | 3.62E-05 | 2.63E-09 |
| 1247.83 | 0.999 | 0.546 | 0.992 | | | | |
| 312.12 | 1.043 | 0.614 | 1.021 | | | | |
| 78.20 | 1.096 | 0.696 | 1.070 | | | | |
| 19.67 | 1.159 | 0.794 | 1.128 | | | | |
| 4.87 | 1.206 | 0.866 | 1.183 | | | | |

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

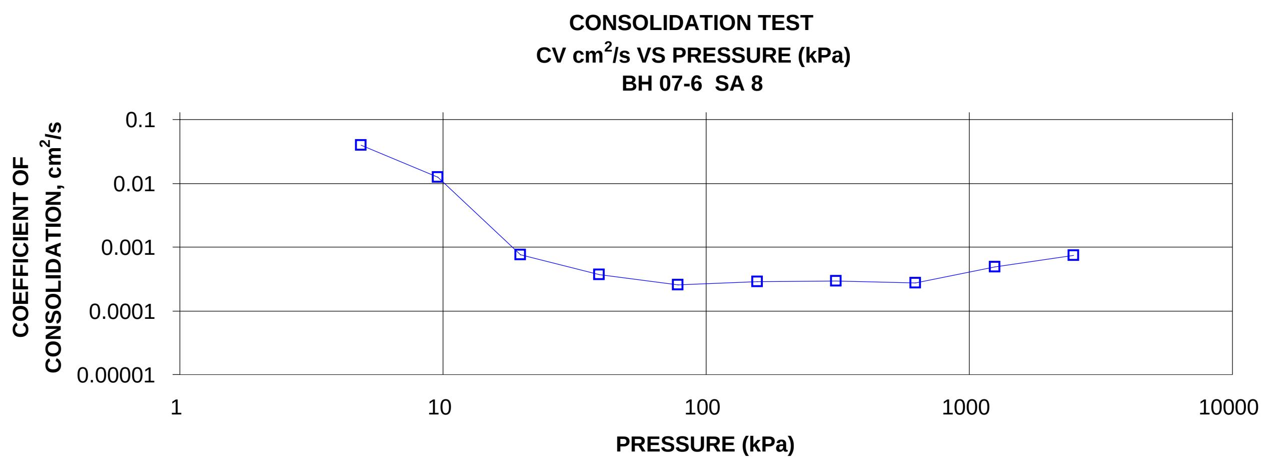
## SAMPLE DIMENSIONS AND PROPERTIES - FINAL

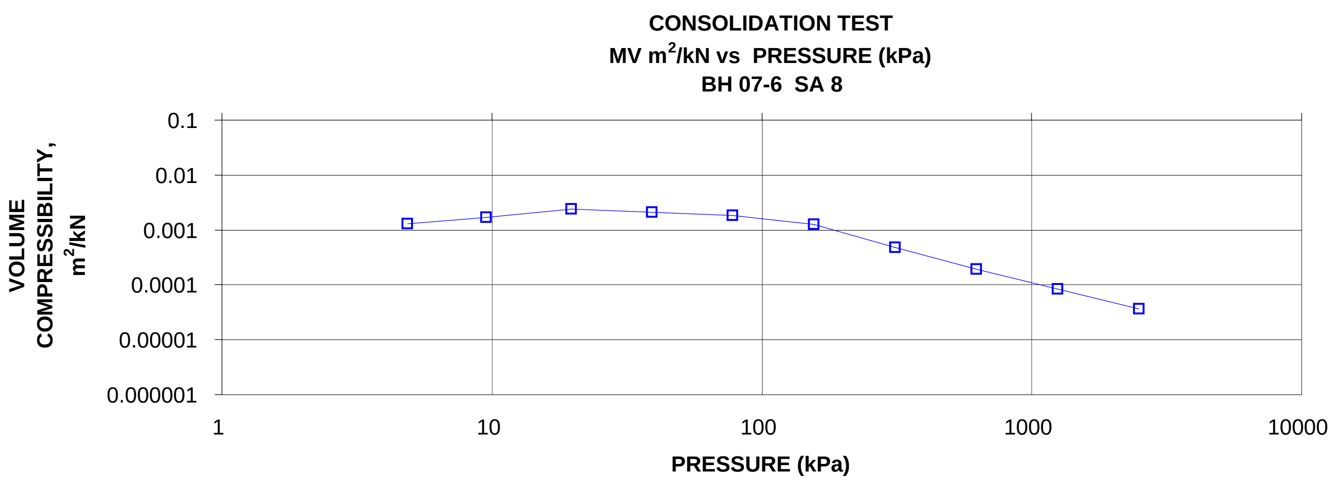
| | | | |
|---|---|---|---|
| Sample Height, cm | 1.21 | Unit Weight, kN/m$^3$ | 19.67 |
| Sample Diameter, cm | 6.32 | Dry Unit Weight, kN/m$^3$ | 14.19 |
| Area, cm$^2$ | 31.39 | Specific Gravity, measured | 2.70 |
| Volume, cm$^3$ | 37.86 | Solids Height, cm | 0.646 |
| Water Content, % | 38.63 | Volume of Solids, cm$^3$ | 20.29 |
| Wet Mass, g | 75.93 | Volume of Voids, cm$^3$ | 17.57 |
| Dry Mass, g | 54.77 | | |

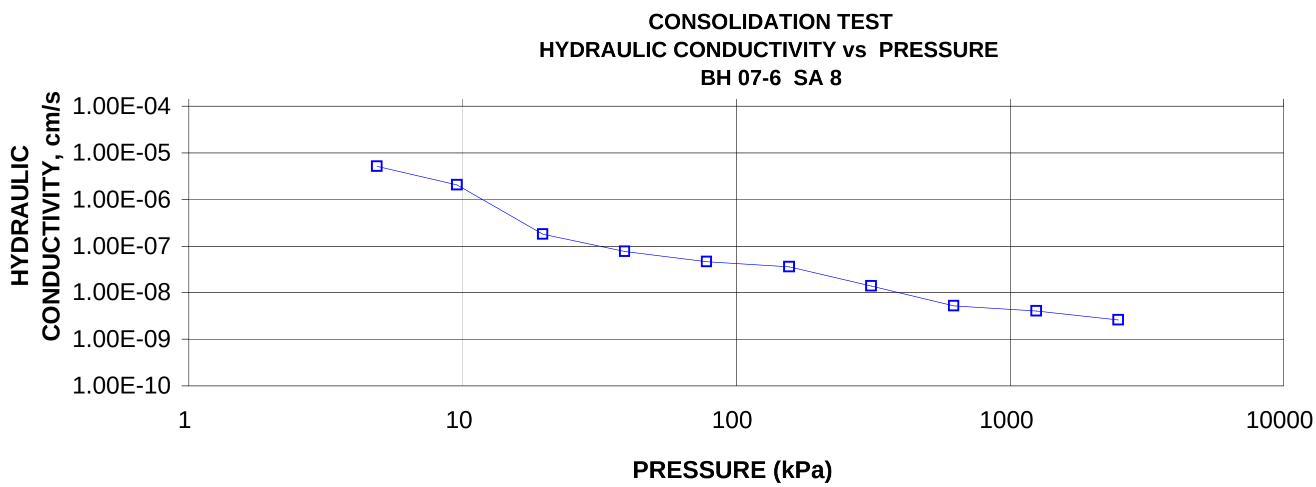

CONSOLIDATION TEST
VOID RATIO vs PRESSURE
BH 07-6 SA 8
P'c = 55 kPa
VOID RATIO
PRESSURE (kPa)
2.1
1.9
1.7
1.5
1.3
1.1
0.9
0.7
0.5
0.3
1
10
100
1000
10000

# OEDOMETER CONSOLIDATION SUMMARY

**FIGURE 8B**


Project No. 07-1191-0014

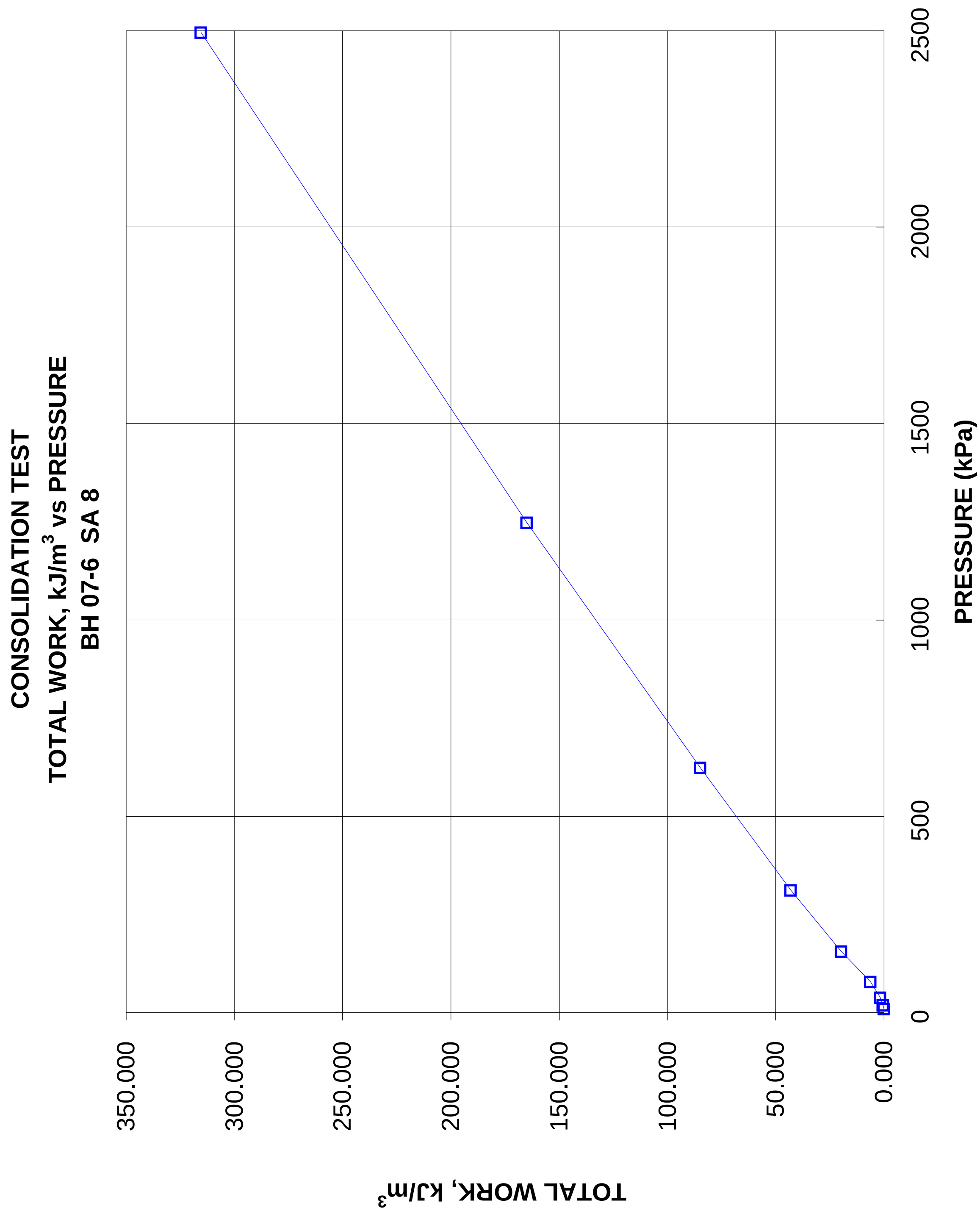
Prepared By: LFG

**Golder Associates**

Checkey By: MM

**PRIMARY CONSOLIDATION TEST**
**TOTAL WORK VS. PRESSURE**



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**Golder Associates**

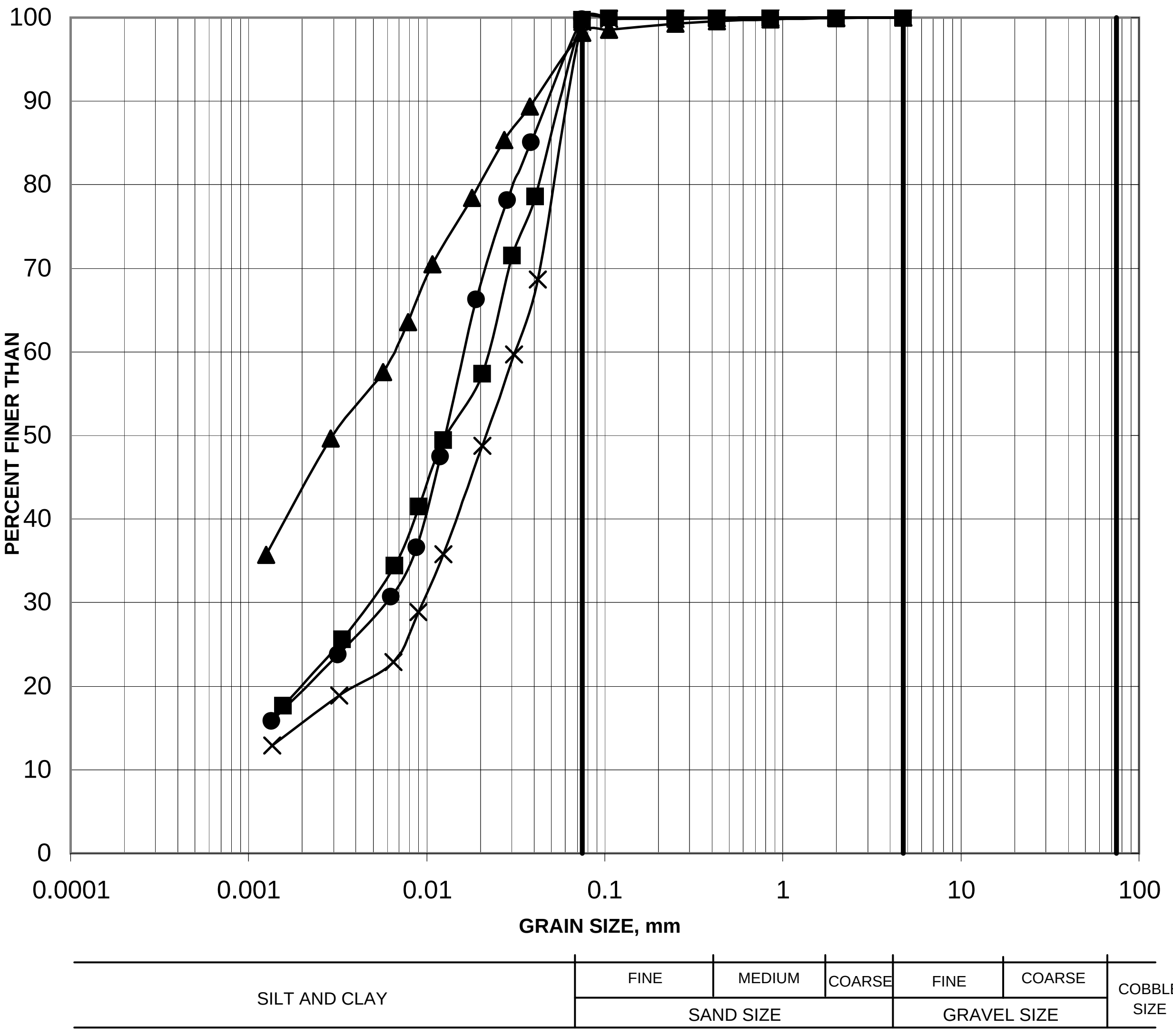
Prepared By: LFG

Checked By: MM

# GRAIN SIZE DISTRIBUTION

## Lower Silt

**FIGURE 9**



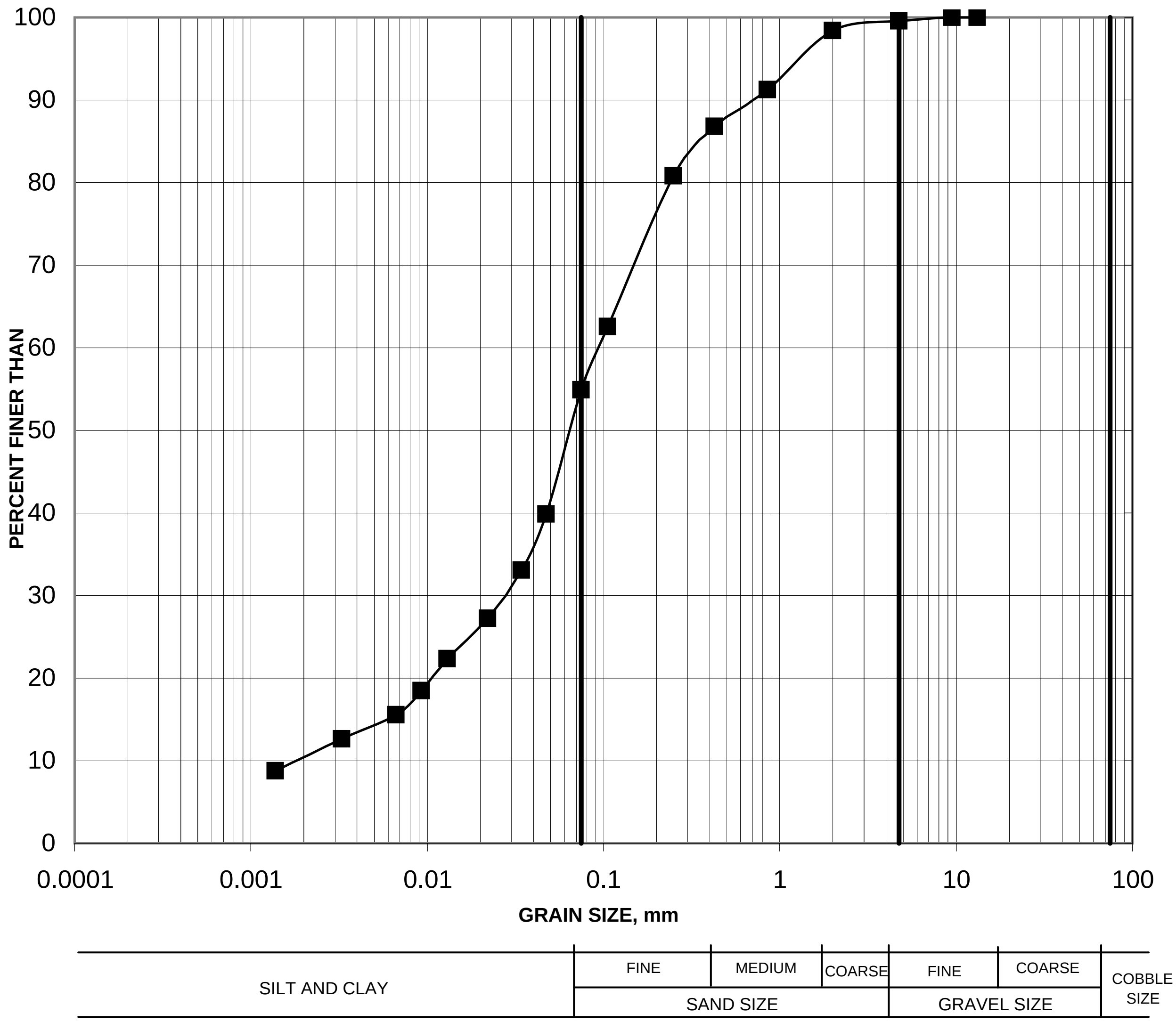

| Borehole | Sample | Elevation (m) |
|---|---|---|
| ■ 07-1 | 17 | 168.8 |
| × 07-6 | 17 | 170.0 |
| ● 07-6 | 20 | 160.9 |
| ▲ 07-6 | 23 | 151.7 |

Date: October, 2007
Project: 07-1191-0014

**Golder Associates**

Created by: TR
Checked by: SEMC

| GRAIN SIZE DISTRIBUTION<br>Sand and Silt TILL | FIGURE<br>10 |
|---|---|




| Borehole | Sample | Elevation (m) |
|---|---|---|
| 07-6 | 25 | 145.6 |

Date: October, 2007
Project: 07-1191-0014

**Golder Associates**

Created by: TR
Checked by: SEMC