



September 28, 2011

## FOUNDATION INVESTIGATION REPORT

REPLACEMENT OF WICKLOW RIVER BRIDGE SOUTH  
HIGHWAY 7036, SITE NO. 39E-073  
TOWNSHIP OF NEWMARKET, ONTARIO  
MINISTRY OF TRANSPORTATION, ONTARIO  
GWP 5139-06-00, AGREEMENT NO. 5008-E-0037

**Submitted to:**  
LEA Consulting Ltd.  
625 Cochrane Drive, Suite 900  
Markham, Ontario  
L3R 9R9



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REPORT





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## **1.0 INTRODUCTION**

Golder Associates Ltd. (Golder) has been retained by LEA Consulting Ltd. (LEA) on behalf of Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the replacement of the Wicklow River South Bridge (Site No. 39E-073), located on Highway 7036 (southeast of Cochrane) in the Township of Newmarket.

The terms of reference and scope of work for the foundation investigation are outlined in MTO's Request for Proposal (RFP) dated November 17, 2008. Golder's proposal P81-1685, dated December 2008, for foundation engineering services associated with the replacement is contained in Sections 5.8 and 6.8 of LEA's Technical Proposal that forms part of the Consultant's Agreement Number 5008-E-0037 for this project. Subsequent to the award of the engineering services contract, the Preliminary and Detail Design investigation phases were combined to Detail Design level only. The work was carried out in accordance with Golder's Supplemental Specialty Quality Control Plan for this project dated September 16, 2009. The General Arrangement drawing for the replacement bridge was provided to Golder by LEA on April 14, 2011.

Information on the subsurface conditions for the existing bridge site is not available on MTO's GEOCREST library.

The purpose of this investigation is to establish the subsurface conditions at the proposed replacement location by borehole drilling, in situ testing and laboratory testing on selected samples. The location of the investigated area is shown on the Contract Drawings.

## **2.0 SITE DESCRIPTION**

The site is situated in the Township of Newmarket on Highway 7036 crossing the Wicklow River, approximately 1.2 km west of the junction with Highway 11. The surrounding table land is generally flat but slopes down towards the river banks along the west and east sides of the river. The area is occupied mainly by residential development with grass and tree covered terrain beyond the various property limits. The river banks adjacent to the existing bridge area are vegetated with landscaped grass and small shrubs. The river flows in a northerly direction and is less than 9 m wide at the existing bridge location.

The existing structure consists of a 27 m long by 9 m wide, two-lane bridge constructed in 1941. The existing structure is founded on timber piles. The length of the piles is unknown. The existing ground surface along the existing highway alignment ranges from Elevation 269.2 m to 269.8 m sloping upwards from west to east. The existing embankment front slopes are formed at approximately 2.9 horizontal to 1 vertical (2.9H:1V) and 2.5H:1V on the west and east sides of the river, respectively. The existing embankment side slopes are greater than about 2H:1V.

The water level in the river was measured between Elevation 266.0 m and 266.2 m during the field investigation (i.e. April 16 to 27, 2011). The high water level is reported to be Elevation 266.9 m. The existing highway is approximately 3.5 m above the river water level or about 3 m above the surrounding ground surface at the west side of the bridge and about 1 m to 2 m above the surrounding ground surface at the east side of the bridge.



### 3.0 INVESTIGATION PROCEDURES

The fieldwork at the bridge site was carried out between April 16 and 27, 2011, at which time a total of five (5) boreholes (WS-1 to WS-3, WS-3A and WS-4) were advanced: two boreholes (WS-1 and WS-4) at the proposed bridge approaches; and three boreholes (WS-2, WS-3 and WS-3A) at the bridge abutments. The locations of and ground surface elevations at the boreholes are shown on the Contract Drawings.

All boreholes were drilled using a CME 55 track-mounted drill supplied and operated by George Downing Estate Drilling Ltd. (Downing) of Grenville-Sur-La-Rouge, Quebec. The boreholes were advanced using 108 mm inside diameter (I.D.) continuous flight hollow stem augers, NW casing with wash boring and NQ size core barrels. Soil samples were obtained at intervals of depth of about 0.75 m to 3.0 m, using a 50 mm outer diameter (O.D.) split-spoon sampler operated by an automatic hammer on the drill rig, in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586). Selected samples of the cohesive soils were obtained using 76 mm O.D. thin-walled 'Shelby' tubes (ASTM D1587, Standard Practice for Thin-Walled Tube Sampling) for relatively undisturbed samples. Field vane shear tests were conducted in cohesive soils for determination of undrained shear strengths (ASTM D2573, Standard Test Method for Field Vane Strength Shear Test) using MTO Standard 'N' size vanes. All boreholes were backfilled upon completion in accordance with Ontario Regulation 903 Wells (as amended).

The boreholes for the bridge approaches, WS-1 and WS-4, were advanced to a depth of 15.8 m below ground surface. Borehole WS-2 was advanced at the south side of the west abutment to a depth of 33.6 m below ground surface, including 3.1 m of bedrock coring.

Borehole WS-3 was advanced at the north side of the east abutment to a depth of 34.1 m below ground surface. Difficulty was encountered during the advancement of Borehole WS-3 through the gravelly sand to sand deposit below a depth of about 30 m. Casing refusal was initially encountered at a depth of 30.0 m and a split-spoon was attempted and was noted to be bouncing (i.e. no penetration). An NQ size core barrel was then used to advance the borehole to a depth of 30.5 m. After coring to 30.5 m depth, the casing was further advanced to a depth of 33.5 m. While attempting to obtain a split-spoon sample at a depth of 33.5 m, it was noted that there was approximately 0.6 m of material (gravel and cobbles) inside the casing (i.e. from 32.9 m to 33.5 m). The NQ core barrel was advanced in an attempt to "clean out" the material from inside the casing but the core barrel became lodged inside the casing. After dislodging the core barrel, an attempt was made to remove the gravel and cobbles and dislodge the casing using a "tricone" bit. The tricone was advanced below the bottom of the NW casing to a depth of 34.1 m at which depth the tricone became lodged inside the casing. Several attempts were made to dislodge the tricone but were unsuccessful and the AW drill rods (for the tricone advance) broke at a depth of 12.2 m. Borehole WS-3 was abandoned by tremie grouting with cement grout and Borehole WS-3A was advanced at the south side of the east abutment to penetrate this deposit using drilling mud. Borehole WS-3A was advanced to a depth of 35.0 m below ground surface, including 3.2 m of bedrock coring. It should be noted that in Borehole WS-3A, soil sampling commenced at a depth of 22.9 m below ground surface.

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. Piezometers were installed in Boreholes WS-1 and WS-4 to allow monitoring of the groundwater level at these locations. The piezometers consist of 19 mm O.D. rigid PVC tubing with 1.5 m and 3 m long slotted screen sealed within the silty clay deposit. Flush mounted caps were used at the ground surface. Details of the piezometer installations and water level readings are presented on the attached Record of Borehole sheets in Appendix A. The piezometers will be decommissioned at a later date.



Flowing artesian groundwater conditions were encountered in Boreholes WS-2, WS-3 and WS-3A upon encountering the silt deposit underlying the silty clay deposit. Details of the sealing of the artesian boreholes are given in Section 4.2.8.

Traffic protection was implemented for the boreholes drilled within the roadway in accordance with the Traffic Protection Plan for this project and MTO Book 7 "Temporary Conditions Manual of the Ontario Traffic Manual" (2001).

The fieldwork was supervised throughout by a member of our 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 and rock core 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 one Shelby tube samples of the cohesive soil. An additional one-dimensional consolidation test is being carried out and the results will be included in the final report. Uniaxial compressive strength (UCS) testing was carried out on two selected specimens of the bedrock core recovered from the boreholes.

The locations of the boreholes were laid out in the field by Golder relative to the existing bridge features. Golder surveyed the geodetic ground surface elevation of the boreholes once completed, referencing an existing benchmark located approximately 18.8 m south of the roadway centreline and approximately 79.0 m west of the west limit of the existing bridge. The northing and easting coordinates were determined by plotting the boreholes relative to the existing bridge features shown on the General Arrangement drawing. The MTM NAD 83 northing and easting coordinates, ground surface elevations referenced to Geodetic datum and depth of each borehole are presented on the Record of Borehole sheets in Appendix A and summarised below.

Borehole	Borehole Location		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
WS-1	5414654.3	313731.7	269.2	15.8
WS-2	5414648.9	313753.7	269.4	33.6
WS-3	5414655.7	313780.8	269.5	34.1
WS-3A	5414649.8	313781.0	269.6	35.0
WS-4	5414649.7	313801.4	269.8	15.8

## 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

### 4.1 Regional Geology

Based on terrain mapping by the Ontario Geological Survey<sup>1</sup>, the subsurface soils in the vicinity of the site consist of glaciolacustrine plain deposits comprised of clay bordering with areas of organic terrain.

<sup>1</sup> Northern Ontario Engineering Geology Terrain Study, OGS Survey Map 5027



Based on bedrock geology mapping by the Ministry of Northern Development and Mines<sup>2</sup>, the bedrock of this domain consists of massive granodiorite to granite from the neoarchean to mesoarchean era.

## 4.2 Subsurface 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 presented on the Record of Borehole and Drillhole sheets in Appendix A. 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 in profile on the Contract Drawings.

The existing ground surface at the boreholes along Highway 7036 ranges from Elevation 269.2 m to 269.8 m sloping upwards from west to east.

In general, the subsoils consist of fill and alluvium underlain generally by a soft to firm silty clay to clay deposit. Underlying the silty clay to clay deposit are cohesionless deposits of silt and sand to sand and gravel underlain by granite bedrock. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

### 4.2.1 Asphalt

A 50 mm to 200 mm thick layer of asphalt was encountered from ground surface in all boreholes (WS-1 to WS-3, WS-3A and WS-4).

### 4.2.2 Fill

Boreholes WS-1 to WS-4 encountered embankment fill consisting of granular and/or clayey soils underlying the asphalt. The total thickness of the fill is between 2.3 m and 3.9 m.

#### *Granular Fill*

Granular fill consisting of frozen, brown sand and gravel to sand containing some gravel was encountered in Boreholes WS-1 to WS-4. The granular fill contains trace silt, trace clay and, in Boreholes WS-3 and WS-4, is slightly organic. The granular fill is between 0.05 m and 0.8 m thick.

A grain size distribution test was carried out on one sample of the granular fill and the result is shown on Figure B-1.

The natural water content measured on one sample of the granular fill is 11 percent.

<sup>2</sup> Ministry of Northern Development and Mines, Bedrock Geology of Ontario, East-Central Sheet, Map 2543





### ***Silty Clay Fill***

Cohesive fill consisting of frozen to moist, brown silty clay was encountered in Boreholes WS-1 to WS-4 underlying the granular fill. The cohesive fill contains trace to with sand, trace to some gravel and is slightly organic. The surface of the cohesive fill was encountered between Elevation 269.7 m and 268.6 m and the thickness of the deposit ranges from 2.2 m to 3.0 m.

SPT 'N'-values recorded in the frozen cohesive fill range from 11 blows to 36 blows per 0.3 m of penetration. The SPT 'N'-values recorded in the non-frozen cohesive fill range from 3 blows to 10 blows per 0.3 m of penetration suggesting a soft to stiff consistency.

Grain size distribution tests were carried out on two samples of the cohesive fill and the results are presented on Figure B-2. Atterberg limits tests were carried out on five samples of the cohesive fill and test results are presented on Figure B-3. The liquid limits range from about 34 percent to 47 percent, the plastic limits range from about 15 percent to 19 percent and the plasticity indices range between about 16 percent and 28 percent. These results indicate the fill deposit is generally classified as silty clay of intermediate plasticity with one test result plotting in the range of a clayey silt of low plasticity.

The natural water content measured on several samples of the cohesive fill ranges from 23 percent to 27 percent.

An organic content test was carried out on two sample of the cohesive fill and indicates about 1 percent and 3 percent organics.

### **4.2.3 Silty Clay to Clay (Alluvium)**

A deposit of moist, brown grey silty clay to clay alluvium containing trace to some sand was encountered below the fill materials in Boreholes WS-1 and WS-2, both located on the west side of the river. The surface of the alluvium deposit was encountered at Elevation 266.2 m and the thickness of the deposit is between 2.6 m and 2.4 m at the respective boreholes.

The SPT 'N'-values measured within the silty clay to clay alluvium range from 6 blows to 14 blows per 0.3 m of penetration suggesting a firm to stiff consistency.

Grain size distribution tests were carried out on two samples of the alluvium and the results are presented on Figure B-4. Atterberg limits tests were carried out on two samples of the alluvium deposit and the results are presented on Figure B-5. The liquid limits are about 38 percent and 53 percent, the plastic limits are about 22 percent and 23 percent and the plasticity indices are about 16 percent and 30 percent. The results indicate the deposit is classified as silty clay of intermediate plasticity to clay of high plasticity.

The natural moisture content measured on five samples of the alluvium range from about 25 percent to 43 percent.

An organic content test carried out on one sample of the alluvium indicates about 8 percent organics.





#### 4.2.4 Silty Clay to Clay

A cohesive deposit of moist to wet, brown to grey, silty clay to clay containing trace sand was encountered below the alluvium in Boreholes WS-1 and WS-2 on the west side of the river and below the fill in Borehole WS-3 and WS-4 on the east side of the river. In Boreholes WS-2 and WS-3, silt layers were noted within the silty clay to clay deposit below about Elevation 252 m. The surface of the silty clay to clay deposit was encountered between Elevation 267.5 m and 263.6 m and the thickness of the deposit is 17.3 m and 19.0 m where the deposit was fully penetrated. Boreholes WS-1 and WS-4 were terminated within this deposit.

The SPT 'N'-values measured in the upper 0.8 m to 2.6 m of the silty clay to clay range from 1 blow to 6 blows per 0.3 m of penetration. Below generally the upper 0.8 m, the SPT 'N'-values are 0 blows per 0.3 m of penetration (i.e. weight of hammer). In situ field vane test carried out within the silty clay to clay ranged from 11 kPa to 57 kPa suggesting a soft to stiff consistency. Generally, the in situ vanes measured undrained shear strengths between 17 kPa and 34 kPa above Elevation 254 m and between 38 kPa and 42 kPa below Elevation 254 m. In Borehole WS-3, the vanes were noted to sink under the weight of the rods on three test attempts between about Elevation 261 m and 254 m. The in situ vane test results indicate that the silty clay to clay deposit generally has a soft to firm consistency. The sensitivity is calculated to be between 2 and 5.

Grain size distribution tests were carried out on two samples of this deposit and the results are presented on Figure B-6. Atterberg limits tests were carried out on thirteen samples of the cohesive deposit and the test results are presented on Figure B-7. The liquid limits range from about 35 percent to 59 percent, the plastic limits range from about 17 percent to 21 percent and the plasticity indices range between about 19 percent and 38 percent. The results indicate this deposit is classified as silty clay of intermediate plasticity to clay of high plasticity.

The natural moisture content measured on twenty-one samples of the silty clay range from 29 percent to 61 percent.

Two laboratory consolidation (oedometer) tests were carried out on specimens of the silty clay to clay obtained from Boreholes WS-2 and WS-3 and the test results are shown on Figures B-8 and B-9, respectively. The preconsolidation stresses were estimated from the Void Ratio versus logarithmic Pressure plots using the Casagrande method as well as from the Total Work versus Pressure plots. The unit weight of the two consolidation samples as well as additional tests from other Shelby tubes was measured between 18.0 kN/m<sup>3</sup> and 18.8 kN/m<sup>3</sup>, and the measured specific gravity was 2.7. The relevant consolidation test results are summarized below:

Borehole/ Sample Number	Elevation (m)	$\sigma_{vo}'$ (kPa)	$\sigma_p'$ (kPa)	$\sigma_p' - \sigma_{vo}'$ (kPa)	OCR	$e_o$	$C_r$	$C_c$	$c_v^*$ (cm <sup>2</sup> /s)
WS-2/10	260.0	79	133	54	1.7	1.1	0.04	0.3	$8.0 \times 10^{-4}$
WS-3/8	261.6	91	125	34	1.4	1.1	0.02	0.2	$3.0 \times 10^{-4}$

Note: \*For approximate stress range between the effective overburden stress and the final stress due to a 2.0 m high embankment, that is  $80 \text{ kPa} \leq \sigma_v' \leq 150 \text{ kPa}$

where:

- $\sigma_{vo}'$  effective overburden stress in kPa
- $\sigma_p'$  preconsolidation stress 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<sup>2</sup>/s in the normally consolidated range



#### 4.2.5 Silt

A deposit of wet, grey silt containing some clay and trace sand was encountered underlying the silty clay to clay deposit in Boreholes WS-2 and WS-3. The surface of the silt deposit was encountered at Elevation 246.5 m and 246.6 m and the thickness of the deposit was 4.5 m and 6.0 m in Boreholes WS-2 and WS-3, respectively. Sampling in Borehole WS-3A commenced within the silt deposit at Elevation 246.7 m and the thickness of the deposit at this location is about 6.5 m. Since sampling was not performed prior to encountering the silt deposit in Boreholes WS-3A, the surface of the silt deposit may be higher and the deposit may be thicker than indicated above.

The SPT 'N'-values measured in the silt deposit range from 4 blows to 11 blows per 0.3 m of penetration indicating a loose to compact relative density.

Grain size distribution tests were carried out on three samples of the silt deposit and the results are shown on Figure B-10. An Atterberg limits test was carried out on one sample of the silt deposit and the test result is presented on Figure B-11. The liquid limit is about 23 percent, the plastic limit is about 18 percent and the plasticity index is about 5 percent and indicate that the (upper portion of the) silt deposit where it transitions from the upper silty clay to clay deposit is classified as a clayey silt of slight plasticity.

The natural moisture content measured on six samples of the silt ranges from 23 percent to 29 percent.

#### 4.2.6 Sand to Sand and Gravel

A deposit of wet, brown to grey sand to sand and gravel was encountered underlying the silt deposit in Boreholes WS-2, WS-3 and WS-3A. The sand to sand and gravel deposit contains trace silt, trace clay, and cobbles were noted at various depths. The surface of the sand to sand and gravel deposit was encountered between Elevation 242.0 m and 240.2 m and, in Boreholes WS-2 and WS-3A, the deposit is 3.1 m and 2.4 m thick, extending to the bedrock surface. In Borehole WS-3, the sand to sand and gravel was not fully penetrated, as described in Section 3.0, and the deposit is at least 5.2 m thick, extending to the borehole termination depth.

The SPT 'N'-values measured in the sand to sand and gravel deposit range from 29 blows to 69 blows per 0.3 m of penetration indicating a compact to very dense relative density. In two samples, soil/rock coring using an NQ sized core barrel was required to advance the borehole. The recovered soil cores consist of sand to sand and gravel containing cobbles between 0.04 m and 0.18 m thick. Split-spoon refusal (i.e. greater than 100 blows per 0.3 m of penetration) was encountered at the bedrock surface contact at the bottom of the sand to sand and gravel deposit in Boreholes WS-2 and WS-3A.

Grain size distribution tests were carried out on three samples of the sand to sand and gravel deposit and the results are shown on Figure B-12.

The natural moisture content measured on four samples of the sand to sand and gravel deposit ranges from 10 percent to 23 percent.

#### 4.2.7 Bedrock

Bedrock was encountered at Elevation 238.9 m and 237.8 m (i.e. at depths of 30.5 m and 31.8 m below existing ground surface) in Boreholes WS-2 and WS-3A, respectively. As noted in Section 3.0, Borehole WS-3 could not be advanced deeper than Elevation 235.4 m (i.e. corresponding to a depth of 34.1 m below ground surface) through the overburden, indicating that the bedrock is sloping downwards to the north.



Bedrock was cored for 3.1 m and 3.2 m lengths in Boreholes WS-2 and WS-3A, respectively. The retrieved bedrock core is described as coarse grained, slightly weathered, pinkish grey, granite bedrock, as presented in the Record of Drillhole sheets in Appendix A. Photographs of the retrieved bedrock cores are shown on Figures B-13 and B-14.

The Rock Quality Designation (RQD) measured on the core samples ranges from 80 percent to 100 percent, indicating a rock mass of good to excellent quality as per Table 3.10 of the Canadian Foundation Engineering Manual (CFEM, 2006). The Total Core Recovery (TCR) during bedrock coring was 100 percent.

Laboratory Uniaxial Compression Strength (UCS) testing was carried out on two core samples of the bedrock. The UCS values are presented on the Record of Drillhole Sheets in Appendix A and are summarized below and indicate that the bedrock is strong to very strong as per Table 3.5 of CFEM (2006).

Borehole	Elevation (m)	UCS (MPa)
WS-2	237.5	86
WS-3A	236.2	128

#### 4.2.8 Groundwater Conditions

Groundwater levels were measured in the open boreholes during and upon completion of drilling. Piezometers were installed in Boreholes WS-1 and WS-4 and sealed within the silty clay to clay deposit to allow for monitoring of the groundwater levels. The measured groundwater levels in the open boreholes and piezometers are presented below.

Borehole	Installation	Time and/or Date	Groundwater Depth	Groundwater Elevation
WS-1	Open borehole	Upon completion of drilling	13.5 m	255.7 m
	Piezometer	April 28, 2011	3.5 m	265.7 m
		July 3, 2011	2.3 m	266.9 m
WS-2	Open borehole	Prior to coring bedrock	1.1 m above ground surface (4.4 m above river level at time of drilling)	270.5 m
		After coring bedrock	3.7 m	265.7 m
WS-3	Open borehole	Upon completion of drilling	2.1 m above ground surface (5.5 m above river level at time of drilling)	271.6 m
WS-3A	Open borehole	Upon completion of drilling	2.4 m above ground surface (5.9 m above river level at time of drilling)	272.0 m
WS-4	Open borehole	Dry to bottom of borehole at 15.8 m depth (Elev. 254.0 m) upon completion of drilling	--	--
	Piezometer	April 28, 2011	4.2 m	265.6 m
		July 03, 2011	1.7 m	268.1



Groundwater levels encountered in the boreholes during and shortly after drilling may not be representative of static levels since the groundwater levels in the boreholes may not have stabilized on completion of drilling.

The water level in Wicklow River was measured between Elevation 266.0 m and 266.2 m (shown on the Contract Drawings) during the field investigation from April 16 to 27, 2011 and at Elevation 265.6 m on July 3, 2011. The high water level is reported to be Elevation 266.9 m.

Groundwater and river water levels in the area are subject to seasonal fluctuations and to fluctuations after precipitation events and snowmelt.

Artesian groundwater conditions were encountered in Boreholes WS-2, WS-3 and WS-3A upon penetrating into the silt deposit. The groundwater levels were measured between Elevation 270.5 m and 272.0 m (corresponding to 1.1 m and 2.4 m above the river level, respectively). These boreholes were sealed full column with cement grout, consistent with Ontario Regulation 903 Wells (as amended).

Water level readings were obtained in the piezometers prior to leaving the site on April 28, 2011 and upon returning to the site on July 3, 2011. At the time of the piezometer readings, it was confirmed visually that Boreholes WS-2, WS-3 and WS-3A did not show flowing artesian groundwater conditions.

## **5.0 CLOSURE**

The field drilling program was supervised by Mr. Indulis Dumpis and Mr. David Muldowney, P.Eng. This report was prepared by Mr. David Muldowney, P.Eng., and the technical aspects were reviewed by Ms. Sarah E.M. Coyne, P.Eng., Associate. A quality control review of the report was provided by Mr. Jorge M.A. Costa, P.Eng., Principal and Golder's Designated MTO Contact for this project.



## Report Signature Page

**GOLDER ASSOCIATES LTD.**

David Muldowney, P.Eng.  
Geotechnical Engineer



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



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

DAM/SEMC/JMAC/lb

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# APPENDIX A

## Record of Boreholes and Drillholes



## LIST OF SYMBOLS

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

### 1. GENERAL

$\pi$	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

$\gamma$	shear strain
$\Delta$	change in, e.g. stress: $\Delta\sigma$
$\epsilon$	linear strain
$\epsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	Poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma_{vo}$	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 ( $\gamma' = \gamma - \gamma_w$ )
$D_R$	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 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
$\sigma'_p$	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





## 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.).

<b>PH:</b>	Sampler advanced by hydraulic pressure
<b>PM:</b>	Sampler advanced by manual pressure
<b>WH:</b>	Sampler advanced by static weight of hammer
<b>WR:</b>	Sampler advanced by weight of sampler and rod

#### Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm<sup>2</sup> 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.

### 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

### 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 <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
$D_R$	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.



## LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

### WEATHERING STATE

**Fresh:** no visible sign of weathering

**Faintly weathered:** weathering limited to the surface of Major discontinuities

**Slightly weathered:** penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

**Moderately weathered:** weathering extends throughout the rock mass but the rock material is not friable.

**Highly weathered:** weathering extends throughout rock Mass and the rock material is partly friable.

**Completely weathered:** rock is wholly decomposed and in a friable condition but the rock texture and structure are preserved.

### BEDDING THICKNESS

<u>Description</u>	<u>Bedding Plane Spacing</u>
Very thickly bedded	> 2 m
Thickly bedded	0.6 m to 2 m
Medium bedded	0.2 m to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	< 6 mm

### JOINT OR FOLIATION SPACING

<u>Description</u>	<u>Spacing</u>
Very wide	> 3 m
Wide	1 – 3 m
Moderately close	0.3 – 1 m
Close	50 – 300 mm
Very close	< 50 mm

### GRAIN SIZE

<u>Terms</u>	<u>Size*</u>
Very Coarse Grained	> 60 mm
Coarse Grained	2 – 60 mm
Medium Grained	60 microns – 2 mm
Fine Grained	2 – 60 microns
Very Fine Grained	< 2 microns

\* Note: Grains > 60 microns diameter are visible to the naked eye.

### CORE CONDITION

#### Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

#### Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

#### Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varies from 0% for completely broken core to 100% for core in solid sticks.

### DISCONTINUITY DATA

#### Fracture Index

A count of the number of discontinuities (physical separation) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

#### Dip with Respect to (W.R.T.) Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole, a discontinuity with a 90° angle is horizontal.

#### Description and Notes

An abbreviated description of the discontinuities, whether naturally occurring separation such as fractures, bedding planes and foliation planes or mechanically induced fractures caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

#### Abbreviations



B - Bedding	⊥ - Perpendicular To
FO - Foliation / Schistosity	- Parallel To
CL - Cleavage	P - Polished
SH - Shear Plane / Zone	K - Slickensided
VN - Vein	SM - Smooth
F - Fault	R - Rough
CO - Contact	ST - Stepped
J - Joint	PL - Planar
FR - Fracture	U - Undulating
MF - Mechanical Fracture	C - Curved

PROJECT 09-1191-0022				RECORD OF BOREHOLE No WS-1				1 OF 2 METRIC							
W.P. 5139-06-00				LOCATION N 5414654.3; E 313731.7				ORIGINATED BY DAM							
DIST Cochrane HWY 7036				BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers				COMPILED BY JLL							
DATUM Geodetic				DATE April 17, 2011				CHECKED BY SC							
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE		DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		20	40	60	80					
269.2	GROUND SURFACE														
0.0	APSHALT (Surface Treatment)		1	AS	-										
0.2	Sand and gravel, trace silt (FILL) Frozen Brown		2	SS	36										
	Silty clay with sand, some gravel, slightly organic (FILL) (Frozen) Stiff and moist below 2.3 m depth Brown to black		3	SS	11										
			4	SS	9										
266.2															
3.0	SILTY CLAY, trace to some sand, slightly organic (ALLUVIUM) Firm to stiff Grey Moist		5	SS	9										
			6	SS	10										
			7	SS	6										
263.6															
5.6	SILTY CLAY, trace sand Firm Grey Wet		8	SS	5										
			9	SS	1										
			10	SS	WH										
			11	SS	WH										
			12	SS	WH										
			13	SS	PM										
	Soft below 14.6 m depth.														

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

SUD-MTO 001 09-1191-0022.GPJ GAL-MISS.GDT 28/09/11 DATA INPUT:

PROJECT		RECORD OF BOREHOLE				No WS-1		2 OF 2		METRIC								
W.P. 5139-06-00		LOCATION				N 5414654.3; E 313731.7		ORIGINATED BY DAM										
DIST Cochrane HWY 7036		BOREHOLE TYPE				108 mm I.D. Continuous Flight Hollow Stem Augers		COMPILED BY JJJ										
DATUM Geodetic		DATE				April 17, 2011		CHECKED BY SC										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
	--- CONTINUED FROM PREVIOUS PAGE ---						20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%) 20 40 60						
253.4	SILTY CLAY, trace sand Firm Grey Wet		14	SS	WH		254											
15.8	END OF BOREHOLE  Note: 1. Water level at a depth of 13.5 m below ground surface (Elev. 255.7 m) upon completion of drilling. 2. Water level in piezometer at a depth of 3.5 m (Elev. 265.7 m) on April 28, 2011, and 2.3 m (Elev. 266.9 m) on July 3, 2011.																	



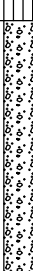
PROJECT		09-1191-0022		RECORD OF BOREHOLE No WS-2		1 OF 3 METRIC											
W.P.		5139-06-00		LOCATION		N 5414648.9; E 313753.7											
DIST		Cochrane HWY 7036		BOREHOLE TYPE		108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring											
DATUM		Geodetic		DATE		April 25 and 26, 2011											
				ORIGINATED BY		ID											
				COMPILED BY		JJL											
				CHECKED BY		SC											
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	20 40 60	W <sub>p</sub> W W <sub>L</sub>	γ	GR SA SI CL					
269.4	GROUND SURFACE																
0.0	ASPHALT (Surface Treatment)																
0.2	Sand and gravel, trace silt (FILL)		1	AS	-		269										
268.6	Frozen Brown																
0.8	Clayey silt to silty clay, trace to some sand, trace to some gravel, slightly organic (FILL) (Frozen)		2	SS	27		268										
	Very stiff and moist below 2.3 m depth																
	Brown		3	SS	26		267										
			4	SS	18												
266.2			5a				266										
3.2	SILTY CLAY to CLAY, some sand, organic (ALLUVIUM)		5b	SS	14												
	Firm to stiff																
	Brown to grey		6	SS	10		265										
	Moist		7	SS	6												
263.8							264										
5.6	SILTY CLAY to CLAY, trace sand																
	Soft to firm		8	SS	1		263										
	Grey																
	Wet																
	Switched to NW Casing at 15.2 m depth.						262										
			9	SS	WH												
							261										
			10	TO	PH		260										
							259										
			11	SS	WH												
							258										
			12	TO	PH		257										
							256										
			13	SS	WH		255										

Continued Next Page

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

SUD-MTO 001 09-1191-0022.GPJ GAL-MISS.GDT 28/09/11 DATA INPUT:


<b>PROJECT</b> 09-1191-0022		<b>RECORD OF BOREHOLE No WS-2</b>		2 OF 3 <b>METRIC</b>	
W.P. 5139-06-00		LOCATION N 5414648.9; E 313753.7		ORIGINATED BY ID	
DIST Cochrane HWY 7036		BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring		COMPILED BY JJL	
DATUM Geodetic		DATE April 25 and 26, 2011		CHECKED BY SC	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)	
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × REMOULDED							
--- CONTINUED FROM PREVIOUS PAGE ---																
246.5 22.9	SILTY CLAY to CLAY, trace sand Soft to firm Grey Wet  Switched to NW Casing at 15.2 m depth.  Silt layers below 16.8 m depth.		14	TO	PH	254										
						253		4	+	4						
						252										
						251										
						250					4	+	4			
						249										
						248										
						247					4	+	5			
						246										
						245										
242.0 27.4	SILT, some clay and / or clay layers, trace sand Loose Grey Wet  Artesian conditions (water flowing out of casing) below 25.9 m depth.		19	SS	4	244										
						243										
						242										
						241										
240	SAND and GRAVEL, trace to some silt, trace clay, containing cobbles Very dense Grey Wet  Casing refusal at 28.0 m depth. Switched to NQ coring between 28.0 m and 29.0 m depth. Recovered gravel and cobbles between 0.05 m and 0.18 m sizes.  NQ coring used to pilot borehole between 29.5 m and 30.5 m depth prior to advancing casing.		20	SS	5	240										
						239										
						238										
			21	SS	4	237										
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+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity    ○ 3% STRAIN AT FAILURE

SUD-MTO 001 09-1191-0022.GPJ GAL-MISS.GDT 28/09/11 DATA INPUT:

PROJECT <u>09-1191-0022</u>		<b>RECORD OF BOREHOLE No WS-2</b>				3 OF 3 <b>METRIC</b>											
W.P. <u>5139-06-00</u>		LOCATION <u>N 5414648.9; E 313753.7</u>				ORIGINATED BY <u>ID</u>											
DIST <u>Cochrane</u> HWY <u>7036</u>		BOREHOLE TYPE <u>108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring</u>				COMPILED BY <u>JJL</u>											
DATUM <u>Geodetic</u>		DATE <u>April 25 and 26, 2011</u>				CHECKED BY <u>SC</u>											
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									WATER CONTENT (%)
	--- CONTINUED FROM PREVIOUS PAGE ---						<div style="display: flex; justify-content: space-between;"> <span>20 40 60 80 100</span> <span>20 40 60 80 100</span> </div> <div style="display: flex; justify-content: space-between;"> <span>○ UNCONFINED</span> <span>+ FIELD VANE</span> </div> <div style="display: flex; justify-content: space-between;"> <span>● QUICK TRIAXIAL</span> <span>× REMOULDED</span> </div>					<div style="display: flex; justify-content: space-between;"> <span>20 40 60</span> <span>20 40 60</span> </div>					
238.9 30.5	Spoon refusal at 30.5 m depth. <b>GRANITE (BEDROCK)</b>  Bedrock cored from 30.5 m depth to 33.6 m depth.  For coring details see Record of Drillhole WS-2.		24	SS	07/0.65	239											
			1	RC	REC 100%	238											RQD = 80%
			2	RC	REC 100%	237											RQD = 90%
235.8 33.6	<b>END OF BOREHOLE</b>  Note:  1. Water level at 1.1 m above ground surface (Elev. 270.5 m) upon penetrating the silt deposit.  2. Water level at a depth of 3.7 m below ground surface (Elev. 265.7 m) upon penetrating the gravelly sand deposit.					236											



PROJECT: 09-1191-0022

**RECORD OF DRILLHOLE: WS-2**

SHEET 1 OF 1

LOCATION: N 5414648.9 ;E 313753.7

DRILLING DATE: April 26, 2011

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: CME 55

DRILLING CONTRACTOR: George Downing Estate Drilling Ltd.

DEPTH SCALE METRES	DRILLING RECORD		DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	JN - Joint FLT - Fault SHR - Shear VN - Vein CJ - Conjugate BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular PO - Polished K - Slickensided SM - Smooth Ro - Rough MB - Mechanical Break BR - Broken Rock NOTE: For additional abbreviations refer to list of abbreviations & symbols.															NOTES WATER LEVELS INSTRUMENTATION		
								RECOVERY		R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA						HYDRAULIC CONDUCTIVITY k, cm/s			Diametral Point Load Index (MPa)	RMC -Q AVG			
								TOTAL CORE %	SOLID CORE %			B Angle	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	φ	ψ	τ					σ
								88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88 88																	

DEPTH SCALE

1 : 50



LOGGED: ID

CHECKED: SC

SUD-RCK 09-1191-0022.GPJ GAL-MISS.GDT 2809/11 DATA INPUT:

PROJECT		09-1191-0022		<b>RECORD OF BOREHOLE No WS-3</b>		1 OF 3 <b>METRIC</b>							
W.P.		5139-06-00		LOCATION		N 5414655.7; E 313780.8							
DIST		Cochrane HWY 7036		BOREHOLE TYPE		108 mm I.D. Continuous Flight Hollow Stem Augers							
DATUM		Geodetic		DATE		April 17 - 20, 2011							
						ORIGINATED BY ID							
						COMPILED BY JJL							
						CHECKED BY SC							
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT		REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa		WATER CONTENT (%)		γ	
269.5	GROUND SURFACE							20 40 60 80 100	W <sub>p</sub> W W <sub>L</sub>	20 40 60	OC=0.8%	GR SA SI CL	
0.0	ASPHALT (Surface Treatment)		1	AS	-		269	○ UNCONFINED + FIELD VANE	○			13 52 13 12	
0.1	Sand, some gravel, silt and clay, slightly organic (FILL)							● QUICK TRIAXIAL × REMOULDED					
268.6	Frozen Brown		2	SS	17		268						
0.9	Silty clay, trace to some sand, trace to some gravel, slightly organic (FILL) (Frozen)		3	SS	22		267						
	Soft to firm and moist below 2.3 m depth		4	SS	6		266						
	Brown		5	SS	3		265						
265.6	SILTY CLAY to CLAY, trace sand		6	SS	1		264						
3.9	Soft to firm						263						
	Grey		7	SS	WH		262						
	Wet		8	TO	PH		261						
	Vane sank 0.3 m at 8.5 m depth.		9	SS	WH		260						
							259						
			10	TO	PH		258						
	Vane sank 0.3 m at 11.6 m depth.		11	SS	WH		257						
							256						
			12	TO	PH		255						
	Vane sank 0.3 m at 14.6 m depth.												

Continued Next Page

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

SUD-MTO 001 09-1191-0022.GPJ GAL-MISS.GDT 28/09/11 DATA INPUT:

PROJECT <u>09-1191-0022</u>		<b>RECORD OF BOREHOLE No WS-3</b>		2 OF 3 <b>METRIC</b>	
W.P. <u>5139-06-00</u>	LOCATION <u>N 5414655.7; E 313780.8</u>	ORIGINATED BY <u>ID</u>			
DIST <u>Cochrane</u> HWY <u>7036</u>	BOREHOLE TYPE <u>108 mm I.D. Continuous Flight Hollow Stem Augers</u>	COMPILED BY <u>JJL</u>			
DATUM <u>Geodetic</u>	DATE <u>April 17 - 20, 2011</u>	CHECKED BY <u>SC</u>			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
	--- CONTINUED FROM PREVIOUS PAGE ---													
	SILTY CLAY to CLAY, trace sand Soft to firm Grey Wet  Switched to NW Casing at 15.2 m depth.		13	SS	WH		254							
							253							
							252							
	Silt layers below 18.3 m depth.						251							
							250							
							249							
			14	SS	WH									
			15	SS	WH									
			16	SS	WH									
							248							
							247							
246.6														
22.9	SILT, some clay and / or clay layers Loose to compact Grey Wet  Artesian conditions noted below 24.4 m depth.		17	SS	5		246							0 0 77 23
			18	SS	11		245							
			19	SS	8		244							
			20	SS	6		243							
							242							
							241							
240.6														
28.9	Gravelly SAND to SAND, some silt, trace clay, containing cobbles Compact to very dense Grey Wet		21	SS	29		240							28 53 14 5

Continued Next Page

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

SUD-MTO 001 09-1191-0022.GPJ GAL-MISS.GDT 28/09/11 DATA INPUT:

PROJECT <u>09-1191-0022</u>		<b>RECORD OF BOREHOLE No WS-3</b>				3 OF 3 <b>METRIC</b>														
W.P. <u>5139-06-00</u>		LOCATION <u>N 5414655.7; E 313780.8</u>				ORIGINATED BY <u>ID</u>														
DIST <u>Cochrane</u> HWY <u>7036</u>		BOREHOLE TYPE <u>108 mm I.D. Continuous Flight Hollow Stem Augers</u>				COMPILED BY <u>JJL</u>														
DATUM <u>Geodetic</u>		DATE <u>April 17 - 20, 2011</u>				CHECKED BY <u>SC</u>														
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									WATER CONTENT (%)			
--- CONTINUED FROM PREVIOUS PAGE ---																				
235.4 34.1	Gravelly SAND to SAND, some silt, trace clay, containing cobbles Compact to very dense Grey Wet  Casing refusal at 30.0 m depth. Spoon attempted / bouncing.  Switched to NQ coring between 30.0 m and 30.5 m depth. Recovered gravel and cobbles between 0.04 m and 0.13 m sizes, advanced casing.  Casing refusal at 33.5 m depth.		22	RC	REC 50%	239												1 86 10 3		
			23	SS	36		238													
			24	SS	60			237												
						236														
	END OF BOREHOLE Tricone equipment lodged / lost at bottom of borehole  Note:  1. Water level at 2.1m above ground surface (Elev. 271.6 m) upon penetrating the silt deposit.  2. Casing refusal encountered at 33.5 m depth. About 0.6 m of material (gravel and cobbles) inside the casing. Core barrel lodged inside casing after attempting to remove gravel and cobbles. After dislodging core barrel, tricone was used to remove cobbles from casing. Tricone advanced to 34.1 m depth and became lodged inside borehole. Tricone could not be dislodged.  3. Moved 5.9 m south and advanced new Borehole 22.9 m without sampling. See Record of Borehole WS-3A.																			

SUD-MTO 001 09-1191-0022.GPJ GAL-MISS.GDT 28/09/11 DATA INPUT:

PROJECT <u>09-1191-0022</u>		<b>RECORD OF BOREHOLE No WS-3A</b>				1 OF 3 <b>METRIC</b>							
W.P. <u>5139-06-00</u>		LOCATION <u>N 5414649.8; E 313781.0</u>				ORIGINATED BY <u>ID</u>							
DIST <u>Cochrane</u> HWY <u>7036</u>		BOREHOLE TYPE <u>108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring</u>				COMPILED BY <u>JJL</u>							
DATUM <u>Geodetic</u>		DATE <u>April 27, 2011</u>				CHECKED BY <u>SC</u>							
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					
269.6 0.0	<b>GROUND SURFACE</b>  Hollow stem augers advanced from ground surface to 4.6 m depth.  NW Casing advanced from ground surface through augers to a depth of 22.9 m (Elev. 246.7 m) without sampling. Stratigraphy assumed as per Record of Borehole No. WS-3.						<div style="display: flex; justify-content: space-between; font-size: small;"> <span>20 40 60 80 100</span> <span>20 40 60 80 100</span> </div> <div style="display: flex; justify-content: space-between; font-size: x-small;"> <span>○ UNCONFINED    + FIELD VANE</span> <span>● QUICK TRIAXIAL    × REMOULDED</span> </div>						
						269							
						268							
						267							
						266							
						265							
						264							
						263							
						262							
						261							
						260							
						259							
						258							
						257							
						256							
						255							

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE



2 OF 3 METRIC

ORIGINATED BY ID

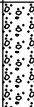


COMPILED BY J.J.L.

CHECKED BY SC

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○<sup>3%</sup> STRAIN AT FAILURE

SUD-MTO 001 09-1191-0022.GPJ GAL-MISS.GDT 28/09/11 DATA INPUT:

PROJECT		RECORD OF BOREHOLE				No WS-3A		3 OF 3		METRIC							
W.P. 5139-06-00		LOCATION N 5414649.8; E 313781.0				ORIGINATED BY ID											
DIST Cochrane HWY 7036		BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring				COMPILED BY JJL											
DATUM Geodetic		DATE April 27, 2011				CHECKED BY SC											
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	--- CONTINUED FROM PREVIOUS PAGE ---																
237.8	Gravelly SAND to SAND, trace to some silt, trace clay Dense to very dense Grey Wet		4	SS	45		239										
31.8	Spoon refusal at 31.8 m depth. GRANITE (BEDROCK)		5	SS	102/0.2		238										
	Bedrock cored from 31.8 m depth to 35.0 m depth.  For coring details see Record of Drillhole WS-3A		1	RC	REC 100%		237									RQD = 80%	
			2	RC	REC 100%		236									RQD = 95%	
			3	RC	REC 100%		235									RQD = 100%	
234.6	END OF BOREHOLE																
35.0	Note:  1. Water level at 2.4 m above ground surface (Elev. 272.0 m) upon penetrating the silt deposit.																

SUD-MTO 001 09-1191-0022.GPJ GAL-MISS.GDT 28/09/11 DATA INPUT:



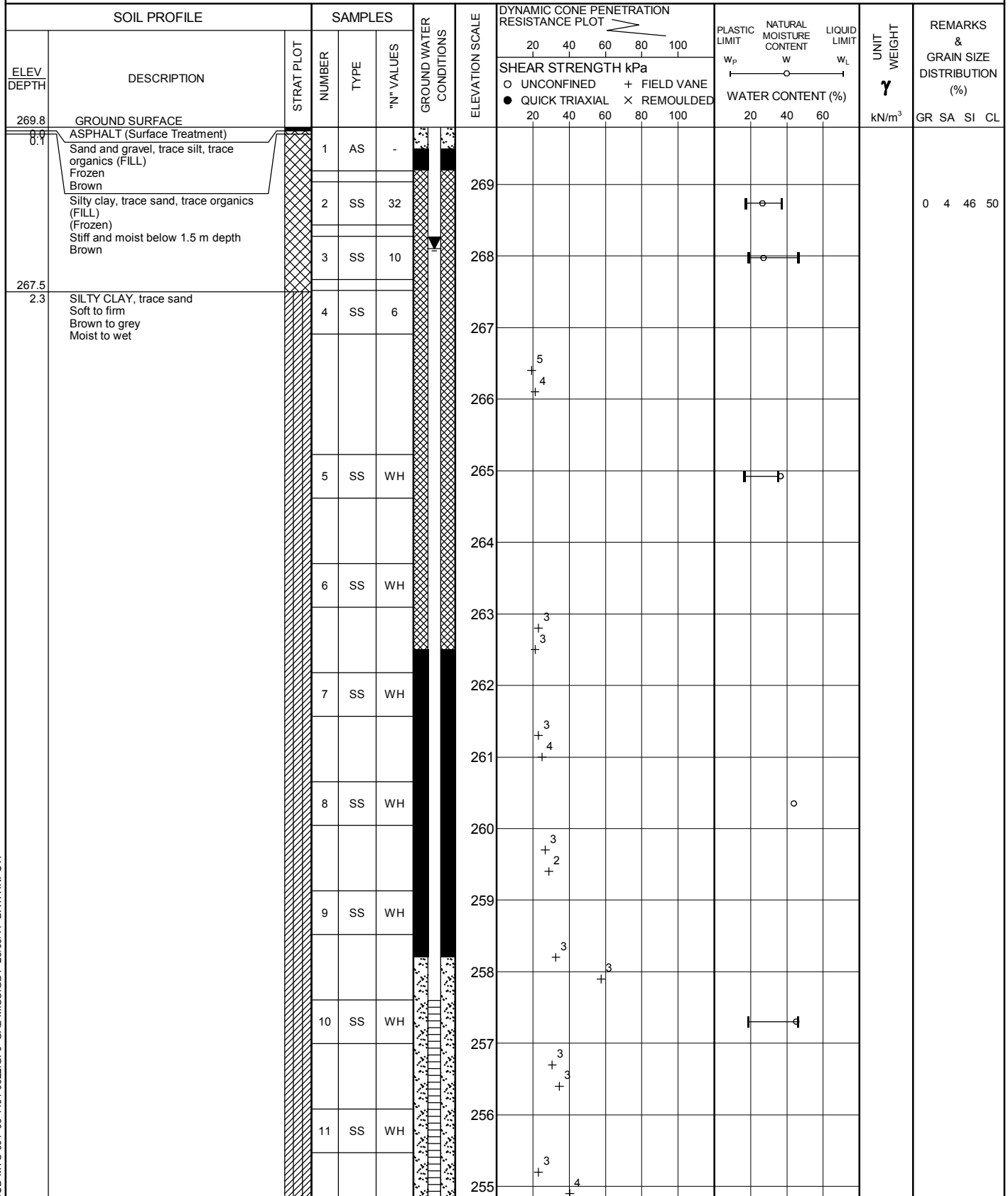
SHEET 1 OF 1

DATUM: Geodetic

DRILLING CONTRACTOR: George Downing Estate Drilling Ltd.

CHECKED: SC

<b>PROJECT</b> 09-1191-0022		<b>RECORD OF BOREHOLE No WS-4</b>		1 OF 2 <b>METRIC</b>
W.P. 5139-06-00		LOCATION N 5414649.7; E 313801.4		ORIGINATED BY DAM
DIST Cochrane HWY 7036		BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers		COMPILED BY JLL
DATUM Geodetic		DATE April 16, 2011		CHECKED BY SC



Continued Next Page

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

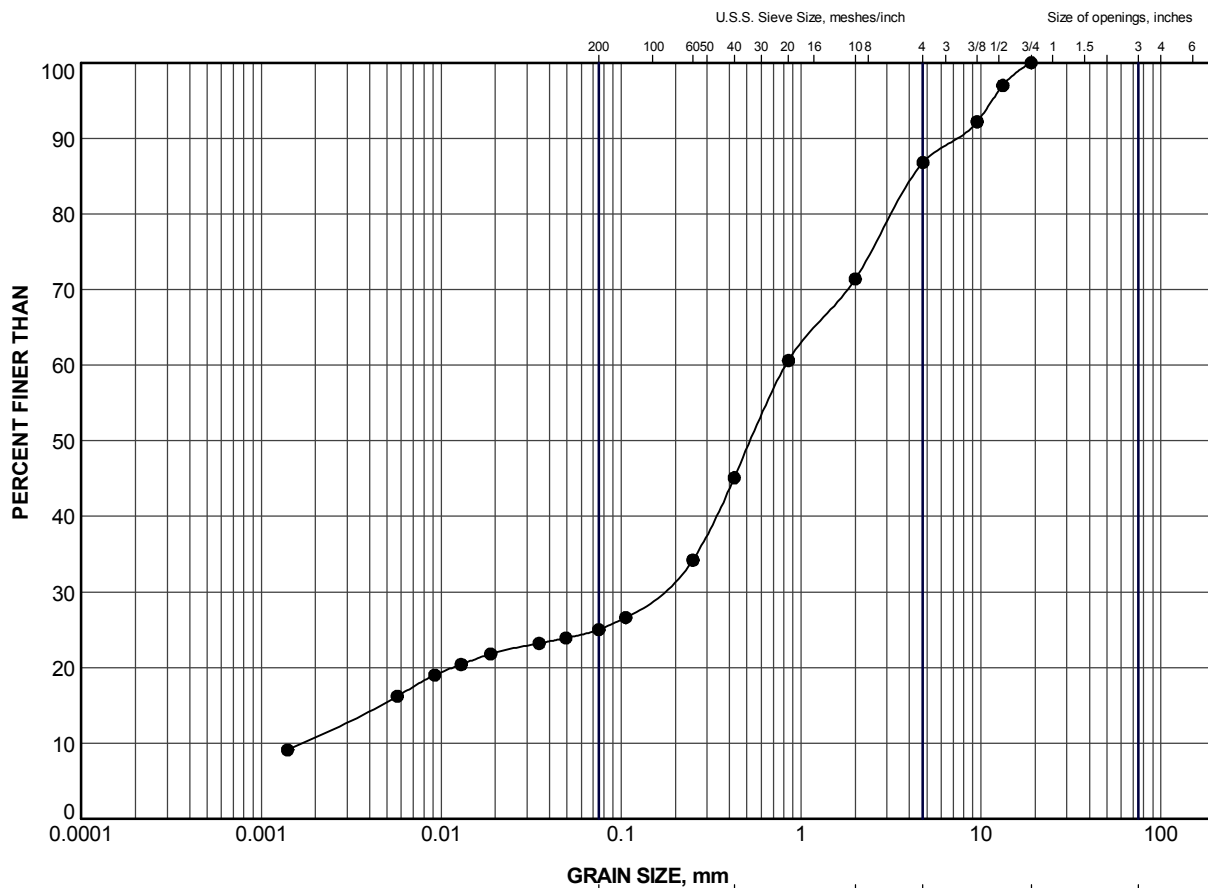
+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○<sup>3%</sup> STRAIN AT FAILURE

SUD-MTO 001 09-1191-0022.GPJ GAL-MISS.GDT 28/09/11 DATA INPUT:



# APPENDIX B

## Laboratory Test Results

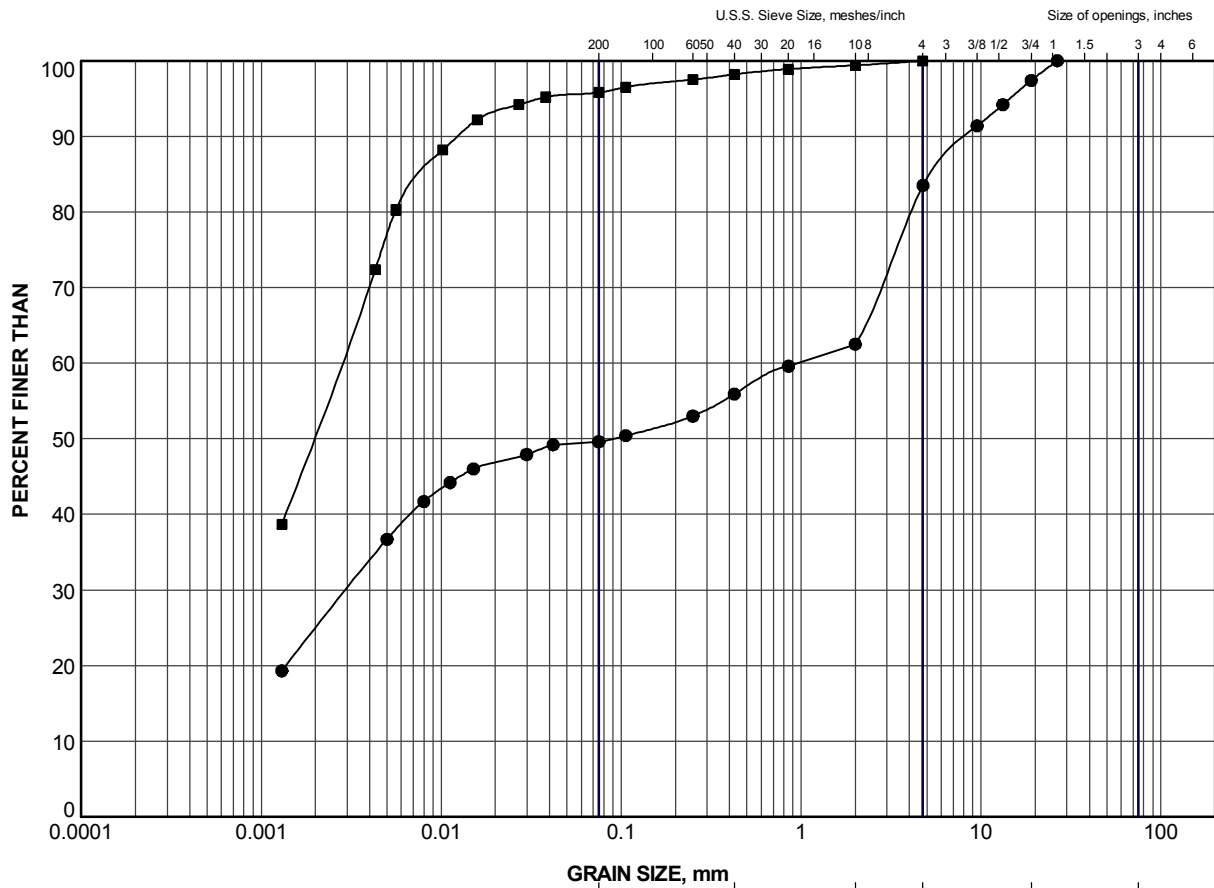


CLAY AND SILT		GRAVEL SIZE, mm				Cobble Size	
		fine	medium	coarse	fine		coarse
		SAND SIZE			GRAVEL SIZE		

#### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	WS-3	1	269.1


PROJECT					WICKLOW RIVER BRIDGE SOUTH HIGHWAY 7036				
TITLE					GRAIN SIZE DISTRIBUTION SAND (FILL)				
PROJECT No.		09-1191-0022		FILE No.		09-1191-0022.GPJ			
DRAWN	JJL	Sep 2011	SCALE	N/A	REV.				
CHECK	DAM	Sep 2011							
APPR		Sep 2011							
 <b>Golder Associates</b> SUDBURY, ONTARIO			<b>FIGURE B-1</b>						

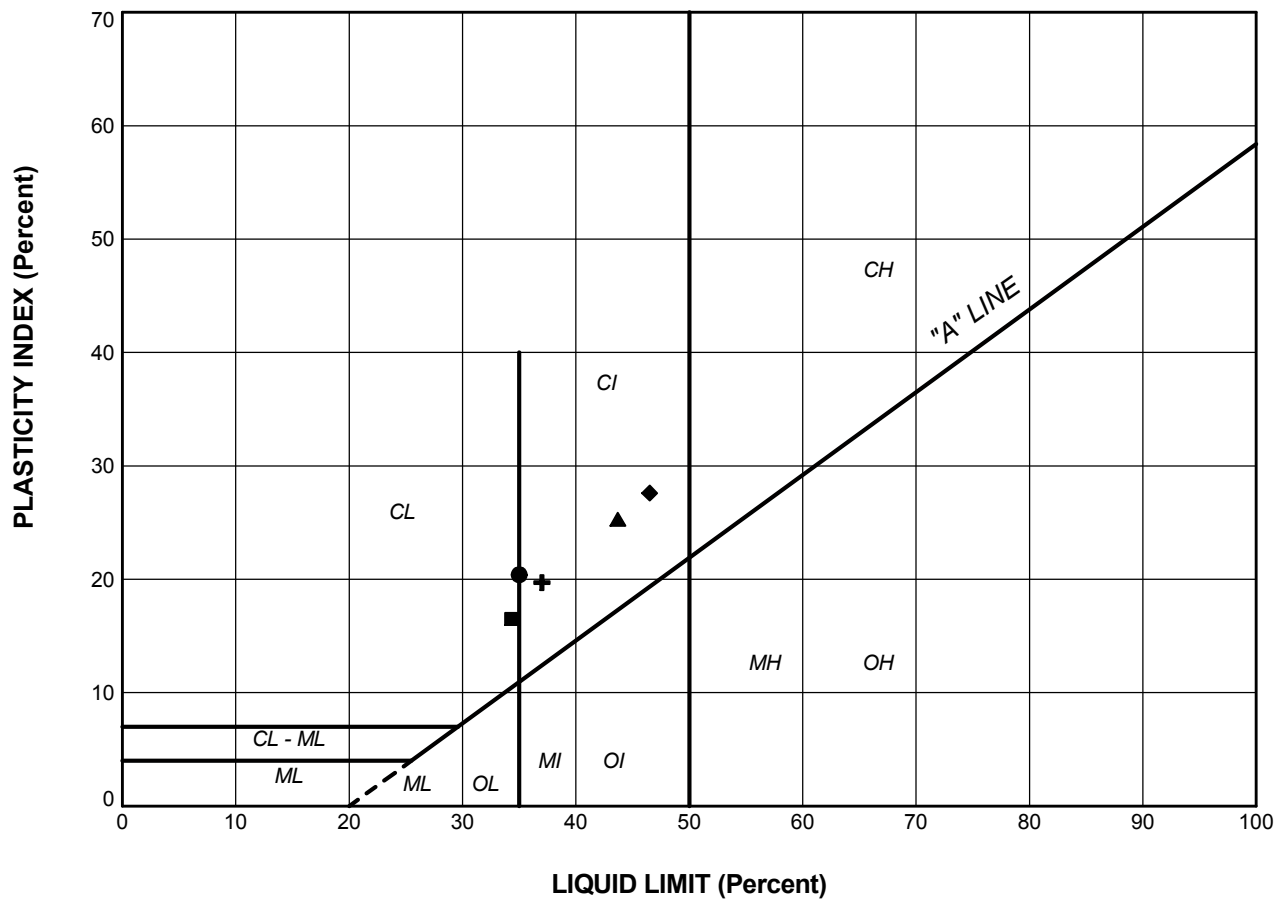


GRAVEL SIZE, mm						
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	WS-1	1	268.8
■	WS-4	2	268.7

PROJECT					
WICKLOW RIVER BRIDGE SOUTH HIGHWAY 7036					
TITLE					
GRAIN SIZE DISTRIBUTION SILTY CLAY (FILL)					
PROJECT No.		09-1191-0022		FILE No. 09-1191-0022.GPJ	
DRAWN	JJL	Sep 2011	SCALE	N/A	REV.
CHECK	DAM	Sep 2011			
APPR		Sep 2011			
 <b>Golder Associates</b> SUDBURY, ONTARIO			<b>FIGURE B-2</b>		



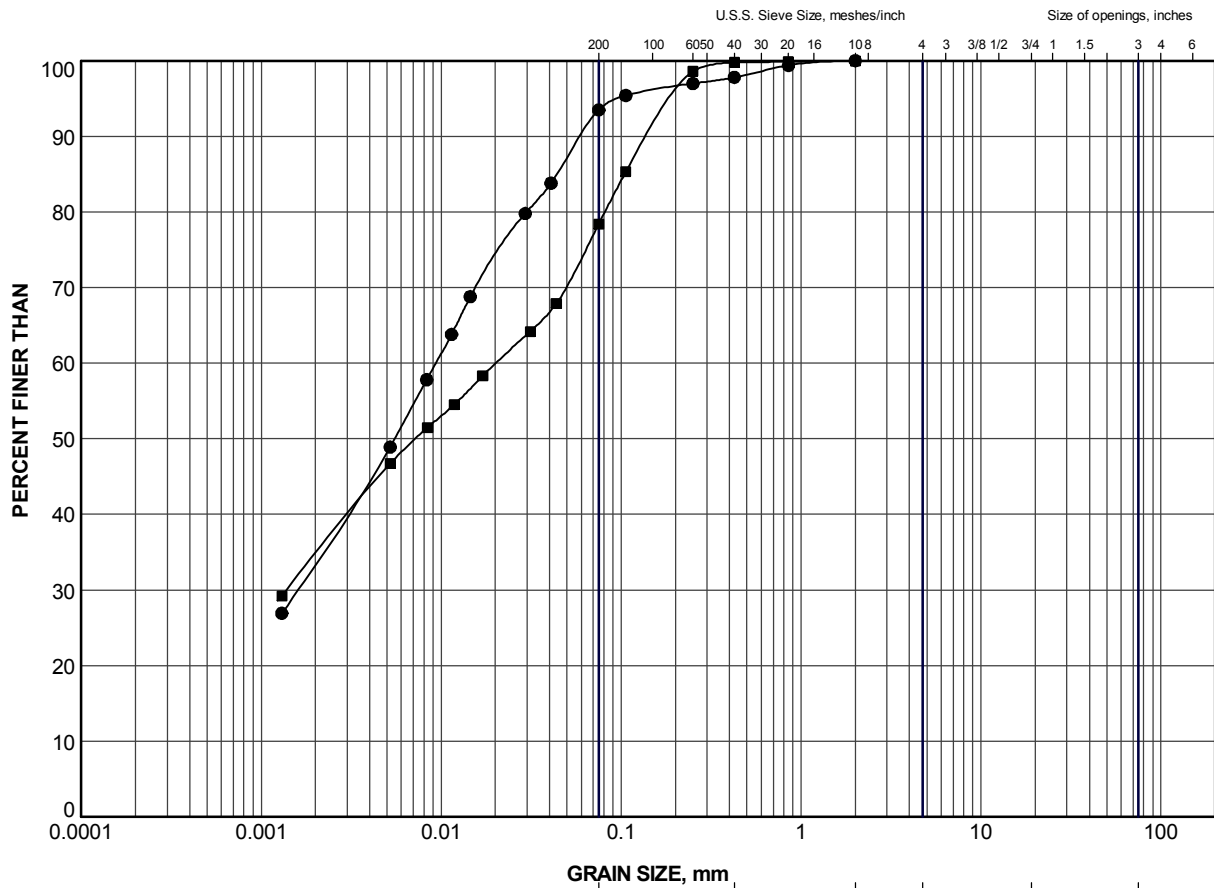
### LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	WS-1	1	35.0	14.6	20.4
■	WS-2	3	34.3	17.8	16.5
▲	WS-3	3	43.7	18.4	25.3
+	WS-4	2	37.0	17.3	19.7
◆	WS-4	3	46.5	18.9	27.6

PROJECT					
WICKLOW RIVER BRIDGE SOUTH HIGHWAY 7036					
TITLE					
PLASTICITY CHART CLAYEY SILT TO SILTY CLAY (FILL)					
PROJECT No.		09-1191-0022		FILE No. 09-1191-0022.GPJ	
DRAWN	JJL	Sep 2011	SCALE	N/A	REV.
CHECK	DAM	Sep 2011	<b>FIGURE B-3</b>		
APPR		Sep 2011			






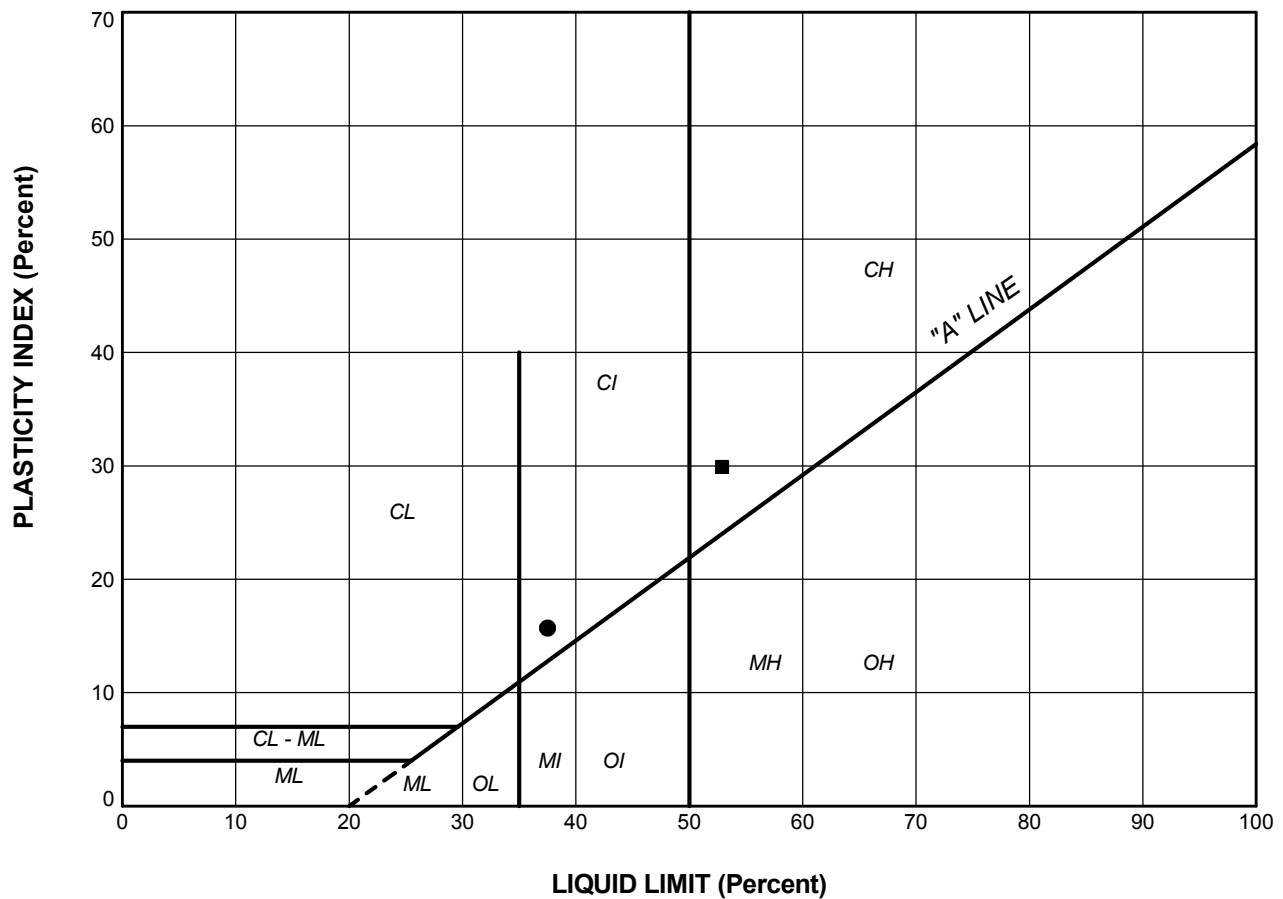


CLAY AND SILT	SAND SIZE, mm						Cobble Size
	fine	medium	coarse	fine	coarse		
	SAND SIZE			GRAVEL SIZE			

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	WS-1	5	265.9
■	WS-2	6	265.3

PROJECT						WICKLOW RIVER BRIDGE SOUTH HIGHWAY 7036					
TITLE						<b>GRAIN SIZE DISTRIBUTION</b> SILTY CLAY TO CLAY (ALLUVIUM)					
PROJECT No.			09-1191-0022			FILE No.			09-1191-0022.GPJ		
DRAWN	JJL	Sep 2011	SCALE		N/A	REV.					
CHECK	DAM	Sep 2011									
APPR		Sep 2011									
 <b>Golder Associates</b> SUDBURY, ONTARIO						<b>FIGURE B-4</b>					



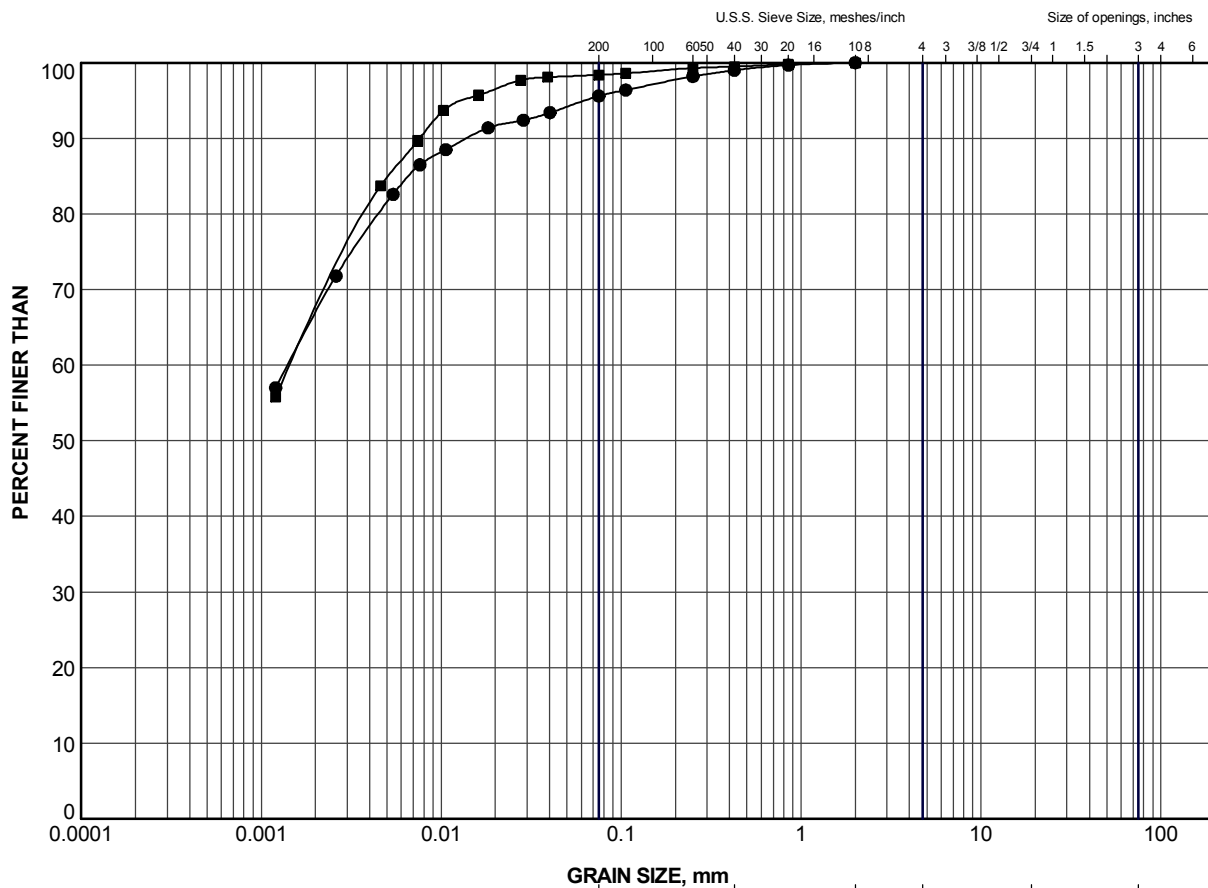
### LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	WS-1	5	37.5	21.8	15.7
■	WS-2	7	52.9	23.0	29.9

PROJECT					
WICKLOW RIVER BRIDGE SOUTH HIGHWAY 7036					
TITLE					
PLASTICITY CHART SILTY CLAY TO CLAY (ALLUVIUM)					
PROJECT No.		09-1191-0022		FILE No.	
				09-1191-0022.GPJ	
DRAWN	JJL	Sep 2011	SCALE	N/A	REV.
CHECK	DAM	Sep 2011			
APPR		Sep 2011			



**FIGURE B-5**



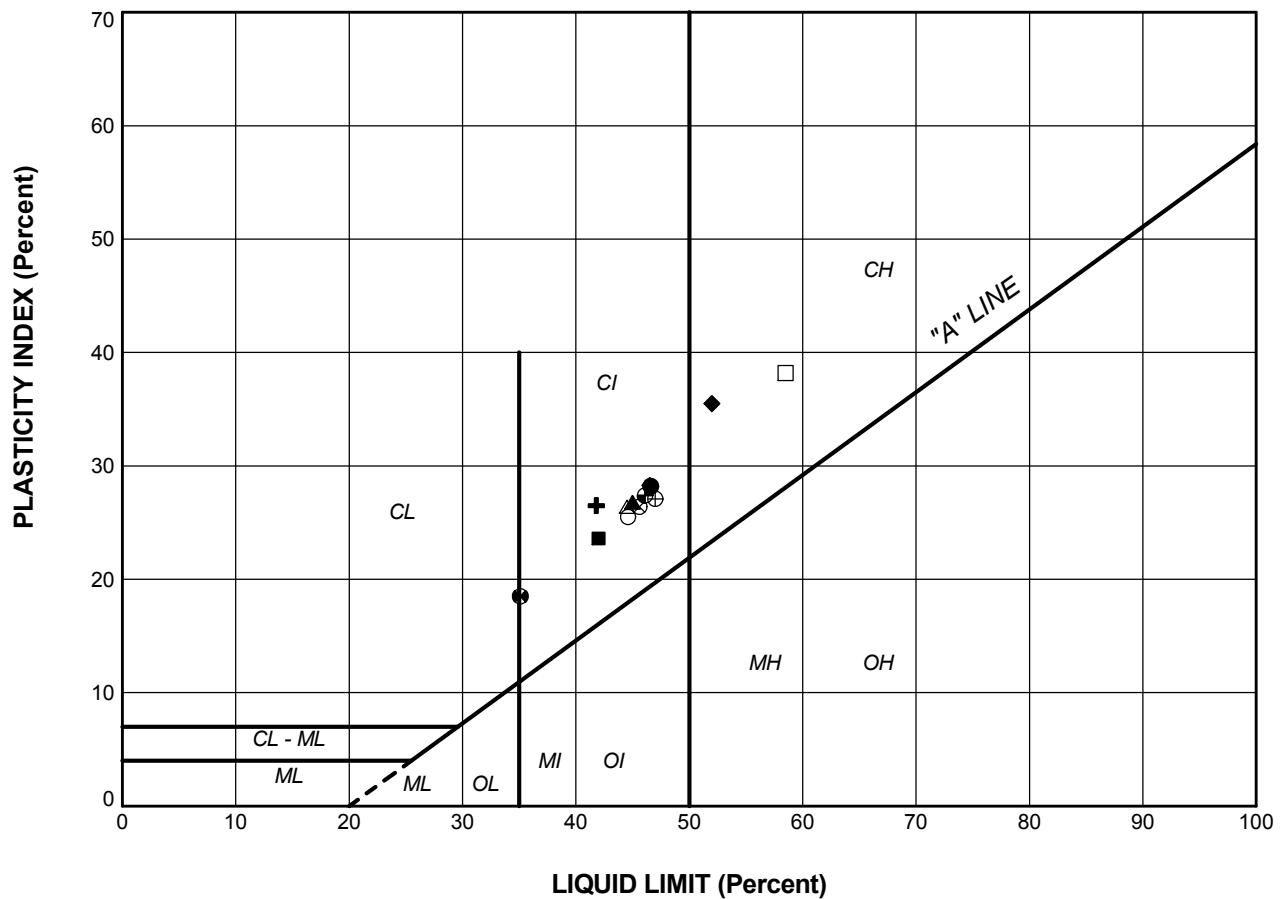
		GRAVEL SIZE, mm					
CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size	
	SAND SIZE			GRAVEL SIZE			

### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	WS-2	10	260.0
■	WS-3	9	260.1


PROJECT						WICKLOW RIVER BRIDGE SOUTH HIGHWAY 7036					
TITLE						GRAIN SIZE DISTRIBUTION SILTY CLAY					
PROJECT No.			09-1191-0022			FILE No.			09-1191-0022.GPJ		
DRAWN	JJL	Sep 2011	SCALE			N/A			REV.		
CHECK	DAM	Sep 2011									
APPR		Sep 2011									
						<b>FIGURE B-6</b>					





### LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	WS-1	9	46.6	18.4	28.2
■	WS-1	13	42.0	18.4	23.6
▲	WS-2	9	45.0	18.2	26.8
+	WS-2	10	41.8	15.3	26.5
◆	WS-2	13	52.0	16.5	35.5
◇	WS-2	17	46.5	18.2	28.3
○	WS-3	8	44.6	19.1	25.5
△	WS-3	9	44.5	18.1	26.4
⊗	WS-3	10	45.6	19.2	26.4
⊕	WS-3	12	47.0	19.9	27.1
□	WS-3	13	58.5	20.3	38.2
⊙	WS-4	5	35.1	16.6	18.5
●	WS-4	10	46.1	18.7	27.4

PROJECT					
WICKLOW RIVER BRIDGE SOUTH HIGHWAY 7036					
TITLE					
PLASTICITY CHART SILTY CLAY TO CLAY					
PROJECT No.		09-1191-0022		FILE No.	
				09-1191-0022.GPJ	
DRAWN	JJL	Sep 2011	SCALE	N/A	REV.
CHECK	DAM	Sep 2011			
APPR		Sep 2011			
 <b>Golder Associates</b> SUDBURY, ONTARIO			<b>FIGURE B-7</b>		

**CONSOLIDATION TEST SUMMARY****FIGURE B-8**

Pg. 1 of 4

**SAMPLE IDENTIFICATION**

Project Number: 09-1191-0022

Sample Number: 10

Borehole Number: WS-2

Sample Depth, m: 9.1

**TEST CONDITIONS**

Test Type Standard

Load Duration, hr 24

Oedometer Number 1

Date Started May 26/11

Date Completed June 9/11

**SAMPLE DIMENSIONS AND PROPERTIES - INITIAL**

Sample Height, cm	2.550	Unit Weight, kN/m <sup>3</sup>	18.21
Sample Diameter, cm	6.330	Dry Unit Weight, kN/m <sup>3</sup>	13.01
Area, cm <sup>2</sup>	31.47	Specific Gravity, measured	2.74
Volume, cm <sup>3</sup>	80.25	Solids Height, cm	1.234
Water Content, %	39.97	Volume of Solids, cm <sup>3</sup>	38.84
Wet Mass, g	149.05	Volume of Voids, cm <sup>3</sup>	41.41
Dry Mass, g	106.49	Degree of Saturation, %	102.8

**TEST COMPUTATIONS**

Pressure kPa	Primary Consolidation	Corr. Height cm	Void Ratio	Average Height cm	t <sub>90</sub> sec	cv. cm <sup>2</sup> /s	mv m <sup>2</sup> /kN	k cm/s	Total Work kJ/m <sup>3</sup>
0	0	2.550	1.066	2.550					
9	0.02	2.548	1.064	2.549	220	0.0063	1.00E-04	6.15E-08	0.004
18	0.04	2.544	1.061	2.546	780	0.0018	1.74E-04	3.01E-08	0.025
35	0.10	2.534	1.053	2.539	1160	0.0012	2.31E-04	2.66E-08	0.129
69	0.17	2.517	1.039	2.525	870	0.0016	1.96E-04	2.99E-08	0.478
143	0.44	2.473	1.004	2.495	2090	0.0006	2.31E-04	1.43E-08	2.310
285	1.30	2.343	0.899	2.408	5415	0.0002	3.59E-04	7.99E-09	13.559
571	1.10	2.233	0.810	2.288	2310	0.0005	1.51E-04	7.10E-09	33.651
1140	0.91	2.142	0.736	2.188	1500	0.0007	6.27E-05	4.16E-09	68.512
2279	0.72	2.071	0.678	2.106	960	0.0010	2.46E-05	2.36E-09	125.570
1140	-0.09	2.080	0.686	2.075					
285	-0.37	2.117	0.715	2.099					
69	-0.50	2.167	0.756	2.142					
9	-0.782	2.245	0.819	2.206					

Note:

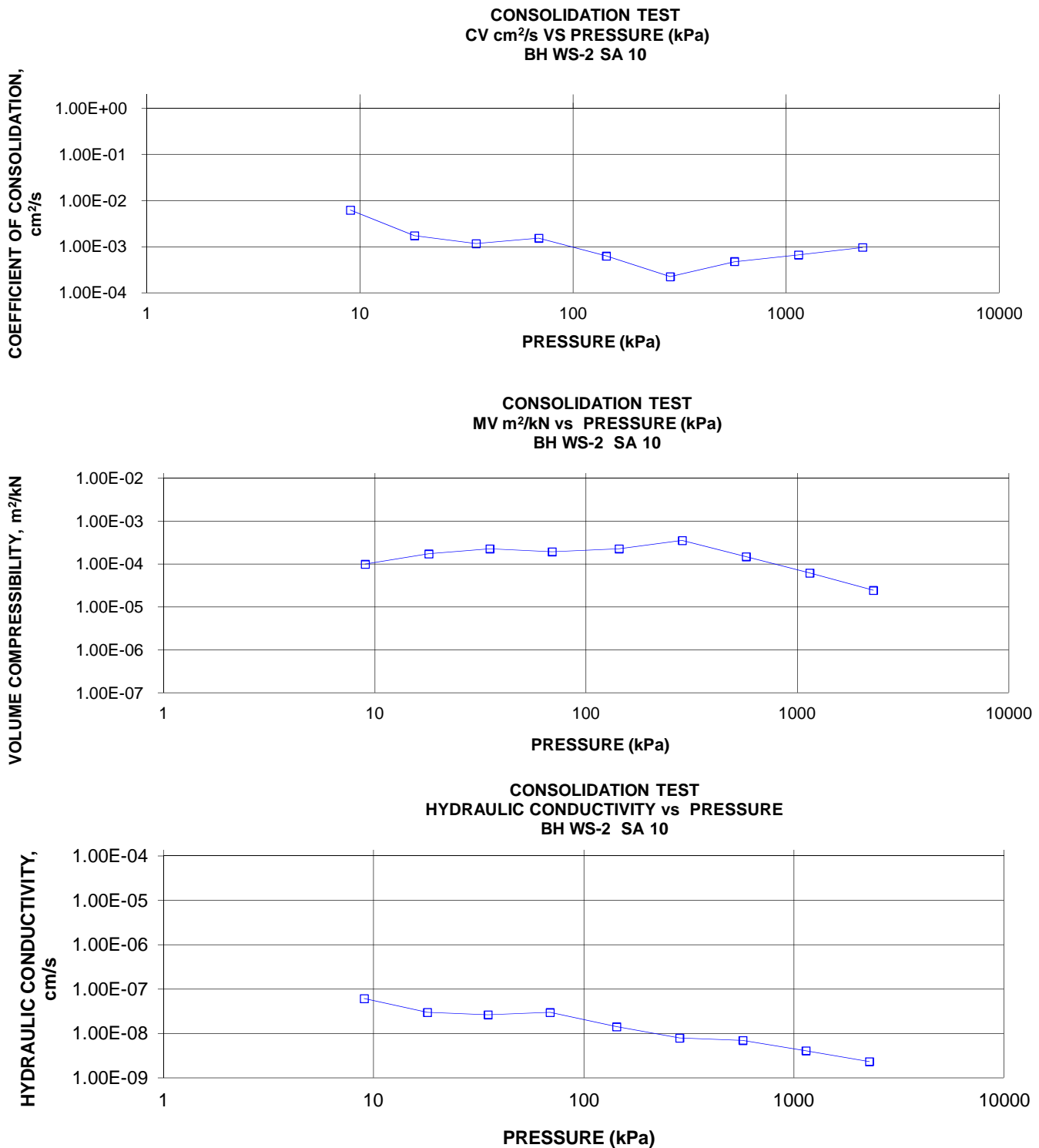
k calculated using  $\alpha$  based on t<sub>90</sub> values.**SAMPLE DIMENSIONS AND PROPERTIES - FINAL**

Sample Height, cm	2.245	Unit Weight, kN/m <sup>3</sup>	18.83
Sample Diameter, cm	6.33	Dry Unit Weight, kN/m <sup>3</sup>	14.78
Area, cm <sup>2</sup>	31.47	Specific Gravity, measured	2.74
Volume, cm <sup>3</sup>	70.64	Solids Height, cm	1.234
Water Content, %	27.36	Volume of Solids, cm <sup>3</sup>	38.84
Wet Mass, g	135.63	Volume of Voids, cm <sup>3</sup>	31.80
Dry Mass, g	106.49		

# CONSOLIDATION TEST SUMMARY

FIGURE B-8

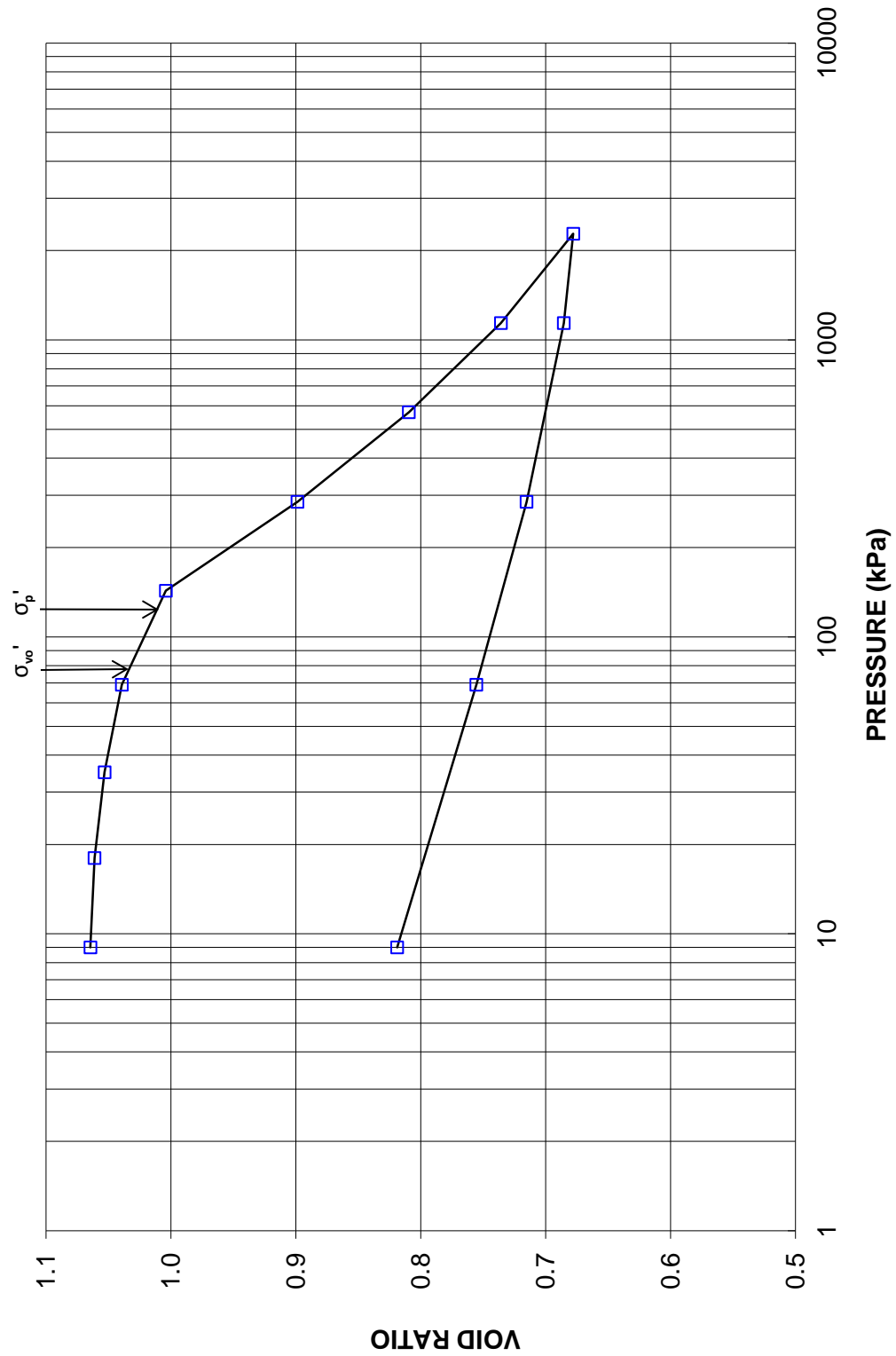
Pg. 2 of 4



# CONSOLIDATION TEST VOID RATIO VS LOG PRESSURE

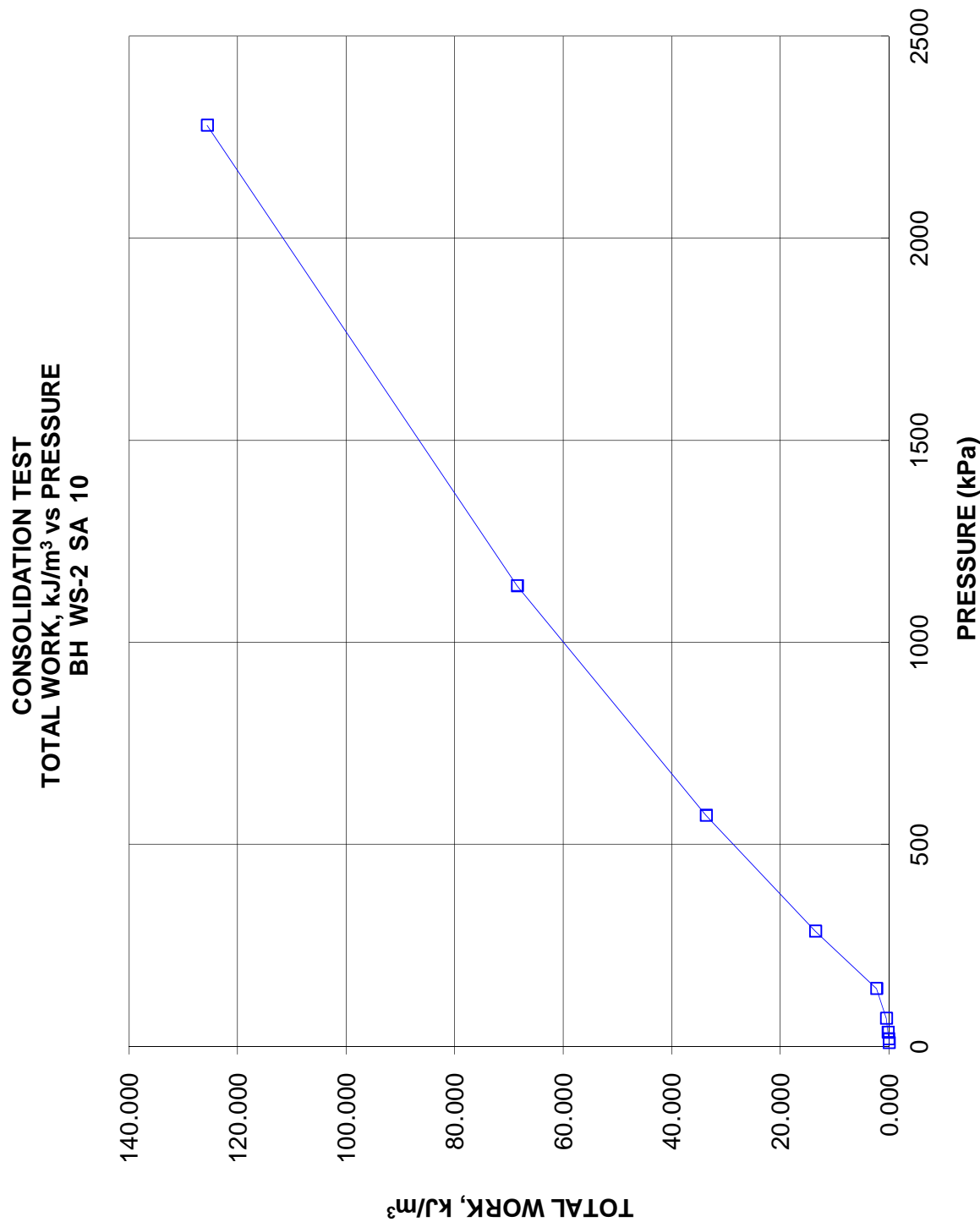
FIGURE B-8  
Pg. 3 of 4

CONSOLIDATION TEST  
VOID RATIO vs PRESSURE  
BH WS-2 SA 10



CONSOLIDATION TEST  
TOTAL WORK VS PRESSURE

FIGURE B-8  
Pg. 4 of 4





**CONSOLIDATION TEST SUMMARY****FIGURE B-9****Pg. 1 of 4****SAMPLE IDENTIFICATION**Project Number: 09-1191-0022  
Borehole Number: WS-3Sample Number: 8  
Sample Depth, m: 7.6**TEST CONDITIONS**Test Type Standard Load Duration, hr 24  
Oedometer Number 1  
Date Started 4-Jul-11  
Date Completed 19-Jul-11**SAMPLE DIMENSIONS AND PROPERTIES - INITIAL**Sample Height, cm 2.550 Unit Weight, kN/m<sup>3</sup> 17.95  
Sample Diameter, cm 6.330 Dry Unit Weight, kN/m<sup>3</sup> 12.73  
Area, cm<sup>2</sup> 31.47 Specific Gravity, measured 2.71  
Volume, cm<sup>3</sup> 80.25 Solids Height, cm 1.221  
Water Content, % 41.06 Volume of Solids, cm<sup>3</sup> 38.42  
Wet Mass, g 146.89 Volume of Voids, cm<sup>3</sup> 41.82  
Dry Mass, g 104.13 Degree of Saturation, % 102.2**TEST COMPUTATIONS**

Pressure	Primary	Corr.		Average					Total
kPa	Consolidation	Height	Void	Height	t <sub>90</sub>	cv.	mv	k	Work
		cm	Ratio	cm	sec	cm <sup>2</sup> /s	m <sup>2</sup> /kN	cm/s	kJ/m3
0	0	2.550	1.088	2.550					
9	0.02	2.548	1.087	2.549	200	0.0069	1.05E-04	7.06E-08	0.004
18	0.04	2.544	1.084	2.546	375	0.0037	1.58E-04	5.68E-08	0.023
35	0.10	2.534	1.075	2.539	614	0.0022	2.28E-04	4.98E-08	0.127
69	0.19	2.515	1.060	2.524	960	0.0014	2.22E-04	3.06E-08	0.522
107	0.24	2.491	1.040	2.503	3650	0.0004	2.50E-04	8.90E-09	1.368
143	0.28	2.463	1.017	2.477	6615	0.0002	2.74E-04	5.28E-09	2.701
285	1.14	2.349	0.924	2.406	3110	0.0004	3.15E-04	1.22E-08	12.605
571	1.10	2.239	0.834	2.294	2018	0.0006	1.51E-04	8.17E-09	32.647
1140	0.92	2.147	0.758	2.193	1500	0.0007	6.37E-05	4.24E-09	67.950
2279	0.94	2.053	0.682	2.100	1058	0.0009	3.22E-05	2.79E-09	142.407
1140	-0.08	2.062	0.688	2.057					
285	-0.34	2.095	0.716	2.079					
69	-0.46	2.142	0.754	2.119					
9	-0.93	2.235	0.830	2.188					

Note:

k calculated using  $\alpha$  based on t<sub>90</sub> values.**SAMPLE DIMENSIONS AND PROPERTIES - FINAL**Sample Height, cm 2.235 Unit Weight, kN/m<sup>3</sup> 18.41  
Sample Diameter, cm 6.33 Dry Unit Weight, kN/m<sup>3</sup> 14.52  
Area, cm<sup>2</sup> 31.47 Specific Gravity, measured 2.71  
Volume, cm<sup>3</sup> 70.33 Solids Height, cm 1.221  
Water Content, % 26.82 Volume of Solids, cm<sup>3</sup> 38.42  
Wet Mass, g 132.06 Volume of Voids, cm<sup>3</sup> 31.91  
Dry Mass, g 104.13

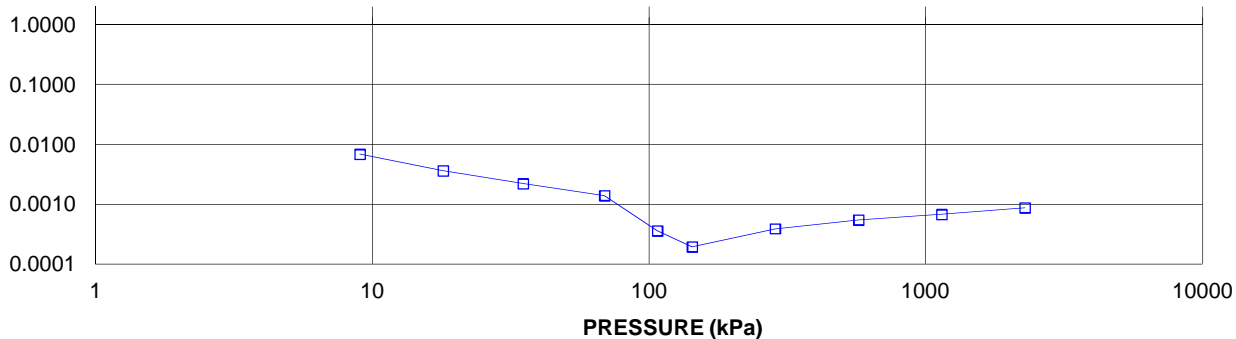
# CONSOLIDATION TEST SUMMARY

FIGURE B-9

Pg. 2 of 4

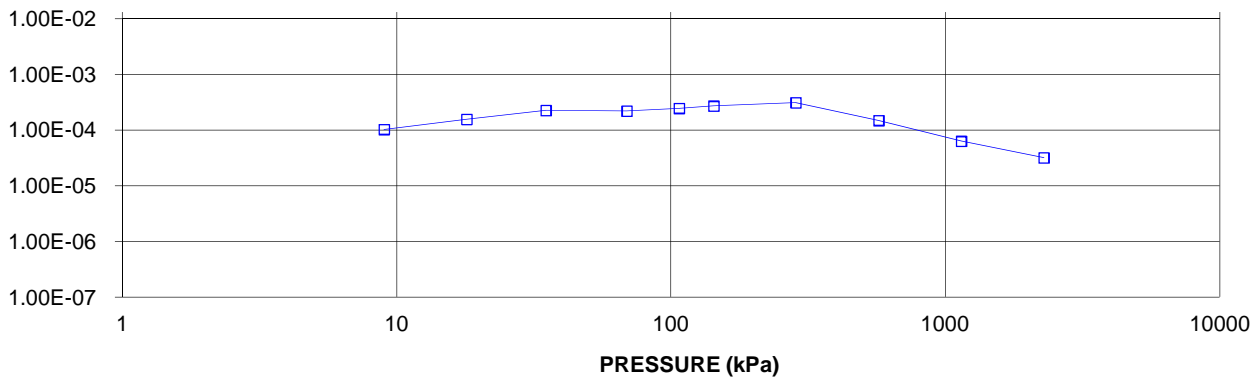
COEFFICIENT OF CONSOLIDATION,  
cm<sup>2</sup>/s

CONSOLIDATION TEST  
CV cm<sup>2</sup>/s VS PRESSURE (kPa)  
BH WS-3 SA 8



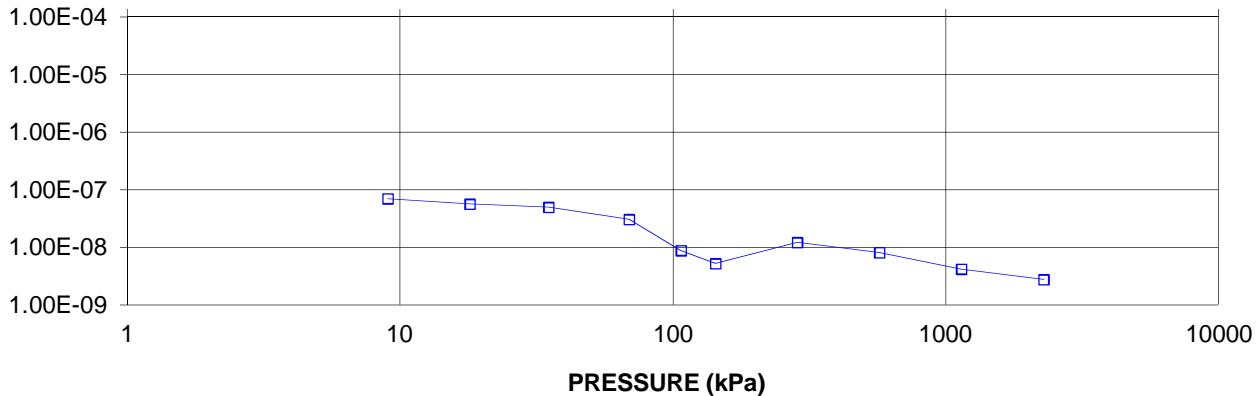
VOLUME COMPRESSIBILITY, m<sup>2</sup>/kN

CONSOLIDATION TEST  
MV m<sup>2</sup>/kN vs PRESSURE (kPa)  
BH WS-3 SA 8



HYDRAULIC CONDUCTIVITY,  
cm/s

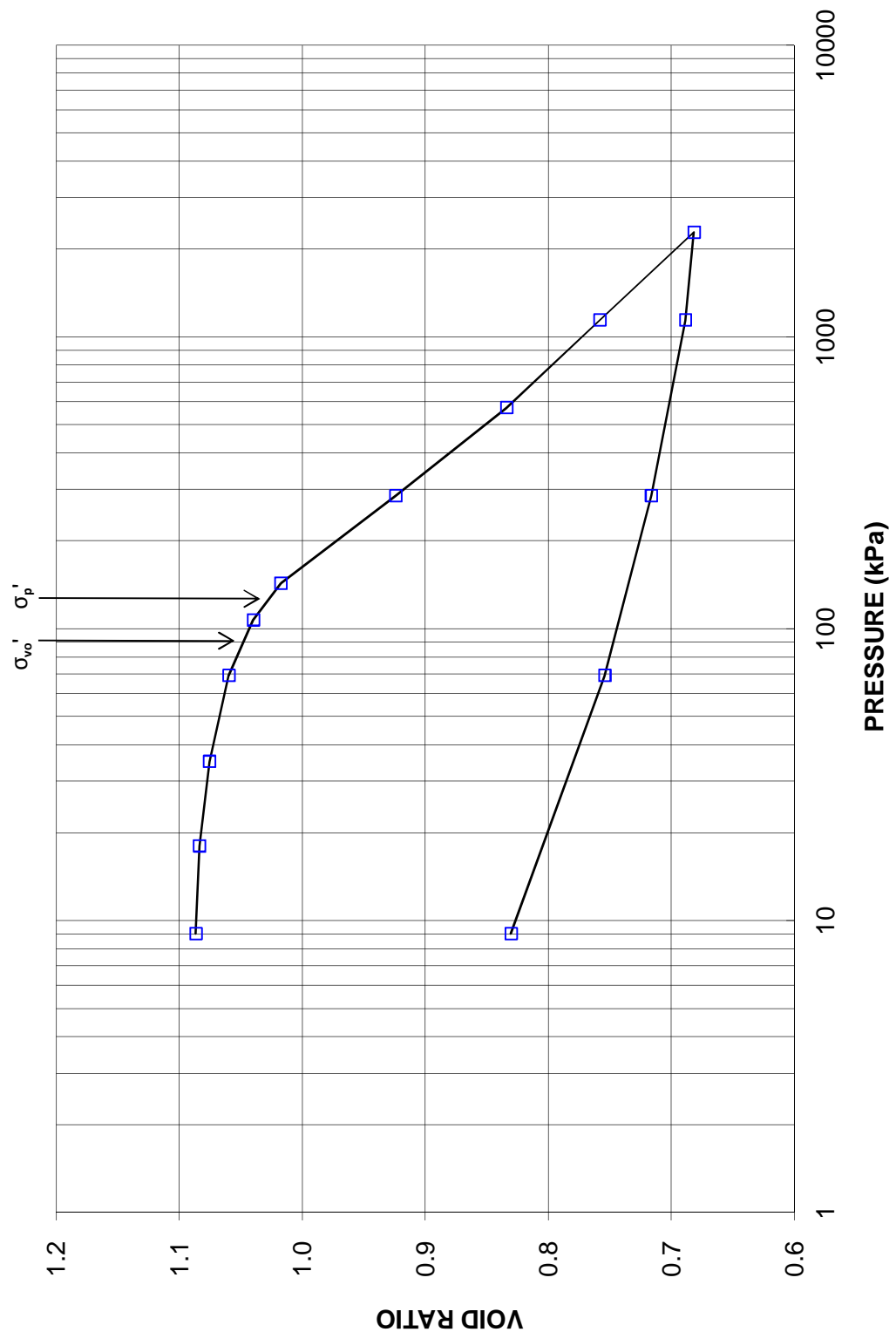
CONSOLIDATION TEST  
HYDRAULIC CONDUCTIVITY vs PRESSURE  
BH WS-3 SA 8



# CONSOLIDATION TEST VOID RATIO VS LOG PRESSURE

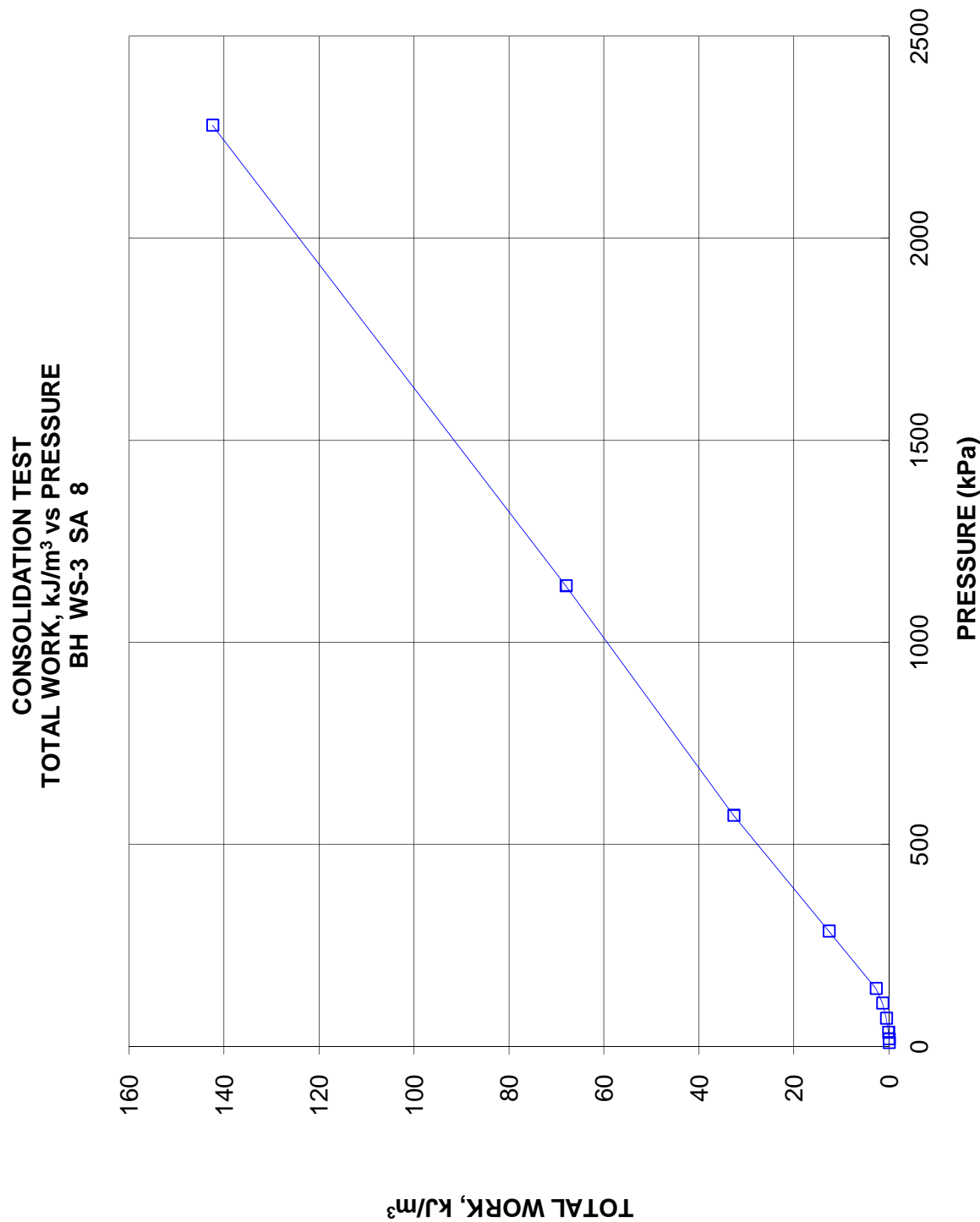
FIGURE B-9  
Pg. 3 of 4

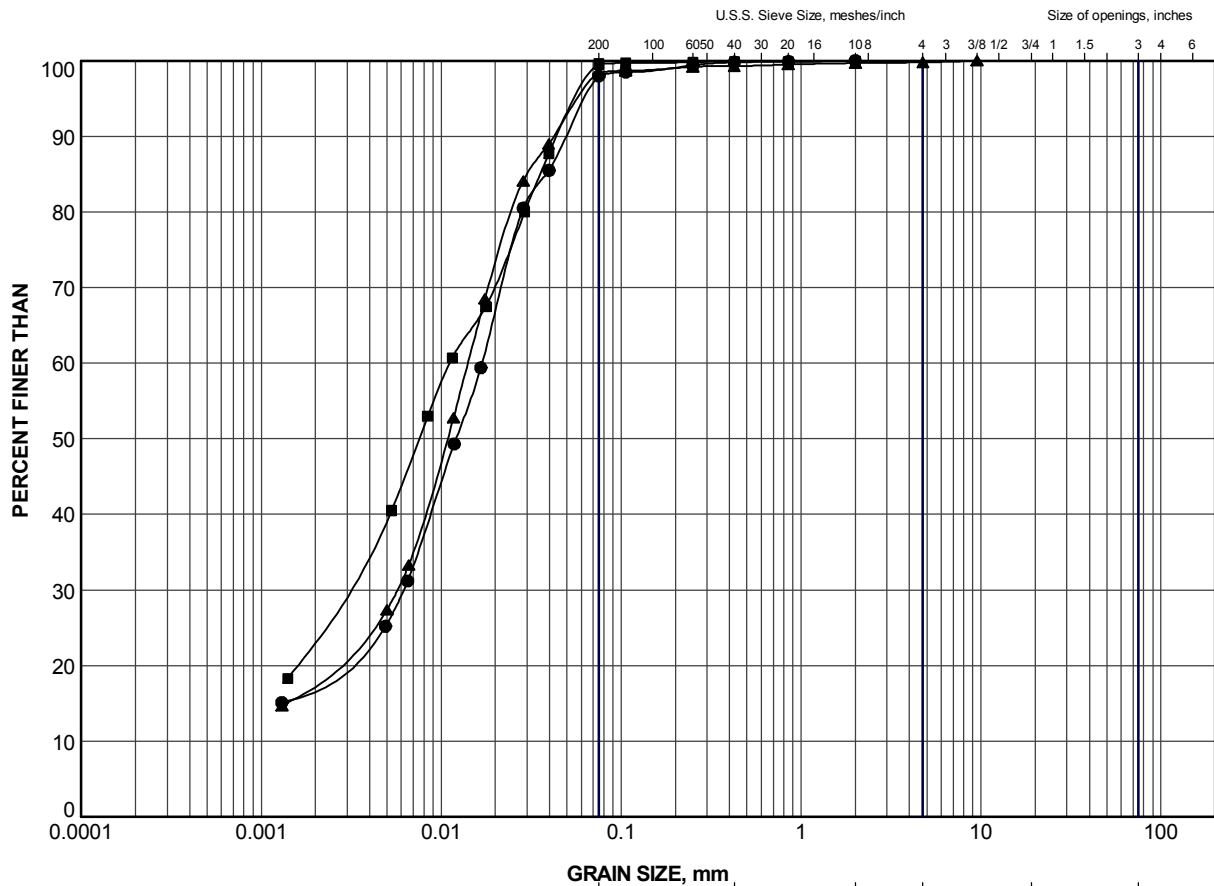
CONSOLIDATION TEST  
VOID RATIO vs PRESSURE  
BH WS-3 SA 8



CONSOLIDATION TEST  
TOTAL WORK VS PRESSURE

FIGURE B-9  
Pg. 4 of 4




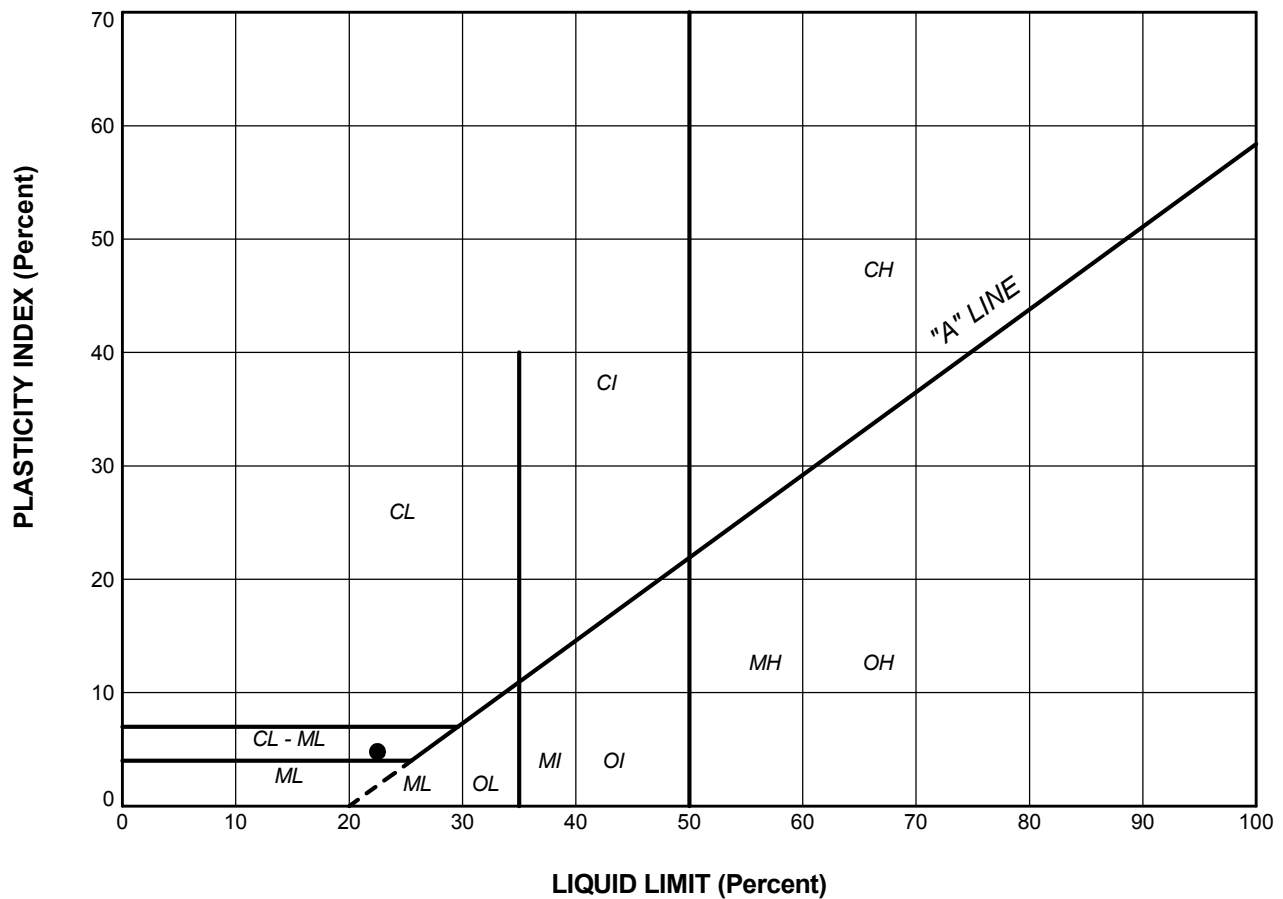


GRAVEL SIZE, mm						Cobble Size
CLAY AND SILT	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

### LEGEND


SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	WS-2	21	243.2
■	WS-3	17	246.3
▲	WS-3A	2	243.4

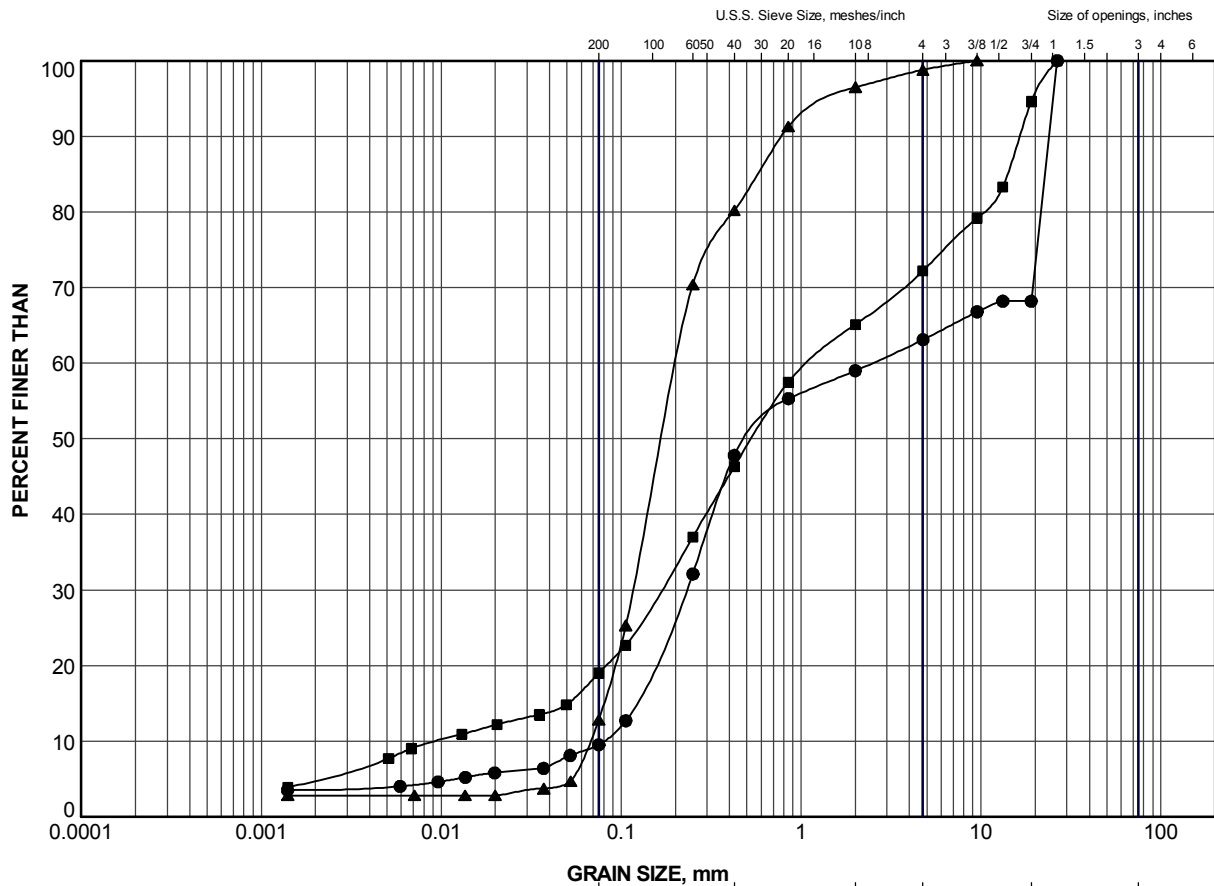
PROJECT					
WICKLOW RIVER BRIDGE SOUTH HIGHWAY 7036					
TITLE					
GRAIN SIZE DISTRIBUTION SILT					
PROJECT No.		09-1191-0022		FILE No. 09-1191-0022.GPJ	
DRAWN	JJL	Sep 2011	SCALE	N/A	REV.
CHECK	DAM	Sep 2011			
APPR		Sep 2011			
 <b>Golder Associates</b> SUDBURY, ONTARIO			<b>FIGURE B-10</b>		



### LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	WS-3	17	22.5	17.7	4.8


PROJECT					
WICKLOW RIVER BRIDGE SOUTH HIGHWAY 7036					
TITLE					
PLASTICITY CHART silt					
PROJECT No.		09-1191-0022		FILE No.	
DRAWN		J.J.L.		Sep 2011	
CHECK		DAM		Sep 2011	
APPR				Sep 2011	
 <b>Golder Associates</b> SUDBURY, ONTARIO				SCALE N/A REV.	
				<b>FIGURE B-11</b>	



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

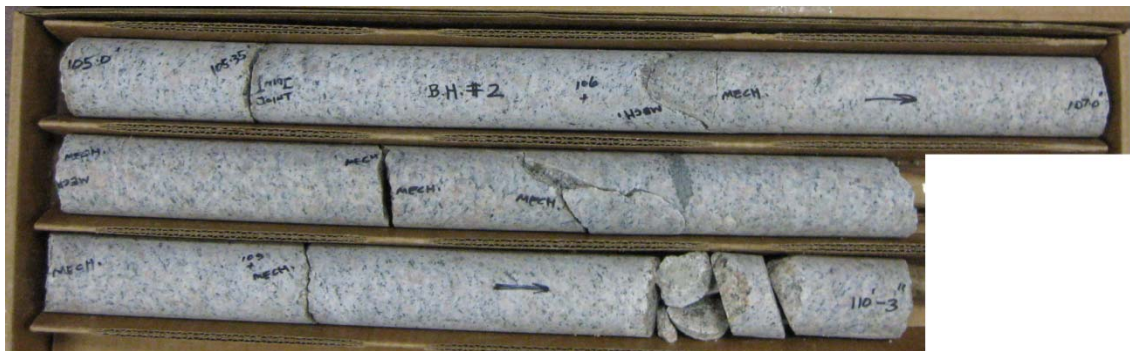
### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	WS-2	22	241.7
■	WS-3	21	240.2
▲	WS-3	23	238.7

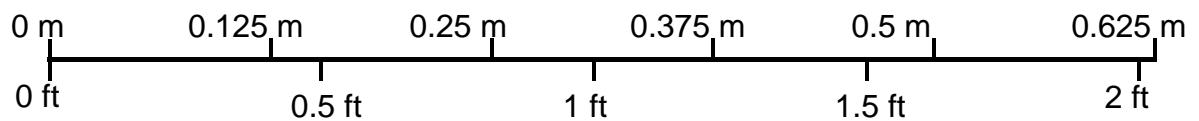
PROJECT						WICKLOW RIVER BRIDGE SOUTH HIGHWAY 7036					
TITLE						GRAIN SIZE DISTRIBUTION SAND TO SAND AND GRAVEL					
PROJECT No.			09-1191-0022			FILE No.			09-1191-0022.GPJ		
DRAWN	JJL	Sep 2011	SCALE		N/A	REV.					
CHECK	DAM	Sep 2011									
APPR		Sep 2011									
 <b>Golder Associates</b> SUDBURY, ONTARIO						<b>FIGURE B-12</b>					



Box 1: 30.5 m – 32.0 m



Box 2: 32.0 m – 33.6 m




PROJECT					WICKLOW RIVER BRIDGE SOUTH HIGHWAY 7036			
TITLE					BEDROCK CORE (Borehole WS-2)			
		PROJECT No. 09-1191-0022			FILE No. ----			
		DESIGN	DAM	SEPT 2011	SCALE AS SHOWN REV.			
		CADD	--					
		CHECK	SEMC	SEPT 2011				
		REVIEW						

Figure B-13

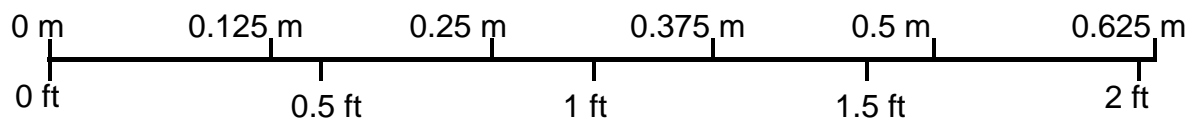





Box 1: 31.8 m – 34.0 m



Box 2: 34.0 m – 35.0 m



PROJECT		WICKLOW RIVER BRIDGE SOUTH HIGHWAY 7036	
TITLE		BEDROCK CORE (Borehole WS-3A)	
	PROJECT No.	09-1191-0022	FILE No. ----
	DESIGN	DAM	SEPT 2011
	CADD	--	
	CHECK	SEMC	SEPT 2011
	REVIEW		
		SCALE	AS SHOWN
		REV.	
Figure B-14			

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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[solutions@golder.com](mailto:solutions@golder.com)  
[www.golder.com](http://www.golder.com)

**Golder Associates Ltd.**  
**1010 Lorne Street**  
**Sudbury, Ontario, P3C 4R9**  
**Canada**  
**T: +1 (705) 524 6861**

