



August 2, 2011

FOUNDATION INVESTIGATION REPORT

**POND CROSSING - PHASE 2
HIGHWAY 69 FOUR-LANING
FROM 0.4 KM NORTH OF HIGHWAY 7182
(SHEBESHEKONG ROAD)
NORTHERLY 11 KM
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5005-08-00**

Submitted to:
MMM Group
100 Commerce Valley Drive West
Thornhill, Ontario
L3T 0A1

REPORT



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GEOCRES No.: 41H-82

Report Number: 07-1191-0020-2

1 e-copy Ministry of Transportation, Ontario, North Bay, Ontario (Northeastern Region)
1 e-copy Ministry of Transportation, Ontario, Downsview, Ontario (Foundations Section)
1 e-copy MMM Group, Thornhill, Ontario
1 copy Golder Associates Ltd., Sudbury, Ontario





Table of Contents

| | |
|---|----------|
| 1.0 INTRODUCTION..... | 1 |
| 2.0 SITE DESCRIPTION..... | 1 |
| 3.0 INVESTIGATION PROCEDURES | 1 |
| 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS | 3 |
| 4.1 Regional Geology | 3 |
| 4.2 Subsurface Conditions..... | 3 |
| 5.0 CLOSURE | 6 |

DRAWINGS

| | |
|-----------|-----------------------------------|
| Drawing 1 | Borehole Location and Soil Strata |
| Drawing 2 | Soil Strata |

APPENDICES

Appendix A Record of Boreholes

List of Symbols and Abbreviations

| | |
|----------------------------|--------------------------------------|
| Record of Boreholes | P1-1, P1-3 to P1-5 and P1-7 to P1-15 |
| Record of Penetration Test | P1-DC1 and P1-DC3 |

Appendix B Laboratory Test Results

| | |
|------------|---|
| Figure B-1 | Grain Size Distribution – Silty Sand |
| Figure B-2 | Plasticity Chart- Clayey Silt to Silty Clay |
| Figure B-3 | Grain Size Distribution –Silty Clay |
| Figure B-4 | Oedometer Consolidation Summary |
| Figure B-5 | Grain Size Distribution – Sand and Gravel |



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by MMM Group (MMM) on behalf of Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for one (1) pond crossing for the proposed Highway 69 northbound lane (NBL) road embankment. This project is part of the detail design for the four-laning of Highway 69 from 0.4 km north of Highway 7182 (Shebeshekong Road) northerly for 11 km. The general location of this section of the Highway 69 four-laning alignment is shown on the Key Plan on Drawing 1 following the text of this report.

This report addresses the investigation carried out for the Phase 2 pond crossing. Separate reports will be submitted for the foundation investigations for Phase 1 swamp and pond crossings, culverts and bridge structures.

The purpose of this investigation is to establish the subsurface conditions along the proposed roadway alignment for the Phase 2 pond crossing by borehole drilling, in situ testing and laboratory testing on selected samples. The centreline of the proposed highway was staked in the field by MMM and the limits of the pond were reviewed by Golder in the field.

2.0 SITE DESCRIPTION

The proposed Highway 69 NBL embankment crossing the pond is located between Stations 14+450 and 14+550 in the Township of Harrison, approximately 600 m south of Sucker Creek and about 250 m east of the existing Highway 69 alignment. The proposed NBL embankment will be up to about 2.6 m above existing shoreline grade at this pond crossing.

In general, the topography in the area of the overall project limits consists of rolling terrain including densely treed areas and numerous bedrock outcrops separated by low-lying swamps. At the pond crossing location, the shoreline is about 1 m to 2 m above the pond water level and is relatively flat inland towards the area of the SBL. The ice surface at the borehole locations at the time of drilling ranged between Elevation 199.8 m and 200.4 m, while the ground surface at the boreholes (including below ice/water) ranges between 198.8 m and 202.0 m.

3.0 INVESTIGATION PROCEDURES

The investigation for the pond crossing was carried out on February 22 and 25, 2008 and February 9 and 10, 2009 during which time a total of 13 boreholes (Boreholes P1-1, P1-3 to P1-5 and P1-7 to P1-15) and 2 Dynamic Cone Penetration Tests (DCPTs) (DCPTs P1-DC1 and P1-DC3) were advanced generally along or near the centreline and the toes of the proposed embankment. The field investigation was carried out using Portable Equipment supplied and operated by Walker Drilling Ltd. of Utopia, Ontario and OGS Inc. of Almonte, Ontario. The locations of the boreholes and DCPTs are shown in plan on Drawing 1 following the text of this report

The boreholes were advanced through the overburden using NW or BW casing. Hand excavation/sampling methods were used, as appropriate, depending on the terrain and anticipated thickness of overburden. Soil samples were obtained continuously or at intervals of depth of about 0.75 m and 1.5 m, using a 50 mm outer diameter (O.D.) split-spoon sampler, performed in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586-08a), employing ½ weight hammers lifted manually to the SPT height. The 'N'-values recorded were then corrected for the lower energy drive. A sample of the cohesive soils was obtained using a 48 mm



FOUNDATION REPORT - POND CROSSING - PHASE 2

HIGHWAY 69 GWP 5005-08-00

O.D. Shelby tube (ASTM D1587) where BW casing was used to advance the boreholes. Field vane shear tests were conducted in cohesive soils for determination of undrained shear strengths (ASTM D2573-08) using MTO Standard 'N' size and 'B' size vanes. All boreholes were backfilled with bentonite upon completion in accordance with Ontario Reg. 903 (as amended by Ontario Reg. 372).

The boreholes and DCPTs were advanced to depths up to 6.6 m below existing ground surface or pond bottom (up to 8.1 m below ice/water surface) and were terminated on refusal to further casing and/or split-spoon advancement or cone penetration. These depths to refusal do not confirm bedrock surface elevations, but may be inferred to indicate potential proximity to the bedrock surface. At various borehole locations where refusal was encountered at shallow depth, the bedrock was exposed by hand shovel excavation to confirm the refusal condition.

The groundwater conditions and water levels in the open boreholes were observed during the drilling operations and are described on the Record of Borehole sheets in Appendix A. It should be noted that groundwater elevations as encountered in the boreholes may not be representative of static groundwater levels since most boreholes were advanced through ice/water columns and because the groundwater levels in the boreholes may not have stabilized on completion of drilling. Furthermore, groundwater elevations will vary depending on ponded water conditions and seasonal fluctuations, precipitation and local soil permeability.

The fieldwork was observed by members of our engineering and technical staff, who located the boreholes, arranged for the clearance of underground services, observed the drilling, sampling and in situ testing operations, logged the boreholes, and examined and cared for the soil samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Sudbury geotechnical laboratory where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. Classification testing (water content, Atterberg limits and grain size distribution) was carried out on selected soil samples. In addition, one (1) one-dimensional consolidation (oedometer) test was carried out on a sample of the cohesive deposit.

The centreline of the highway was surveyed and staked in the field by MMM prior to drilling. The as-drilled borehole locations and ground surface elevations were measured/surveyed by members of our technical staff, referenced to the survey stakes. The borehole locations given on the Record of Borehole and DCPT sheets and shown on Drawing 1 are positioned relative to MTM NAD 83 northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum.

The borehole and dynamic cone penetration test locations and ground surface elevations are as follows:

| BH/DCPT | Location | | Ground Surface Elevation (m) | Drilled Depth (m) |
|---------|-----------|----------|------------------------------|-------------------|
| | Northing | Easting | | |
| P1-1 | 5051063.2 | 236953.5 | 200.0 | 0.9 |
| P1-3 | 5051039.5 | 236961.3 | 200.0 | 0.2 |
| P1-4 | 5051031.6 | 236977.6 | 199.8 | 1.7 |
| P1-5 | 5051015.7 | 236969.2 | 202.0 | 0.1 |
| P1-7 | 5050991.9 | 236976.8 | 199.8 | 0.6 |
| P1-8 | 5050984.4 | 236994.2 | 199.8 | 0.5 |
| P1-9 | 5050968.2 | 236984.5 | 199.8 | 0.9 |
| P1-10 | 5051045.5 | 236973.1 | 199.8 | 4.3 |
| P1-11 | 5051073.0 | 236982.7 | 200.3 | 1.6 |



| BH/DCPT | Location | | Ground Surface Elevation (m) | Drilled Depth (m) |
|---------|-----------|----------|---------------------------------|----------------------|
| P1-12 | 5051048.4 | 236988.2 | 200.3 | 8.1 |
| P1-13 | 5051024.6 | 236993.5 | 200.3 | 7.2 |
| P1-14 | 5050999.7 | 236999.1 | 200.3 | 2.3 |
| P1-15 | 5050974.9 | 237004.7 | 200.4 | 0.8 |
| P1-DC1 | 5051055.4 | 236969.8 | 199.8 | 3.5 |
| P1-DC3 | 5051007.9 | 236985.6 | 199.8 | 1.1 |

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

As delineated in *The Physiography of Southern Ontario*¹, this section of Highway 69 lies within the physiographic region known as the Georgian Bay Fringe, which extends along the east side of Georgian Bay through the Parry Sound and Muskoka areas, then eastward from Muskoka in patches into the area north of the Kawartha Lakes.

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

The bedrock in the area consists typically of gneisses of the Britt Domain of the Central Gneiss Belt, a subdivision of the Grenville Structural Province, as described in *Geology of Ontario*, OGS Special Volume 4². Deposition of Paleozoic strata initially covered the bedrock and later erosion during glaciation exposed these Precambrian rocks.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced during this investigation (including hand shovel excavated overburden to expose the bedrock where boreholes encountered refusal at shallow depth, typically less than 0.3 m), together with the results of the laboratory tests carried out on selected soil samples, are presented on the Record of Borehole sheets included in Appendix A and the laboratory test sheets included in Appendix B. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non continuous sampling, observations of drilling progress and the results of SPTs and in situ testing. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations. The thickness of the overburden in the investigated areas as inferred from the resistance to DCPT results are shown on the Record of Penetration Test sheets in Appendix A, as applicable.

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

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



The inferred soil stratigraphy as encountered in the boreholes and DCPTs advanced in the pond crossing area is shown in profile on Drawings 1 and 2. It should be noted that the orientation (i.e. north, south, east, west) stated in the text of the report is typically referenced to project north (and up-chainage along the proposed Highway 69 alignment) and therefore may differ from the Magnetic North shown on the drawing.

In general, the subsurface soils along the NBL alignment in this pond area consist of a surficial layer of peat underlain by deposits of silty sand, sand and gravel and clayey silt to silty clay, to the refusal depths encountered. A detailed description of the surface conditions encountered in the boreholes is provided in the following sections.

Ice/Water

Boreholes P1-4, P1-7, P1-8 and P1-10 to P1-15 were advanced from the ice surface and penetrated an ice/water layer to depths between 0.3 m and 1.5 m.

Peat

A deposit of black, fibrous/amorphous peat was encountered in all boreholes except Borehole P1-15. The deposit was encountered below ice/water in Boreholes P1-4, P1-7, P1-8 and P1-10 to P1-14 and from ground surface in Boreholes P1-1, P1-3, P1-5 and P1-9. The thickness of the peat deposit is between 0.1 m and 4.2 m and the top of the deposit was encountered between Elevation 202.0 m and 198.8 m.

The SPT 'N'-values measured within the peat are between 0 blows (i.e. weight of hammer) and 6 blows per 0.3 m of penetration suggesting a very soft to firm consistency.

The measured water content on samples of the peat ranges between about 68 percent and 1175 percent.

Silty Sand

A deposit of grey to brown silty sand was encountered underlying the peat in Boreholes P1-1, P1-9 and P1-10. The top of the deposit ranges between about Elevation 199.8 m and 198.6 m in these boreholes and the thickness of the deposit ranges from 0.6 m to 1.1 m. In Boreholes P1-1 and P1-9, the bottom of this deposit was defined by refusal to further split-spoon advancement.

The SPT 'N'-values measured within this deposit are 1 blow per 0.3 m of penetration and 1 and 23 blows per 0.15 m of penetration, indicating a very loose to dense relative density.

The grain size distributions of three samples of this deposit are presented on Figure B-1 in Appendix B. An Atterberg limits test on one (1) sample of this deposit indicates that the material is non-plastic.

The measured water content on samples of this deposit ranges between about 22 percent and 56 percent.

Clayey Silt to Silty Clay

A deposit of grey clayey silt to silty clay, trace to some sand was encountered in Boreholes P1-10 to P1-13. The top of the deposit ranges from Elevation 199.1 m to 194.6 m and the thickness of the deposit ranges from 0.4 m to 2.2 m.



The SPT 'N'-values measured within the cohesive deposit range from 0 blows (i.e. weight of hammer) to 1 blow per 0.3 m of penetration and 1 blow per 0.15 m of penetration. In situ field vane testing carried out within this stratum measured undrained shear strengths ranging from about 9 kPa to 26 kPa. The results of the SPT 'N'-values together with the in situ field vanes indicate that the cohesive deposit has a very soft to firm consistency.

Atterberg limits tests were carried out on six (6) samples of the clayey silt to silty clay deposit. The test results indicate liquid limits ranging from 31 percent to 46 percent, plastic limits ranging from 15 percent to 20 percent and plasticity indices ranging from 12 percent to 24 percent. The results of the Atterberg limits tests are shown on the plasticity chart on Figure B-2 in Appendix B and indicate that the material is classified as a clayey silt of low plasticity to a silty clay of medium plasticity.

The grain size distribution of one sample from this deposit is shown on Figure B-3 in Appendix B.

The measured water content on samples of this deposit ranges between about 54 percent and 81 percent.

One laboratory consolidation test was carried out on a specimen of the silty clay obtained from Borehole P1-13 and the test results are shown on Figure B-4. The pre-consolidation pressure was estimated from the Void Ratio versus logarithmic Pressure plots using the Casagrande method as well as from the Total Work versus Pressure plots. The relevant consolidation test results are summarized below.

| Borehole / Sample Number | Elevation (m) | σ_{vo}' (kPa) | σ_p' (kPa) | $\sigma_p' - \sigma_{vo}'$ (kPa) | OCR | e_o | C_r | C_c | c_v^* (cm ² /s) |
|-----------------------------|------------------|-------------------------|----------------------|-------------------------------------|-----|-------|-------|-------|---------------------------------|
| P1-13 / 6 | 193.9 | 20 | 30 | 10 | 1.5 | 1.66 | 0.08 | 0.44 | 3.9×10^{-3} |

Note: * For approximate stress range of $15 \leq \sigma_v' \leq 113$ kPa
where: σ_{vo}' effective overburden pressure in kPa
 σ_p' preconsolidation pressure in kPa
OCR overconsolidation ratio
 e_o initial void ratio
 C_c compression index (based on void ratio)
 C_r recompression index (based on void ratio)
 c_v coefficient of consolidation in cm²/s in the normally consolidated range

Sand and Gravel

A deposit of grey sand and gravel was encountered underlying the peat in Borehole P1-14 and overlying the clayey silt in Borehole P1-12. The top of the sand and gravel deposit was encountered at Elevation 198.2 m and 192.7 m in the respective boreholes and the thickness of the deposit is 0.2 m and 0.5 m, respectively. The bottom of this deposit was defined by refusal to further split-spoon advancement in both boreholes.

The SPT 'N'-values measured within this deposit are 50 blows per 0.3 m of penetration and 23 blows per 0.3 m of penetration in Boreholes P1-14 and P1-12, respectively, indicating a compact to very dense relative density.

The grain size distribution of one sample of this deposit is presented on Figure B-5 in Appendix B.

The measured water content on one sample of this deposit is about 26 percent.



Bedrock / Refusal

In all boreholes and in DCPTs P1-DC1 and P1-DC3, refusal to further split-spoon or casing advancement or cone penetration was encountered at depths between about 0.1 m and 8.1 m below ground/ice surface, corresponding to between Elevation 201.9 m and 192.2 m.

Groundwater Conditions

In general, the samples taken in the boreholes were wet with free water noted in select non-cohesive samples. Water levels observed in the boreholes upon completion of drilling were essentially at ground/ice surface, ranging from Elevation 200.4 m to 199.8 m. Boreholes P1-3, P1-5 and P1-9 were found to be dry upon completion of drilling. It should also be noted that the groundwater levels in the area are subject to seasonal fluctuations.

5.0 CLOSURE

The field drilling program was carried out under the supervision of Mr. Indulis Dumpis and Mr. Trevor Moxam, field technicians with Golder, under the overall direction of Mr. André Bom, P.Eng. This report was prepared by Mr. Adam Wissink, EIT, and under the direction and review of Mr. André Bom, P.Eng. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for this project and Principal with Golder, conducted an independent quality control review of the report.



Report Signature Page

GOLDER ASSOCIATES LTD.

Adam Wissink, EIT



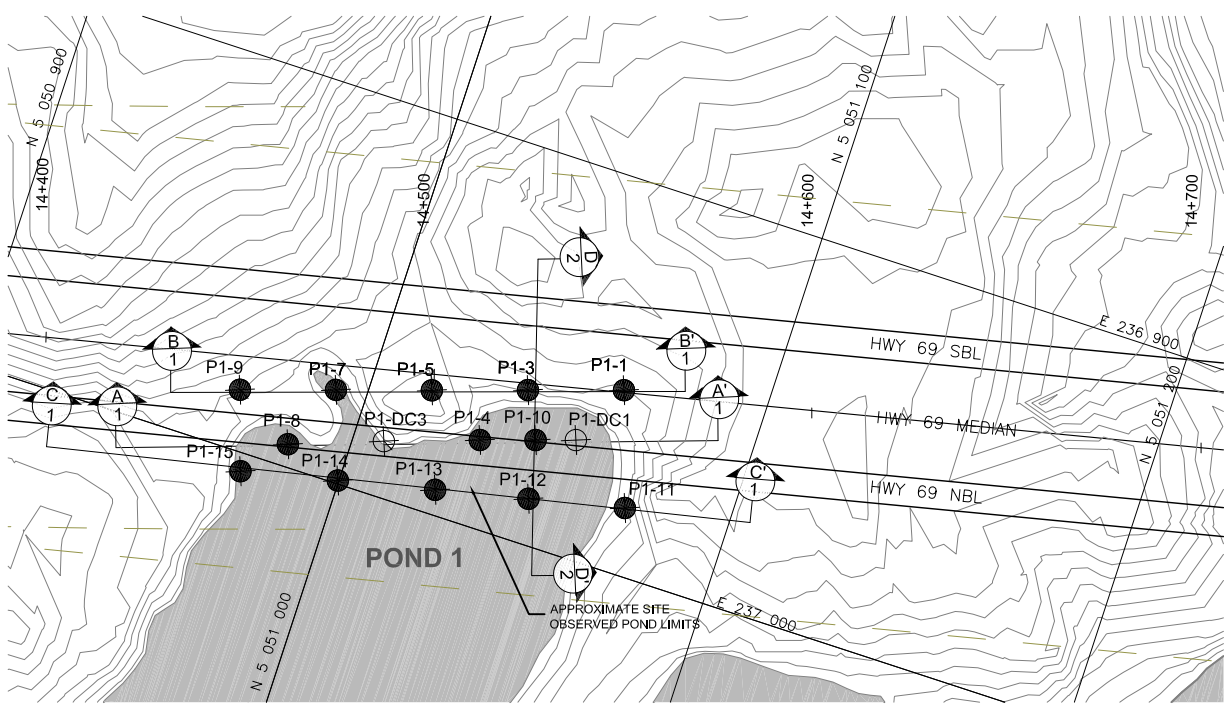
André Bom, P.Eng.
Geotechnical Engineer



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

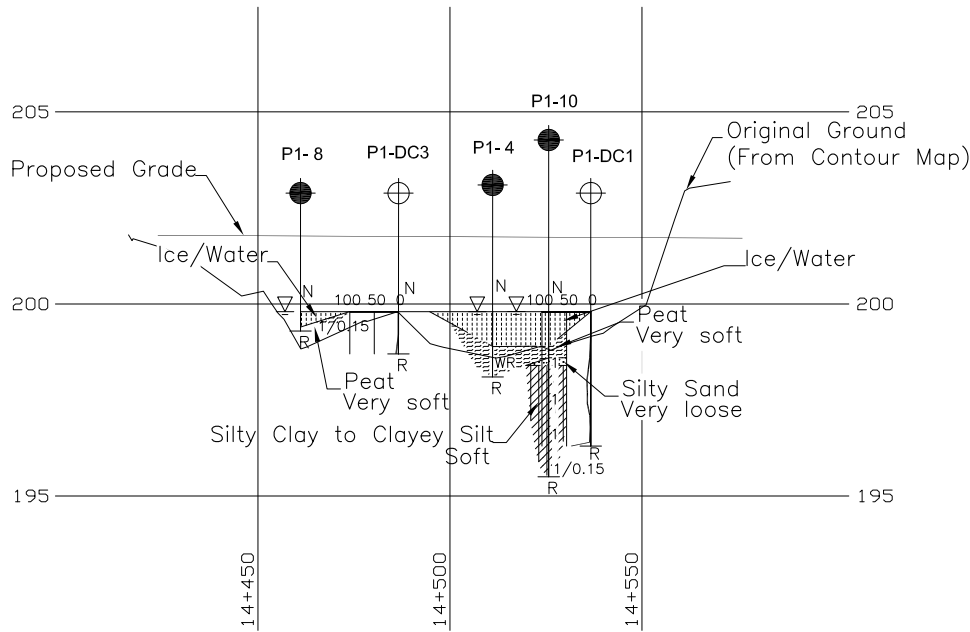
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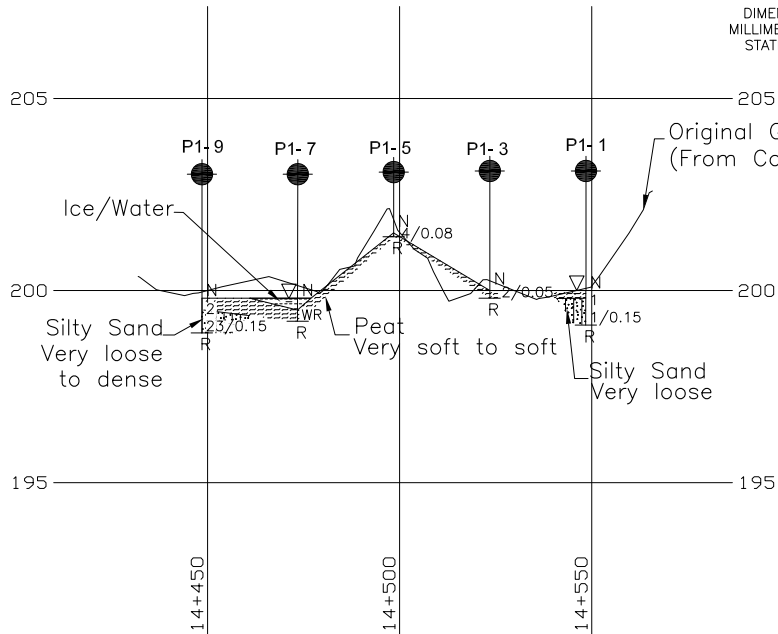
PLAN

SCALE
20 0 20 40 m



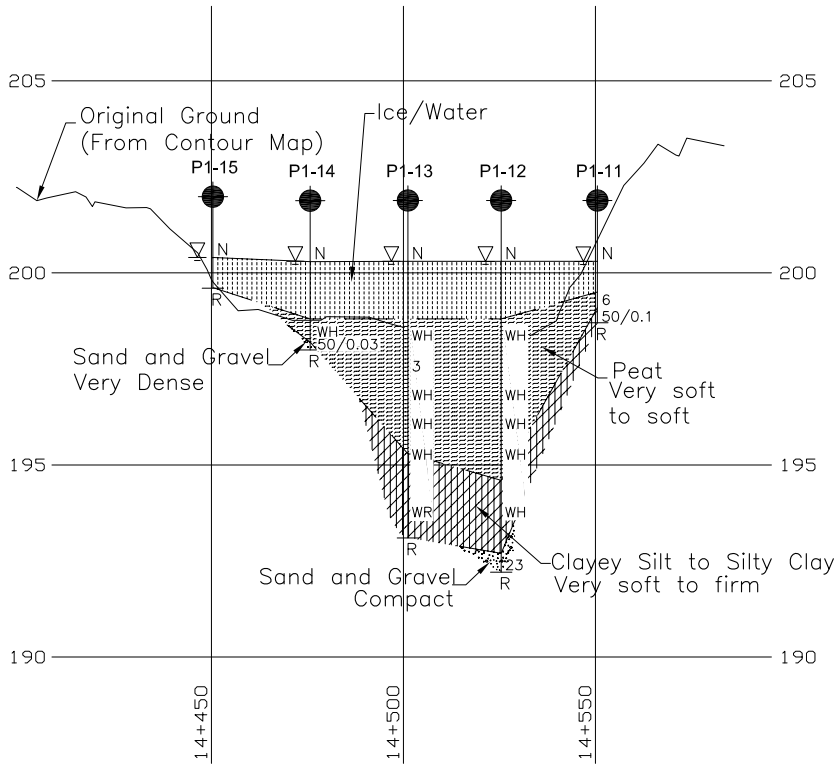
A-A' 1
CENTRELINE PROFILE
HIGHWAY 69 (NBL)

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



B-B' 1
EMBANKMENT TOE PROFILE
HIGHWAY 69 (NBL)

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



C-C' 1
EMBANKMENT TOE PROFILE
HIGHWAY 69 (NBL)

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

REFERENCE

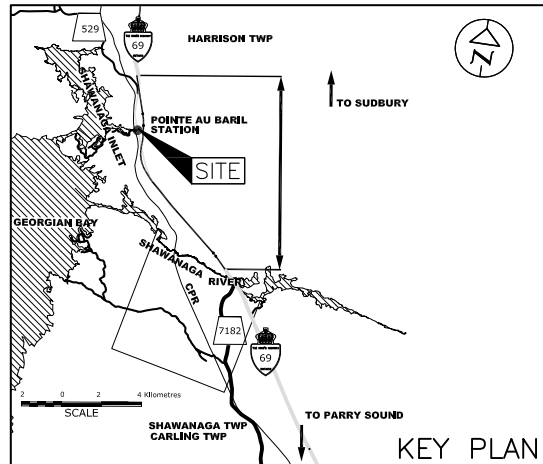
Base plan provided in digital format by MMM Group, drawing file no. HWY69 5403-05-00 Design.dwg (received Oct. 2008) and key plan, drawing file no. Hwy 69-529-Project key plan (received Apr. 2008)

CONT No.
WP No.5005-08-00

HIGHWAY 69 (NBL)
STA 14+450 TO 14+550
BOREHOLE LOCATION AND
SOIL STRATA



Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA



LEGEND

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

| No. | ELEVATION(m) | CO-ORDINATES | |
|--------|--------------|--------------|----------|
| | | NORTHING | EASTING |
| P1-1 | 200.0 | 5051063.2 | 236953.5 |
| P1-3 | 200.0 | 5051039.5 | 236961.3 |
| P1-4 | 199.8 | 5051031.6 | 236977.6 |
| P1-5 | 202.0 | 5051015.7 | 236969.2 |
| P1-7 | 199.8 | 5050991.9 | 236976.8 |
| P1-8 | 199.8 | 5050984.4 | 236994.2 |
| P1-9 | 199.8 | 5050968.2 | 236984.5 |
| P1-10 | 199.8 | 5051045.5 | 236973.1 |
| P1-11 | 200.3 | 5051073.0 | 236982.7 |
| P1-12 | 200.3 | 5051048.4 | 236988.2 |
| P1-13 | 200.3 | 5051024.6 | 236993.5 |
| P1-14 | 200.3 | 5050999.7 | 236999.1 |
| P1-15 | 200.4 | 5050974.9 | 237004.7 |
| P1-DC1 | 199.8 | 5051055.4 | 236969.8 |
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NOTES

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

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

| NO. | DATE | BY | REVISION |
|--------------------|----------|-------------------------|----------|
| Geocres No. 41H-82 | | | |
| HWY. 69 | | PROJECT NO.07-1191-0020 | DIST. |
| SUBM'D. AB | CHKD. AB | DATE: AUG 2011 | SITE: |
| DRAWN: MM | CHKD. | APPD. JMAC | DWG. 1 |

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

CONT No.
WP No.5005-08-00

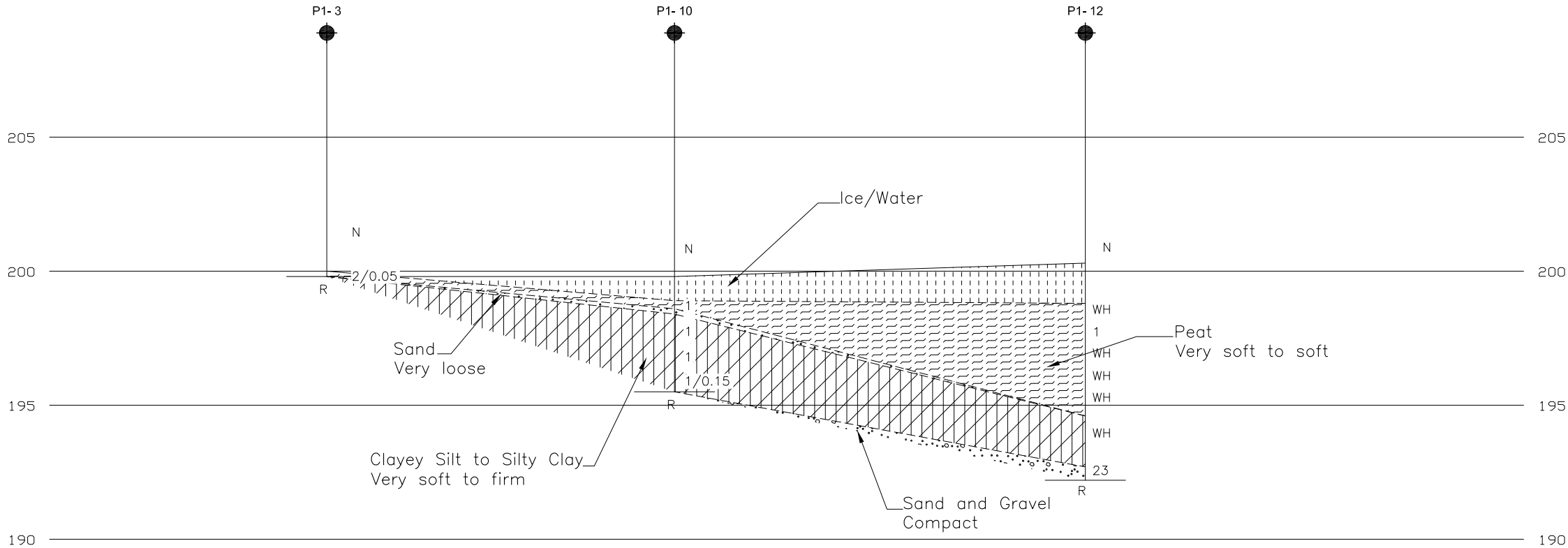
HIGHWAY 69
STA 14+450 TO 14+550
SOIL STRATA



SHEET



Golder Associates Ltd.
SUDBURY, ONTARIO, CANADA



CROSS SECTION AT STA. 14+530
HIGHWAY 69 (NBL)



LEGEND

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

| No. | ELEVATION(m) | CO-ORDINATES | |
|--------|--------------|--------------|----------|
| | | NORTHING | EASTING |
| P1-1 | 200.0 | 5051063.2 | 236953.5 |
| P1-3 | 200.0 | 5051039.5 | 236961.3 |
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| P1-8 | 199.8 | 5050984.4 | 236994.2 |
| P1-9 | 199.8 | 5050968.2 | 236984.5 |
| P1-10 | 199.8 | 5051045.5 | 236973.1 |
| P1-11 | 200.3 | 5051073.0 | 236982.7 |
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| P1-13 | 200.3 | 5051024.6 | 236993.5 |
| P1-14 | 200.3 | 5050999.7 | 236999.1 |
| P1-15 | 200.4 | 5050974.9 | 237004.7 |
| P1-DC1 | 199.8 | 5051055.4 | 236969.8 |
| P1-DC3 | 199.8 | 5051007.9 | 236985.6 |

NOTES

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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 plan provided in digital format by MMM Group, drawing file no. HWY69 5403-05-00 Design.dwg (received Oct. 2008) and key plan, drawing file no. Hwy 69-529-Project key plan (received Apr. 2008)



| | | | |
|--------------------|-------------------------|----------------|----------|
| NO. | DATE | BY | REVISION |
| Geocres No. 41H-82 | | | |
| HWY. 69 | PROJECT NO.07-1191-0020 | DIST. | |
| SUBM'D. AB | CHKD. AB | DATE: AUG 2011 | SITE: |
| DRAWN: MM | CHKD. | APPD. JMAC | DWG. 2 |



APPENDIX A

Record of Boreholes



LIST OF SYMBOLS

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

1. GENERAL

| | |
|-------------|---------------------------------------|
| π | 3.1416 |
| $\ln x$, | natural logarithm of x |
| \log_{10} | x or log x, logarithm of x to base 10 |
| g | acceleration due to gravity |
| t | time |
| FoS | Factor of Safety |
| V | volume |
| W | weight |

II. STRESS AND STRAIN

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

III. SOIL PROPERTIES

(a) Index Properties

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

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

| | |
|-------------|---|
| C_c | compression index (normally consolidated range) |
| C_r | recompression index (over-consolidated range) |
| C_s | swelling index |
| C_a | coefficient of secondary consolidation |
| m_v | coefficient of volume change |
| c_v | coefficient of consolidation |
| T_v | time factor (vertical direction) |
| U | degree of consolidation |
| σ'_p | pre-consolidation pressure |
| OCR | over-consolidation ratio $= \sigma'_p / \sigma'_{vo}$ |

(d) Shear Strength

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

Notes: 1 $\tau = c' + \sigma' \tan \phi'$
2 Shear strength = (Compressive strength)/2



LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

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

Dynamic Cone Penetration Resistance; N_d :

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

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

Piezo-Cone Penetration Test (CPT)

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

III. SOIL DESCRIPTION

(a) Cohesionless Soils

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

(b) Cohesive Soils Consistency

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

IV. SOIL TESTS

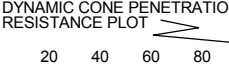
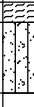
| | |
|-----------------|---|
| w | water content |
| w_p | plastic limit |
| w_l | liquid limit |
| C | consolidation (oedometer) test |
| CHEM | chemical analysis (refer to text) |
| CID | consolidated isotropically drained triaxial test ¹ |
| CIU | consolidated isotropically undrained triaxial test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

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

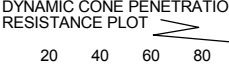

V. MINOR SOIL CONSTITUENTS

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

| | | | | | | | |
|--------------------------------------|--|--|--|--|--|-------------------------|--|
| PROJECT <u>07-1191-0020</u> | | RECORD OF BOREHOLE No P1- 1 | | | | 1 OF 1 METRIC | |
| W.P. <u>5005-08-00</u> | | LOCATION <u>N 5051063.2 ;E 236953.5</u> | | | | ORIGINATED BY <u>ID</u> | |
| DIST <u> </u> HWY <u>69</u> | | BOREHOLE TYPE <u>Hand Sampling Equipment</u> | | | | COMPILED BY <u>MM</u> | |
| DATUM <u>Geodetic</u> | | DATE <u>February 25, 2008</u> | | | | CHECKED BY <u>AB</u> | |

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT  | PLASTIC LIMIT W _p | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|--|---|---------|------|------------|----------------------------|-----------------|---|---------------------------------|----------------------------------|--------------------------------|--|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | | | | | | |
| 200.0 | GROUND SURFACE | | | | | | | | | | | | |
| 0.0 | PEAT (Fibrous) |  | 1 | SS | 1 | | | | | | | | |
| 0.2 | Very soft Black Wet | | | | | | | | | | | | |
| 199.1 | Silty SAND, trace gravel | | 2 | SS | 1/0.15 | | | | | | | | 3 68 (29) |
| 0.9 | Very loose Brown Wet | | | | | | | | | | | | |
| | End of Borehole Spoon Refusal (Hammer Bouncing) | | | | | | | | | | | | |
| Notes: 1. Water level at ground surface (Elev. 200.0 m) upon completion of drilling. 2. Split spoon samples obtained by driving with a 1/2 weight hammer; SPT 'N' values have been adjusted to the inferred values that would be obtained using a standard weight hammer. | | | | | | | | | | | | | |

| | | | | | | | |
|--------------------------------------|--|--|--|--|--|-------------------------|--|
| PROJECT <u>07-1191-0020</u> | | RECORD OF BOREHOLE No P1- 3 | | | | 1 OF 1 METRIC | |
| W.P. <u>5005-08-00</u> | | LOCATION <u>N 5051039.5 ;E 236961.3</u> | | | | ORIGINATED BY <u>ID</u> | |
| DIST <u> </u> HWY <u>69</u> | | BOREHOLE TYPE <u>Hand Sampling Equipment</u> | | | | COMPILED BY <u>MM</u> | |
| DATUM <u>Geodetic</u> | | DATE <u>February 25, 2008</u> | | | | CHECKED BY <u>AB</u> | |

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT  | PLASTIC LIMIT W _p | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---|--|---|---------|------|------------|----------------------------|-----------------|---|---------------------------------|----------------------------------|--------------------------------|--|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | | | | | | |
| 200.0 | GROUND SURFACE | | | | | | | | | | | | |
| 0.0 | PEAT (Fibrous) |  | 1 | SS | 2/0.05 | | | | | | | | |
| 0.2 | Very Soft Black Wet | | | | | | | | | | | | |
| | End of Borehole Spoon Refusal (Hammer Bouncing) | | | | | | | | | | | | |
| Notes: 1. Borehole dry upon completion of drilling. 2. Bedrock exposed at borehole location with hand shovel upon completion of drilling. 3. Split spoon sample obtained by driving with a 1/2 weight hammer; SPT 'N' value has been adjusted to the inferred value that would be obtained using a standard weight hammer. | | | | | | | | | | | | | |

MIS-MTO 002 07-1191-0020 P1 METRIC.GPJ GAL-MISS.GDT 03/02/11 DATA INPUT:

| PROJECT <u>07-1191-0020</u> | | | | | | | | | | RECORD OF BOREHOLE No P1- 4 | | | | | | | | | | 1 OF 1 | | METRIC | |
|--------------------------------------|--|------------|---------|------|--|-------------------------|-----------------|--|----|------------------------------------|-----|----|---|----|-------|----------------------|---------------------------------------|--|--|--------|--|---------------|--|
| W.P. <u>5005-08-00</u> | | | | | LOCATION <u>N 5051031.6 ;E 236977.6</u> | | | | | ORIGINATED BY <u>ID</u> | | | | | | | | | | | | | |
| DIST <u> </u> HWY <u>69</u> | | | | | BOREHOLE TYPE <u>Portable Equipment, NW Casing Wash Boring</u> | | | | | COMPILED BY <u>MM</u> | | | | | | | | | | | | | |
| DATUM <u>Geodetic</u> | | | | | DATE <u>February 25, 2008</u> | | | | | CHECKED BY <u>AB</u> | | | | | | | | | | | | | |
| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT | | | UNIT WEIGHT γ | REMARKS & GRAIN SIZE DISTRIBUTION (%) | | | | | | |
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | WATER CONTENT (%) | | | | | | | | | | |
| 199.8 | ICE SURFACE | | | | | 199 | 20 | 40 | 60 | 80 | 100 | 20 | 40 | 60 | 190.1 | GR SA SI CL | | | | | | | |
| 199.5 | ICE | | | | | | | | | | | | | | | | | | | | | | |
| 0.3 | WATER | | | | | | | | | | | | | | | | | | | | | | |
| 198.9 | PEAT (Fibrous) Very soft Black Wet | | 1 | SS | WR | | | | | | | | | | | | | | | | | | |
| 198.1 | End of Borehole Casing Refusal | | | | | | | | | | | | | | | | | | | | | | |
| 1.7 | Notes: 1. Water level at ice surface (Elev. 199.8 m) upon completion of drilling. 2. Split spoon sample obtained by driving with a 1/2 weight hammer; SPT 'N' value has been adjusted to the inferred value that would be obtained using a standard weight hammer. | | | | | | | | | | | | | | | | | | | | | | |

| PROJECT <u>07-1191-0020</u> | | | | | | | | | | RECORD OF BOREHOLE No P1- 5 | | | | | | | | | | 1 OF 1 | | METRIC | |
|--------------------------------------|---|------------|---------|------|--|-------------------------|-----------------|--|----|------------------------------------|-----|----|---|----|-------|----------------------|---------------------------------------|--|--|--------|--|---------------|--|
| W.P. <u>5005-08-00</u> | | | | | LOCATION <u>N 5051015.7 ;E 236969.2</u> | | | | | ORIGINATED BY <u>ID</u> | | | | | | | | | | | | | |
| DIST <u> </u> HWY <u>69</u> | | | | | BOREHOLE TYPE <u>Hand Sampling Equipment</u> | | | | | COMPILED BY <u>MM</u> | | | | | | | | | | | | | |
| DATUM <u>Geodetic</u> | | | | | DATE <u>February 25, 2008</u> | | | | | CHECKED BY <u>AB</u> | | | | | | | | | | | | | |
| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT | | | UNIT WEIGHT γ | REMARKS & GRAIN SIZE DISTRIBUTION (%) | | | | | | |
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | WATER CONTENT (%) | | | | | | | | | | |
| 202.0 | GROUND SURFACE | | | | | 222 | 20 | 40 | 60 | 80 | 100 | 20 | 40 | 60 | 40.08 | GR SA SI CL | | | | | | | |
| 0.1 | PEAT (Fibrous) Soft Black Wet End of Borehole Spoon Refusal (Hammer Bouncing) | | 1 | SS | 40.08 | | | | | | | | | | | | | | | | | | |
| | Notes: 1. Borehole dry upon completion of drilling. 2. Bedrock exposed at borehole location with hand shovel upon completion of drilling. 3. Split spoon sample obtained by driving with a 1/2 weight hammer; SPT 'N' value has been adjusted to the inferred value that would be obtained using a standard weight hammer. | | | | | | | | | | | | | | | | | | | | | | |

MIS-MTO 002 07-1191-0020 P1 METRIC.GPJ GAL-MISS.GDT 03/02/11 DATA INPUT:

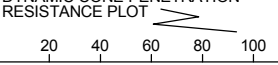


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|------------------------------------|--|--|--|-------------------------|--|
| PROJECT <u>07-1191-0020</u> | | RECORD OF BOREHOLE No P1-7 | | 1 OF 1 METRIC | |
| W.P. <u>5005-08-00</u> | | LOCATION <u>N 5050991.9 ; E 236976.8</u> | | ORIGINATED BY <u>ID</u> | |
| DIST <u> </u> HWY <u>69</u> | | BOREHOLE TYPE <u>Portable Equipment, NW Casing Wash Boring</u> | | COMPILED BY <u>MM</u> | |
| DATUM <u>Geodetic</u> | | DATE <u>February 25, 2008</u> | | CHECKED BY <u>AB</u> | |

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT NATURAL MOISTURE LIQUID CONTENT | | | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---------------|---|------------|---------|------|------------|----------------------------|-----------------|---|----|----|----|-----|---|---|----------------|--------------------------------------|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | 20 | 40 | 60 | 80 | 100 | W _P | W | W _L | | |
| 199.8 | ICE SURFACE | | | | | | | | | | | | | | | | |
| 199.5 | ICE | | 1 | SS | WR | | | | | | | | | | | | |
| 199.2 | PEAT (Fibrous) Very Soft Black Wet End of Borehole Spoon Refusal (Hammer Bouncing) Notes: 1. Water level at ice surface (Elev. 199.8 m) upon completion of drilling. 2. Split spoon sample obtained by driving with a 1/2 weight hammer; SPT 'N' value has been adjusted to the inferred value that would be obtained using a standard weight hammer. | | | | | | | | | | | | | | | | |
| 0.6 | | | | | | | 199 | | | | | | | | | | |

| | | | | | |
|------------------------------------|--|--|--|-------------------------|--|
| PROJECT <u>07-1191-0020</u> | | RECORD OF BOREHOLE No P1-8 | | 1 OF 1 METRIC | |
| W.P. <u>5005-08-00</u> | | LOCATION <u>N 5050984.4 ; E 236994.2</u> | | ORIGINATED BY <u>ID</u> | |
| DIST <u> </u> HWY <u>69</u> | | BOREHOLE TYPE <u>Portable Equipment, NW Casing Wash Boring</u> | | COMPILED BY <u>MM</u> | |
| DATUM <u>Geodetic</u> | | DATE <u>February 25, 2008</u> | | CHECKED BY <u>AB</u> | |

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT w _p | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL | |
|---------------|---|------------|---------|------|------------|----------------------------|-----------------|---|--|--|--|--|--|---|---------------------------------------|--|--|-------------------|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | | | | | WATER CONTENT (%) |
| | | | | | | | | ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED | | | | | | | | | | |
| 199.8 | ICE SURFACE | | | | | | | | | | | | | | | | | |
| 199.5 | ICE | | | | | | | | | | | | | | | | | |
| | WATER | | 1 | SS | 1/0 15 | | | | | | | | | | | | | |
| 0.5 | PEAT (Fibrous) Very soft Black Wet End of Borehole Spoon Refusal (Hammer Bouncing) Notes: 1. Water level at ice surface (Elev. 199.8 m) upon completion of drilling. 2. Split spoon sample obtained by driving with a 1/2 weight hammer; SPT 'N' value has been adjusted to the inferred value that would be obtained using a standard weight hammer. | | | | | | 199 | | | | | | | | | | | |

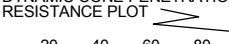
MIS-MTO 002 07-1191-0020 P1 METRIC.GPJ GAL-MISS.GDT 03/02/11 DATA INPUT:

| PROJECT 07-1191-0020 | | | RECORD OF BOREHOLE No P1-9 | | | | 1 OF 1 METRIC | | | | |
|--|---|---|----------------------------|------|------------|----------------------------|-----------------|--|---|---------------------------------------|--|
| W.P. 5005-08-00 | | LOCATION N 5050968.2; E 236984.5 | | | | ORIGINATED BY ID | | | | | |
| DIST HWY 69 | | BOREHOLE TYPE Hand Sampling Equipment | | | | COMPILED BY MM | | | | | |
| DATUM Geodetic | | DATE February 25, 2008 | | | | CHECKED BY AB | | | | | |
| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT  SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED | PLASTIC LIMIT W _p NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L WATER CONTENT (%) | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | | | | |
| 199.8 | GROUND SURFACE | | | | | | | | | | |
| 0.0 199.5 0.3 | PEAT (Fibrous) Very soft Black Wet |  | 1 | SS | 2 | | | | | | |
| 198.9 | Silty SAND, trace gravel Very loose to dense Brown Moist |  | 2 | SS | 23/0.15 | | 199 | | | | 9 69 (22) |
| 0.9 | End of Borehole Spoon Refusal (Hammer Bouncing) | | | | | | | | | | |
| Notes: 1. Borehole dry upon completion of drilling. 2. Split spoon samples obtained by driving with a 1/2 weight hammer; SPT 'N' values have been adjusted to the inferred values that would be obtained using a standard weight hammer. | | | | | | | | | | | |

MIS-MTO001 07-1191-0020 P1 METRIC.GPJ GAL-MISS.GDT 03/02/11 DATA INPUT:

| PROJECT 07-1191-0020 | | RECORD OF BOREHOLE No P1-10 | | | | 1 OF 1 METRIC | | | | | | | | |
|--|---|---|---------|------|------------|----------------------------|-----------------|---|--|------------------------------------|-------------------------------------|-----------------------------------|---|--|
| W.P. 5005-08-00 | | LOCATION N 5051045.5; E 236973.1 | | | | ORIGINATED BY ID | | | | | | | | |
| DIST HWY 69 | | BOREHOLE TYPE Portable Equipment, NW Casing Wash Boring | | | | COMPILED BY MM | | | | | | | | |
| DATUM Geodetic | | DATE February 25, 2008 | | | | CHECKED BY AB | | | | | | | | |
| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | PLASTIC LIMIT W _p | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | |
| 199.8 | ICE SURFACE | | | | | | | | | | | | | |
| 0.0 | ICE | | | | | | | | | | | | | |
| 199.5 | | | | | | | | | | | | | | |
| 0.3 | WATER | | | | | | | | | | | | | |
| 198.9 | | | | | | | 199 | | | | | | | |
| 198.6 | PEAT (Fibrous) Very soft Black Wet | | 1 | SS | 1 | | | | | | | | 87.5 | |
| 1.2 | Silty SAND, some clay, trace gravel Very loose Grey Wet | | 2 | SS | 1 | | 198 | | | | | | | 2 48 24 26 |
| 197.5 | | | 3 | SS | 1 | | 197 | | | | | | 80.7 | 0 10 43 47 |
| 2.3 | SILTY CLAY to CLAYEY SILT, trace to some sand Soft Grey Wet | | | | | | 196 | | | | | | | |
| 195.5 | | | 4 | SS | 1/0.15 | | | | | | | | | |
| 4.3 | End of Borehole Spoon Refusal (Hammer Bouncing) | | | | | | | | | | | | | |
| Notes: 1. Water level at ice surface (Elev. 199.8 m) upon completion of drilling. 2. Split spoon samples obtained by driving with a 1/2 weight hammer; SPT 'N' values have been adjusted to the inferred values that would be obtained using a standard weight hammer. | | | | | | | | | | | | | | |

MIS-MTO001 07-1191-0020 P1 METRIC.GPJ GAL-MASS.GDT 03/02/11 DATA INPUT:

| PROJECT 07-1191-0020 | | | RECORD OF BOREHOLE No P1-11 | | | 1 OF 1 METRIC | | | | | |
|--|---|------------|---|------|------------|----------------------------|-----------------|--|---|---------------------------------------|--|
| W.P. 5005-08-00 | | | LOCATION N 5051073.0; E 236982.7 | | | ORIGINATED BY TDM | | | | | |
| DIST HWY 69 | | | BOREHOLE TYPE Portable Equipment, BW Casing Wash Boring | | | COMPILED BY MM | | | | | |
| DATUM Geodetic | | | DATE February 10, 2009 | | | CHECKED BY AB | | | | | |
| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT  SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED | PLASTIC LIMIT W _p NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L WATER CONTENT (%) | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | | | | |
| 200.3 | ICE SURFACE | | | | | | | | | | |
| 0.0 | ICE | | | | | | | | | | |
| 200.0 | | | | | | | | | | | |
| 0.3 | WATER | | | | | | | | | | |
| 199.5 | | | | | | | | | | | |
| 199.1 | PEAT (Fibrous) Very Soft Firm Black Wet | | 1 | SS | 6 | | | | | | |
| 198.7 | CLAYEY SILT Stiff Grey Wet | | 2 | SS | 50/0.1 | | | | | | |
| 1.6 | End of Borehole Spoon Refusal (Hammer Bouncing) | | | | | | | | | | |
| Notes: 1. Water level at ice surface (Elev. 200.3 m) upon completion of drilling. 2. Split spoon samples obtained by driving with a 1/2 weight hammer; SPT 'N' values have been adjusted to the inferred values that would be obtained using a standard weight hammer. | | | | | | | | | | | |

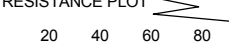
| PROJECT 07-1191-0020 | | | RECORD OF BOREHOLE No P1-12 | | | 1 OF 1 METRIC | | | | | | | | |
|----------------------|---|------------|---|------|------------|----------------------------|-----------------|---|--|------------------------------------|-------------------------------------|-----------------------------------|--|--|
| W.P. 5005-08-00 | | | LOCATION N 5051048.4; E 236988.2 | | | ORIGINATED BY TDM | | | | | | | | |
| DIST _____ HWY 69 | | | BOREHOLE TYPE Portable Equipment, BW Casing Wash Boring | | | COMPILED BY MM | | | | | | | | |
| DATUM Geodetic | | | DATE February 10, 2009 | | | CHECKED BY AB | | | | | | | | |
| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | PLASTIC LIMIT W _p | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | |
| 200.3 | ICE SURFACE | | | | | | | | | | | | | |
| 0.0 | ICE | | | | | | | | | | | | | |
| 200.0 | | | | | | | | | | | | | | |
| 0.3 | WATER | | | | | | | | | | | | | |
| 198.8 | | | | | | | | | | | | | | |
| 1.5 | PEAT (Amorphous) Very soft Black Wet | | 1 | SS | WH | | | | | | | | | |
| | | | 2 | SS | 1 | | | | | | | | 504.2 | |
| | | | 3 | SS | WH | | | | | | | | | |
| | | | 4 | SS | WH | | | | | | | | 503.7 | |
| | | | 5 | SS | WH | | | | | | | | | |
| 194.6 | | | | | | | | | | | | | | |
| 5.7 | CLAYEY SILT Soft Grey Wet | | 6 | SS | WH | | | | | | | | | |
| | | | | | | | | | | | | | | |
| 192.7 | | | | | | | | | | | | | | |
| 7.6 | SAND and GRAVEL, some silt, trace to some clay | | 7 | SS | 23 | | | | | | | | | 31 49 14 6 |
| 192.2 | Compact Grey Wet | | | | | | | | | | | | | |
| 8.1 | End of Borehole Spoon Refusal (Hammer Bouncing) | | | | | | | | | | | | | |
| | Notes: 1. Water level at ice surface (Elev. 200.3 m) upon completion of drilling. 2. Split spoon samples obtained by driving with a 1/2 weight hammer; SPT 'N' values have been adjusted to the inferred values that would be obtained using a standard weight hammer. | | | | | | | | | | | | | |

MIS-MTO001 07-1191-0020 P1 METRIC.GPJ GAL-MISS.GDT 03/02/11 DATA INPUT:

| PROJECT 07-1191-0020 | | | RECORD OF BOREHOLE No P1-13 | | | 1 OF 1 METRIC | | | | | | | | |
|----------------------|---|------------|---|------|------------|----------------------------|-----------------|---|--|------------------------------------|-------------------------------------|-----------------------------------|--|--|
| W.P. 5005-08-00 | | | LOCATION N 5051024.6; E 236993.5 | | | ORIGINATED BY TDM | | | | | | | | |
| DIST HWY 69 | | | BOREHOLE TYPE Portable Equipment, BW Casing Wash Boring | | | COMPILED BY MM | | | | | | | | |
| DATUM Geodetic | | | DATE February 9, 2009 | | | CHECKED BY AB | | | | | | | | |
| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | PLASTIC LIMIT W _p | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | |
| 200.3 | ICE SURFACE | | | | | | | | | | | | | |
| 0.0 | ICE | | | | | | | | | | | | | |
| 200.0 | | | | | | | | | | | | | | |
| 0.3 | WATER | | | | | | | | | | | | | |
| 198.8 | | | | | | | | | | | | | | |
| 1.5 | PEAT (Amorphous) Very soft to soft Black Wet | | 1 | SS | WH | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | Sand seam 0.3 m thick at a depth of 2.6 m | | 2 | SS | 3 | | | | | | | | 495.6 | |
| | | | | | | | | | | | | | | |
| | | | 3 | SS | WH | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | 4 | SS | WH | | | | | | | | 1174.5 | |
| | | | | | | | | | | | | | | |
| 195.3 | | | 5A | SS | WH | | | | | | | | | |
| 5.0 | SILTY CLAY Very soft Grey Wet | | 5B | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | 6 | TO | WR | | | | | | | | | |
| | | | | | | | | | | | | | | |
| 193.1 | | | | | | | | | | | | | | |
| 7.2 | End of Borehole Casing Refusal | | | | | | | | | | | | | |
| | Notes: 1. Water level at ice surface (Elev. 200.3 m) upon completion of drilling. 2. Split spoon samples obtained by driving with a 1/2 weight hammer; SPT 'N' values have been adjusted to the inferred values that would be obtained using a standard weight hammer. | | | | | | | | | | | | | |

MIS-MTO 001 07-1191-0020 P1 METRIC.GPJ GAL-MISS.GDT 03/02/11 DATA INPUT:

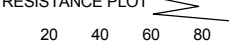
| PROJECT | | RECORD OF BOREHOLE No P1-14 | | | | 1 OF 1 | | METRIC | |
|-----------------|--|---|--|--|--|-------------------|--|--------|--|
| W.P. 5005-08-00 | | LOCATION N 5050999.7 ; E 236999.1 | | | | ORIGINATED BY TDM | | | |
| DIST HWY 69 | | BOREHOLE TYPE Portable Equipment, BW Casing Wash Boring | | | | COMPILED BY MM | | | |
| DATUM Geodetic | | DATE February 9, 2009 | | | | CHECKED BY AB | | | |

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT <div style="text-align: center;">  </div> | PLASTIC LIMIT W _p | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W _L | UNIT WEIGHT γ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|---------------|--|------------|---------|------|------------|-------------------------|-----------------|---|---------------------------------|-------------------------------|--------------------------------|------------------|---------------------------------------|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | | | | | | |
| 200.3 | ICE SURFACE | | | | | | | | | | | | |
| 0.0 | ICE | | | | | | | | | | | | |
| 200.0 | | | | | | | | | | | | | |
| 0.3 | WATER | | | | | | | | | | | | |
| 198.8 | | | | | | | | | | | | | |
| 1.5 | PEAT (Amorphous) Very soft Black Wet | | 1 | SS | WH | | | | | | | 351.5 | |
| 198.2 | | | | | | | | | | | | | |
| 2.3 | SAND and GRAVEL Very dense Grey Wet End of Borehole Spoon Refusal | | 2 | SS | 50/0.03 | | | | | | | | |

Notes:

- Water level at ice surface (Elev. 200.3 m) upon completion of drilling.
- Split spoon samples obtained by driving with a 1/2 weight hammer; SPT 'N' values have been adjusted to the inferred values that would be obtained using a standard weight hammer.

| PROJECT | | RECORD OF BOREHOLE No P1-15 | | | | 1 OF 1 | | METRIC | |
|-----------------|--|---|--|--|--|-------------------|--|--------|--|
| W.P. 5005-08-00 | | LOCATION N 5050974.9 ; E 237004.7 | | | | ORIGINATED BY TDM | | | |
| DIST HWY 69 | | BOREHOLE TYPE Portable Equipment, BW Casing Wash Boring | | | | COMPILED BY MM | | | |
| DATUM Geodetic | | DATE February 10, 2009 | | | | CHECKED BY AB | | | |

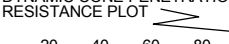
| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT <div style="text-align: center;">  </div> | PLASTIC LIMIT W _p | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W _L | UNIT WEIGHT γ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|---------------|-----------------------------------|------------|---------|------|------------|-------------------------|-----------------|---|---------------------------------|-------------------------------|--------------------------------|------------------|---------------------------------------|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | | | | | | |
| 200.4 | ICE SURFACE | | | | | | | | | | | | |
| 0.0 | ICE | | | | | | | | | | | | |
| 200.1 | | | | | | | | | | | | | |
| 0.3 | WATER | | | | | | | | | | | | |
| 199.6 | | | | | | | | | | | | | |
| 0.8 | End of Borehole Casing Refusal | | | | | | | | | | | | |

Note:

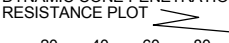
- Water level at ice surface (Elev. 200.4 m) upon completion of drilling.

MIS-MTO 002 07-1191-0020 P1 METRIC.GPJ GAL-MISS.GDT 03/02/11 DATA INPUT:

| | | | | | |
|--------------------------------------|--|--|--|-------------------------|--|
| PROJECT <u>07-1191-0020</u> | | RECORD OF PENETRATION TEST No P1-DC1 | | 1 OF 1 METRIC | |
| W.P. <u>5005-08-00</u> | | LOCATION <u>N 5051055.4 ;E 236969.8</u> | | ORIGINATED BY <u>ID</u> | |
| DIST <u> </u> HWY <u>69</u> | | BOREHOLE TYPE <u>Dynamic Cone Penetration Test</u> | | COMPILED BY <u>MM</u> | |
| DATUM <u>Geodetic</u> | | DATE <u>February 22, 2008</u> | | CHECKED BY <u>AB</u> | |

| SOIL PROFILE | | SAMPLES | | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT  SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _p — W — W _L WATER CONTENT (%) | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|--------------|---|------------|--------|------|------------|-------------------------|-----------------|---|---|---------------------------------------|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | | | | |
| 199.8 | ICE SURFACE | | | | | | | | | | |
| | | | | | | | 199 | | | | |
| | | | | | | | 198 | | | | |
| | | | | | | | 197 | | | | |
| 196.3 | End of DCPT Refusal to Further Penetration (40 Blows/0.0 m) | | | | | | | | | | |
| 3.5 | | | | | | | | | | | |

| | | | | | |
|--------------------------------------|--|--|--|-------------------------|--|
| PROJECT <u>07-1191-0020</u> | | RECORD OF PENETRATION TEST No P1-DC3 | | 1 OF 1 METRIC | |
| W.P. <u>5005-08-00</u> | | LOCATION <u>N 5051007.9 ;E 236985.6</u> | | ORIGINATED BY <u>ID</u> | |
| DIST <u> </u> HWY <u>69</u> | | BOREHOLE TYPE <u>Dynamic Cone Penetration Test</u> | | COMPILED BY <u>MM</u> | |
| DATUM <u>Geodetic</u> | | DATE <u>February 22, 2008</u> | | CHECKED BY <u>AB</u> | |

| SOIL PROFILE | | SAMPLES | | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT  SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _p — W — W _L WATER CONTENT (%) | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|--------------|--|------------|--------|------|------------|-------------------------|-----------------|---|---|---------------------------------------|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | | | | |
| 199.8 | ICE SURFACE | | | | | | | | | | |
| | | | | | | | 199 | | | | |
| 198.7 | End of DCPT Refusal to Further Penetration (Hammer Bouncing) | | | | | | | | | | |
| 1.1 | | | | | | | | | | | |

MIS-MTO 002 07-1191-0020 P1 METRIC.GPJ GAL-MISS.GDT 03/02/11 DATA INPUT:



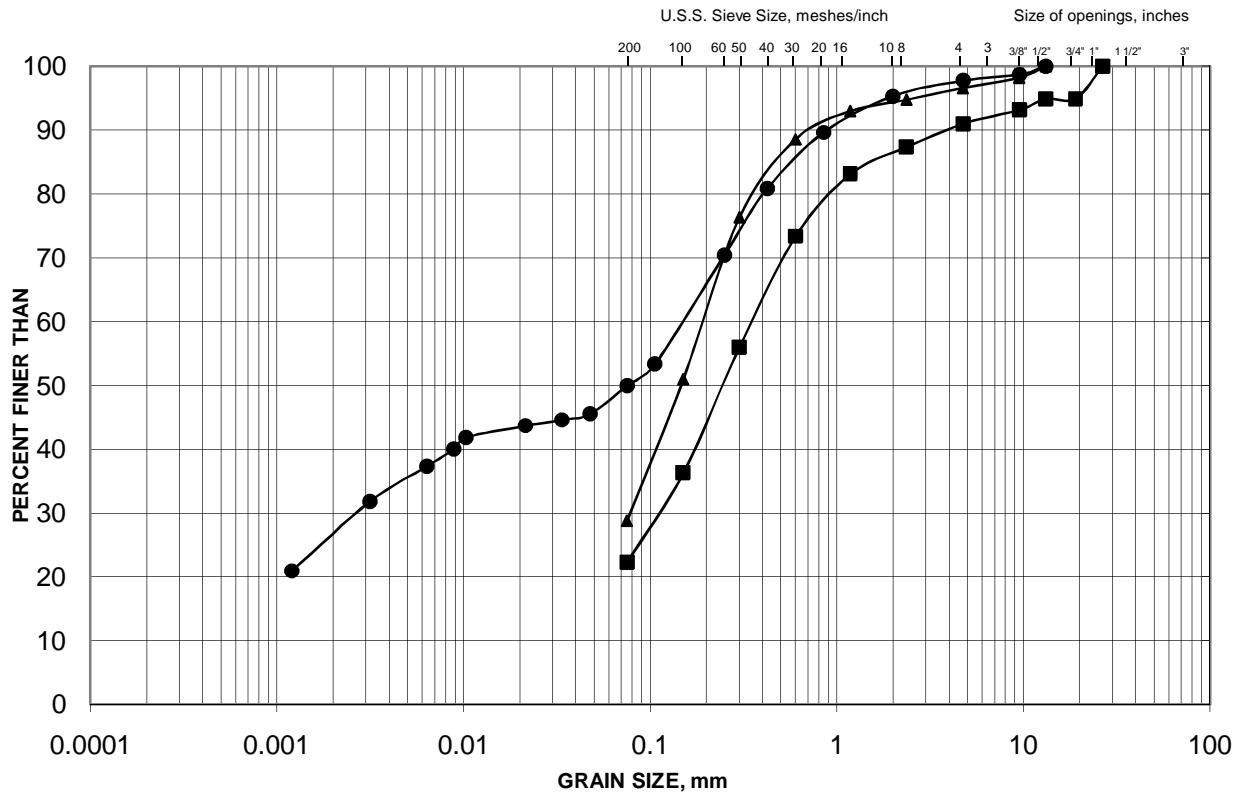
APPENDIX B

Laboratory Test Results

GRAIN SIZE DISTRIBUTION

Silty Sand

FIGURE
B-1



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

LEGEND

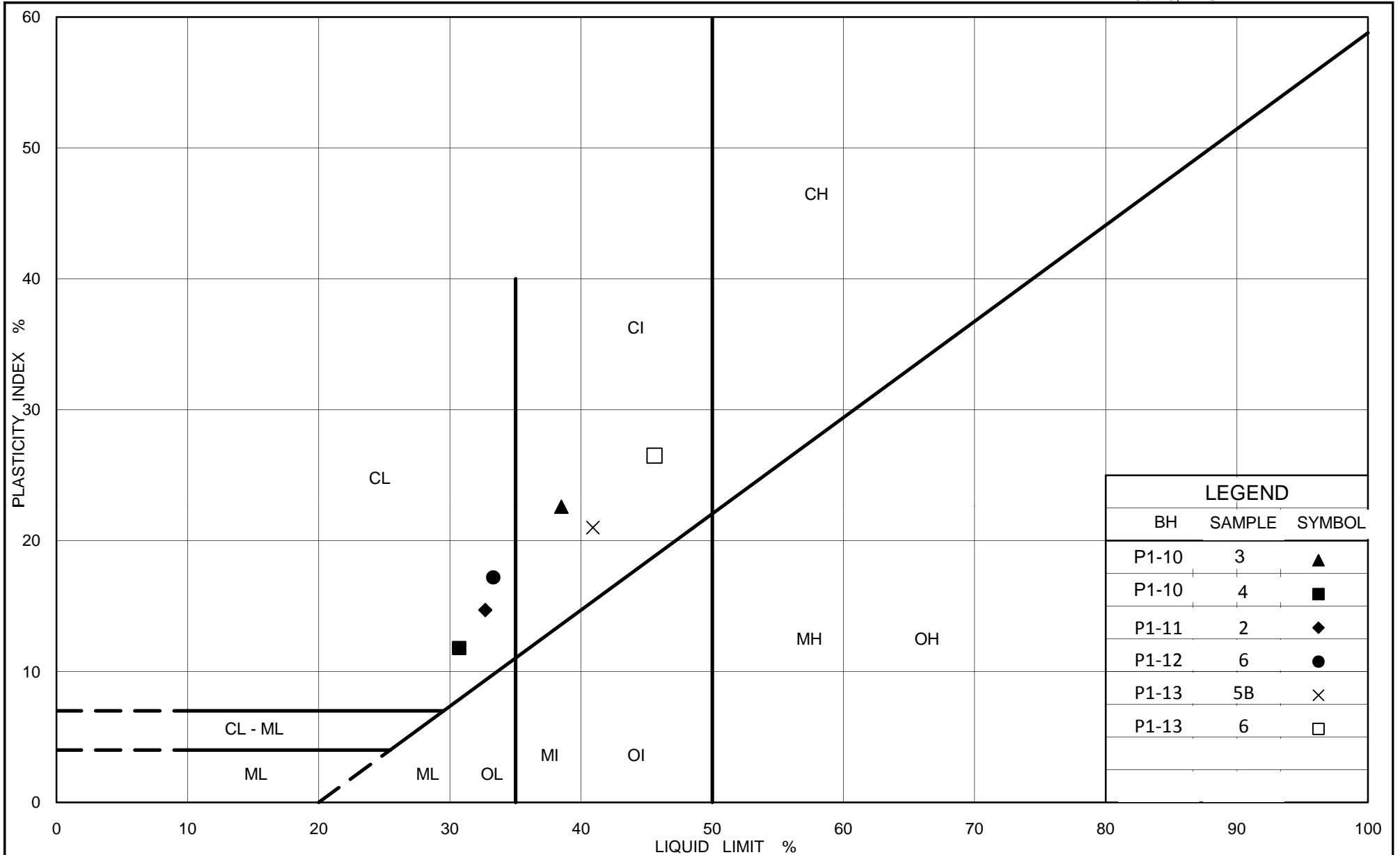
| SYMBOL | BOREHOLE | SAMPLE | ELEVATION (m) |
|--------|----------|--------|---------------|
| ▲ | P1-1 | 2 | 199.2 |
| ■ | P1-9 | 2 | 199.0 |
| ● | P1-10 | 2 | 197.8 |

Project Number: 07-1191-0020-2

Checked By: AB

Golder Associates

Date: August 2011



Ministry of Transportation
Ontario

PLASTICITY CHART Clayey Silt to Silty Clay

Figure B-2

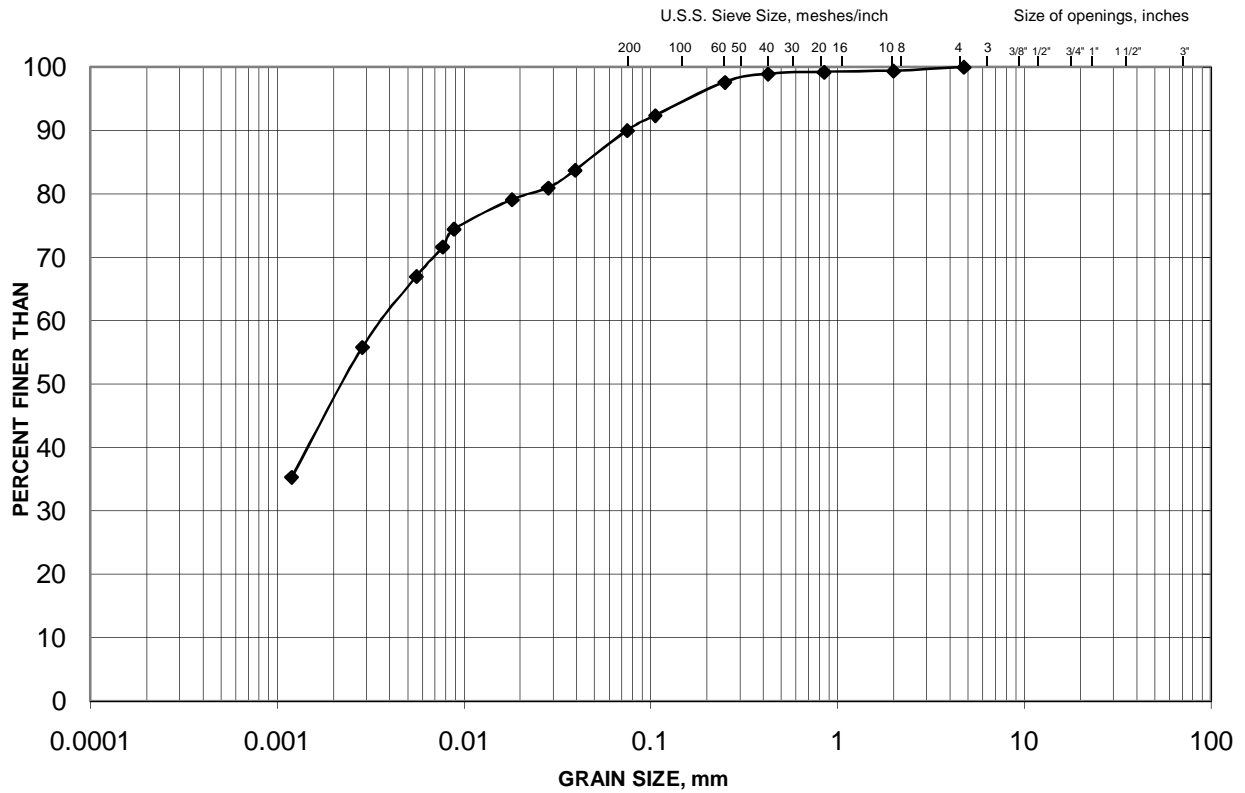
Project No. 07-1191-0020-2

Checked By: AB

GRAIN SIZE DISTRIBUTION

Silty Clay

FIGURE
B-3



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

LEGEND

| SYMBOL | BOREHOLE | SAMPLE | ELEVATION (m) |
|--------|----------|--------|---------------|
| —◆— | P1-10 | 3 | 197.1 |

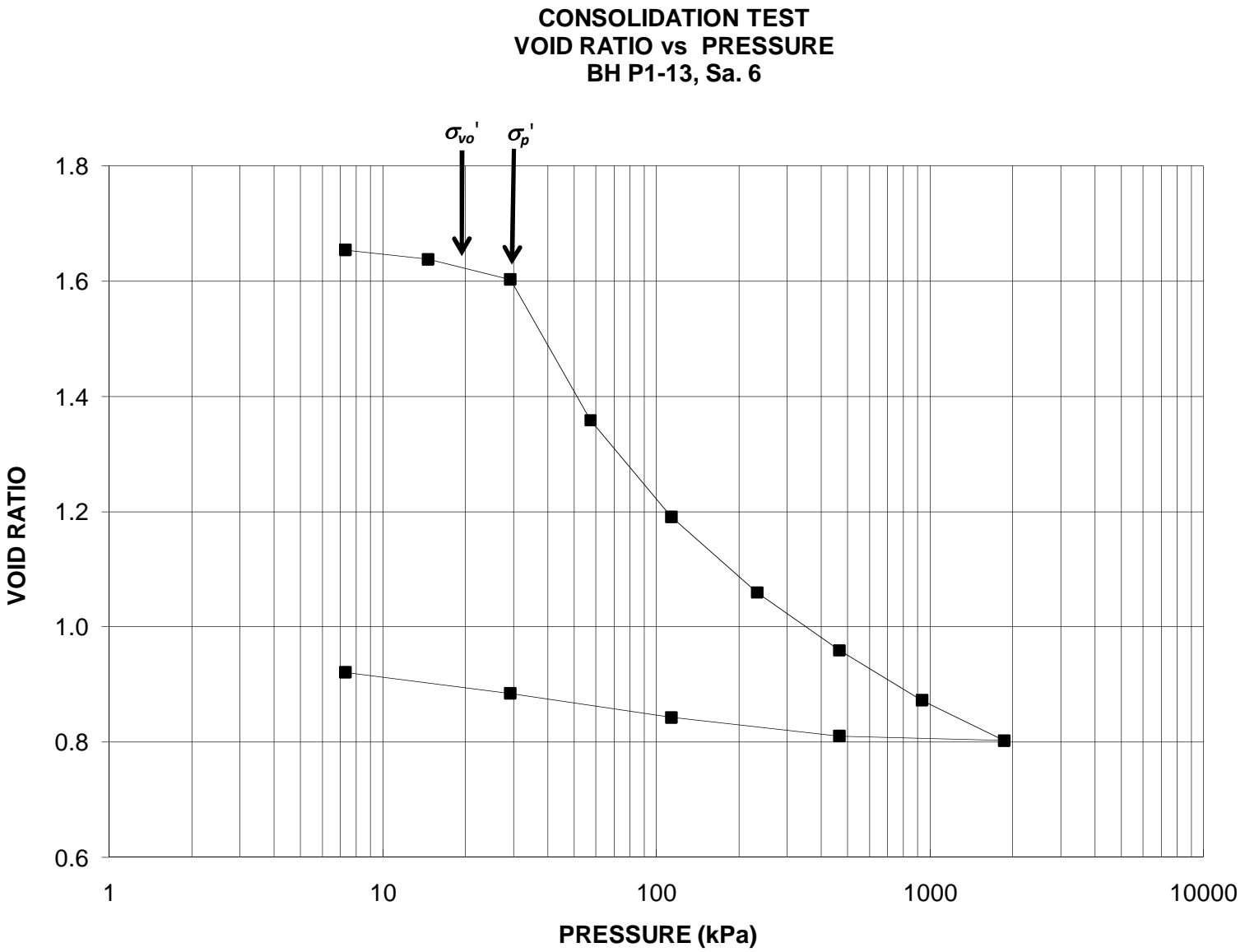
Project Number: 07-1191-0020-2

Checked By: AB

Golder Associates

Date: August 2011

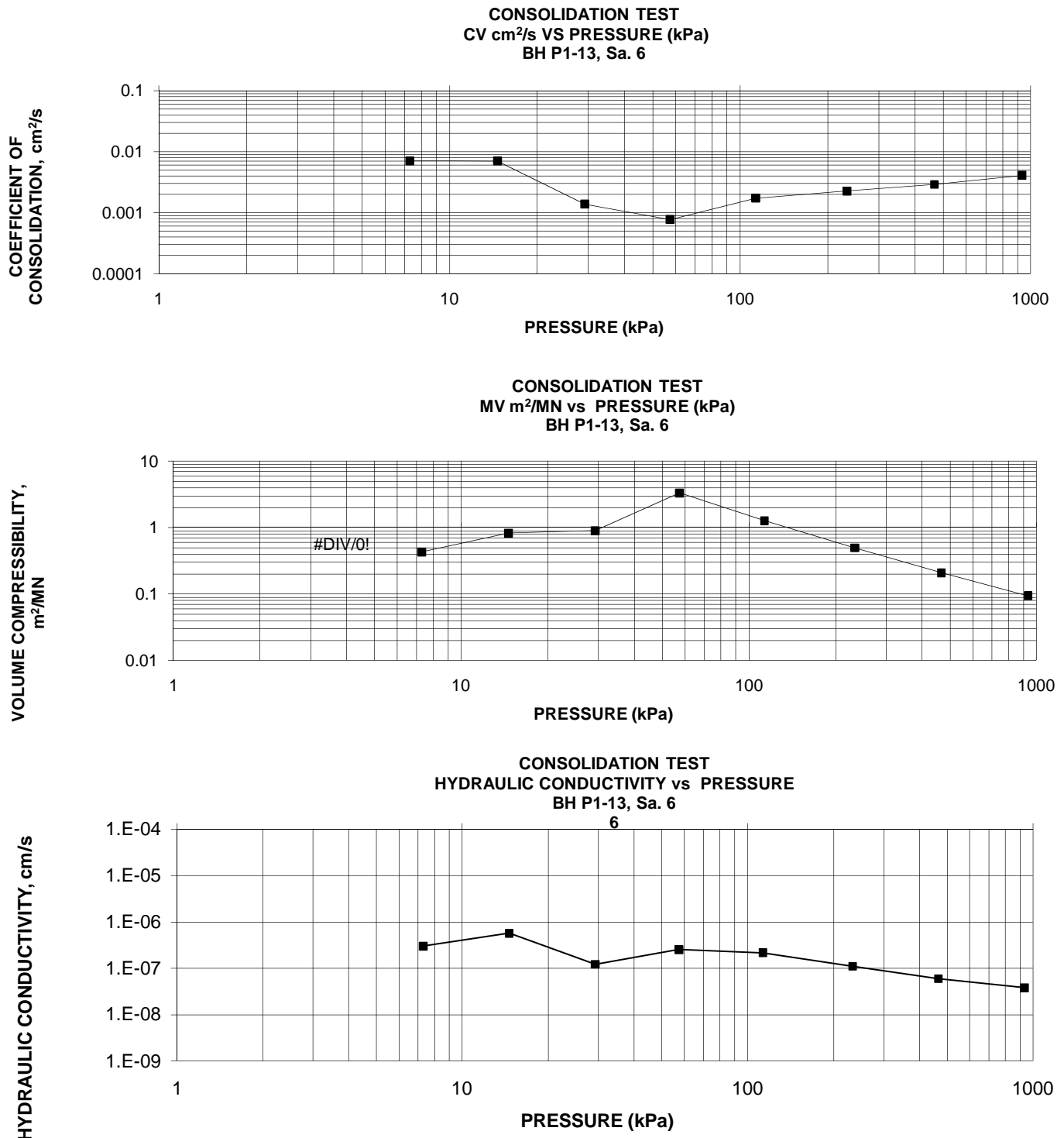
| OEDOMETER CONSOLIDATION SUMMARY | | | | | | FIGURE B-4 Page 1 of 4 | | |
|--|-----------------------|----------------|-------------------|----------------|------------------------------------|---------------------------|--------------------|-----------|
| SAMPLE IDENTIFICATION | | | | | | | | |
| Project Number | | 07-1191-0020-2 | | | Borehole, Sample | | P1-13, 6 | |
| Pond: | | 1 | | | Sample Depth, (m) | | 6.4 | |
| TEST CONDITIONS | | | | | | | | |
| Test Type | | Standard | | | Load Duration, hr | | 24 | |
| Oedometer Number | | 1 | | | | | | |
| Date Started | | June 23/09 | | | | | | |
| Date Completed | | July 9/09 | | | | | | |
| SAMPLE DIMENSIONS AND PROPERTIES - INITIAL | | | | | | | | |
| Sample Height, cm | | 1.906 | | | Unit Weight, kN/m ³ | | 15.9 | |
| Sample Diameter, cm | | 5.000 | | | Dry Unit Weight, kN/m ³ | | 9.9 | |
| Area, cm ² | | 19.63 | | | Specific Gravity, assumed | | 2.7 | |
| Volume, cm ³ | | 37.42 | | | Solids Height, cm | | 0.716 | |
| Water Content, % | | 59.8 | | | Volume of Solids, cm ³ | | 14.06 | |
| Wet Mass, g | | 60.64 | | | Volume of Voids, cm ³ | | 23.37 | |
| Dry Mass, g | | 37.95 | | | Degree of Saturation, % | | 97.1 | |
| TEST COMPUTATIONS | | | | | | | | |
| Pressure | Primary Consolidation | Corr. Height | Void | Average Height | t ₅₀ | cv. | m _v | k |
| kPa | mm | cm | Ratio | cm | s | cm ² /s | m ² /MN | cm/s |
| 0 | 0.00 | 1.906 | 1.663 | 1.906 | | | | |
| 7.3 | 0.06 | 1.900 | 1.654 | 1.903 | 100 | 0.00710 | 0.431 | 3.003E-07 |
| 14.6 | 0.12 | 1.889 | 1.638 | 1.894 | 100 | 0.00703 | 0.828 | 5.713E-07 |
| 29.2 | 0.25 | 1.864 | 1.603 | 1.876 | 500 | 0.00138 | 0.905 | 1.225E-07 |
| 57.4 | 1.75 | 1.689 | 1.359 | 1.776 | 800 | 0.00077 | 3.336 | 2.529E-07 |
| 113.1 | 1.20 | 1.569 | 1.191 | 1.629 | 300 | 0.00173 | 1.275 | 2.167E-07 |
| 233.3 | 0.94 | 1.475 | 1.060 | 1.522 | 200 | 0.00227 | 0.499 | 1.110E-07 |
| 466.1 | 0.72 | 1.403 | 0.959 | 1.439 | 140 | 0.00290 | 0.210 | 5.962E-08 |
| 933.2 | 0.62 | 1.341 | 0.873 | 1.372 | 90 | 0.00410 | 0.095 | 3.803E-08 |
| 1864.2 | 0.50 | 1.291 | 0.803 | 1.316 | 50 | 0.00678 | 0.040 | 2.666E-08 |
| 466.1 | -0.05 | 1.296 | 0.810 | 1.293 | | | | |
| 113.1 | -0.23 | 1.319 | 0.843 | 1.308 | | | | |
| 29.2 | -0.30 | 1.349 | 0.884 | 1.334 | | | | |
| 7.3 | -0.26 | 1.375 | 0.921 | 1.362 | | | | |
| Notes: k calculated using cv based on t ₅₀ values. | | | | | | | | |
| SAMPLE DIMENSIONS AND PROPERTIES - FINAL | | | | | | | | |
| Sample Height, cm | | 1.375 | | | Unit Weight, kN/m ³ | | 17.6 | |
| Sample Diameter, cm | | 5.000 | | | Dry Unit Weight, kN/m ³ | | 13.8 | |
| Area, cm ² | | 19.63 | | | Specific Gravity, assumed | | 2.7 | |
| Volume, cm ³ | | 27.00 | | | Solids Height, cm | | 0.716 | |
| Water Content, % | | 27.7 | | | Volume of Solids, cm ³ | | 14.06 | |
| Wet Mass, (after test) g | | 48.461 | | | Volume of Voids, cm ³ | | 12.95 | |
| Dry Mass, g (oven) | | 37.95 | | | Degree of Saturation, % | | 84.6 | |
| Prepared By: SL | | | Golder Associates | | | Checked By: AB | | |

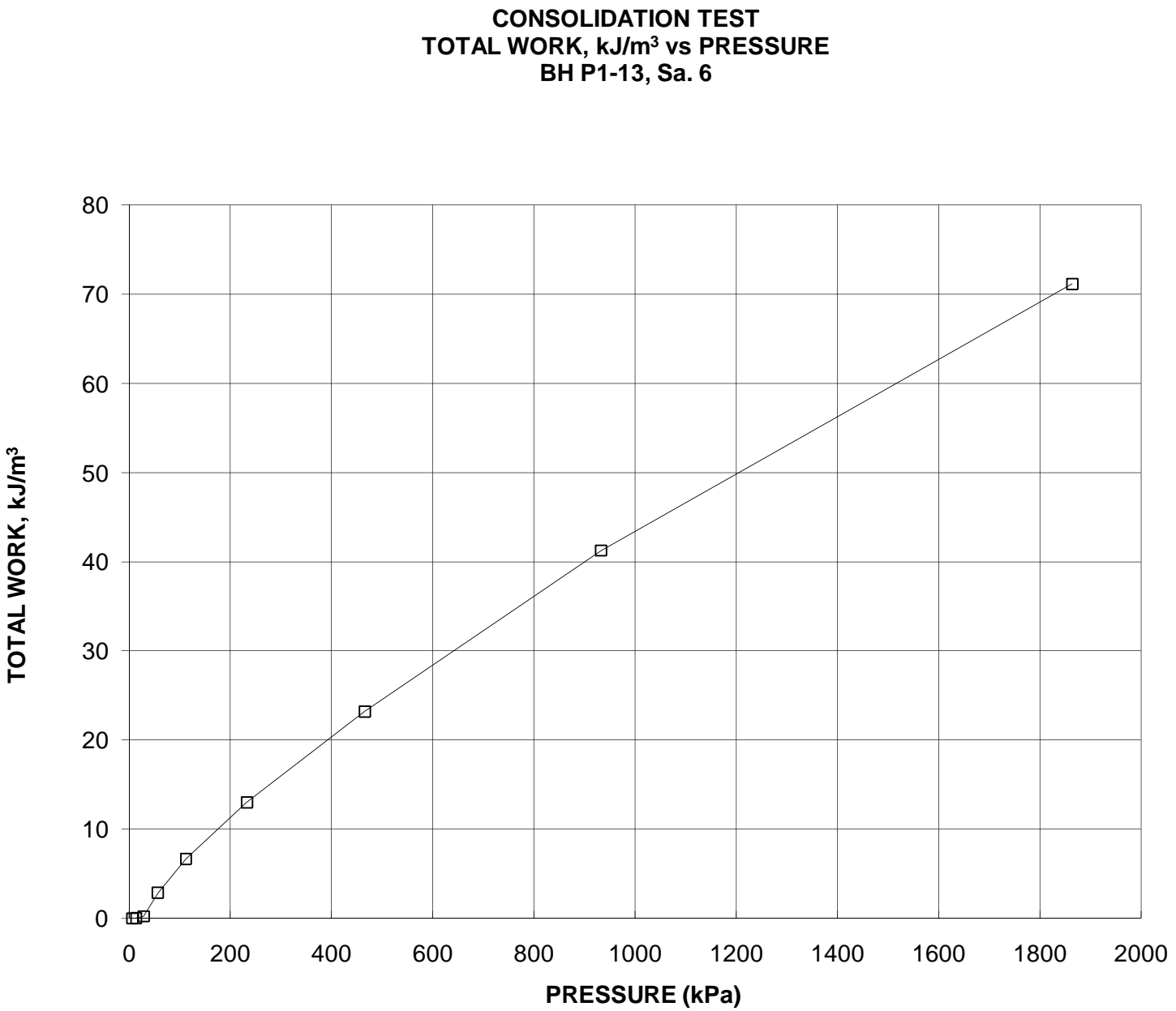


OEDOMETER CONSOLIDATION SUMMARY

FIGURE B-4

Page 3 of 4

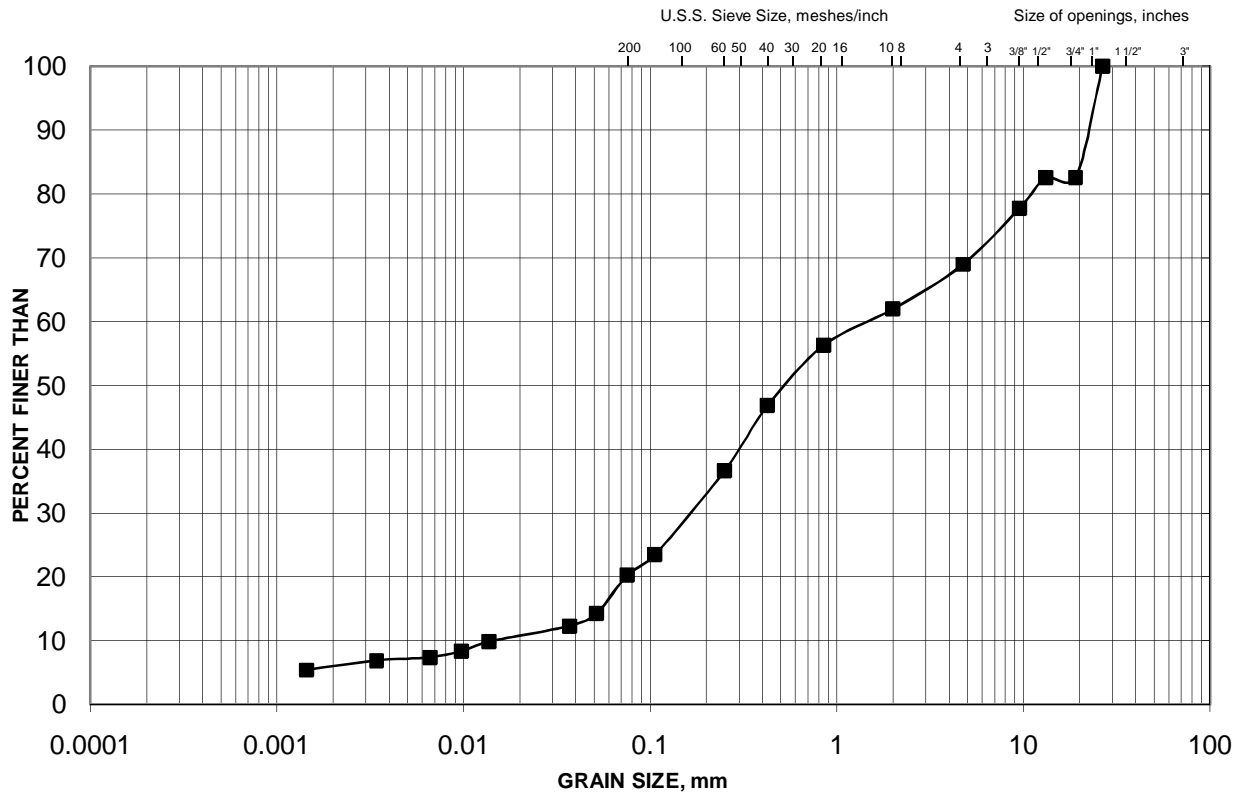




GRAIN SIZE DISTRIBUTION

Sand and Gravel

**FIGURE
B-5**



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

LEGEND

| SYMBOL | BOREHOLE | SAMPLE | ELEVATION (m) |
|--------|----------|--------|---------------|
| —■— | P1-12 | 7 | 192.5 |

Project Number: 07-1191-0020-2

Checked By: AB

Golder Associates

Date: August 2011

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

| | |
|---------------|-------------------|
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| Asia | + 852 2562 3658 |
| Australasia | + 61 3 8862 3500 |
| Europe | + 356 21 42 30 20 |
| North America | + 1 800 275 3281 |
| South America | + 55 21 3095 9500 |

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