Foundation Investigation Report – Highway 17B Duchesnay Creek Sanitary Forcemain Crossing, Site No. 46-067

G.W.P. 5120-07-00

Geocres No. 31L-190

Prepared for:
Ministry of Transportation Ontario

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Project No. 165000836

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1.0 INTRODUCTION

Stantec Consulting Ltd. (Stantec) was retained by the Ministry of Transportation of Ontario (MTO) to undertake the foundations work required for the preliminary design for the rehabilitation or replacement for the Duchesnay Creek Bridge. A 150 mm sanitary forcemain is suspended along the span of the existing bridge. The forcemain will be relocated away from the existing and future bridge alignment.

This report has been prepared for the 150 mm sanitary forcemain crossing below Duchesnay Creek by means of Horizontal Directional Drilling (HDD). The preliminary proposed crossing is located on the north side of the existing Duchesnay Creek Bridge on Highway 17B. Stantec has also completed a Foundation Investigation and Design Report for the replacement of the Highway 17B bridge. Six additional boreholes were drilled for the forcemain crossing and a Geophysical Investigation which included seismic refraction and Ground Penetrating Radar (GPR) survey was completed to supplement the existing foundation information.

The site is located on Highway 17B, approximately 1.0 km east of Highway 17 and at the west end of the City of North Bay City Limits.

The Duchesnay Creek Bridge on Highway 17B is located at approximate Station 11+029.

This Investigation has been prepared specifically and solely for the proposed sanitary forcemain crossing of Duchesnay Creek at Highway 17B in North Bay, Ontario, and is in addition to the June 2014 Stantec report for the proposed replacement of the Duchesnay Creek Bridge titled 'Preliminary Foundation Investigation and Design Report – Highway 17B Duchesnay Creek Bridge Replacement, Site 43-067 (Geocres No. 31L-179)' and supersedes the January 2015 Draft Stantec report for a proposed utility bridge titled 'Draft Preliminary Foundation and Design Report – Highway 17B Duchesnay Creek Utility Bridge. Site No. 43-067 (Geocres No.31L-179).'

Project Number:	G.W.P.: 5120-07-00
Geocres No:	41L-190
Agreement Number:	5009-E-0064
Project Location:	Duchesnay Creek within the City of North Bay
Site Location:	Approximately 1.0 km east of Highway 17

2.0 SITE DESCRIPTION AND GEOLOGY

Site Location

The site location is shown on the Key Plan inset to Drawing No. 1, provided in Appendix A. The existing Bridge carries Highway 17B traffic across the Duchesnay Creek at Structure Site No. 43-067.

General Site Description

At this site, Highway 17B is oriented approximately in a west-east direction with chainage increasing from west to east. Highway 17B has a single lane of traffic in each direction with approximately 3 m wide shoulders (see Photographs 1 through 4 in Appendix A). Duchesnay Creek flows southerly at the Bridge location, emptying into Lake Nippissing approximately 70 m downstream. The proposed HDD crossing is approximately 6 m north of the north edge of the existing Duchesnay Creek Bridge.

In the vicinity of the existing bridge the surrounding area gently rises going southeast along Highway 17B. A CPR railway is located approximated 30 m south of the bridge location.

Existing Forcemain and Structure

The 150 mm sanitary forcemain is suspended on the north side of the existing structure. The approximate location of the forcemain is shown in Drawing No. 1 in Appendix A. The bridge is a 10-span 74 m long timber bridge with a 33 m main span timber truss resting on concrete piers. The remaining spans are 4.5 m long timber beams on timber pile bents.

The proposed HDD crossing is located on the north side of the existing Duchesnay Creek Bridge as shown in Drawing No. 1, in Appendix A.

Physiographic Description

The project site is located within the Canadian Shield and is characterized by frequent rock knobs. Soil and bedrock rock mapping published by the Ontario Geological Survey suggests that the subsurface conditions at the site consist of gravel and sand of glaciofluvial origin underlain by Mesoproterozoic migmatitic rock and gneisses of the Grenville Province's Central Gneiss Belt.

3.0 INVESTIGATION PROCEDURES

3.1 FIELD INVESTIGATION

3.1.1 Borehole Investigation

Prior to carrying out the field investigation, Stantec contacted the public utility authorities to clear the borehole locations of public and private utilities.

A geotechnical field investigation consisting of six additional boreholes was carried out for this assignment. The boreholes were designated BH14-5, BH14-6, BH15-7, BH15-8, BH15-9 and BH15-10. The six boreholes are in addition to BH13-3 and BH13-4 that were drilled for the previous foundation investigation for the bridge replacement. The borehole locations are shown on the Borehole Location Plan and Soil Strata, Drawing No.1 in Appendix A.

The field drilling program for BH13-3 and BH13-4 was carried out between September 25 and October 1, 2013. The drilling programs for the HDD alignment were carried out between November 11 and November 13, 2014, and March 31 to April 2, 2015. BH13-3 and BH13-4 were advanced with a truck-mounted CME 55 drill rig equipped for soil and bedrock sampling. BH14-5 and BH14-6 were advanced with portable drilling equipment capable of soil and bedrock sampling. BH15-7 to BH15-10 were advanced with a track-mounted CME drill rig equipped for soil and bedrock sampling.

The subsurface stratigraphy encountered in each borehole was recorded in the field by an experienced Stantec Field Technologist and Geotechnical Engineer. Split spoon samples were collected at regularly spaced intervals (typically every 760 mm for the top 10 m and every 1.5, for deeper strata) during the course of Standard Penetration Testing (ASTM D1586). In-situ shear vane tests were also performed at selected locations in the cohesive deposit using an MTO field vane in BH13-3, BH13-4 and BH15-7 to BH15-10 and using a GEOTECH EVT 2000 electric vane equipped with a slip-coupling above the vane to measure rod friction in BH14-5 and BH14-6. Dynamic cone penetration testing was carried out between 9.8 m and 16.8 m below ground surface in BH14-6. Bedrock coring was carried out in BH13-3, BH13-4 and BH14-5 with NQ size coring equipment.

All samples recovered were returned to Stantec's Ottawa laboratory for detailed classification and testing.

A vibrating wire piezometer (VWP) was installed in BH13-4 on September 26, 2013. Two VWPs were installed in BH13-3 on October 1, 2013. The VWP consisted of a sensor element with a small diameter cylindrical housing containing a pressure transducer and a thermistor. An output cable is attached to this unit to transmit the readings to the ground surface. The installation of the vibrating wire piezometer was carried out in accordance with the manufacturer's instructions. The collection zone consisted of at least 300 mm long region above and below the sensor tip and was backfilled with sand. The portion of the hole below the collection zone was backfilled with a bentonite seal. The portion of the hole above the collection zone was backfilled with a mix of bentonite and drill cuttings. Groundwater readings were carried out immediately upon completion of the installation and a week later on September 26 and five days later, on October 1, 2013. Calibration data sheets for the vibrating wire pressure transducers are provided in Appendix B.

After completion of drilling, boreholes were backfilled with auger cuttings mixed with bentonite. BH15-7 to BH15-10 were backfilled with cement based grout. Road holes were sealed with cold asphalt patch where applicable.

Rock core samples were logged and photographed and the Rock Quality Designation (RQD) and Mohs Hardness values were estimated for recovered samples. Mohs Hardness tests were performed on representative rock samples to estimate the Mohs scale of relative hardness value of the rock for each core run. The hardness scale ranges from 1 (talc) to 10 (diamond). The hardness of a rock sample was estimated by trying to scratch it with several materials of known hardness. According to Mohs hardness rating, objects with higher Mohs numbers will scratch those lower on the scale.

Hydro-excavation operations were undertaken to locate the existing sanitary forcemain in proximity to BH15-7 to BH15-10. The hydro-excavation holes were backfilled with granular material.

3.1.2 Geophysical Investigation

A Geophysical Investigation using seismic refraction and Ground Penetrating Radar (GPR) was completed by Geophysics GPR International Incorporated to provide more information on the depth of bedrock at the proposed HDD crossing. Three seismic refraction profiles were completed, with two in the north/south direction along the east and west shores of the creek and one in the east/west direction along the proposed HDD alignment. GPR profiles were completed across the river at three locations to estimate the bathymetry of the creek. The Geophysical Investigation report from Geophysics GPR International Inc. is included in Appendix D. The seismic refraction profiles were completed using an ABEM Terraloc Mark 6 Seismograph with twenty-four (24) geophones spaced every three meters and a combination of twenty-four (24) geophones and hydrophones for the river crossing profile. A Buffalo gun source was used to generate the seismic signal. The GPR profiles for the three river crossings were completed using an SIR-3000 Single-Channel GPR Data Acquisition System, placed on a floatation device, using a rope system to allow the equipment across the river.

3.2 LOCATION AND ELEVATION SURVEY

The elevation and coordinates (northing and easting) of the boreholes, the geophones for seismic refraction, and the start and end points for the GPR crossings were determined using a Global Positioning System (GPS) navigation device, Trimble Geo XH, capable of decimeter accuracy.

The ground surface elevations and coordinates of the borehole locations are provided in Drawing 1 of Appendix A.

The ground surface elevations at the borehole locations are also shown on the Borehole Records included in Appendix B. Summary information pertaining to the boreholes included in this report is given in Table 3.1.

Table 3.1: Borehole Information Summary

	Borehole Location							
	BH13-3	**BH13-4**	**BH14-5**	**BH14-6**	**BH15-7**	**BH15-8**	**BH15-9**	**BH15-10**
MTM Zone 10 Coordinates Northing Easting	5132120 304519	5132061 304580	5132111 304542	5132082 304571	5132174 304474	5132150 304497	5132042 304614	5132006 304651
Ground Surface Elevation, m	204.5	206.4	196.0	202.1	203.8	204.0	207.5	207.9
Total Depth Drilled, m	22.8	29.7	9.0	16.8	8.2	15.1	15.1	8.2
End of Borehole Elevation, m	181.7	176.7	187.0	185.3	195.6	188.9	192.4	199.7
Depth Augered, m	19.6	26.7	5.6	16.8	8.2	15.1	15.1	8.2
Depth Cored, m	3.2	3.0	3.4	0	0	0	0	0
Number of Soil Samples	19	21	8	12	8	20	20	11

3.3 LABORATORY TESTING

All samples were taken to Stantec's Ottawa laboratory where they were subjected to a detailed visual examination by a Geotechnical Engineer.

The geotechnical laboratory testing program for the borehole samples is summarized in Table 3.2.

Table 3.2: Geotechnical Laboratory Testing Program

Test Description	Number of Tests	Remarks
Moisture Content	119	by Stantec
Atterberg Limits	22	by Stantec
Grain Size Distribution	32	by Stantec
Consolidation (oedometer)	4	by Golder
Unconfined Compression (soil)	4	by Golder
Unconfined Compression (rock)	3	by Stantec
Specific Gravity	4	by Golder

Three soil samples were tested for pH, soluble sulphate content, chloride content, and resistivity.

Samples remaining after testing will be placed in storage for a period of one year after issuance of the final report. After the storage period, the samples will be discarded.

4.0 SUBSURFACE CONDITIONS

The details of the subsurface conditions observed in the eight boreholes are presented in the Borehole Records provided in Appendix B. An explanation of the symbols and terms used to describe the Borehole Records is also provided in Appendix B.

The borehole location plan and stratigraphic section of the soils encountered within the boreholes is provided in Drawing No. 1 of Appendix A.

4.1 OVERBURDEN

In general, the subsurface stratigraphy of BH13-3 and BH13-4 consisted of asphalt pavement over roadway / embankment fill materials over silty sand, over silty clay, over a thin silty sand to sandy clayey silt till deposits overlying granitic bedrock. The subsurface stratigraphy of BH14-5 and BH14-6 consisted of organic soil, over silty sand to sandy silt, over silty clay to clayey silt, over a thin till deposit overlying granitic bedrock. The soil stratigraphy of BH15-7 to BH15-10 generally consisted of organic soil, over embankment fill materials or sand, over silty sand to sandy silt, over silt to clayey silt to silty clay.

Where a value is provided for the percentage of clay-sized particles, the value represents the percentage of particles finer than a nominal size of 0.002 mm.

4.1.1 Pavement Structure and Fill Material

The pavement structure observed in both boreholes advanced within Highway 17B at this site included:

Asphalt	200 to 250 mm
Fill	3.6 to 4.4 m

The soil fill within the roadway platform generally consisted of sand with silt and gravel. The fill layers at BH13-3 and BH13-4 had bottom elevations of 200.7 m and 201.8 m.

A layer of rockfill was encountered in BH13-4 between elevation 205.0 m to 201.8 m.

In BH13-4, coring was carried out to advance through the inferred rockfill. The Standard Penetration Test (SPT) blow count (N-values) for fill materials ranged from 1 to 36 blows per 0.3 m suggesting a very loose to dense state.

Borehole BH15-7 and BH15-8 were advanced on the shoulder of Highway 17B. The soil fill in BH15-7 and BH15-8 consisted of poorly graded sand; as noted in Section 4.1.2 topsoil was present overlying the fill. The fill layers at BH15-7 and BH15-8 had bottom elevations of 202.3 m and 202.0 m, respectively.

Index tests carried out on representative samples from the fill material yielded:

Gravel:	6 to 16%
Sand:	78 to 89%
Fines (silt & clay):	1 to 13%
Moisture content:	3 to 19%

The Unified Soil Classification System group symbol for the fill material is SM (silty sand with gravel) and SP (poorly graded sand with/without gravel).

Hydro-excavations in proximity to BH15-7 to BH15-10 were backfilled with granular material and compacted with a vibratory tamper. An index test carried out on a representative sample from the BH15-7 material yielded:

Gravel:	52%
Sand:	42%
Fines (silt & clay):	6%
Moisture content:	8%

A representative grain size distribution plot is provided on Figure 1 in Appendix C. The Unified Soil Classification System group symbol for the fill is GW-GM (well graded gravel with silt and sand).

4.1.2 Organic Soil and Topsoil

A 600 mm thick layer of organic soil with wood was encountered at ground surface in borehole BH14-5. Topsoil layers encountered at ground surface in BH14-6, BH15-7, BH15-9 and BH15-10 were 100 mm, 450 mm, 50 mm and 150 mm thick, respectively.

4.1.3 Sand and Silty Sand

A 1.2 m thick poorly graded sand layer was encountered directly beneath the fill in BH13-4; this layer had a bottom elevation of 200.6 m. Layers of poorly graded sand were also encountered beneath the topsoil or at ground surface in BH15-9 and BH15-10 and were 3.8 m and 1.9 m thick respectively, with base elevations of 203.7 and 205.8 m respectively.

A silty sand deposit was encountered beneath the fill material in BH13-3, BH15-7 and BH15-8, beneath the poorly graded sand in BH13-4, BH15-9 and BH15-10, and beneath the organic soil in BH14-5 and BH14-6. The layer was 0.9 m to 3.8 m thick with base elevations from 193.7 m to 202.5 m.

The SPT N-values for these deposits ranged between 1 and 21 blows per 0.3 m suggesting a very loose to compact state.

Index tests carried out on representative samples from the poorly graded sand and silty sand deposits yielded the following:

Gravel:	0 to 5%
Sand:	57 to 96%
Fines (silt & clay):	4 to 43%
Moisture content:	3 to 32%

The Unified Soil Classification System group symbols for this material are SP (poorly graded sand), SP-SM (poorly graded sand with silt), and SM (silty sand).

Representative grain size distribution plots are provided on Figure 2 in Appendix C.

4.1.4 Silt and Sandy Silt

A silt deposit was encountered in BH14-5 and BH15-9 immediately beneath the sand deposit. The layers were 0.8 and 5.4 m thick with base elevations of 193.0 and 194.7 m.

A sandy silt deposit was encountered in BH13-4 and BH14-6, immediately beneath the sand deposit. The layer was 1.5 m thick with base elevations of 196.5 and 198.2 m.

The SPT N-values for this deposit ranged between 2 and 6 suggesting a very loose to loose state.

Index tests carried out on representative samples from the silt layer yielded the following results:

Gravel:	0%
Sand:	2 to 42%
Silt:	52 to 77%
Clay:	6 to 22%
Moisture Content:	18 to 33%
Limits:	Non-plastic

The Unified Soil Classification system group symbol for this material is ML (silt, silt with sand, or sandy silt). Representative grain size distribution plots for this layer are given in Figures 2 and 3 in Appendix C.

4.1.5 Silty Clay and Clayey Silt

A silty clay to clayey silt layer was encountered in all eight boreholes immediately beneath the silty sand, sandy silt and silt layers. This deposit consisted predominantly of a mixture of silty clay and clayey silt material. This layer was 2.2 m to 15.4 m thick with base elevations of 188.0, 181.1 and 190.7 m in BH13-3, BH13-4 and BH14-5 respectively. The remaining boreholes were terminated in the layer.

The SPT N-values for the silty clay layer ranged from 0 (weight of hammer) to 15 blows per 0.3 m. Dynamic cone penetration results ranged from 5 to 14 blows per 0.3 m.

The in-situ undrained shear strength of the silty clay layer ranged from 15 kPa to greater than 100 kPa suggesting a soft to very stiff consistency. The typical in-situ undrained shear strength of the silty clay layer ranged from 40 kPa to 70 kPa with and average value of 50 kPa suggesting a firm to stiff consistency. The undrained shear strength is generally higher (greater than 100 kPa) below approximate elevation 194.0 m in BH13-3 and below elevation 185.0 m in BH13-4.

The unconfined compression test results indicated an undrained shear strength range of 26 to 55 kPa. The unconfined compression test results are summarized in the following table. The results are also provided in Appendix C.

Table 4.1: Unconfined Compression Test Results (silty clay layer)

Sample ID	Sample Elevation (m)	Moisture Content (%)	Unconfined Compressive Strength, UCS (kPa)	Estimated Undrained Shear Strength, S_u (=1/2*UCS) (kPa)	Strain at Failure (%)
BH13-3 ST-9	198.1	44.5	53	26	2.8
BH13-3 ST-14	192.0	29.1	93	46	10.0
BH13-4 ST-12	194.0	33.0	59	29	15.0
BH13-4 ST-16	188.0	36.5	111	55	7.4

Index tests carried out on representative samples from the clayey silt and silty clay layer yielded the following results:

Gravel:	0%
Sand:	0 to 2%
Silt:	47 to 78%
Clay:	18 to 52%
Moisture Content:	23 to 50%

Atterberg limits tests carried out on twenty-two representative samples from this layer indicated a plasticity index range of 9 to 26. The USCS group symbol for this layer is CI (silty clay; intermediate plasticity) to CL (clayey silt; low plasticity). Representative grain size distribution plots for this layer are given in Figures 3 and 4 of Appendix C and the corresponding plasticity charts are given in Figure 6 and 7 of Appendix C.

The results of consolidation tests carried out on four silty clay samples from BH13-3 and BH13-4 are provided in Appendix C. The consolidation and index property test results for these samples are summarized in the following table.

Table 4.2: Consolidation Test Results

Sample ID	Sample Elevation	Moisture Content	Initial Void Ratio/Initial Unit Weight	Estimated Effective Overburden Stress P'_o	Estimated Preconsolidation Stress, P'_c	Recompression Index, Cr	Compression Index, Cc
BH13-3 ST-9	198.0	50.2	1.36/17.0 kN/m^3	84	146	0.066	0.85
BH13-3 ST-14	192.1	35.1	0.96/18.4 kN/m^3	131	156	0.050	0.35
BH13-4 ST-12	193.7	38.7	1.05/18.1 kN/m^3	182	235	0.039	0.52
BH13-4 ST-16	187.6	39.1	1.07/18.1 kN/m^3	230	290	0.051	0.58

4.1.6 Silty Sand

A 1.8 m thick layer of sand was encountered immediately beneath the silty clay layer in BH13-3 with a base elevation of 186.2 m.

An SPT N-value of 11 was obtained in this deposit suggesting a compact state. One sample of this layer had a moisture content of 29%.

4.1.7 Till

A till deposit with predominantly granular material was encountered in BH13-3 and BH13-4 beneath the silty clay. A till deposit of silt with sand material was encountered in BH14-5 beneath the clayey silt. The thickness of the till deposit was approximately 0.3 m to 1.4 m and extended to an approximate base elevations 184.9, 179.7 and 190.4 m.

The Standard Penetration Test (SPT) blow count (N-values) for this deposit ranged from 38 to greater than 100 blows per 0.3 m.

Index tests carried out on representative samples from this material yielded the following:

Gravel: 0 to 7%
Sand: 16 to 59%
Fines (silt and clay): 34 to 84%
Moisture content: 12 to 43%

The Unified Soil Classification System group symbol for this deposit ranged from SM (silty sand) in BH13-3 to CL (sandy clayey silt some gravel) in BH13-4 to ML (silt with sand) in BH14-5.

Representative grain size distribution plots for this material are provided in Figure 5 of Appendix C. The plasticity chart is provided in Figure 6.

4.1.8 Bedrock

Bedrock was encountered in boreholes BH13-3, BH13-4 and BH14-5 immediately beneath the till deposit at approximate elevations of 184.9, 179.7 and 190.4 m. The bedrock consisted predominantly of granite with minor calcite intrusions.

The Rock Quality Designation (RQD) values ranged between 18% and 96%, indicating a very poor to excellent rock mass quality. The typical range in RQD within the three rock cored boreholes was 50% to 96% indicating a fair to excellent rock quality. The lower RQD values of 18% and 21% were encountered within the top 1.5 m of bedrock and were observed to be slightly weathered. The Total Core Recovery (TCR) was 51% to 100%. A detailed description of the rock core is provided in Field Core Logs. Rock core photographs are provided in Appendix B.

Unconfined compressive strength tests were carried out on three bedrock samples. The results of this test are summarized in Table 4.3. The average unconfined compressive strength from the three tests ranged from 35 MPa to 208 MPa with an average of 126 MPa which indicates very strong bedrock strength.

Table 4.3: Unconfined Compressive Strength of Rock Cores

Borehole No	Test Elevation (m)	Unconfined Compressive Strength (MPa)
BH13-3	184.1	136
BH13-4	179.8	35
BH14-5	189.5	208

The Geophysical Investigation report prepared by GPR Geophysics International Inc. is provided in Appendix D and presents interpreted bedrock depths along three seismic refraction profiles. Drawing No. 2 in Appendix A shows a Bedrock Elevation Contour Plot and the bedrock profile along the three sections interpreted from the seismic data.

The geophysical survey data indicates that the bedrock surface rises up to about elevation 193.2 m beneath the creek on the north side of the bridge.

4.1.9 Chemical Analysis

Three representative samples retrieved from BH13-3, BH15-8 and BH15-9 were tested for resistivity, pH, and water soluble sulphates and chloride concentrations. The results of this chemical analysis are provided in Table 4.4.

Table 4.4: Results of Chemical Analysis

Borehole No	Sample No.	Depth (m)	pH	Chloride (µg/g)	Sulphate (µg/g)	Resistivity (Ohm-m)
BH13-3	SS-5	3.05 to 3.66	6.5	477	16	12
BH15-8	SS-1	0 to 0.61	7.6	639	24	8
BH15-9	SS-2	0.76 to 1.37	7.3	7	<5	210

4.2 GROUNDWATER

Vibrating wire piezometers (VWP) were installed in BH13-3 (two VWP) and BH13-4 after completion of drilling on October 1 and September 26, 2013. The groundwater in these piezometers was measured on October 1, 2013. The depth to groundwater was also inferred in all eight boreholes at the time of drilling, on September 25 and 30, 2013, November 11 and 12, 2014, and March 30 to April 2, 2015. The measured and inferred (i.e., at the time of drilling) groundwater levels are summarized in Table 4.5 below.

Table 4.5: Measured and Inferred Groundwater Levels (time of drilling)

Borehole No	Ground Surface Elevation (m)	Vibrating Wire Tip Elevation (m)	Groundwater	
			Depth (m)	Elevation (m)
		Measured		
BH13-3	204.5	199.9	2.4	202.1
		195.4	3.1	201.4
BH13-4	206.4	191.2	6.4	200.0
		Inferred		
BH13-3	204.5	-	4.8	199.7
BH13-4	206.4	-	6.8	199.6
BH14-5	196.0	-	0.6	195.4
BH14-6	202.1	-	1.8	200.3
BH15-7	203.8	-	1.5	202.3
BH15-8	204.0	-	2.0	202.0
BH15-9	207.5	-	2.4	205.1
BH15-10	207.9	-	2.1	205.8

Notes:

(1) The two vibrating wire piezometers installed at two different elevations in BH13-3 indicate that the groundwater elevation at shallower depth is higher than that at a deeper depth.

(2) The vibrating wire piezometer in BH13-4 was installed in the deeper silty clay deposit whereas the groundwater was inferred in the shallower silty sand deposit.

Fluctuations in the groundwater level due to seasonal variations or in response to a particular precipitation event should be anticipated.

The Geophysical Investigation completed by GPR Geophysics International Inc. found in Appendix D provides interpreted bedrock and water table depths along three seismic refraction profiles. Drawing No. 2 in Appendix A shows the three profiles with interpreted water table depths and the bathymetry of the river.

4.3 SITE RECONNAISSANCE

On October 30, 2013, Mr. Christopher McGrath, P.Eng., visited the site to observe the condition of the creek slopes near the Highway 17B bridge. Several distresses were observed on the east slope of Duchesnay Creek approximately 30 m to 50 m to the north of the bridge which indicate the slope on the north side of the bridge is unstable. These distresses, photographs and slope stability analysis can be found in the June 2014 Stantec report for the proposed rehabilitation or replacement of the Duchesnay Creek Bridge titled 'Preliminary Foundation Investigation and Design Report – Highway 17B Duchesnay Creek Bridge Replacement, Site 43-067 (Geocres No. 31L-179).'

5.0 MISCELLANEOUS

The field work was carried out under the supervision of Alan Brotton, Geotechnical Engineering Technologist and Zachary Popper, P.Eng., Geotechnical Engineer, under the direction of Chris McGrath, P.Eng., Senior Geotechnical Engineer.

The drilling equipment was supplied and operated by Landcore Drilling of Chelmsford, Ontario. Traffic control was provided by Bartletts Towing of North Bay, Ontario. The hydro-excavation equipment was supplied and operated by Badger Daylighting Incorporated of North Bay, Ontario. The Geophysical Investigation was carried out by Geophysics GPR International Inc.

Geotechnical laboratory testing was carried out at the Stantec's Ottawa and Golder's Mississauga laboratories. Chemical testing on soil samples was carried out by Paracel Laboratories in Ottawa.

This report was prepared by Zachary Popper, and reviewed by Chris McGrath and Raymond Haché, MTO Designated Principal Contact.

6.0 CLOSURE

A subsurface investigation is a limited sampling of a site. The subsurface conditions described herein are based on information obtained at specific borehole locations. Conditions between and beyond the borehole locations must be expected to vary beyond that described herein.

Should any conditions be encountered at the site, which differ from those at the borehole locations as described herein, we request that we be notified immediately in order to assess the additional information and revise the content and recommendations in this report, as required.

Respectfully submitted,

STANTEC CONSULTING LTD.

for

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Geotechnical Engineer

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Designated Principal MTO Foundation Contact

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APPENDIX A

Drawing No. 1 – Borehole Location Plan and Soil Strata

Drawing No. 2 –Interpreted Seismic and Radar Profiles

Site Photographs

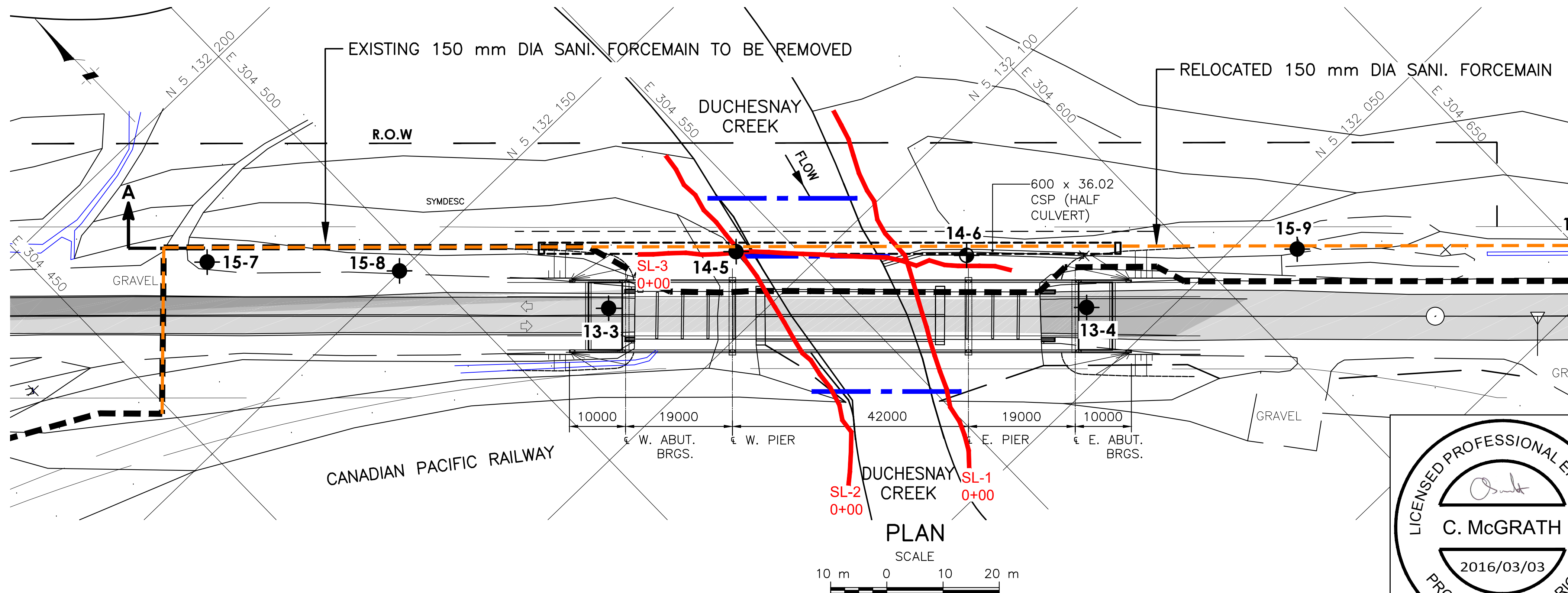
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

PLATE No
CONT
WP 5120-07-00

SHEET

HIGHWAY 17B, SITE 43-067
DUCHESNAY CREEK
BOREHOLE LOCATIONS & SOIL STRATA

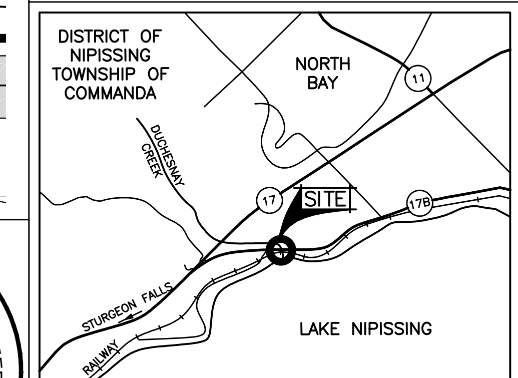
Stantec



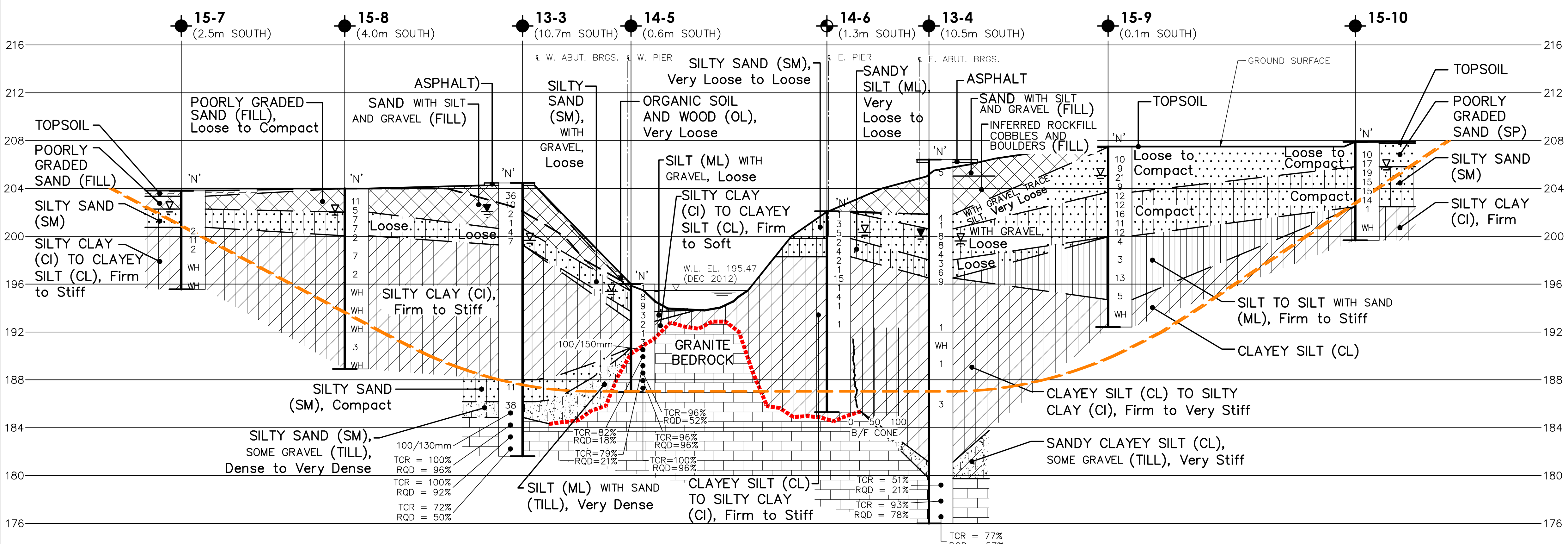
PLAN
SCALE
10 m 0 10 20 m

LICENSED PROFESSIONAL ENGINEER
C. McGRATH
2016/03/03
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
J.G.A.R. HACHÉ
2016/03/03
PROVINCE OF ONTARIO



KEY PLAN
1 km 0 1 2 km



CROSS SECTION A-A'
SCALE
10 m 0 10 20 m (HORIZONTAL)
4 m 0 4 8 m (VERTICAL)

LEGEND

	Borehole
	Borehole & Cone
CONE	Blows/0.3m (60° Cone, 475 J/blow)
N	Blows/0.3m (Std Pen Test, 475 J/blow)
WH	Weight of Hammer
	WL at time of investigation, Sept 2013 to Mar 2015
	WL Measured Oct 2013
(1.5m NORTH)	Offset from Cross Section Line in meters
	Seismic Refraction
	GPR Alignment
	Rock Profile Interpreted From Seismic Refraction
	Proposed 150 mm HDPE Forcemain (Draft)

No	ELEVATION	MTM ZONE 10 COORDINATES NORTH	EAST
13-3	204.5	5 132 119.5	304 518.7
13-4	206.4	5 132 060.5	304 579.9
14-5	196.0	5 132 111.0	304 542.0
14-6	202.1	5 132 082.0	304 571.0
15-7	203.8	5 132 174.4	304 473.8
15-8	204.0	5 132 150.2	304 496.6
15-9	207.5	5 132 041.9	304 614.0
15-10	207.9	5 132 006.1	304 651.4

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

NOTES

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

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

REVISIONS DATE	BY	DESCRIPTION

GEOCRES No 41L-190			
HWY No 17B			DIST
SUBM'D BB	CHECKED	DATE 2015-06-16	SITE 43-067
DRAWN GBB	CHECKED	APPROVED	DWG 1

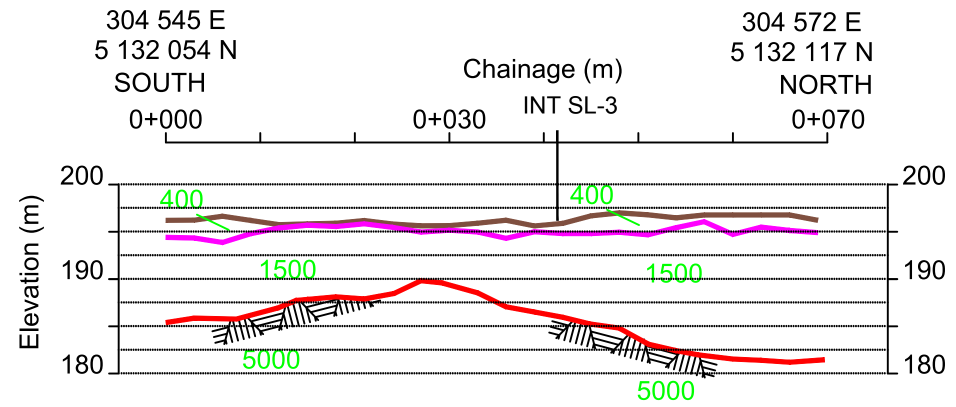
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

PLATE No
CONT
WP 5120–07–00

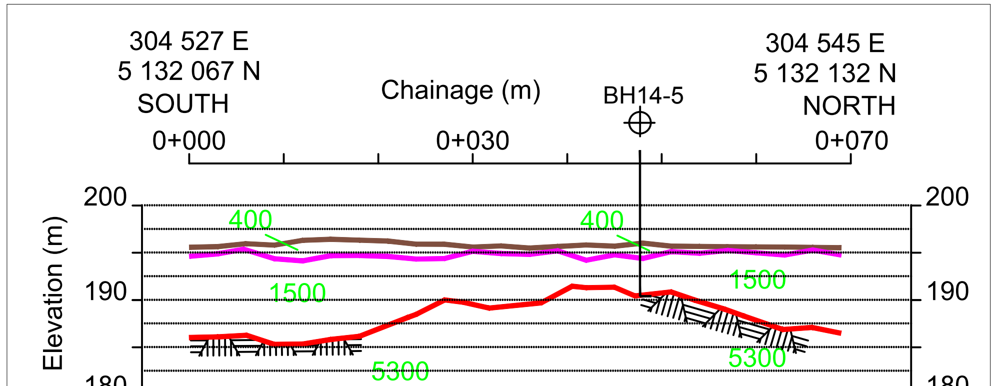
HIGHWAY 17B, SITE 43–067
DUCHESNAY CREEK CROSSING
INTERPRETED SEISMIC & RADAR PROFILES

SHEET

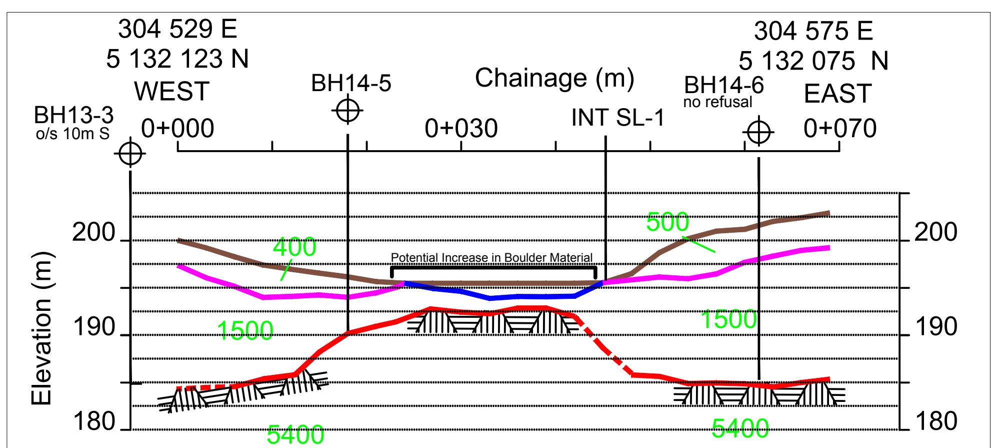
GEOPHYSICS GPR INTERNATIONAL INC.



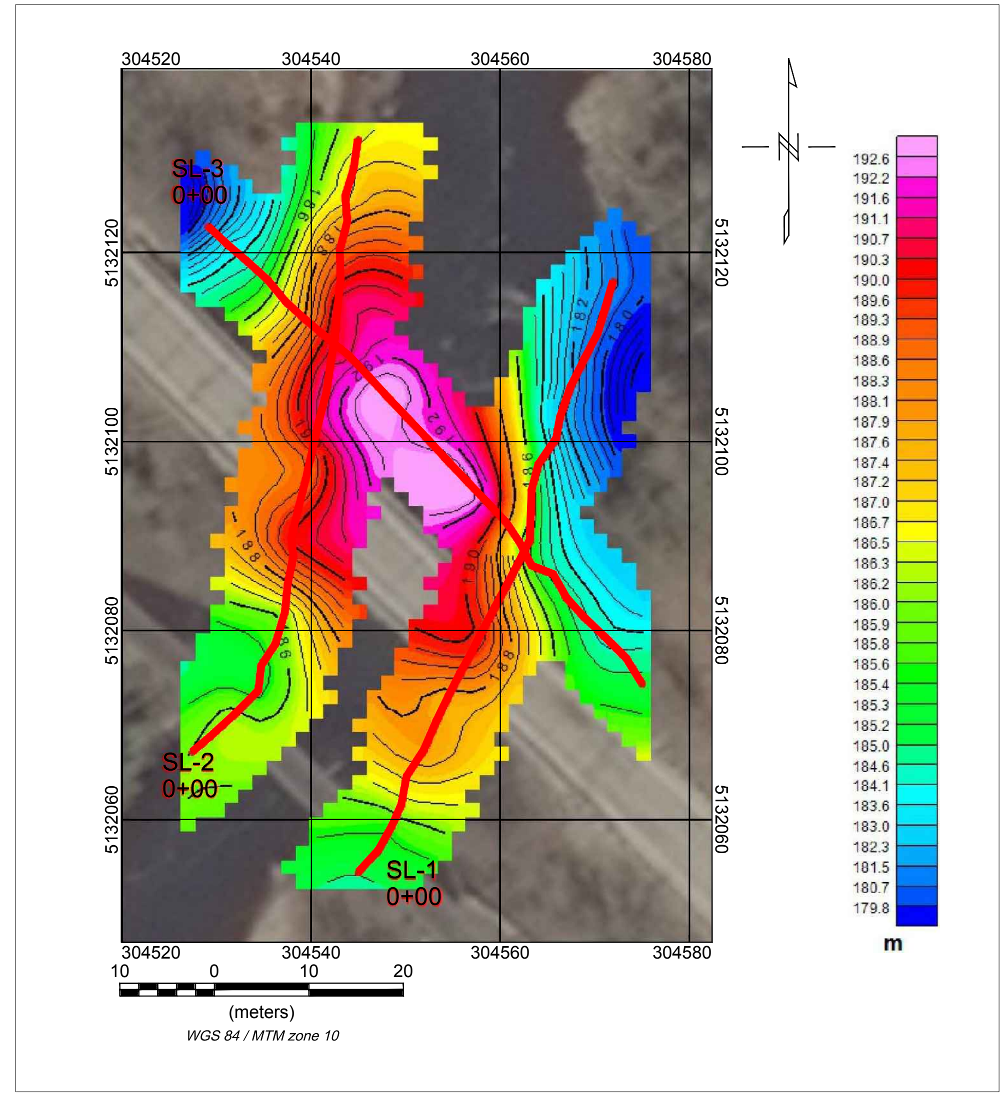
SL-01-2015



SL-02-2015



SL-03-2015



DRAFT

LEGEND

(red hatched line)	Interpreted Bedrock
5200	Seismic P–wave Velocity
(brown line)	Topography
(magenta line)	Water table
(blue line)	Bathymetry (River Bottom)
⊕	Borehole

NOTES

Not Valid for Construction

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102–2 of Form 100.

1	THE GEOPHYSICAL SURVEY WAS EXECUTED BY GEOPHYSICS GPR INTERNATIONAL INC. MAY 2015
2	COORDINATE SYSTEM: MTM ZONE 10N
3	ELEVATION AND POSITIONING DATA PROVIDED BY CLIENT
4	REFER TO THE FULL REPORT FOR A DISCUSSION OF METHODOLOGY, RESULTS, ACCURACIES AND LIMITATIONS

REVISIONS | DATE | BY | DESCRIPTION

GEOCRES No 41L–190

HWY No 17B | DIST
SUBM'D ZP | CHECKED | DATE 2015–06–11 | SITE 43–067
DRAWN GBB | CHECKED | APPROVED | DWG 2

MINISTRY OF TRANSPORTATION, ONTARIO PR–D–707 88–05

Printed: Jan 27, 2016

DRAWING NAME: 165000836_Duchesnay_Seismic Profiles_Jan2016.dwg
CREATED BY: GBB MODIFIED: 2016–01–27
T:\Autocad\Drawings\Project Drawings\2016\165000836\Hwy 17B – Duchesnay Creek\165000836_Duchesnay_Seismic Profiles_Jan2016.dwg (Draft)

Duchesnay Creek Bridge Hwy 17B

Photo No. 1: General view looking west

Photo No. 2: North elevation

Duchesnay Creek Bridge Hwy 17B

Photo No. 3: East bridge pier, looking northeast

Photo No. 4: Looking west along HDD alignment

APPENDIX B

Symbols and Terms Used on Borehole Records

Borehole Records

Rock Core Records

Rock Core Photographs

Calibration Data Sheets, Vibrating Wire Pressure Transducer

SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT RECORDS

SOIL DESCRIPTION

Terminology describing common soil genesis:

Rootmat	- vegetation, roots and moss with organic matter and topsoil typically forming a mattress at the ground surface
Topsoil	- mixture of soil and humus capable of supporting vegetative growth
Peat	- mixture of visible and invisible fragments of decayed organic matter
Till	- unstratified glacial deposit which may range from clay to boulders
Fill	- material below the surface identified as placed by humans (excluding buried services)

Terminology describing soil structure:

Desiccated	- having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc.
Fissured	- having cracks, and hence a blocky structure
Varved	- composed of regular alternating layers of silt and clay
Stratified	- composed of alternating successions of different soil types, e.g. silt and sand
Layer	- > 75 mm in thickness
Seam	- 2 mm to 75 mm in thickness
Parting	- < 2 mm in thickness

Terminology describing soil types:
The classification of soil types are made on the basis of grain size and plasticity in accordance with the Unified Soil Classification System (USCS) (ASTM D 2487 or D 2488) which excludes particles larger than 75 mm. For particles larger than 75 mm, and for defining percent clay fraction in hydrometer results, definitions proposed by Canadian Foundation Engineering Manual, 4th Edition are used. The USCS provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

Terminology describing cobbles, boulders, and non-matrix materials (organic matter or debris):
Terminology describing materials outside the USCS, (e.g. particles larger than 75 mm, visible organic matter, and construction debris) is based upon the proportion of these materials present:

Trace, or occasional	Less than 10%
Some	10-20%
Frequent	> 20%

Terminology describing compactness of cohesionless soils:
The standard terminology to describe cohesionless soils includes compactness (formerly "relative density"), as determined by the Standard Penetration Test (SPT) N-Value - also known as N-Index. The SPT N-Value is described further on page 3. A relationship between compactness condition and N-Value is shown in the following table.

Compactness Condition	SPT N-Value
Very Loose	<4
Loose	4-10
Compact	10-30
Dense	30-50
Very Dense	>50

Terminology describing consistency of cohesive soils:
The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by *in situ* vane tests, penetrometer tests, or unconfined compression tests. Consistency may be crudely estimated from SPT N-Value based on the correlation shown in the following table (Terzaghi and Peck, 1967). The correlation to SPT N-Value is used with caution as it is only very approximate.

Consistency	Undrained Shear Strength		Approximate SPT N-Value
	kips/sq.ft.	kPa	
Very Soft	<0.25	<12.5	<2
Soft	0.25 - 0.5	12.5 - 25	2-4
Firm	0.5 - 1.0	25 - 50	4-8
Stiff	1.0 - 2.0	50 – 100	8-15
Very Stiff	2.0 - 4.0	100 - 200	15-30
Hard	>4.0	>200	>30

ROCK DESCRIPTION

Except where specified below, terminology for describing rock is as defined by the International Society for Rock Mechanics (ISRM) 2007 publication "The Complete ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 1974-2006"

Terminology describing rock quality:

RQD	Rock Mass Quality
0-25	*Very Poor Quality*
25-50	*Poor Quality*
50-75	*Fair Quality*
75-90	*Good Quality*
90-100	*Excellent Quality*

Alternate (Colloquial) Rock Mass Quality	
Very Severely Fractured	*Crushed*
Severely Fractured	*Shattered or Very Blocky*
Fractured	*Blocky*
Moderately Jointed	*Sound*
Intact	*Very Sound*

RQD (Rock Quality Designation) denotes the percentage of intact and sound rock retrieved from a borehole of any orientation. All pieces of intact and sound rock core equal to or greater than 100 mm (4 in.) long are summed and divided by the total length of the core run. RQD is determined in accordance with ASTM D6032.

SCR (Solid Core Recovery) denotes the percentage of solid core (cylindrical) retrieved from a borehole of any orientation. All pieces of solid (cylindrical) core are summed and divided by the total length of the core run (It excludes all portions of core pieces that are not fully cylindrical as well as crushed or rubble zones).

Fracture Index (FI) is defined as the number of naturally occurring fractures within a given length of core. The Fracture Index is reported as a simple count of natural occurring fractures.

Terminology describing rock with respect to discontinuity and bedding spacing:

Spacing (mm)	Discontinuities	Bedding
>6000	*Extremely Wide*	-
2000-6000	*Very Wide*	*Very Thick*
600-2000	*Wide*	*Thick*
200-600	*Moderate*	*Medium*
60-200	*Close*	*Thin*
20-60	*Very Close*	*Very Thin*
<20	*Extremely Close*	*Laminated*
<6	-	*Thinly Laminated*

Terminology describing rock strength:

Strength Classification	Grade	Unconfined Compressive Strength (MPa)
Extremely Weak	R0	<1
Very Weak	R1	1 – 5
Weak	R2	5 – 25
Medium Strong	R3	25 – 50
Strong	R4	50 – 100
Very Strong	R5	100 – 250
Extremely Strong	R6	>250

Terminology describing rock weathering:

Term	Symbol	Description
Fresh	W1	No visible signs of rock weathering. Slight discoloration along major discontinuities
Slightly	W2	Discoloration indicates weathering of rock on discontinuity surfaces. All the rock material may be discolored.
Moderately	W3	Less than half the rock is decomposed and/or disintegrated into soil.
Highly	W4	More than half the rock is decomposed and/or disintegrated into soil.
Completely	W5	All the rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact.
Residual Soil	W6	All the rock converted to soil. Structure and fabric destroyed.

STRATA PLOT

Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.

Boulders Cobbles Gravel	Sand	Silt	Clay	Organics	Asphalt	Concrete	Fill	Igneous Bedrock	Meta-morphic Bedrock	Sedi-mentary Bedrock

SAMPLE TYPE

SS	Split spoon sample (obtained by performing the Standard Penetration Test)
ST	Shelby tube or thin wall tube
DP	Direct-Push sample (small diameter tube sampler hydraulically advanced)
PS	Piston sample
BS	Bulk sample
HQ, NQ, BQ, etc.	Rock core samples obtained with the use of standard size diamond coring bits.

WATER LEVEL MEASUREMENT

▼ measured in standpipe, piezometer, or well

▽ inferred

RECOVERY

For soil samples, the recovery is recorded as the length of the soil sample recovered. For rock core, recovery is defined as the total cumulative length of all core recovered in the core barrel divided by the length drilled and is recorded as a percentage on a per run basis.

N-VALUE

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 140 pound (63.5 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (300 mm) into the soil. In accordance with ASTM D1586, the N-Value equals the sum of the number of blows (N) required to drive the sampler over the interval of 6 to 18 in. (150 to 450 mm). However, when a 24 in. (610 mm) sampler is used, the number of blows (N) required to drive the sampler over the interval of 12 to 24 in. (300 to 610 mm) may be reported if this value is lower. For split spoon samples where insufficient penetration was achieved and N-Values cannot be presented, the number of blows are reported over sampler penetration in millimetres (e.g. 50/75). Some design methods make use of N-values corrected for various factors such as overburden pressure, energy ratio, borehole diameter, etc. No corrections have been applied to the N-values presented on the log.

DYNAMIC CONE PENETRATION TEST (DCPT)

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to 'A' size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone one foot (300 mm) into the soil. The DCPT is used as a probe to assess soil variability.

OTHER TESTS

S	Sieve analysis
H	Hydrometer analysis
k	Laboratory permeability
γ	Unit weight
G_s	Specific gravity of soil particles
CD	Consolidated drained triaxial
CU	Consolidated undrained triaxial with pore pressure measurements
UU	Unconsolidated undrained triaxial
DS	Direct Shear
C	Consolidation
Q_u	Unconfined compression
I_p	Point Load Index (I_p on Borehole Record equals $I_p(50)$ in which the index is corrected to a reference diameter of 50 mm)

	Single packer permeability test; test interval from depth shown to bottom of borehole
	Double packer permeability test; test interval as indicated
	Falling head permeability test using casing
	Falling head permeability test using well point or piezometer

Stantec

RECORD OF BOREHOLE No BH13-3

METRIC

W.P. GWP 5120-07-00	LOCATION Hwy 17B Duchesnay Creek Bridge, North Bay, ON	N: 5 132 120 E: 304 519	ORIGINATED BY AB
DIST	HWY 17B	BOREHOLE TYPE 8" Augers, Splitspoon Sampler, NQ Rock Core	COMPILED BY BB
DATUM Geodetic	DATE 2013 09 30 - 2013 10 01		CHECKED BY CM/SG

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
204.5	Asphalt
0.0	200 mm ASPHALT
204.3 / 0.2	FILL: brown sand with silt and gravel
200.7 / 3.8	SILTY SAND (SM) Loose Light grey - Piezometer tip at 4.6 m
199.3 / 5.2	SILTY CLAY (CI) Firm to stiff Grey, wet - Piezometer tip at 9.1 m - silty sand seams observed between 9.9 and 10.5 m
193.5	

SAMPLES

NUMBER	TYPE	"N" VALUES	LIQUID LIMIT	UNIT WEIGHT γ (kN/m³)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	BS	-			16 78 (6)
2	SS	36			
3	SS	10			
4	SS	2			10 89 (1)
5	SS	1			
6	SS	4			
7	SS	7			
8	SS	WH	48		0 0 57 43
9	ST	-	44, 50	17.5, 17.0	
10	SS	-	42		
11	SS	-	43		
12	SS	-	41		WH = Weight of Hammer
13	SS	-			0 2 53 45
					s_u > 106 kPa

ELEVATION SCALE: 204, 203, 202, 201, 200, 199, 198, 197, 196, 195, 194

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED; ● QUICK TRIAXIAL; × FIELD VANE; × LAB VANE — 20 40 60 80 100

Shear strength results (sensitivity / strain at failure): O 2.8%; × 6.7; × 4.4; × 7.4; × 6.9; × 7.0; × 8.1; × 6.5; × 7.4

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%): 10 20 30

Continued Next Page

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

Stantec

RECORD OF BOREHOLE No BH13-3

METRIC

W.P. GWP 5120-07-00	LOCATION Hwy 17B Duchesnay Creek Bridge, North Bay, ON N: 5 132 120 E: 304 519		ORIGINATED BY AB
DIST	HWY 17B	BOREHOLE TYPE 8" Augers, Splitspoon Sampler, NQ Rock Core	COMPILED BY BB
DATUM Geodetic		DATE 2013 09 30 - 2013 10 01	CHECKED BY CM/SG

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
11.0	*(continued)* SILTY CLAY (CI) Firm to very stiff Grey, wet
192.3 / 12.2	SILTY CLAY (CI) Firm to very stiff Greyish red, wet
188.0 / 16.5	SILTY SAND (SM) Compact Grey
186.2 / 18.3	Silty sand (SM), some gravel TILL Dense to very dense Grey
184.9 / 19.6	Granite BEDROCK - good to excellent quality - grey to pinkish grey - slightly weathered - close to medium joint set spacing (Refer to Field Bedrock Core Log)
182.5	

SAMPLES

NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ (kN/m³)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
14	ST	-	18.4 19.5	
15	SS	-		s_u > 106 kPa
16	SS	-		0 0 52 48 s_u > 106 kPa
17	SS	11		
18	SS	38		7 59 (34)
19	SS	100/ 130mm		
20	NQ	-		TCR = 100% RQD = 96% UCS = 136 MPa
21	NQ	-		TCR = 100% RQD = 92%

Plot columns: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, ✕ FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30. ELEVATION SCALE 193 – 183. Shear strength annotation: 10.0%. Liquid limit annotation: 42.

Continued Next Page

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

W.P. GWP 5120-07-00 LOCATION Hwy 17B Duchesnay Creek Bridge, North Bay, ON N: 5 132 120 E: 304 519 ORIGINATED BY AB

DIST HWY 17B BOREHOLE TYPE 8" Augers, Splitspoon Sampler, NQ Rock Core COMPILED BY BB

DATUM Geodetic DATE 2013 09 30 - 2013 10 01 CHECKED BY CM/SG

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	STRAT PLOT	SAMPLES – NUMBER	SAMPLES – TYPE	SAMPLES – "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (O UNCONFINED, × FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L – WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
22.0	*(continued)* Granite BEDROCK		22	NQ	-		182				TCR = 72% RQD = 50%
181.7 / 22.8	End of Borehole Vibrating wire piezometers installed with tips at 4.6 and 9.1 m below ground surface Inferred water level time of drilling = 4.8 m deep (elevation 199.6 m) Measured water level in shallower piezometer = 2.4 m deep (elevation 202.1 m) Measured water level in deeper piezometer = 3.1 m deep (201.4 m)										

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

W.P. GWP 5120-07-00 LOCATION Hwy 17B Duchesnay Creek Bridge, North Bay, ON N: 5 132 061 E: 304 580 ORIGINATED BY AB

DIST HWY 17B BOREHOLE TYPE 8" Augers, Splitspoon Sampler, NQ Rock Core COMPILED BY BB

DATUM Geodetic DATE 2013 09 25 - 2013 09 26 CHECKED BY CM/SG

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
206.4	Asphalt					
0.0	250 mm ASPHALT					
206.2 / 0.3	FILL: brown sand with silt and gravel	1	BS	-	206	6 81 (13)
		2	SS	5		
205.0 / 1.4	FILL: Inferred rockfill, cobbles and boulders - coring carried out to advance through rockfill (sample #3)	3	NQ	-	205, 204, 203, 202	
201.8 / 4.6	Poorly graded SAND (SP) with gravel, trace silt Very loose Brown, moist	4	SS	4		
		5	SS	1	201	
200.6 / 5.8	SILTY SAND (SM), trace gravel Loose Grey, wet	6	SS	8	200	
		7	SS	8	199	0 66 (34)
		8	SS	4		
198.0 / 8.4	SANDY SILT (ML) Loose Grey, wet	9	SS	3	198	
		10	SS	6	197	
196.5 / 9.9	SILTY CLAY (CI), trace sand Firm Grey, wet	11	SS	9	196	
195.4						

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: O UNCONFINED; × FIELD VANE; ● QUICK TRIAXIAL; × LAB VANE: 20 40 60 80 100
PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%): 10 20 30
UNIT WEIGHT γ kN/m^3

Continued Next Page

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

Stantec

RECORD OF BOREHOLE No BH13-4

METRIC

W.P. GWP 5120-07-00 | LOCATION Hwy 17B Duchesnay Creek Bridge, North Bay, ON N: 5 132 061 E: 304 580 | ORIGINATED BY AB

DIST ____ HWY 17B | BOREHOLE TYPE 8" Augers, Splitspoon Sampler, NQ Rock Core | COMPILED BY BB

DATUM Geodetic | DATE 2013 09 25 - 2013 09 26 | CHECKED BY CM/SG

ELEV DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
11.0	*(continued)* SILTY CLAY (CI), trace sand; Firm; Grey, wet					
		12	ST	-	18.8 / 18.1	
192.7 / 13.7	CLAYEY SILT (CL) to SILTY CLAY (CI); Firm to very stiff; Grey, wet					
		13	SS	1		0 0 66 34
	- Piezometer tip at 15.2 m					
		14	SS	WH		
		15	SS	1		
		16	ST	-	18.4 / 18.1	
		17	SS	3		WH = Weight of Hammer; 0 0 54 46
		18	SS	-		s_u > 106 kPa
184.4						

Elevation scale: 195, 194, 193, 192, 191, 190, 189, 188, 187, 186, 185

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED; ● QUICK TRIAXIAL; × FIELD VANE; × LAB VANE — 20 40 60 80 100

Shear strength plot labels: 15.2%, 4.0, 4.4, 6.4, 6.7, 6.0, 5.6, 4.7, 4.7, 7.4%, 0, 2.4

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L — WATER CONTENT (%): 10 20 30

Water content plot labels: 48, 46

Continued Next Page

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

Stantec

RECORD OF BOREHOLE No BH13-4

METRIC

W.P. GWP 5120-07-00 | LOCATION Hwy 17B Duchesnay Creek Bridge, North Bay, ON N: 5 132 061 E: 304 580 | ORIGINATED BY AB

DIST ____ HWY 17B | BOREHOLE TYPE 8" Augers, Splitspoon Sampler, NQ Rock Core | COMPILED BY BB

DATUM Geodetic | DATE 2013 09 25 - 2013 09 26 | CHECKED BY CM/SG

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
22.0	*(continued)* CLAYEY SILT (CL) to SILTY CLAY (CI); Firm to very stiff; Grey, wet				s_u > 106 kPa
		19	SS	-	s_u > 106 kPa; s_u > 106 kPa
		20	SS	-	s_u > 106 kPa
181.1 / 25.3	Sandy clayey silt (CL), some gravel TILL; Very stiff; Grey, wet				
		21	SS	-	1 48 31 20; s_u > 106 kPa
179.7 / 26.7	Granite BEDROCK - poor to good quality - grey to pinkish grey - slightly weathered - close joint set spacing (Refer to Field Bedrock Core Log)	22	NQ	-	TCR = 51%; RQD = 21%; UCS = 35 MPa
		23	NQ	-	TCR = 93%; RQD = 78%
		24	NQ	-	TCR = 77%; RQD = 57%
176.7 / 29.7	End of Borehole Vibrating wire piezometer installed with its tip at 15.2 m below ground surface Inferred water level at time of drilling = 6.8 m (elevation 199.6 m) Measured water level = 6.4 m (elevation 200.0 m)				

Elevation scale: 184, 183, 182, 181, 180, 179, 178, 177

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED ✕ FIELD VANE ● QUICK TRIAXIAL × LAB VANE — 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30; 42

UNIT WEIGHT γ kN/m³

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

Stantec

RECORD OF BOREHOLE No BH14-5

METRIC

W.P. GWP 5120-07-00 | LOCATION Hwy 17B Duchesnay Creek Bridge, North Bay, ON N: 5 132 111 E: 304 542 | ORIGINATED BY ZP

DIST | HWY 17B | BOREHOLE TYPE Portable drilling with BW casing, Splitspoon Sampler | COMPILED BY ZP

DATUM Geodetic | DATE 2014 11 11 - 2014 11 12 | CHECKED BY CM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
196.0	Organic Soil				
0.0	610mm ORGANIC SOIL and wood (OL) Very loose Brown	1	SS	1	
195.4 / 0.6	SILTY SAND (SM) with gravel Loose Brown	2	SS	8	
		3	SS	9	
193.7 / 2.3	SILT (ML) with gravel Very loose Brown	4	SS	3	
193.0 / 3.1	SILTY CLAY (CI) to CLAYEY SILT (CL) Firm to soft Grey	5	SS	2	0 2 54 44
		6	SS		
		7	SS		
190.7 / 5.3	SILT (ML) with sand, TILL Very dense Grey	8	SS	100/ , 150mm	0 16 78 6 non-plastic
190.4 / 5.6	Granite BEDROCK -very poor to excellent quality -grey to pinkish grey -highly weathered to unweathered -very close to moderate joint set spacing (Refer to Field Bedrock Core Log)	9	NQ	-	TCR=82% RQD=18%
		10	NQ	-	TCR=79% RQD=21% UCS=208MPa
		11	NQ	-	TCR=96% RQD=52%
		12	NQ	-	TCR=96% RQD=96%
		13	NQ	-	TCR=100% RQD=96%
187.0 / 9.0	End of Borehole				

ELEVATION SCALE: 195, 194, 193, 192, 191, 190, 189, 188

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED, ✖ FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100

Field vane values: 7.9 (at approx. elev. 192.1), 5.14 (at approx. elev. 191.1)

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30; values beyond scale: 45, 43

UNIT WEIGHT γ kN/m³

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

Stantec

RECORD OF BOREHOLE No BH14-6

METRIC

W.P. GWP 5120-07-00

LOCATION Hwy 17B Duchesnay Creek Bridge, North Bay, ON N: 5 132 082 E: 304 571

ORIGINATED BY ZP

DIST HWY 17B

BOREHOLE TYPE Portable drilling with BW casing, Splitspoon Sampler

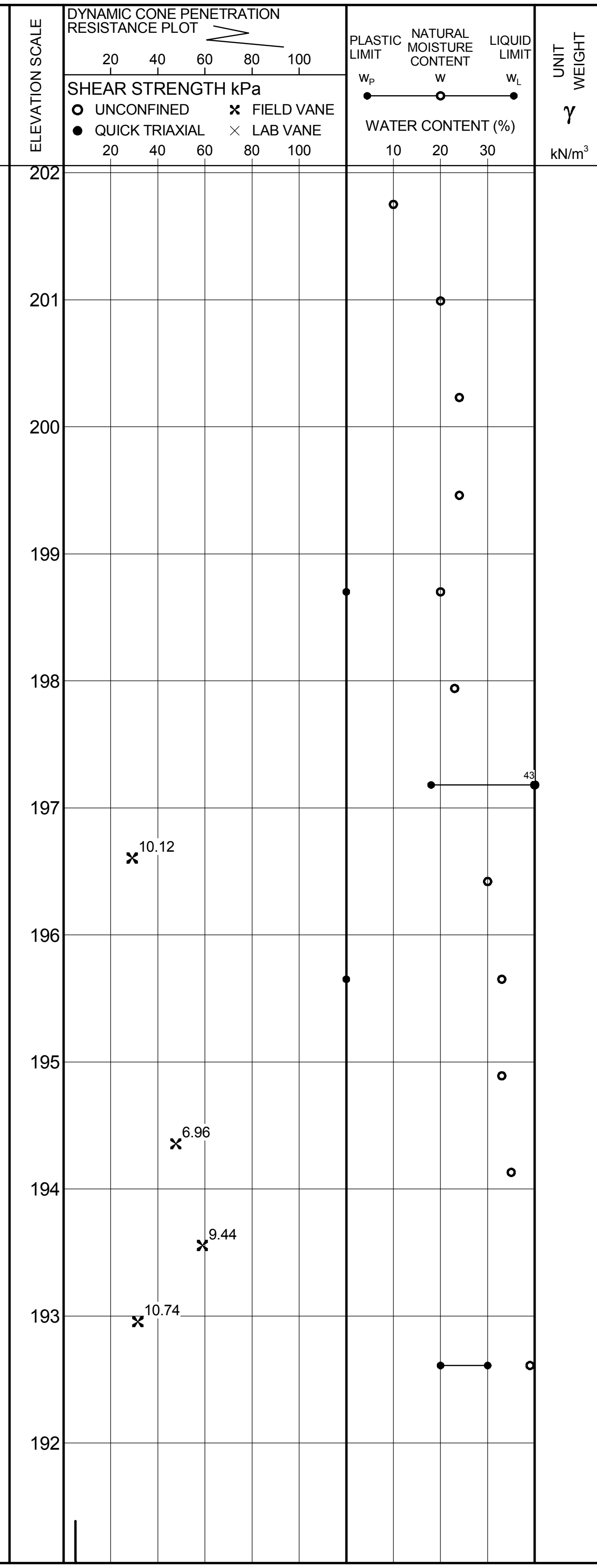
COMPILED BY ZP

DATUM Geodetic

DATE 2014 11 13 - 2014 11 13

CHECKED BY CM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
202.1	Topsoil					
202.0 / 0.1	100mm TOPSOIL					
	SILTY SAND (SM) with rootlets; Very loose to loose; Brown to light brown	1	SS	1		
		2	SS	3		5 70 (25)
		3	SS	5	▽	
199.8 / 2.3	SANDY SILT (ML); Very loose to loose; Grey	4	SS	2		
		5	SS	4		0 42 52 6 non-plastic
198.2 / 3.8	SILTY CLAY (CI); Firm; Grey	6	SS	2		
		7	SS	1		0 3 69 28
196.7 / 5.3	CLAYEY SILT (CL) to SILTY CLAY (CI); Firm to stiff; Grey	8	SS	15		
		9	SS	1		0 0 72 28 non-plastic
		10	SS	4		
		11	SS	1		
		12	SS	1		0 0 56 44
191.4 / 10.7	End of Split Spoon Sampling; Dynamic Cone Penetration Test					
191.1						



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× 3, × 3: Numbers refer to Sensitivity

O 3% STRAIN AT FAILURE

W.P. GWP 5120-07-00   LOCATION Hwy 17B Duchesnay Creek Bridge, North Bay, ON   N: 5 132 082 E: 304 571   ORIGINATED BY ZP

DIST ______ HWY 17B   BOREHOLE TYPE Portable drilling with BW casing, Splitspoon Sampler   COMPILED BY ZP

DATUM Geodetic   DATE 2014 11 13 - 2014 11 13   CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: O UNCONFINED, ✕ FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
11.0	*(continued)* Dynamic Cone Penetration Test						191 190 189 188 187 186				
185.3 16.8	End of Borehole End of Dynamic Cone Penetration Test										

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

Stantec

RECORD OF BOREHOLE No BH15-7

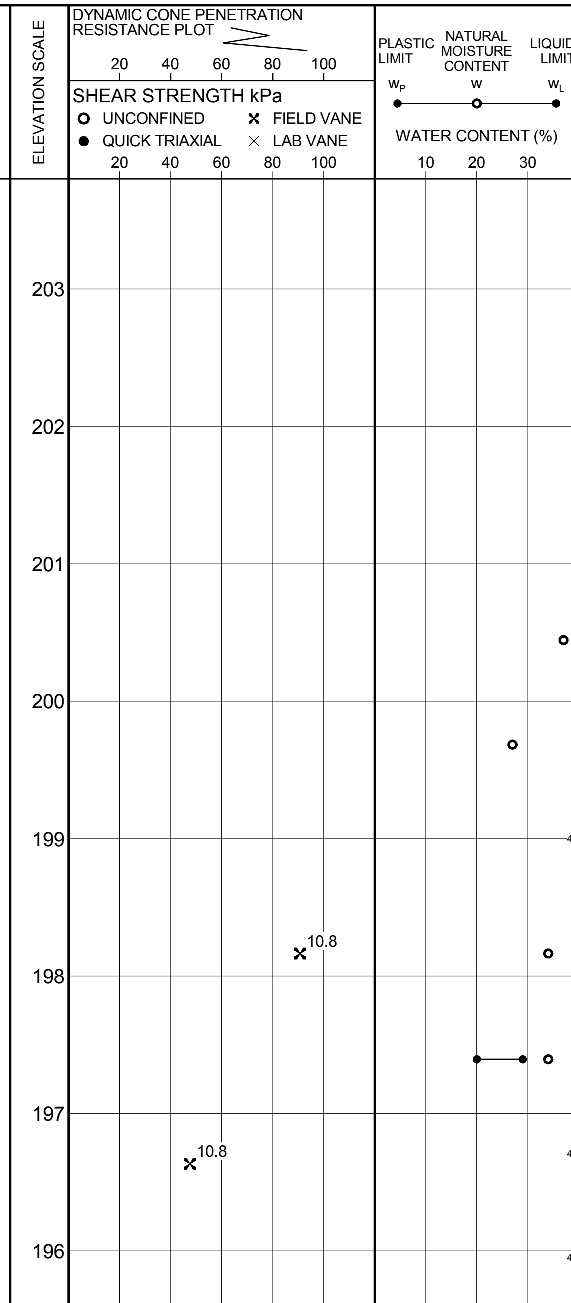
METRIC

W.P. GWP 5120-07-00 LOCATION Hwy 17B Duchesnay Creek Bridge, North Bay, ON N: 5 132 174 E: 304 474 ORIGINATED BY ZP

DIST HWY 17B BOREHOLE TYPE 8" Augers, Splitspoon Sampler COMPILED BY ZP

DATUM Geodetic DATE 2015 04 02 - 2015 04 02 CHECKED BY CM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
203.8	Topsoil					
0.0	450 mm TOPSOIL	1	BS	-		52 42 (6)
203.4 / 0.5	FILL: brown well graded gravel with silt and sand -Inferred from hydroexcavation hole					
202.3 / 1.5	SILTY SAND (SM) Brown, wet -Inferred from hydroexcavation hole				▽	
200.8 / 3.1	CLAYEY SILT (CL) Firm to stiff Light brown to grey	2	SS	2		
		3	SS	11		
		4	SS	2		
		5	SS	-		
		6	SS	WH		0 1 70 29
		7	SS	-		
		8	SS	WH		
195.6 / 8.2	End of Borehole Hydrovac excavation to 3.05 m before drilling and backfilled with Granular A material. Soil stratigraphy from 0 to 3.05 m inferred from hydrovac excavation.					



UNIT WEIGHT γ kN/m³

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

Stantec

RECORD OF BOREHOLE No BH15-8

METRIC

W.P. GWP 5120-07-00	LOCATION Hwy 17B Duchesnay Creek Bridge, North Bay, ON	N: 5 132 150 E: 304 497	ORIGINATED BY ZP
DIST HWY 17B	BOREHOLE TYPE 8" Augers, Splitspoon Sampler		COMPILED BY ZP
DATUM Geodetic	DATE 2015 04 01 - 2015 04 01		CHECKED BY CM

Soil Profile

ELEV / DEPTH	DESCRIPTION
204.0	Sand
0.0	FILL: brown poorly graded sand
202.0 / 2.0	SILTY SAND (SM) to SANDY SILT (ML) Loose Brown, wet
200.0 / 4.0	CLAYEY SILT (CL) Firm to stiff Brown to grey
196.4 / 7.6	SILTY CLAY (CI) Firm to stiff Grey
193.0	

Samples

NUMBER	TYPE	"N" VALUES	Field vane sensitivity	Water content notes	REMARKS GR SA SI CL
1	AS	-			
2	SS	11			
3	SS	5			
4	SS	7			0 38 56 6
5	SS	7			
6	SS	2			
7	SS	-	8.6	47	
8	SS	7			0 4 78 18
9	SS	-	8.6		
10	SS	2			
11	SS	-	10.8		
12	SS	WH		44, 45	0 0 48 52
13	SS	-	10.8	46	
14	SS	WH			
			13.0	48	

Ground water level: approx. elev. 202.0

Elevation scale: 203, 202, 201, 200, 199, 198, 197, 196, 195, 194

Column headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: O UNCONFINED, ✕ FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (10 20 30); UNIT WEIGHT γ kN/m^3; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

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

Stantec

RECORD OF BOREHOLE No BH15-8

METRIC

W.P. GWP 5120-07-00 LOCATION Hwy 17B Duchesnay Creek Bridge, North Bay, ON N: 5 132 150 E: 304 497 ORIGINATED BY ZP

DIST HWY 17B BOREHOLE TYPE 8" Augers, Splitspoon Sampler COMPILED BY ZP

DATUM Geodetic DATE 2015 04 01 - 2015 04 01 CHECKED BY CM

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa	WATER CONTENT (%)	GR	SA	SI	CL
11.0	*(continued)* SILTY CLAY (CI) Firm to stiff Grey	15	SS	-							
		16	SS	WH	192						
		17	SS	-		13.0					
		18	SS	3	191		42				
		19	SS	-	190		42				
		20	SS	WH	189		42 / 43	0	1	47	52
188.9 / 15.1	End of Borehole										

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED ✕ FIELD VANE ● QUICK TRIAXIAL × LAB VANE — 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³

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

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

Stantec

RECORD OF BOREHOLE No BH15-9

METRIC

W.P. GWP 5120-07-00 LOCATION Hwy 17B Duchesnay Creek Bridge, North Bay, ON N: 5 132 042 E: 304 614 ORIGINATED BY ZP

DIST HWY 17B BOREHOLE TYPE 8" Augers, Splitspoon Sampler COMPILED BY ZP

DATUM Geodetic DATE 2015 03 31 - 2015 03 31 CHECKED BY CM

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
207.5	Topsoil									
207.4 0.1	50 mm TOPSOIL									
	Poorly graded SAND (SP) Loose to compact Brown	1	AS	-		207				
		2	SS	10		206				
		3	SS	9						
205.2 2.3	Poorly graded SAND (SP) Loose to compact Brown, wet	4	SS	21	∇	205				1 95 (4)
		5	SS	9		204				
203.7 3.8	SILTY SAND (SM) Compact Brown to greyish brown, wet	6	SS	12		203				
		7	SS	12						
		8	SS	16		202				0 71 (29)
		9	SS	11		201				
		10	SS	12		200				
200.0 7.5	SILT with sand (ML) Loose Grey	11	SS	4						0 22 68 10 non-plastic
199.1 8.4	SILT (ML) Very loose Grey	12	SS	-		199	17.32			
		13	SS	3		198				non-plastic
		14	SS	-		197	8.6			
196.5										

Continued Next Page

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

Stantec

RECORD OF BOREHOLE No BH15-9

METRIC

W.P. GWP 5120-07-00 | LOCATION Hwy 17B Duchesnay Creek Bridge, North Bay, ON N: 5 132 042 E: 304 614 | ORIGINATED BY ZP

DIST | HWY 17B | BOREHOLE TYPE 8" Augers, Splitspoon Sampler | COMPILED BY ZP

DATUM Geodetic | DATE 2015 03 31 - 2015 03 31 | CHECKED BY CM

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	SHEAR STRENGTH (Field Vane, sensitivity)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
11.0	*(continued)* SILT (ML) Loose to compact Grey	15	SS	13		
		16	SS	-	8.6	
194.7		17	SS	5		0 2 77 21 non-plastic
12.8	CLAYEY SILT (CL) Firm Grey	18	SS	-	10.8	
		19	SS	WH		
192.4		20	SS	-	10.8	0 4 69 27
15.1	End of Borehole					

Elevation scale: 196, 195, 194, 193

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED, ✕ FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m^3

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

RECORD OF BOREHOLE No BH15-10

METRIC

Stantec

W.P. GWP 5120-07-00	LOCATION Hwy 17B Duchesnay Creek Bridge, North Bay, ON	N: 5 132 006 E: 304 651	ORIGINATED BY ZP
DIST	HWY 17B	BOREHOLE TYPE 8" Augers, Splitspoon Sampler	COMPILED BY ZP
DATUM Geodetic		DATE 2015 04 01 - 2015 04 01	CHECKED BY CM

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
207.9	Topsoil								
207.8 0.0	150 mm TOPSOIL								
0.2	Poorly graded SAND (SP) to Poorly Graded SAND with silt (SP-SM) Loose to compact Brown	1	AS	-					
		2	SS	10		207			
		3	SS	17		206			0 89 (11)
205.8 2.1	SILTY SAND (SM) Compact Brown, wet				∇				
		4	SS	19					
		5	SS	15		205			
		6	SS	15		204			
		7	SS	14		203			0 57 38 5
202.5 5.4	SILTY CLAY (CI) Firm Grey	8	SS	1		202			
		9	SS	-			8.6	47	
		10	SS	WH		201		41	0 2 53 45
		11	SS	-		200	8.6	46	
199.7 8.2	End of Borehole								

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED; ✕ FIELD VANE; ● QUICK TRIAXIAL; × LAB VANE — 20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ kN/m³

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

Field Bedrock Core Log

Stantec

Client:	Ontario Ministry of Transportation	**Project No.:**	165000836
Project:	Hwy 17B - Duchesnay Creek	**Date:**	October 1, 2013
Contractor:	Landcore Drilling	**Borehole No.:**	BH13-3
		Logger:	AB/SG

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES: NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	OCCASIONAL FEATURES	DRILLING OBSERVATIONS
19.61	NQ20	100%	96%	20.88	Granite bedrock; grey to pinkish grey, medium-coarse texture, calcite intrusions		S			F-D	M	RP		T	Near vertical discontinuities	Mohs Hardness: H=3.5-6.5
20.88	NQ21	100%	92%	21.56	Granite bedrock; grey to pinkish, medium-coarse texture, calcite intrusions		S			D	C	RP		T		H=3.5-6.5
21.56	NQ22	72%	50%	22.83	Granite bedrock; grey to pinkish, medium-coarse texture, calcite intrusions		S			D	M	RP		T		H=3.5-6.5

STRENGTH (MPa)
EH = Extremely Strong = > 250
VS = Very Strong = 100-250
S = Strong = 50-100
MS = Medium Strong = 25-50
W = Weak = 5 - 25
VW = Very Weak = 1-5
EW = Extremely Weak = < 1

WEATHERING
U = Unweathered = No Signs
S = Slightly = Oxidized
M = Moderately = Discoloured
H = Highly = Friable
C = Completely = Soil-like

DISCONTINUITY TYPE
B = Bedding Joint
J = Cross Joint
F = Fault
S = Shear Plane

SPACING
VW = Very Wide = >3m
W = Wide = 1-3 m
M = Moderate = 0.3-1 m
C = Close = 5-30 cm
VC = Very Close = <5 cm

ORIENTATION
F = Flat = 0-20^0
D = Dipping = 20-50^0
V = n-Vertical = >50^0

ROUGHNESS
RU = Rough Undulating
RP = Rough Planar
SU = Smooth Undulating
SP = Smooth Planar
LU = Slickensided Undulating
LP = Slickensided Planar

FILLING
T = Tight, Hard
O = Oxidized
SA = Slightly Altered, Clay Free
S = Sandy, Clay Free
Si = Sandy, Silty, Minor Clay
NC = Non-softening Clay
SC = Swelling, Soft Clay

Field Bedrock Core Log

Stantec

Client:	Ontario Ministry of Transportation	**Project No.:**	165000836
Project:	Hwy 17B - Duchesnay Creek	**Date:**	September 26, 2013
Contractor:	Landcore Drilling	**Borehole No.:**	BH13-4
		Logger:	AB/SG

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES: NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	OCCASIONAL FEATURES	DRILLING OBSERVATIONS
26.67	NQ22	52%	21%	27.76	Granite bedrock; grey to pinkish grey, medium-coarse texture		S	NA		D	C	RP		T		Mohs Hardness: H=3.5-6.5
27.76	NQ23	93%	78%	28.88	Granite bedrock; grey to pinkish, medium-coarse texture, calcite intrusions		S	NA		D	C-M	RP		T	Near vertical discontinuities	H=3.5-6.5
28.88	NQ24	77%	57%	29.72	Granite bedrock; grey to pinkish, medium-coarse texture, calcite intrusions		S	NA		D	M	RP		T		H=3.5-6.5

<u>STRENGTH (MPa)</u>
EH = Extremely Strong = > 250
VS = Very Strong = 100-250
S = Strong = 50-100
MS = Medium Strong = 25-50
W = Weak = 5 - 25
VW = Very Weak = 1-5
EW = Extremely Weak = < 1

<u>WEATHERING</u>
U = Unweathered = No Signs
S = Slightly = Oxidized
M = Moderately = Discoloured
H = Highly = Friable
C = Completely = Soil-like

<u>DISCONTINUITY TYPE</u>
B = Bedding Joint
J = Cross Joint
F = Fault
S = Shear Plane

<u>SPACING</u>
VW = Very Wide = >3m
W = Wide = 1-3 m
M = Moderate = 0.3-1 m
C = Close = 5-30 cm
VC = Very Close = <5 cm

<u>ORIENTATION</u>
F = Flat = 0-20^0
D = Dipping = 20-50^0
V = n-Vertical = >50^0

<u>ROUGHNESS</u>
RU = Rough Undulating
RP = Rough Planar
SU = Smooth Undulating
SP = Smooth Planar
LU = Slickensided Undulating
LP = Slickensided Planar

<u>FILLING</u>
T = Tight, Hard
O = Oxidized
SA = Slightly Altered, Clay Free
S = Sandy, Clay Free
Si = Sandy, Silty, Minor Clay
NC = Non-softening Clay
SC = Swelling, Soft Clay

Field Bedrock Core Log

Stantec

Client: Ontario Ministry of Transportation
Project: Hwy 17B - Duchesnay Creek
Contractor: Landcore Drilling
Project No.: 165000836
Date: November 12, 2014
Borehole No.: BH14-5
Logger: ZP

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES: NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	OCCASIONAL FEATURES	DRILLING OBSERVATIONS
5.6	NQ9	82%	18%	6.5	Granite bedrock; grey to pinkish grey, medium-coarse texture		S	1	J	F	VC-C	RP		SA		Mohs Hardness: H=3.5-6.5
6.5	NQ10	79%	21%	7.1	Granite bedrock; grey to pinkish, medium-coarse texture, calcite intrusions		S	1	J	F	VC-C	RP		SA		H=3.5-6.5
7.1	NQ11	96%	52%	7.8	Granite bedrock; grey to pinkish, medium-coarse texture, calcite intrusions		S	1	J	F	VC-C	RP		SA		H=3.5-6.5
7.8	NQ12	96%	96%	8.4	Granite bedrock; grey to pinkish, medium-coarse texture, calcite intrusions		U	1	J	F	C-M	RP		T		H=3.5-6.5

STRENGTH (MPa)
EH = Extremely Strong = > 250
VS = Very Strong = 100-250
S = Strong = 50-100
MS = Medium Strong = 25-50
W = Weak = 5 - 25
VW = Very Weak = 1-5
EW = Extremely Weak = < 1

WEATHERING
U = Unweathered = No Signs
S = Slightly = Oxidized
M = Moderately = Discoloured
H = Highly = Friable
C = Completely = Soil-like

DISCONTINUITY TYPE
B = Bedding Joint
J = Cross Joint
F = Fault
S = Shear Plane

SPACING
VW = Very Wide = >3m
W = Wide = 1-3 m
M = Moderate = 0.3-1 m
C = Close = 5-30 cm
VC = Very Close = <5 cm

ORIENTATION
F = Flat = 0-20^0
D = Dipping = 20-50^0
V = n-Vertical = >50^0

ROUGHNESS
RU = Rough Undulating
RP = Rough Planar
SU = Smooth Undulating
SP = Smooth Planar
LU = Slickensided Undulating
LP = Slickensided Planar

FILLING
T = Tight, Hard
O = Oxidized
SA = Slightly Altered, Clay Free
S = Sandy, Clay Free
Si = Sandy, Silty, Minor Clay
NC = Non-softening Clay
SC = Swelling, Soft Clay

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Field Bedrock Core Log

Stantec

Client:	Ontario Ministry of Transportation	**Project No.:**	165000836
Project:	Hwy 17B - Duchesnay Creek	**Date:**	November 12, 2014
Contractor:	Landcore Drilling	**Borehole No.:**	BH14-5
		Logger:	ZP

DEPTH FROM (m)	RUN NO.	% CORE RECOVERY	% RQD	DEPTH TO (m)	GENERAL DESCRIPTION (Rock Type/s, %, Colour, Texture, etc.)	STRENGTH	WEATHERING	DISCONTINUITIES: NO. OF SETS	TYPE/S	ORIENTATION	SPACING	ROUGHNESS	APERTURE	FILLING	OCCASIONAL FEATURES	DRILLING OBSERVATIONS
8.4	NQ22	100%	96%	9.0	Granite bedrock; grey to pinkish grey, medium-coarse texture		S	1	J	F	C	RP		SA		Mohs Hardness: H=3.5-6.5

STRENGTH (MPa)
- EH = Extremely Strong = > 250
- VS = Very Strong = 100-250
- S = Strong = 50-100
- MS = Medium Strong = 25-50
- W = Weak = 5 - 25
- VW = Very Weak = 1-5
- EW = Extremely Weak = < 1

WEATHERING
- U = Unweathered = No Signs
- S = Slightly = Oxidized
- M = Moderately = Discoloured
- H = Highly = Friable
- C = Completely = Soil-like

DISCONTINUITY TYPE
- B = Bedding Joint
- J = Cross Joint
- F = Fault
- S = Shear Plane

SPACING
- VW = Very Wide = >3m
- W = Wide = 1-3 m
- M = Moderate = 0.3-1 m
- C = Close = 5-30 cm
- VC = Very Close = <5 cm

ORIENTATION
- F = Flat = $0\text{-}20^0$
- D = Dipping = $20\text{-}50^0$
- V = n-Vertical = $>50^0$

ROUGHNESS
- RU = Rough Undulating
- RP = Rough Planar
- SU = Smooth Undulating
- SP = Smooth Planar
- LU = Slickensided Undulating
- LP = Slickensided Planar

FILLING
- T = Tight, Hard
- O = Oxidized
- SA = Slightly Altered, Clay Free
- S = Sandy, Clay Free
- Si = Sandy, Silty, Minor Clay
- NC = Non-softening Clay
- SC = Swelling, Soft Clay

Stantec	Project No.: 165000836	GWP: 5120-07-00	Rockcore Photographs
	Project Name: Highway 17B Duchesnay Creek Bridge, North Bay, ON		Date: October 1, 2013

Rock Core Photo No.: 1	Borehole:BH13-3	Depth: 19.61 to 22.83 m

Stantec	Project No.: 165000836	GWP: 5120-07-00	Rockcore Photographs
	Project Name: Highway 17B Duchesnay Creek Bridge, North Bay, ON		Date: November 12, 2014

Rock Core Photo No.: 3	Borehole: BH14-5	Depth: 5.63 to 9.00 m

ROCTEST TELEMAC

BH13-3 @ 15'

2.4 m

CALIBRATION DATA SHEET
VIBRATING WIRE PRESSURE TRANSDUCER

Model:	**PWS**
Serial number:	**100D111597**
Range:	**200 kPa**
Temperature:	**22,6 °C**
Barometric pressure:	**102,5 kPa**
Cable model:	**IRC-41A**
Cable length:	**45 m**
Thermistor type:	**3 kOhms**

Color code: **red & black (coil) green & white (thermistor)**

Applied pressure kPa	Reading linear unit LU	Error linear % FS	Error polynomial % FS
0,00	4197,3	0,24	0,03
40,00	3935,1	-0,06	-0,01
80,00	3675,6	-0,15	0,03
120,00	3416,9	-0,18	-0,01
160,00	3161,2	0,03	0,08
200,00	2904,7	0,17	-0,04
200,00	2905,0	0,20	-0,01
160,00	3160,6	-0,01	0,03
120,00	3416,7	-0,18	-0,01
80,00	3674,6	-0,23	-0,05
40,00	3935,1	-0,06	-0,01
-0,10	4197,6	0,21	0,00
	Maximum error (%):	0,24	0,08

Calculated Pressure:

$$P_c = P - P_T - (S - S_0)$$

P, P_c = Raw pressure and corrected one
P_T = Temperature correction
S_0, S = Barometric pressure at installation and current one

Linear regression	Polynomial regression
$P = C_f (L - L_0)$	$P = AL^2 + BL + C'$ (*)
$P_T = C_T (T - T_0)$	$P_T = C_T (T - T_0)$
C_f = -1,5482E-01 kPa / LU	A = 1,9243E-06 kPa / LU²
C_T = 3,5366E-02 kPa / °C	B = -1,6849E-01 kPa / LU
	C_T = 3,5366E-02 kPa / °C
L_0 : Initial reading in LU	(*) C' calculation please refer to instruction manual, § Initial reading
L : Reading in LU , T_0, T Temperatures in °C (initial, current)	

<u>*Note :*</u> LU = Linear Unit with K = 1.0156, position 4 on the MB-6T readout unit

Certificate: 103111C.xls   Traceability: TR-03-03

Calibrated by: Dorina Jugureanu   Date: 2013-09-20

ROCTEST TELEMAC

BH13-3 @30'

3.12 m

CALIBRATION DATA SHEET
VIBRATING WIRE PRESSURE TRANSDUCER

Model:	**PWS**
Serial number:	**100D111587**
Range:	**200 kPa**
Temperature:	**21.1 °C**
Barometric pressure:	**102.0 kPa**
Cable model:	**IRC-41A**
Cable length:	**40 m**
Thermistor type:	**3 kOhms**

Color code: **red & black (coil) green & white (thermistor)**

Applied pressure kPa	Reading linear unit LU	Error linear % FS	Error polynomial % FS
0,00	3883,1	0,24	0,03
40,00	3612,6	-0,04	0,00
80,00	3344,1	-0,18	-0,01
120,10	3077,3	-0,13	0,04
160,00	2812,6	-0,03	0,01
200,00	2549,2	0,22	0,01
200,00	2548,7	0,18	-0,03
160,00	2812,9	-0,01	0,03
120,00	3077,3	-0,18	-0,01
80,00	3344,0	-0,18	-0,01
40,00	3612,0	-0,08	-0,04
-0,10	3883,3	0,21	0,00
	Maximum error (%):	0,24	0,04

Calculated Pressure:

$$P_c = P - P_T - (S - S_0)$$

P, P_c = Raw pressure and corrected one
P_T = Temperature correction
S_0, S = Barometric pressure at installation and current one

Linear regression	Polynomial regression
$P = C_l\,(L - L_0)$ $P_T = C_T\,(T - T_0)$	$P = AL^2 + BL + C'$ (*) $P_T = C_T\,(T - T_0)$
C_l = -1,4998E-01 kPa / LU C_T = 4,6699E-02 kPa / °C	A = 1,7750E-06 kPa / LU² B = -1,6139E-01 kPa / LU C_T = 4,6699E-02 kPa / °C
L_0 Initial reading in LU	(*) C' calculation please refer to instruction manual § Initial reading
L : Reading in LU ; T_0, T : Temperatures in °C (initial, current)	

<u>*Note :*</u> LU = Linear Unit with K = 1.0156, position 4 on the MB-6T readout unit

Certificate: 111811B.xls — Traceability: TR-03-03

Calibrated by: Dorina Jugureanu — Date: 2013-09-20

ROCTEST TELEMAC

BH13-4 @ 50'

CALIBRATION DATA SHEET
VIBRATING WIRE PRESSURE TRANSDUCER

6.4 m

Model:	**PWS**
Serial number:	**100D111588**
Range:	**200 kPa**
Temperature:	**21.1 °C**
Barometric pressure:	**102.0 kPa**
Cable model:	**IRC-41A**
Cable length:	**40 m**
Thermistor type:	**3 kOhms**

Color code: **red & black (coil) green & white (thermistor)**

Applied pressure kPa	Reading linear unit LU	Error linear % FS	Error polynomial % FS
0,00	3771,6	0,09	0,06
40,00	3494,2	-0,03	-0,02
80,00	3219,3	0,02	0,05
120,10	2943,0	0,03	0,05
160,00	2667,6	0,00	0,01
200,00	2392,3	0,03	0,01
200,00	2392,2	0,02	-0,01
160,00	2667,0	-0,04	-0,03
120,00	2943,0	-0,02	0,00
80,00	3218,3	-0,05	-0,03
40,00	3493,7	-0,07	-0,06
-0,10	3771,1	0,01	-0,02
	Maximum error (%):	0,09	0,06

Calculated Pressure:

$$P_c = P - P_T - (S - S_0)$$

P, P_c = Raw pressure and corrected one
P_T = Temperature correction
S_0, S = Barometric pressure at installation and current one

Linear regression	Polynomial regression
$P = C_f (L - L_0)$ $P_T = C_T (T - T_0)$	$P = AL^2 + BL + C'$ (*) $P_T = C_T (T - T_0)$
C_f = -1,4509E-01 kPa / LU C_T = 5,6472E-02 kPa / °C	A = 2,1454E-07 kPa / LU² B = -1,4641E-01 kPa / LU C_T = 5,6472E-02 kPa / °C
L_0 : Initial reading in LU	(*) C' calculation, please refer to instruction manual, § Initial reading

L : Reading in LU ; T_0, T : Temperatures in °C (initial, current)

<u>*Note :*</u> LU = Linear Unit with K = 1.0156, position 4 on the MB-6T readout unit

Certificate: 111811B.xls

Traceability: TR-03-03

Calibrated by: Dorina Jugureanu

Date: 2013-09-20

APPENDIX C

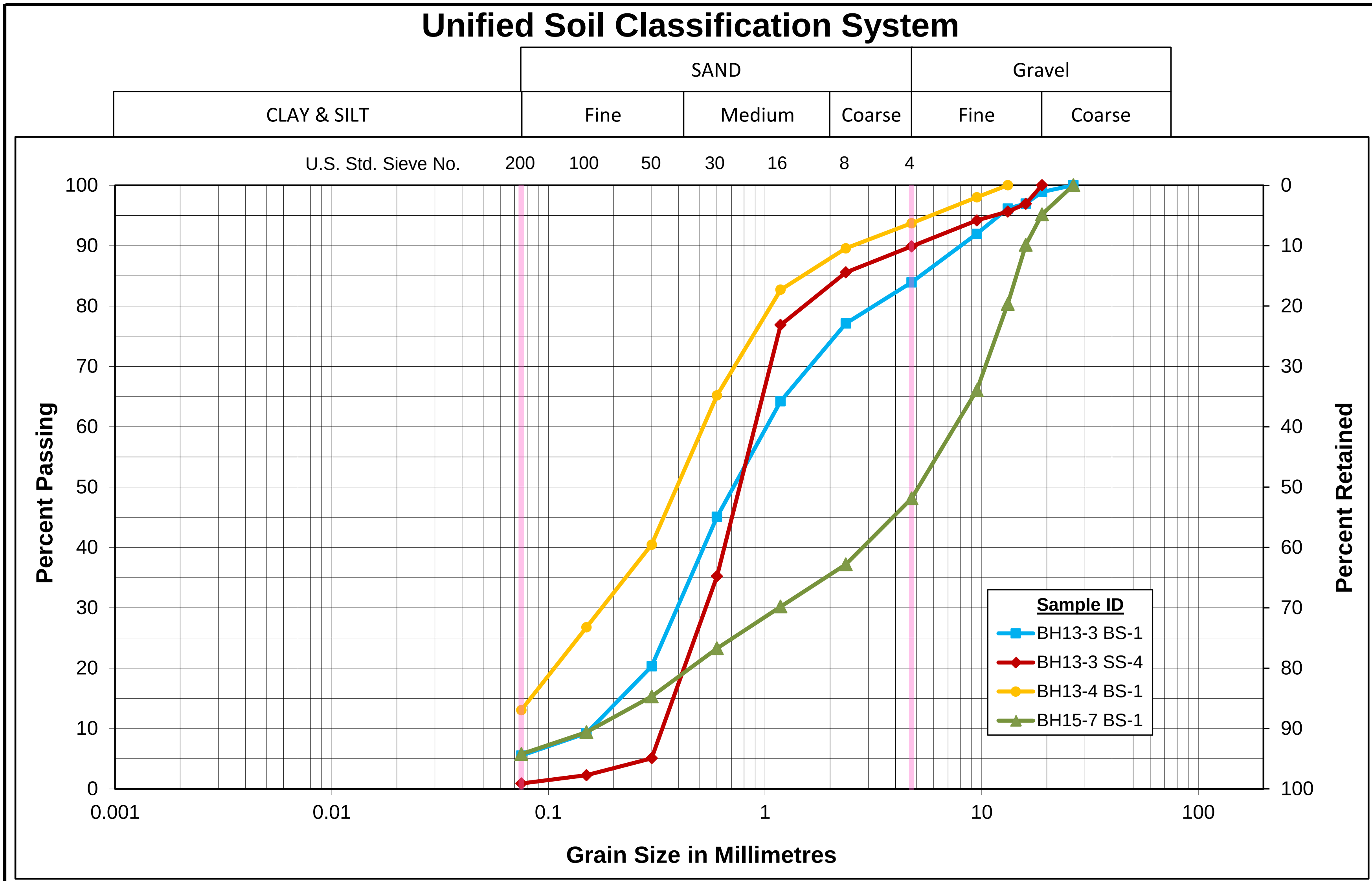
Laboratory Test Results

Figures 1 through 5: Grain Size Distribution Plots

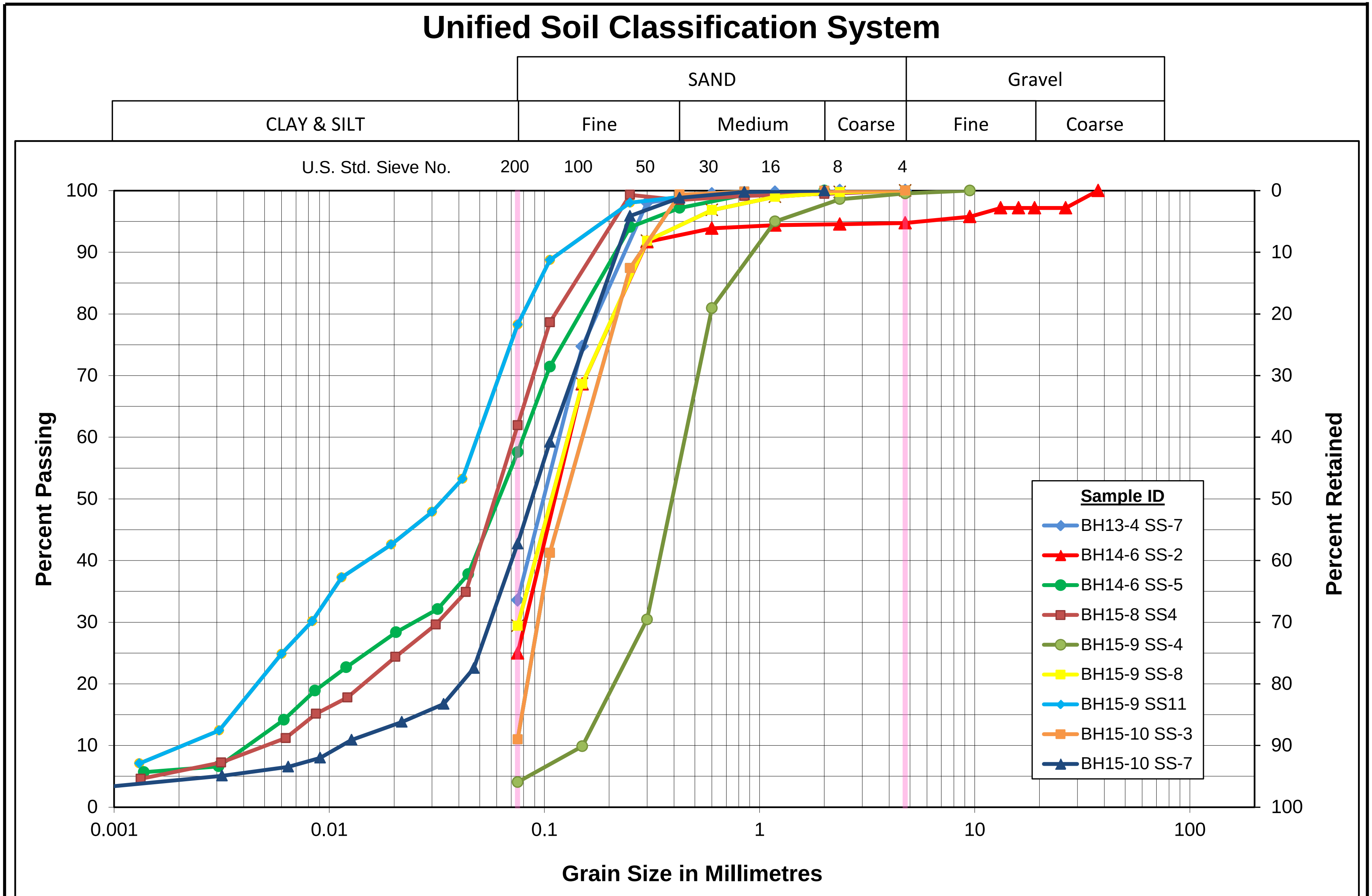
Figure 6 & 7: Plasticity Charts

Laboratory Testing by Golder Associates:

- Unconfined Compression (soil)
- Specific Gravity
- Consolidation



Stantec	GRAIN SIZE DISTRIBUTION Fill: Silty sand (SM), poorly graded sand with/without gravel (SP) and well graded gravel with sand (GW)	Figure No. 1 Project No. 165000836 GWP 5120-07-00



Stantec

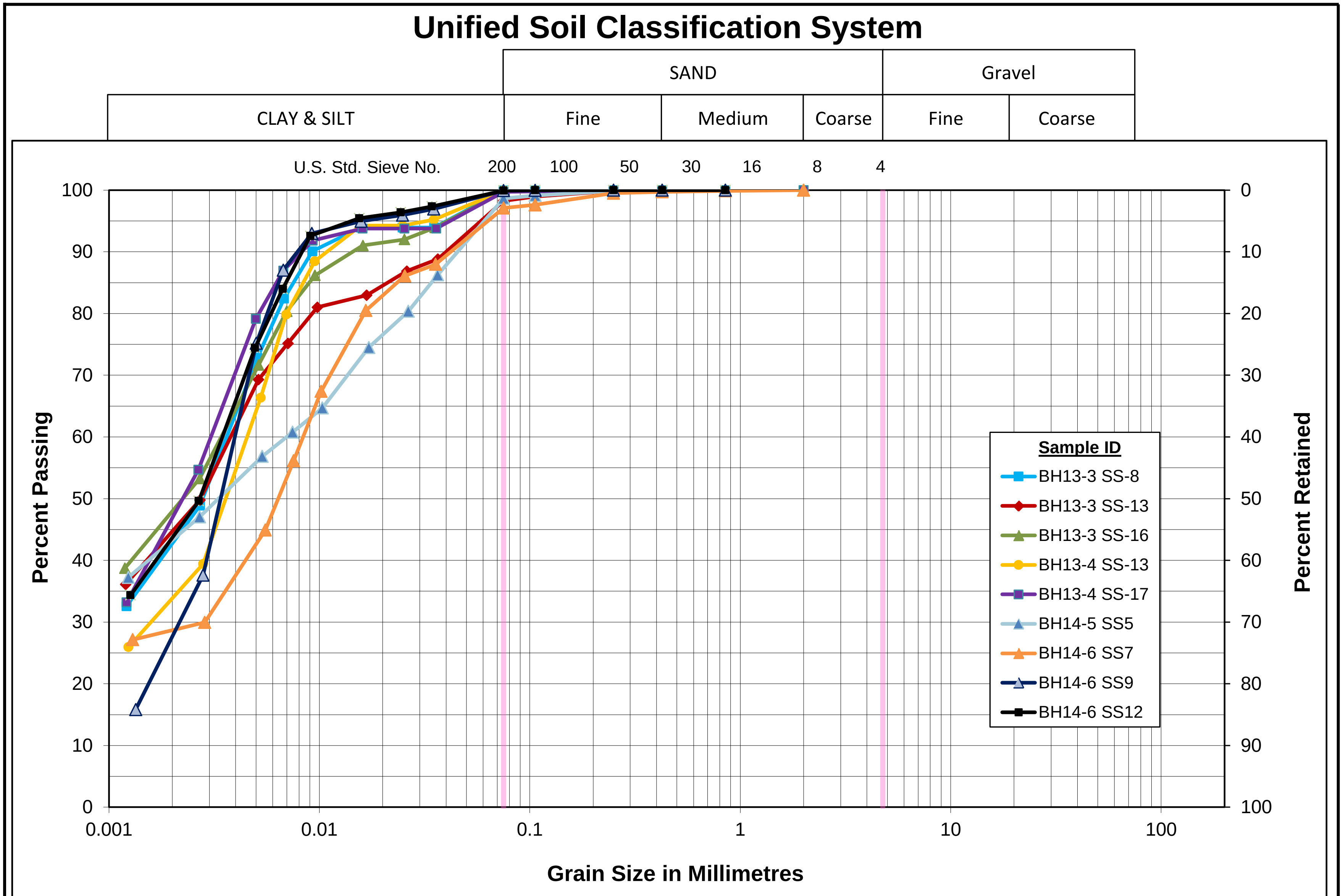
GRAIN SIZE DISTRIBUTION

Poorly graded sand (SP) to Poorly graded sand with silt (SP-SM) to Silty sand (SM) to Sandy silt (ML) to Silt with sand (ML)

Figure No. 2

Project No. 165000836

GWP 5120-07-00



Stantec

GRAIN SIZE DISTRIBUTION

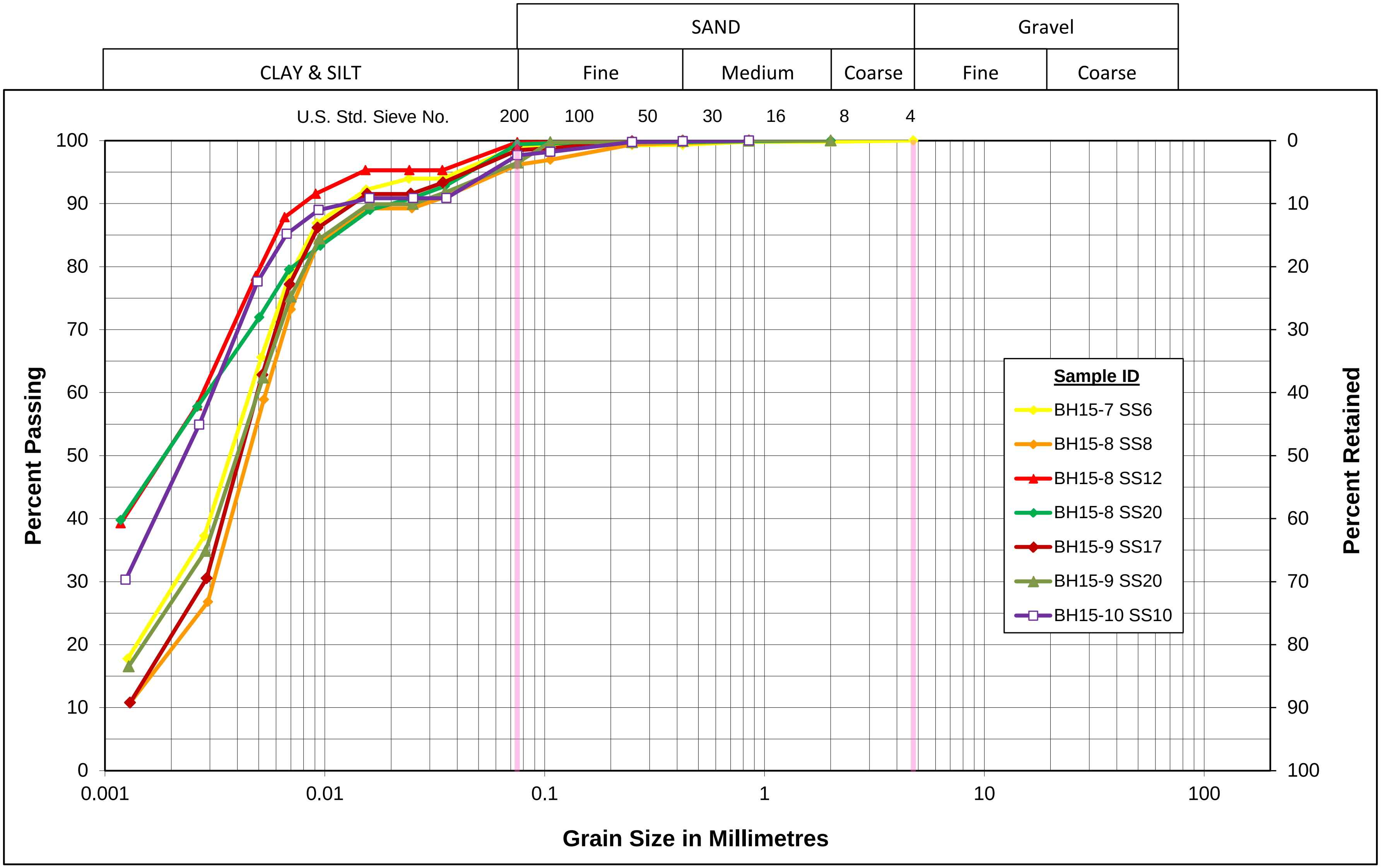
Silt (ML) to Silty clay (CI) to Clayey silt (CL)

Figure No. 3

Project No. 165000836

GWP 5120-07-00

Unified Soil Classification System



Stantec

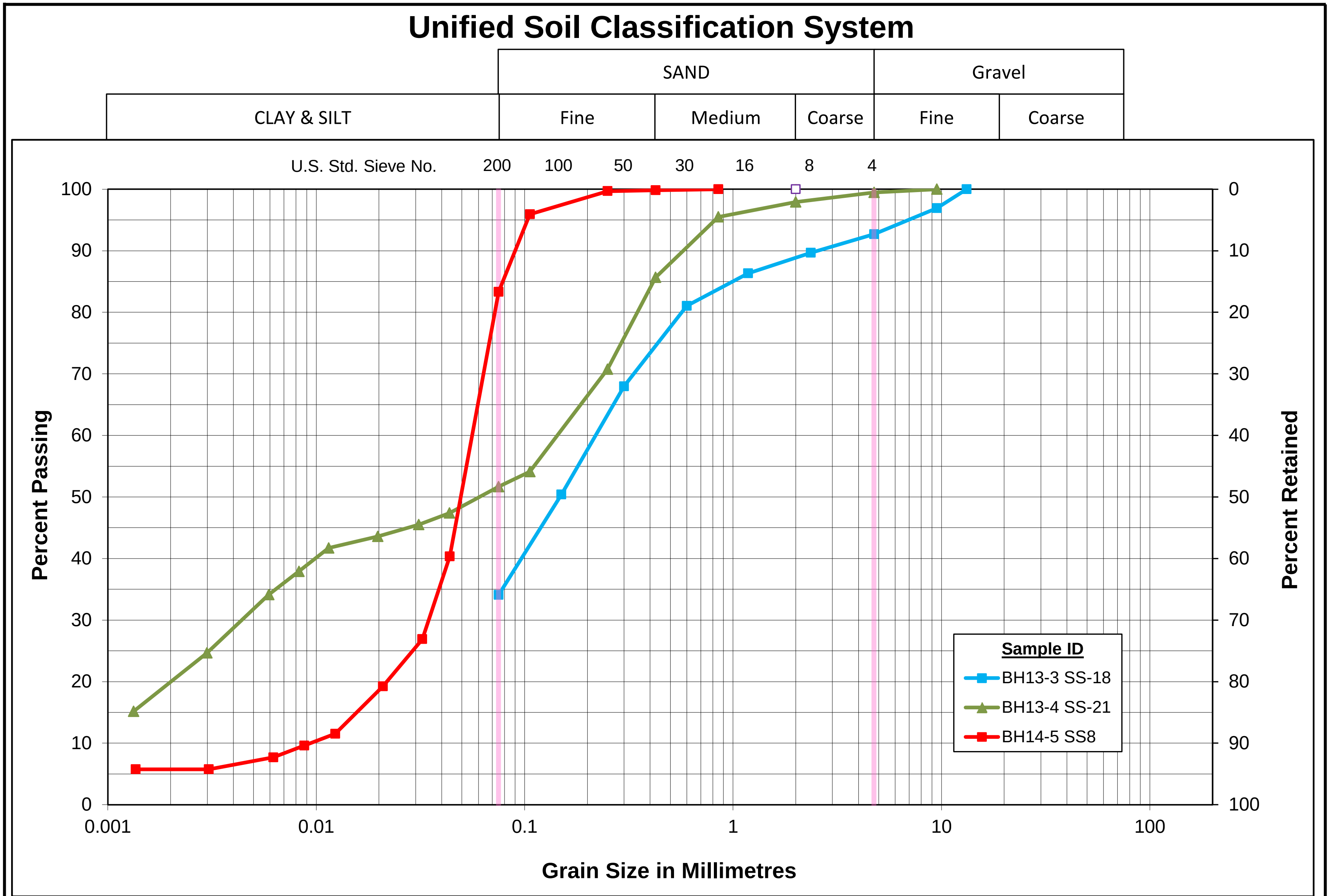
GRAIN SIZE DISTRIBUTION

Silt (ML) to Silty clay (CI) to Clayey silt (CL)

Figure No. 4

Project No. 165000836

GWP 5120-07-00



GRAIN SIZE DISTRIBUTION

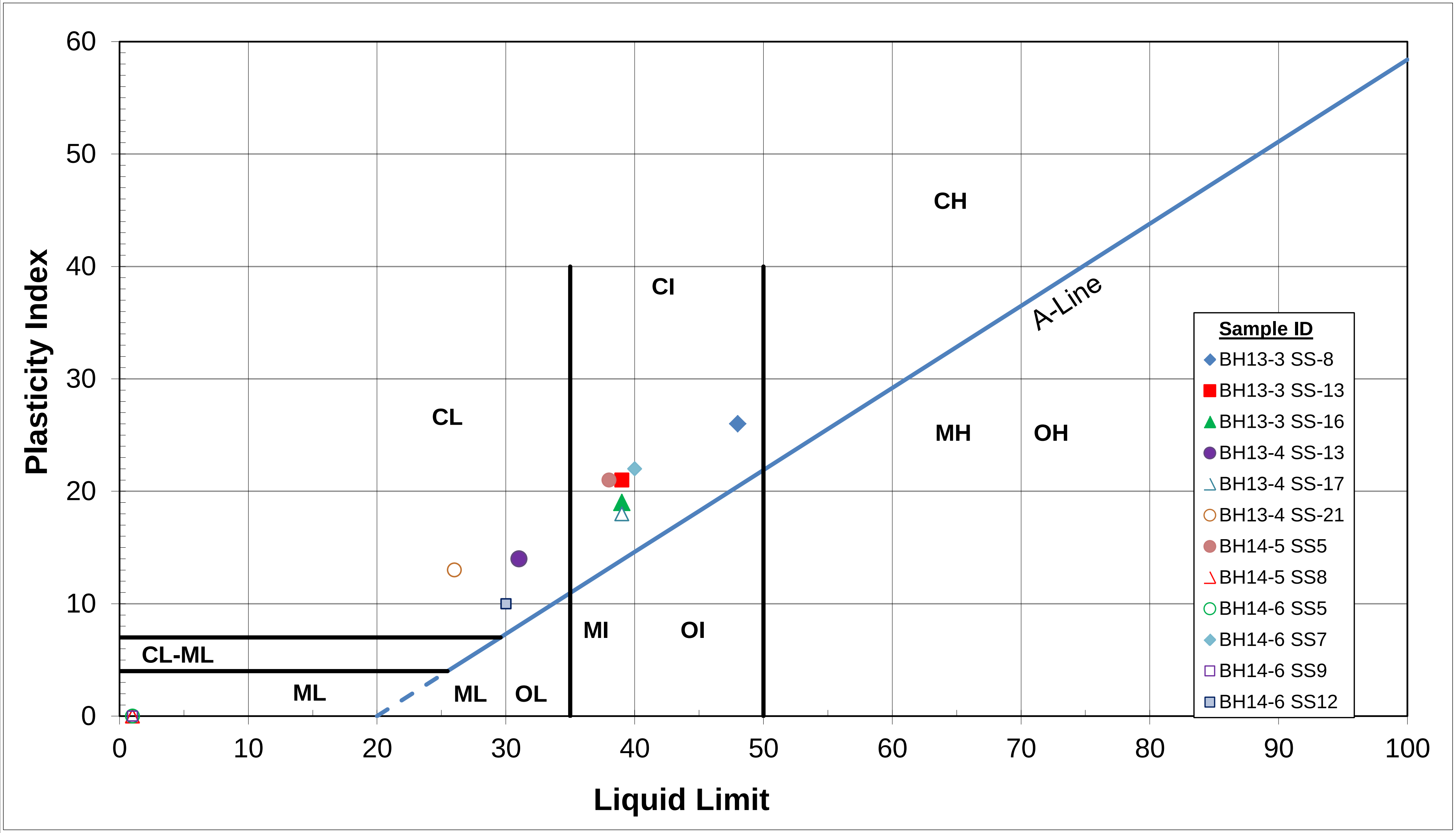
TILL : Silty sand (SM) to Silt (ML) with sand to Sandy clayey silt (CL)

Stantec

Figure No. 5

Project No. 165000836

GWP 5120-07-00



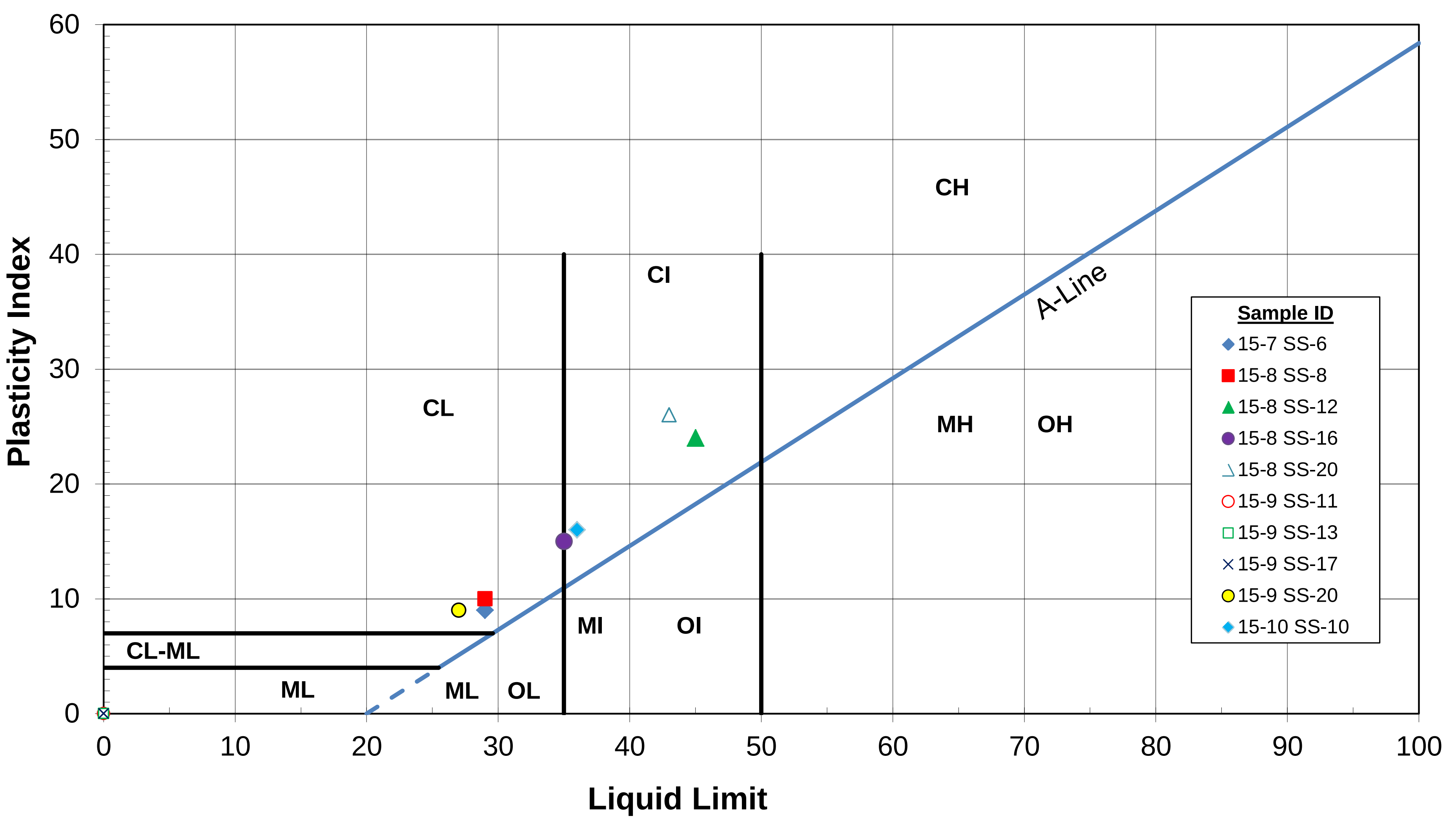
Stantec

PLASTICITY CHART

HWY 17B Duchesnay Creek Bridge

Figure No. 6

Project No. 165000836
GWP 5120-07-00



Stantec

PLASTICITY CHART

HWY 17B Duchesnay Creek Bridge

Figure No. 7

Project No. 165000836
GWP 5120-07-00

Golder Associates

January 13, 2014

Project No. 13-1183-0112

165000836-307

Mr. Simon Gudina
Stantec Consulting Ltd.
400-1331 Clyde Avenue
Ottawa, Ontario
K2C 3G4

GEOTECHNICAL LABORATORY TESTING

Dear Sir,

This letter reports the results of laboratory testing carried out on the samples received at our office in Mississauga. The results of the tests are summarized in the attached tables and figures.

The testing services reported herein have been performed in accordance with the indicated recognized standard, unless noted otherwise. This report is for the sole use of the designated client. This report constitutes a testing service only and does not represent any results interpretation or opinion regarding specification compliance or material suitability.

We trust that the results are sufficient for your current requirements. If you have any questions, please do not hesitate to call us.

Regards

GOLDER ASSOCIATES LTD.

Marijana Manojlovic

Marijana Manojlovic
Laboratory Services

MM/lg

n:\admin\lab\2013\13-1183-0112\letter.dotm

CANADA'S BEST MANAGED COMPANIES Platinum member

UNCONFINED COMPRESSION TEST (UC)

ASTM D 2166 - 06

SAMPLE IDENTIFICATION

PROJECT NUMBER	13-1183-0112	SAMPLE NUMBER	ST-9
BOREHOLE NUMBER	13-3	SAMPLE DEPTH, m	6.1-6.7

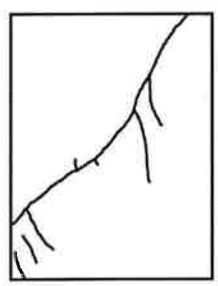
TEST CONDITIONS

MACHINE SPEED, mm/min	1.40	TYPE OF SPECIMEN	thin wall tube sample
RATE OF AXIAL STRAIN, %/min	1.00	L/D	2.03

SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	14.04	WATER CONTENT, (specimen) %	44.45
SAMPLE DIAMETER, cm	6.90	UNIT WEIGHT, kN/m^3	17.47
SAMPLE AREA, cm^2	37.41	DRY UNIT WT., kN/m^3	12.09
SAMPLE VOLUME, cm^3	525.30	SPECIFIC GRAVITY, measured	2.73
WET WEIGHT, g	935.99	VOID RATIO	1.21
DRY WEIGHT, g	647.98		

FAILURE SKETCH



TEST RESULTS

STRAIN AT FAILURE, %	2.8	COMPRESSIVE STRESS, kPa	53

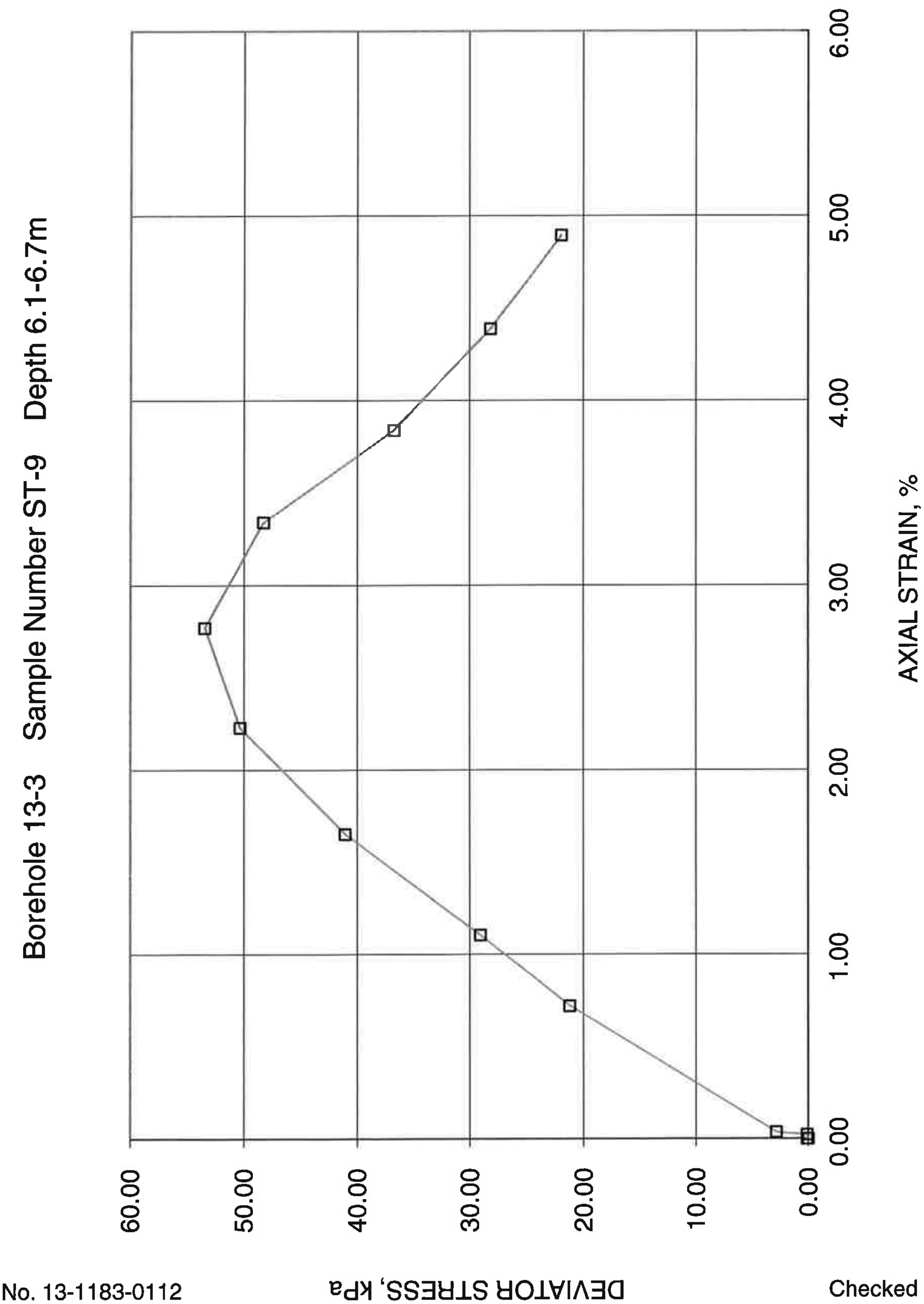
REMARKS: 20 to 38cm from bottom

DATE: 11/13/2013

Checked By: [signature]

Golder Associates

UNCONFINED COMPRESSION TEST (UC)	FIGURE



Project No. 13-1183-0112

Checked By: [signature]

UNCONFINED COMPRESSION TEST (UC)

ASTM D 2166 - 06

SAMPLE IDENTIFICATION

PROJECT NUMBER	13-1183-0112	SAMPLE NUMBER	ST-14
BOREHOLE NUMBER	13-3	SAMPLE DEPTH, m	12.2-12.8

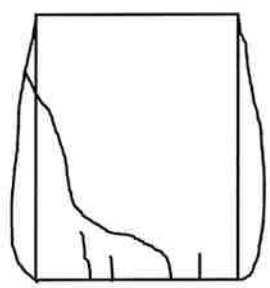
TEST CONDITIONS

MACHINE SPEED, mm/min	1.40	TYPE OF SPECIMEN	thin wall tube sample
RATE OF AXIAL STRAIN, %/min	1.01	L/D	1.99

SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	13.88	WATER CONTENT, (specimen) %	29.10
SAMPLE DIAMETER, cm	6.97	UNIT WEIGHT, kN/m^3	19.50
SAMPLE AREA, cm^2	38.16	DRY UNIT WT., kN/m^3	15.10
SAMPLE VOLUME, cm^3	529.41	SPECIFIC GRAVITY, measured	2.72
WET WEIGHT, g	1052.93	VOID RATIO	0.77
DRY WEIGHT, g	815.59		

FAILURE SKETCH



TEST RESULTS

STRAIN AT FAILURE, %	10.0	COMPRESSIVE STRESS, kPa	93

REMARKS: 23 to 41cm from bottom

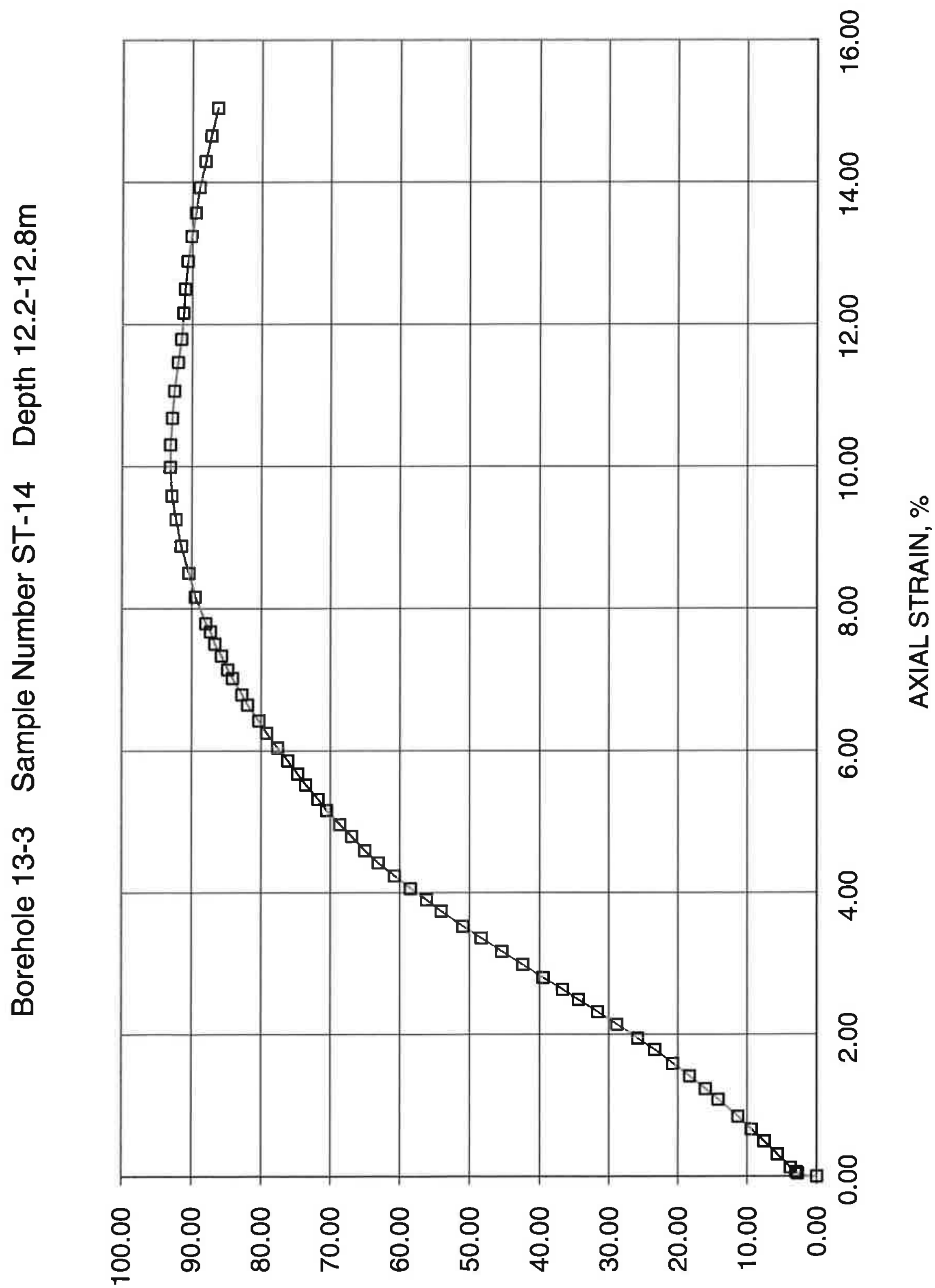
L/D Ratio not in accordance with ASTM Standard

DATE: 11/13/2013

Checked By: [signature]

Golder Associates

UNCONFINED COMPRESSION TEST (UC)	FIGURE



Project No. 13-1183-0112 DEVIATOR STRESS, KPa Checked By:

UNCONFINED COMPRESSION TEST (UC)

ASTM D 2166 - 06

SAMPLE IDENTIFICATION

PROJECT NUMBER	13-1183-0112	SAMPLE NUMBER	ST-12
BOREHOLE NUMBER	13-4	SAMPLE DEPTH, m	12.2-12.8

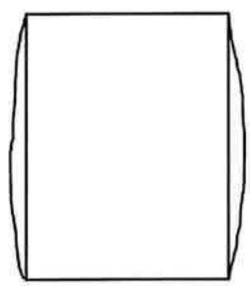
TEST CONDITIONS

MACHINE SPEED, mm/min	1.40	TYPE OF SPECIMEN	thin wall tube sample
RATE OF AXIAL STRAIN, %/min	1.03	L/D	1.92

SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	13.58	WATER CONTENT, (specimen) %	33.03
SAMPLE DIAMETER, cm	7.08	UNIT WEIGHT, kN/m^3	18.81
SAMPLE AREA, cm^2	39.37	DRY UNIT WT., kN/m^3	14.14
SAMPLE VOLUME, cm^3	534.58	SPECIFIC GRAVITY, measured	2.73
WET WEIGHT, g	1025.75	VOID RATIO	0.89
DRY WEIGHT, g	771.04		

FAILURE SKETCH



TEST RESULTS

STRAIN AT FAILURE, %	15.2	COMPRESSIVE STRESS, kPa	59

REMARKS: 49 to 114cm from top

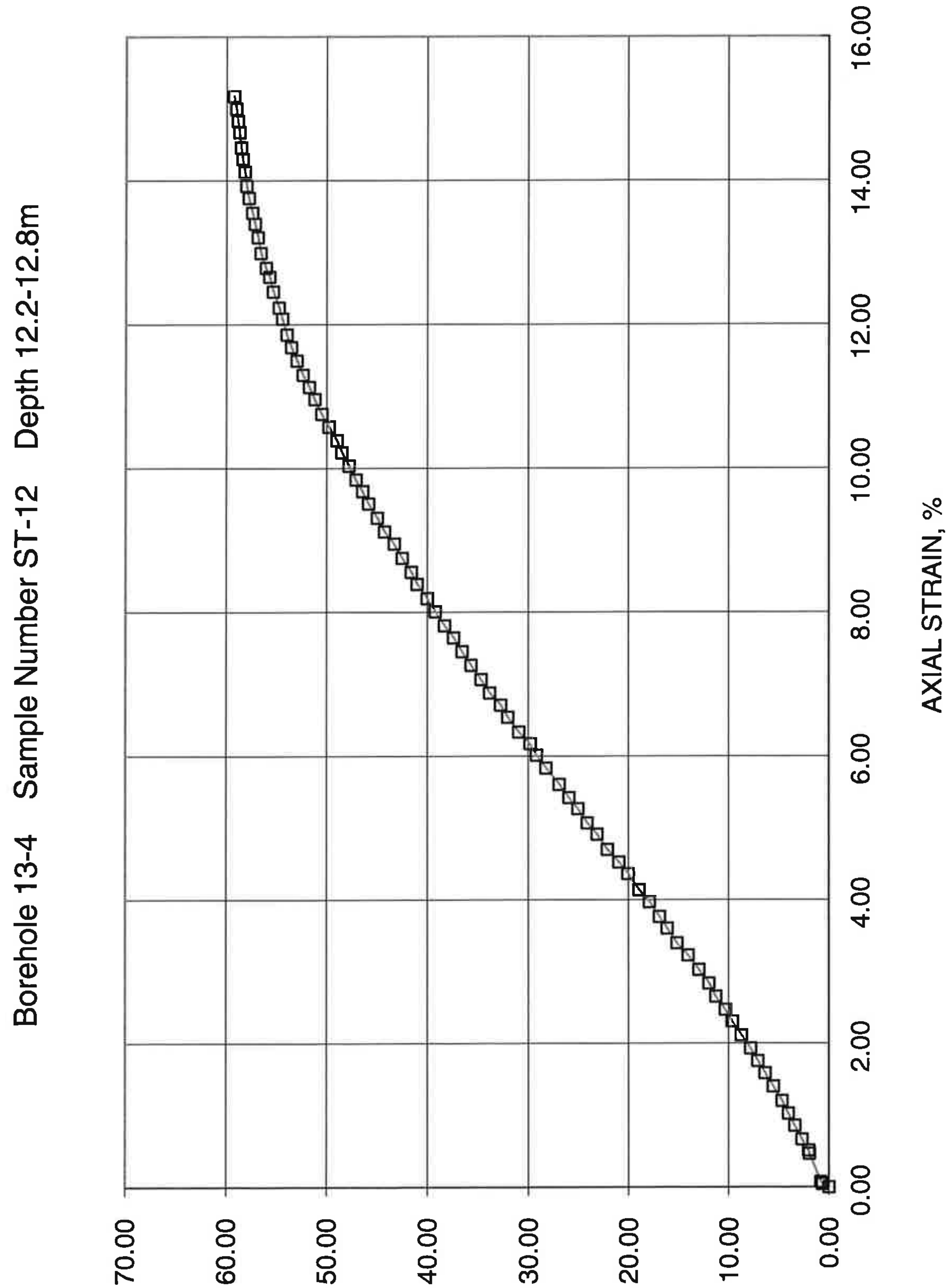
L/D Ratio not in accordance with ASTM Standard

DATE: 11/13/2013

Checked By: [signature]

Golder Associates

UNCONFINED COMPRESSION TEST (UC)	FIGURE



Project No. 13-1183-0112

Checked By: [signature]

UNCONFINED COMPRESSION TEST (UC)

ASTM D 2166 - 06

SAMPLE IDENTIFICATION

PROJECT NUMBER	13-1183-0112	SAMPLE NUMBER	ST-16
BOREHOLE NUMBER	13-4	SAMPLE DEPTH, m	18.3-18.9

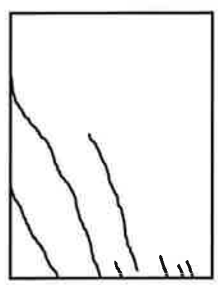
TEST CONDITIONS

MACHINE SPEED, mm/min	1.40	TYPE OF SPECIMEN	thin wall tube sample
RATE OF AXIAL STRAIN, %/min	1.00	L/D	2.01

SPECIMEN INFORMATION

SAMPLE HEIGHT, cm	14.00	WATER CONTENT, (specimen) %	36.49
SAMPLE DIAMETER, cm	6.96	UNIT WEIGHT, kN/m^3	18.38
SAMPLE AREA, cm^2	38.08	DRY UNIT WT., kN/m^3	13.46
SAMPLE VOLUME, cm^3	533.31	SPECIFIC GRAVITY, measured	2.74
WET WEIGHT, g	999.79	VOID RATIO	0.99
DRY WEIGHT, g	732.51		

FAILURE SKETCH



TEST RESULTS

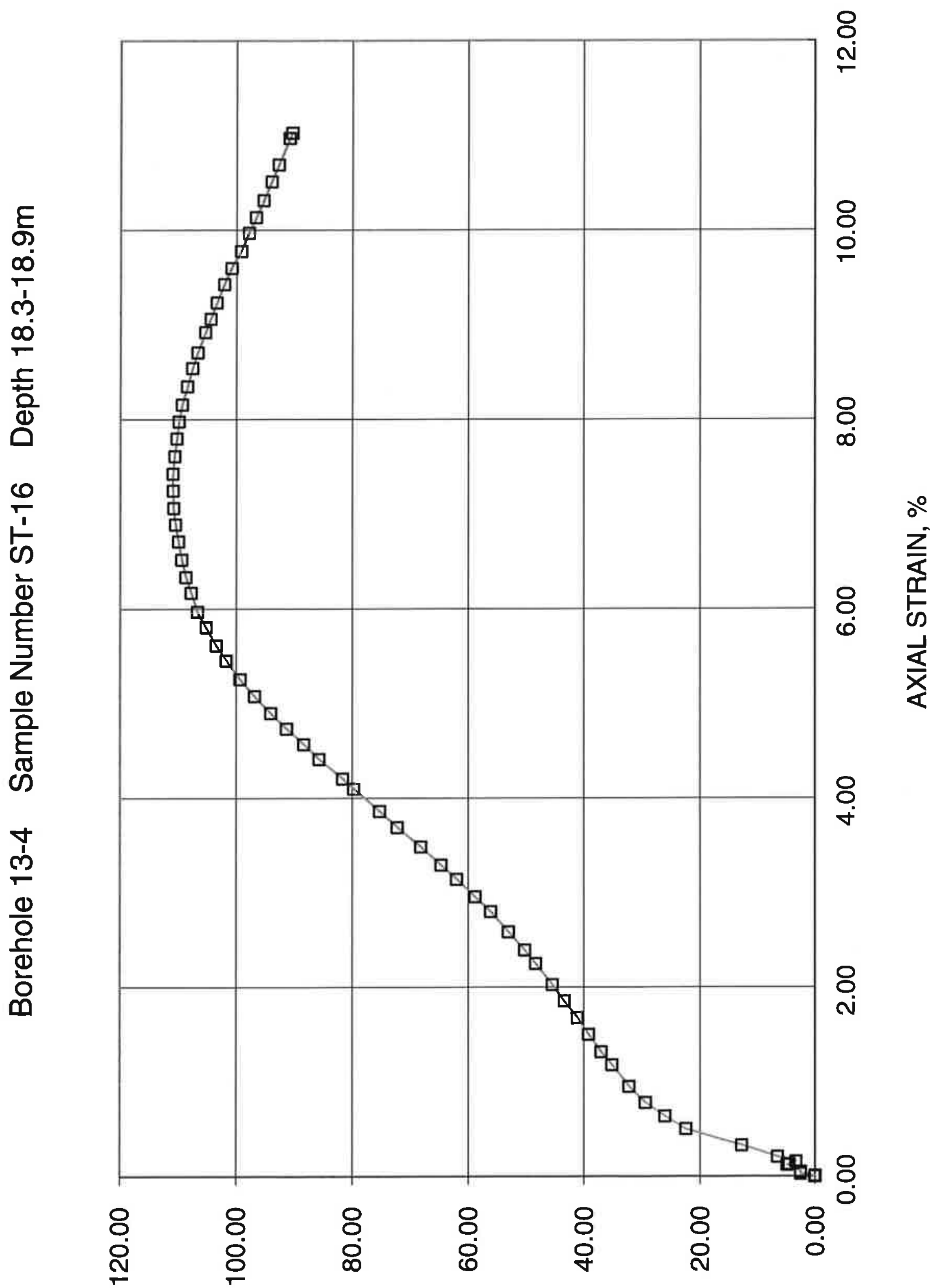
STRAIN AT FAILURE, %	7.4	COMPRESSIVE STRESS, kPa	111

REMARKS:	36 to 58cm from bottom	DATE:	11/13/2013

Checked By: [signature]

Golder Associates

UNCONFINED COMPRESSION TEST (UC)	FIGURE



Project No. 13-1183-0112

Checked By: MM

CONSOLIDATION TEST SUMMARY

FIGURE

SAMPLE IDENTIFICATION

Project Number	13-1183-0112	Sample Number	ST-9
Borehole Number	13-3	Sample Depth, m	6.1-6.7

TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	5		
Date Started	11/12/2013		
Date Completed	11/28/2013		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.88	Unit Weight, kN/m^3	16.99
Sample Diameter, cm	6.31	Dry Unit Weight, kN/m^3	11.31
Area, cm^2	31.29	Specific Gravity, measured	2.73
Volume, cm^3	58.86	Solids Height, cm	0.795
Water Content, %	50.17	Volume of Solids, cm^3	24.88
Wet Mass, g	101.98	Volume of Voids, cm^3	33.98
Dry Mass, g	67.91	Degree of Saturation, %	100.3

TEST COMPUTATIONS

Stress kPa	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv. cm^2/s	mv m^2/kN	k cm/s
0.00	1.881	1.366	1.881				
6.07	1.876	1.360	1.878	14	5.34E-02	4.55E-04	2.38E-06
10.78	1.871	1.353	1.873	591	1.26E-03	5.64E-04	6.96E-08
20.79	1.867	1.349	1.869	747	9.91E-04	2.02E-04	1.96E-08
40.26	1.856	1.334	1.861	759	9.68E-04	3.09E-04	2.93E-08
79.51	1.834	1.307	1.845	628	1.15E-03	2.91E-04	3.28E-08
157.65	1.794	1.257	1.814	540	1.29E-03	2.74E-04	3.47E-08
313.87	1.593	1.003	1.693	1338	4.54E-04	6.85E-04	3.05E-08
626.75	1.453	0.827	1.523	913	5.38E-04	2.38E-04	1.25E-08
1255.60	1.343	0.690	1.398	577	7.18E-04	9.24E-05	6.50E-09
2509.12	1.253	0.577	1.298	217	1.65E-03	3.82E-05	6.17E-09
1255.60	1.259	0.583	1.256				
313.87	1.297	0.631	1.278				
79.51	1.331	0.674	1.314				
20.79	1.366	0.718	1.348				
6.07	1.391	0.750	1.379				

Note:
Consolidation loading and unloading schedule assigned by the client.
Specimen taken 11 to 20cm from bottom of the tube
k calculated using cv based on t_{90} values.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

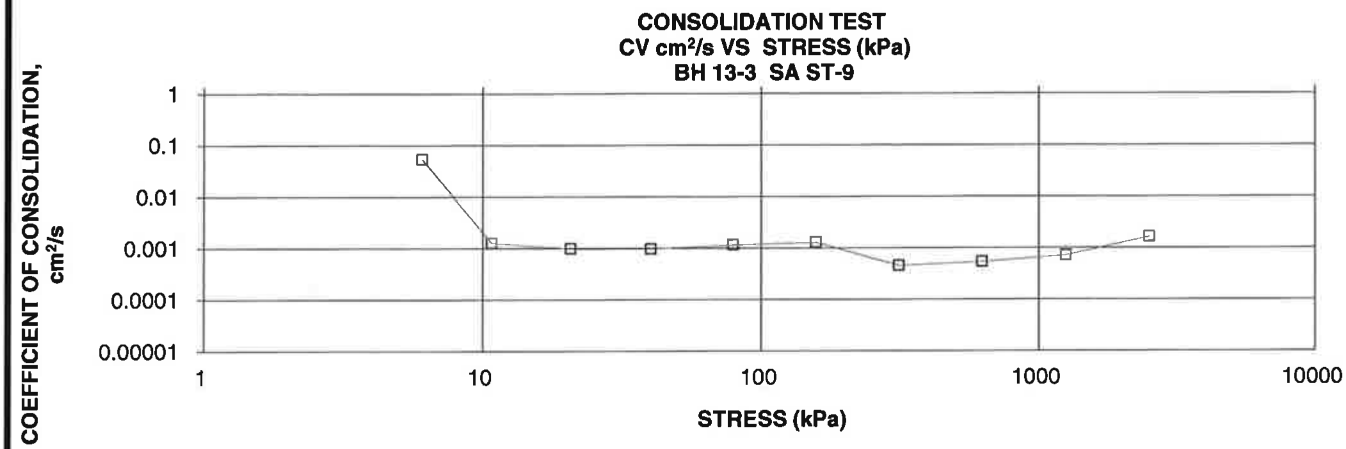
Sample Height, cm	1.39	Unit Weight, kN/m^3	20.42
Sample Diameter, cm	6.31	Dry Unit Weight, kN/m^3	15.30
Area, cm^2	31.29	Specific Gravity, measured	2.73
Volume, cm^3	43.53	Solids Height, cm	0.795
Water Content, %	33.51	Volume of Solids, cm^3	24.88
Wet Mass, g	90.67	Volume of Voids, cm^3	18.66
Dry Mass, g	67.91		

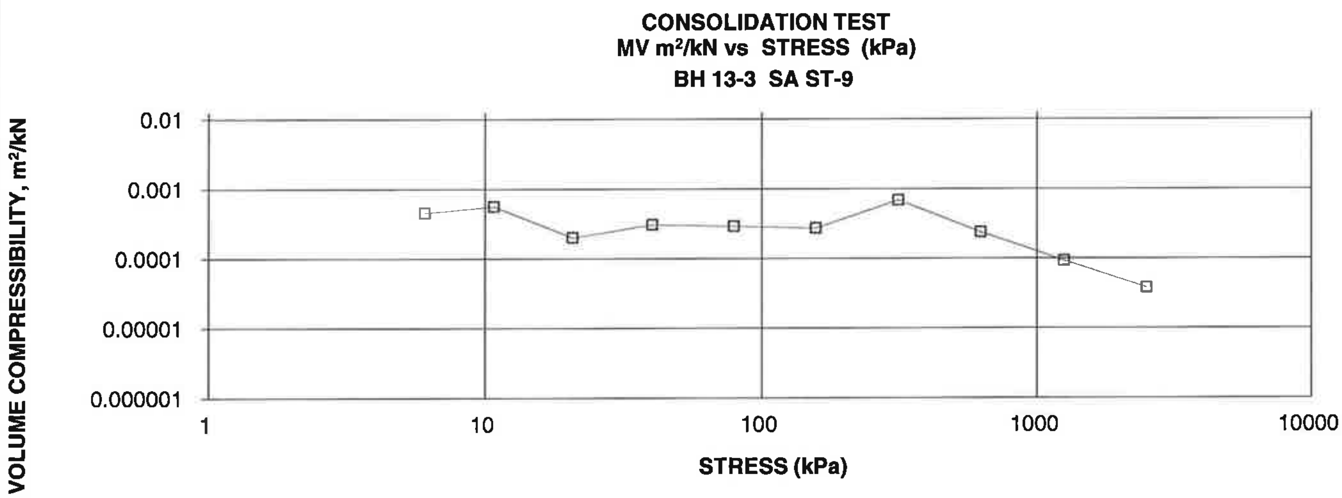
Prepared By: LG

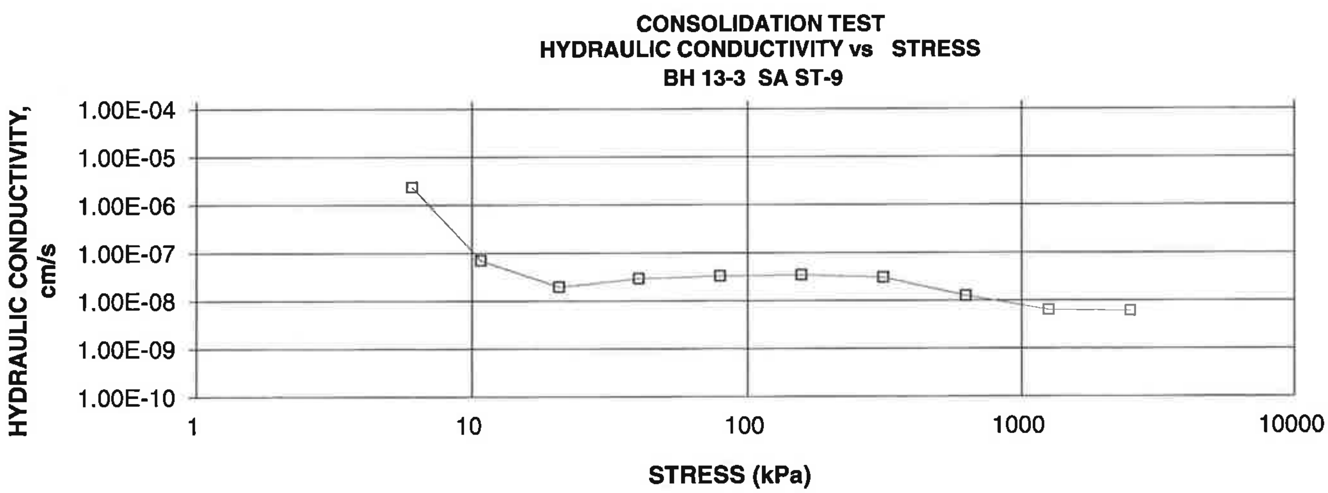
Golder Associates

Checked By: [signature]

CONSOLIDATION TEST SUMMARY	FIGURE





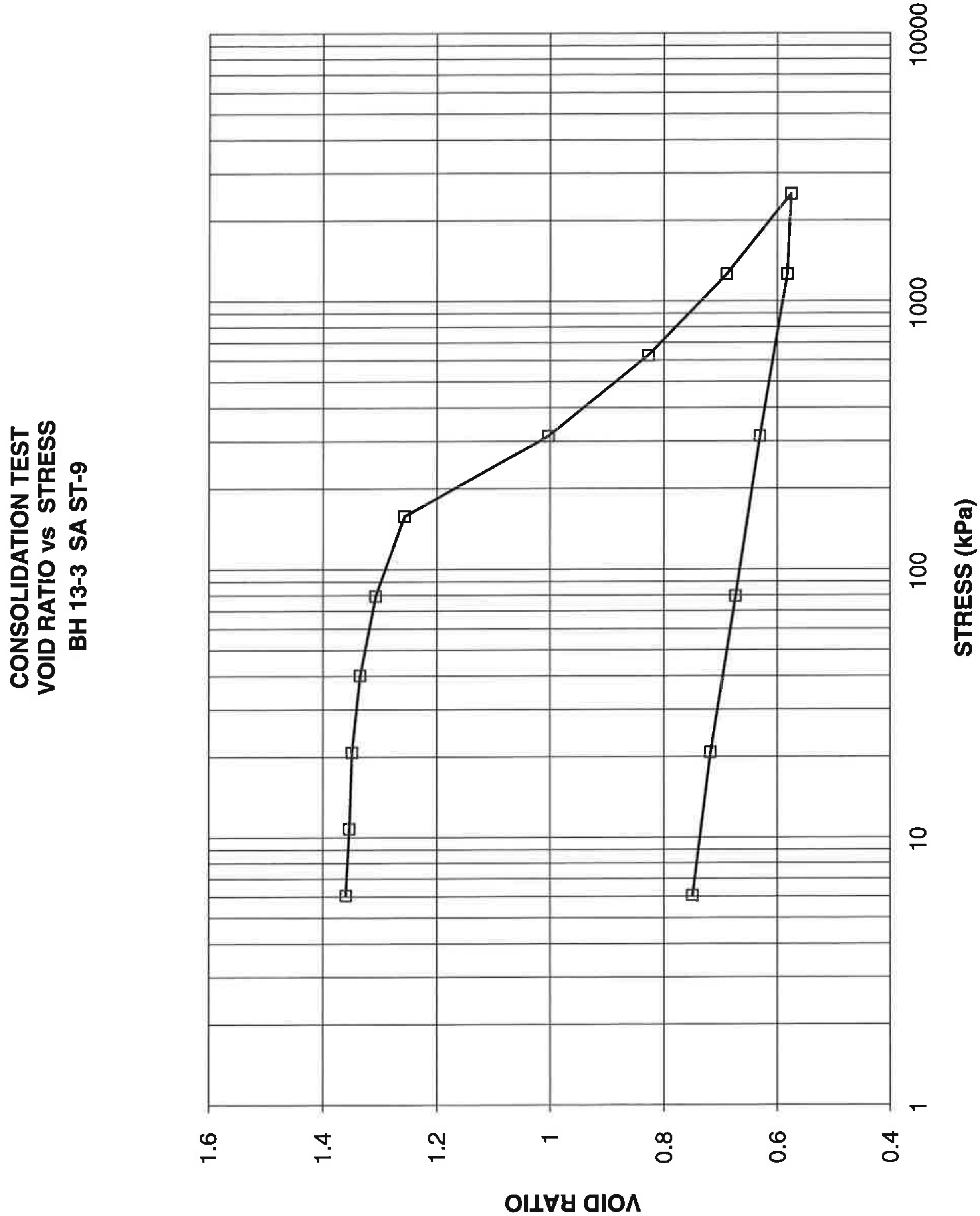


Project No. 13-1183-0112
Prepared By: LG

Golder Associates

Checked By: [signature]

CONSOLIDATION TEST VOID RATIO VS LOG STRESS	FIGURE



Project No. 13-1183-0112

Prepared By: LG

Golder Associates

Checked By: [signature]

CONSOLIDATION TEST SUMMARY	FIGURE

SAMPLE IDENTIFICATION

Project Number	13-1183-0112	Sample Number	ST-14
Borehole Number	13-3	Sample Depth, m	12.2-12.8

TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	6		
Date Started	11/12/2013		
Date Completed	11/27/2013		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.89	Unit Weight, kN/m^3	18.44
Sample Diameter, cm	6.34	Dry Unit Weight, kN/m^3	13.65
Area, cm^2	31.61	Specific Gravity, measured	2.72
Volume, cm^3	59.80	Solids Height, cm	0.968
Water Content, %	35.11	Volume of Solids, cm^3	30.60
Wet Mass, g	112.44	Volume of Voids, cm^3	29.21
Dry Mass, g	83.22	Degree of Saturation, %	100.0

TEST COMPUTATIONS

Stress kPa	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv. cm^2/s	mv m^2/kN	k cm/s
0.00	1.892	0.955	1.892				
5.94	1.886	0.949	1.889	41	1.85E-02	5.16E-04	9.33E-07
10.58	1.878	0.940	1.882	747	1.01E-03	9.57E-04	9.43E-08
20.63	1.865	0.927	1.872	790	9.40E-04	6.57E-04	6.06E-08
40.05	1.846	0.907	1.856	638	1.14E-03	5.17E-04	5.80E-08
78.75	1.824	0.884	1.835	519	1.38E-03	3.11E-04	4.20E-08
156.15	1.784	0.844	1.804	480	1.44E-03	2.67E-04	3.76E-08
311.31	1.681	0.736	1.733	819	7.77E-04	3.53E-04	2.69E-08
620.91	1.581	0.634	1.631	591	9.54E-04	1.70E-04	1.59E-08
1240.46	1.496	0.545	1.538	519	9.67E-04	7.32E-05	6.93E-09
2479.13	1.421	0.468	1.458	280	1.61E-03	3.18E-05	5.02E-09
1240.46	1.431	0.478	1.426				
311.31	1.455	0.503	1.443				
78.75	1.484	0.533	1.469				
20.63	1.521	0.571	1.502				
5.94	1.555	0.607	1.538				

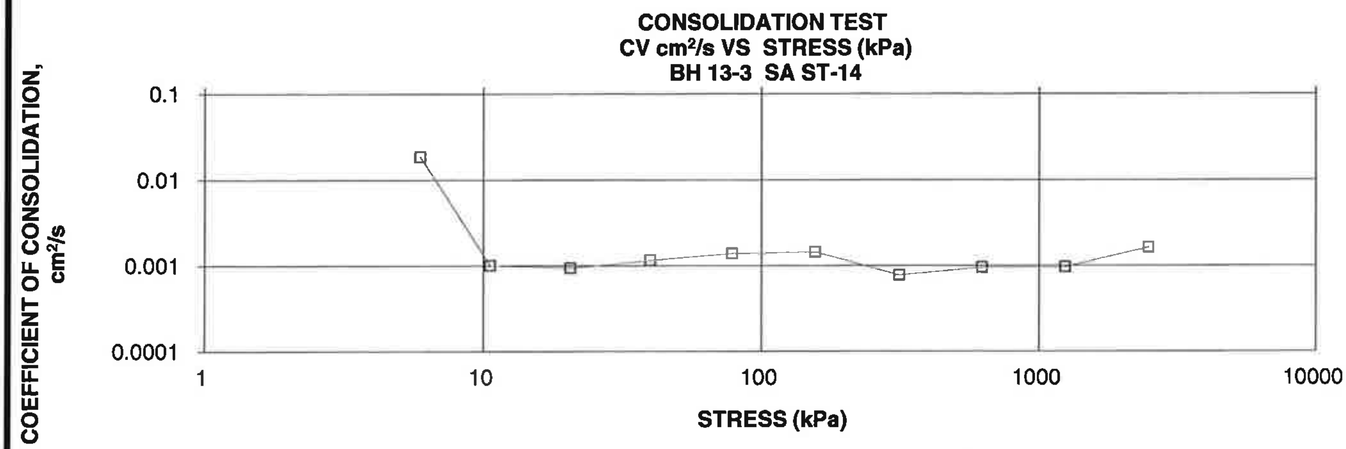
Note:
Consolidation loading and unloading schedule assigned by the client.
Specimen taken 41 to 48cm from bottom of the tube.
k calculated using cv based on t_{90} values.

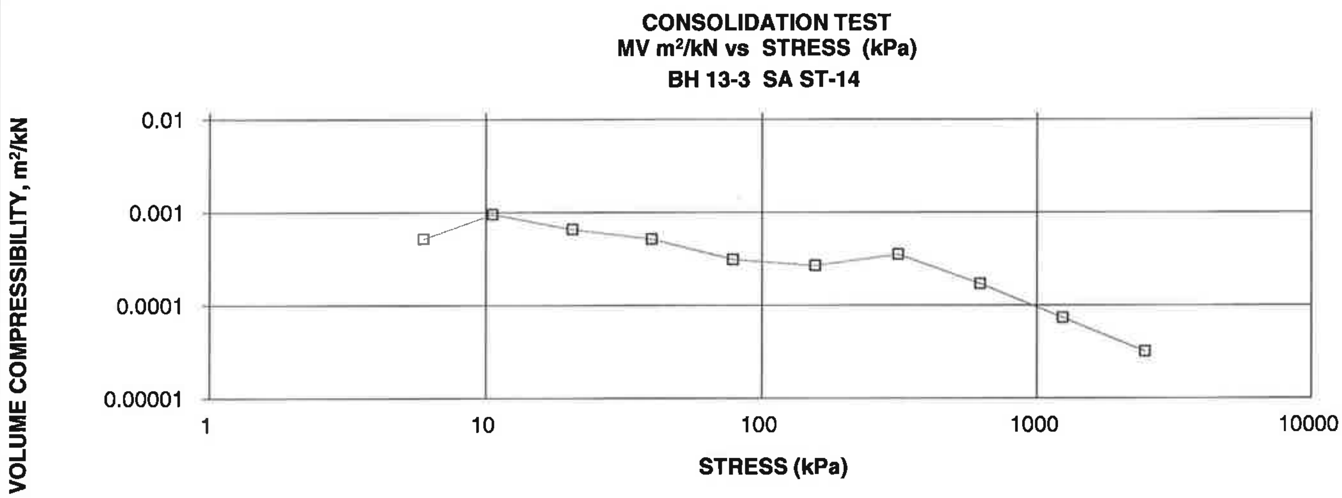
SAMPLE DIMENSIONS AND PROPERTIES - FINAL

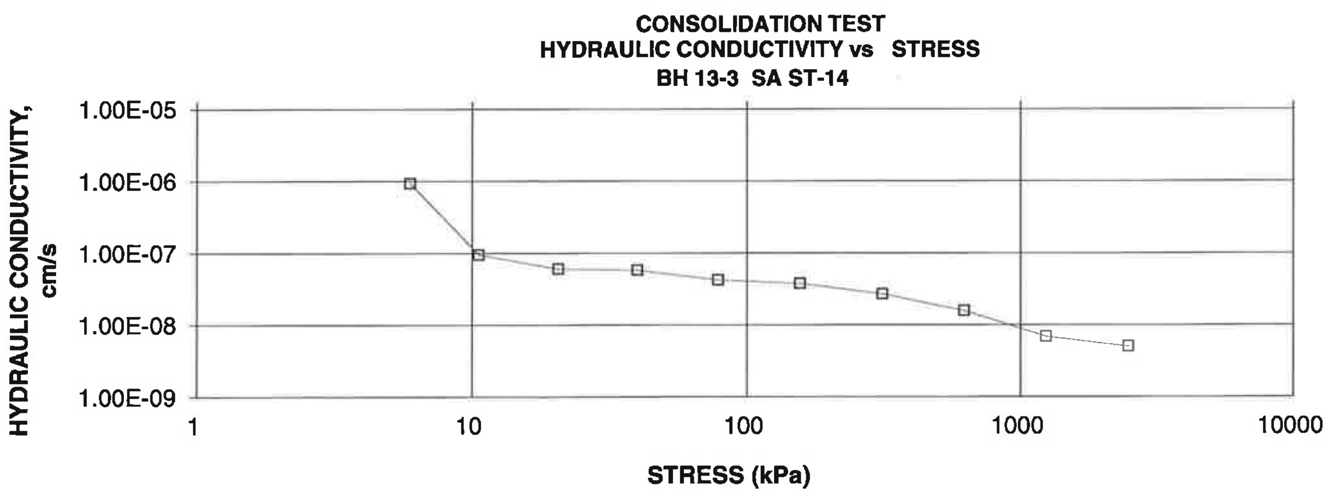
Sample Height, cm	1.56	Unit Weight, kN/m^3	21.11
Sample Diameter, cm	6.34	Dry Unit Weight, kN/m^3	16.60
Area, cm^2	31.61	Specific Gravity, measured	2.72
Volume, cm^3	49.16	Solids Height, cm	0.968
Water Content, %	27.16	Volume of Solids, cm ^{3}	30.60
Wet Mass, g	105.82	Volume of Voids, cm ^{3}	18.56
Dry Mass, g	83.22		

Prepared By: LG **Golder Associates** Checked By: [signature]

CONSOLIDATION TEST SUMMARY	FIGURE







Project No. 13-1183-0112
Prepared By: LG

Golder Associates

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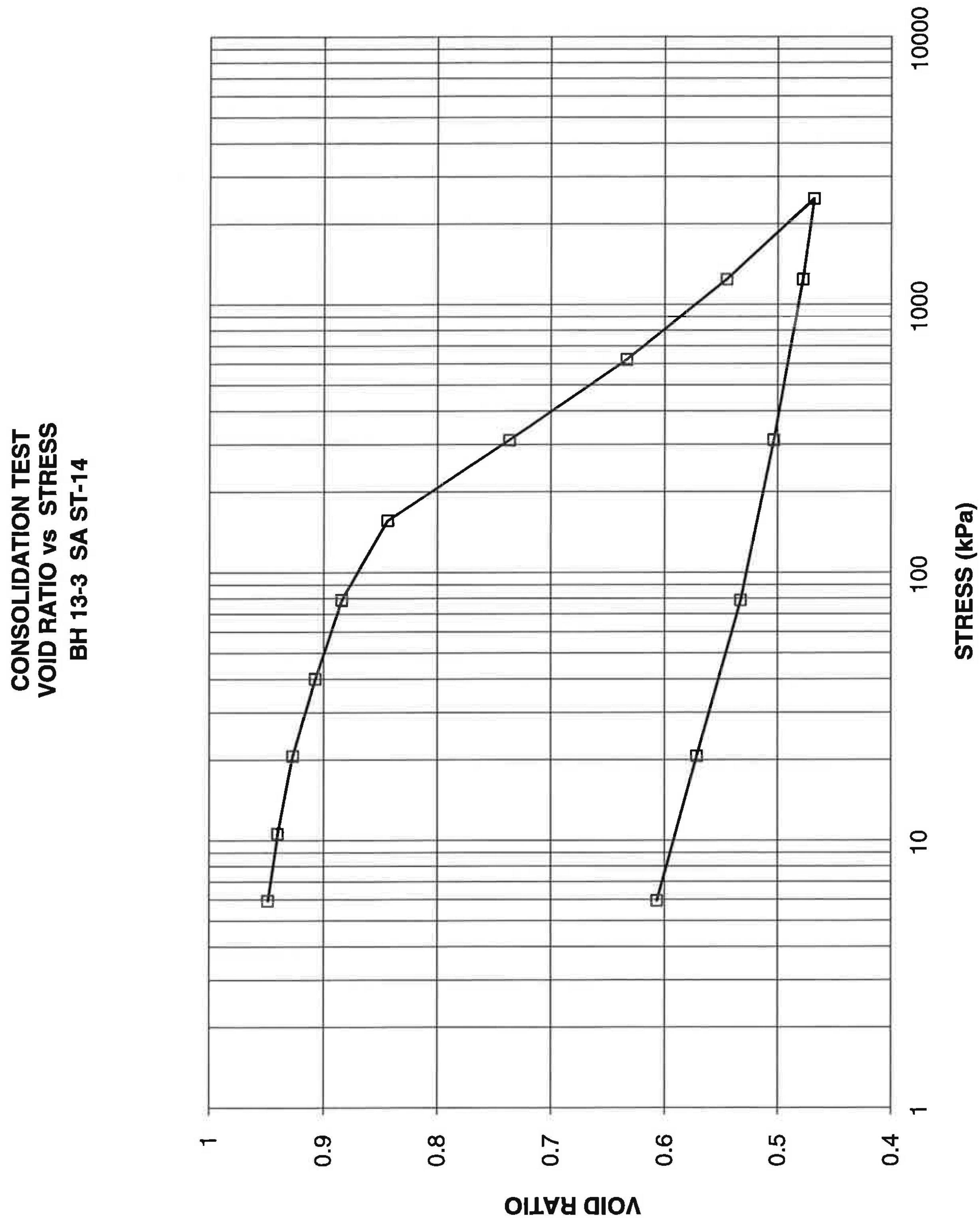
CONSOLIDATION TEST
VOID RATIO VS LOG STRESS

FIGURE



Project No. 13-1183-0112

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Golder Associates

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CONSOLIDATION TEST SUMMARY	FIGURE

SAMPLE IDENTIFICATION

Project Number	13-1183-0112	Sample Number	ST-12
Borehole Number	13-4	Sample Depth, m	12.2-12.8

TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	7		
Date Started	11/12/2013		
Date Completed	11/27/2013		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.89	Unit Weight, kN/m^3	18.09
Sample Diameter, cm	6.31	Dry Unit Weight, kN/m^3	13.04
Area, cm^2	31.23	Specific Gravity, measured	2.73
Volume, cm^3	58.87	Solids Height, cm	0.918
Water Content, %	38.68	Volume of Solids, cm^3	28.68
Wet Mass, g	108.60	Volume of Voids, cm^3	30.19
Dry Mass, g	78.31	Degree of Saturation, %	100.3

TEST COMPUTATIONS

Stress kPa	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv. cm^2/s	mv m^2/kN	k cm/s
0.00	1.885	1.052	1.885				
5.86	1.880	1.047	1.883	22	3.41E-02	4.53E-04	1.51E-06
10.72	1.880	1.046	1.880	360	2.08E-03	5.46E-05	1.11E-08
20.56	1.873	1.040	1.876	332	2.25E-03	3.34E-04	7.36E-08
40.27	1.866	1.032	1.870	759	9.76E-04	1.96E-04	1.88E-08
79.50	1.857	1.022	1.862	747	9.84E-04	1.18E-04	1.13E-08
157.89	1.842	1.006	1.850	240	3.02E-03	1.04E-04	3.07E-08
314.64	1.774	0.931	1.808	581	1.19E-03	2.32E-04	2.71E-08
627.99	1.647	0.793	1.710	228	2.72E-03	2.15E-04	5.73E-08
1253.59	1.559	0.697	1.603	118	4.61E-03	7.45E-05	3.37E-08
2506.19	1.487	0.619	1.523	101	4.87E-03	3.05E-05	1.45E-08
1253.59	1.493	0.625	1.490				
314.64	1.514	0.649	1.503				
79.50	1.537	0.673	1.526				
20.56	1.560	0.698	1.548				
5.86	1.581	0.721	1.570				

Note:
Consolidation loading and unloading schedule assigned by the client.
Specimen taken 7 to 14cm from top of the tube.
k calculated using cv based on t_{90} values.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	1.58	Unit Weight, kN/m^3	20.12
Sample Diameter, cm	6.31	Dry Unit Weight, kN/m^3	15.55
Area, cm^2	31.23	Specific Gravity, measured	2.73
Volume, cm^3	49.38	Solids Height, cm	0.918
Water Content, %	29.37	Volume of Solids, cm ^{3}	28.68
Wet Mass, g	101.31	Volume of Voids, cm ^{3}	20.69
Dry Mass, g	78.31		

Prepared By: LG

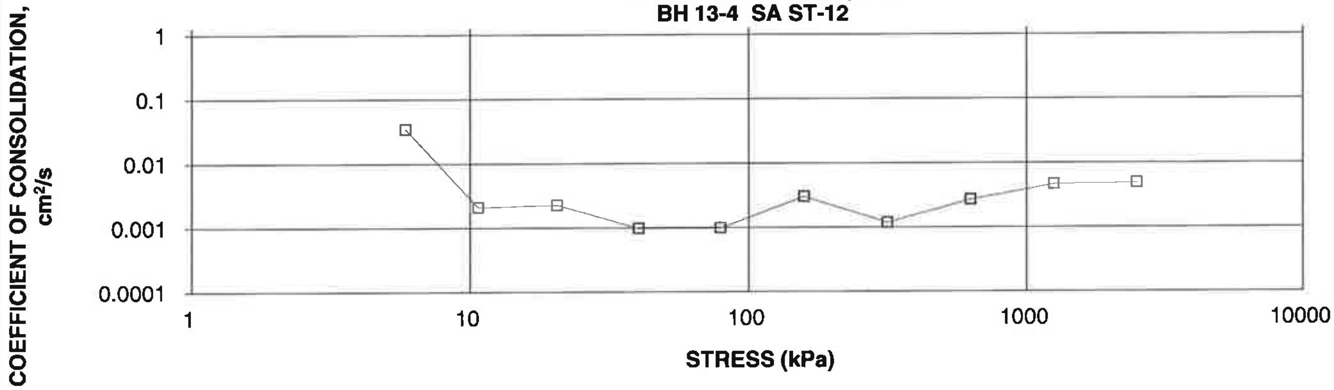
Golder Associates

Checked By: [signature]

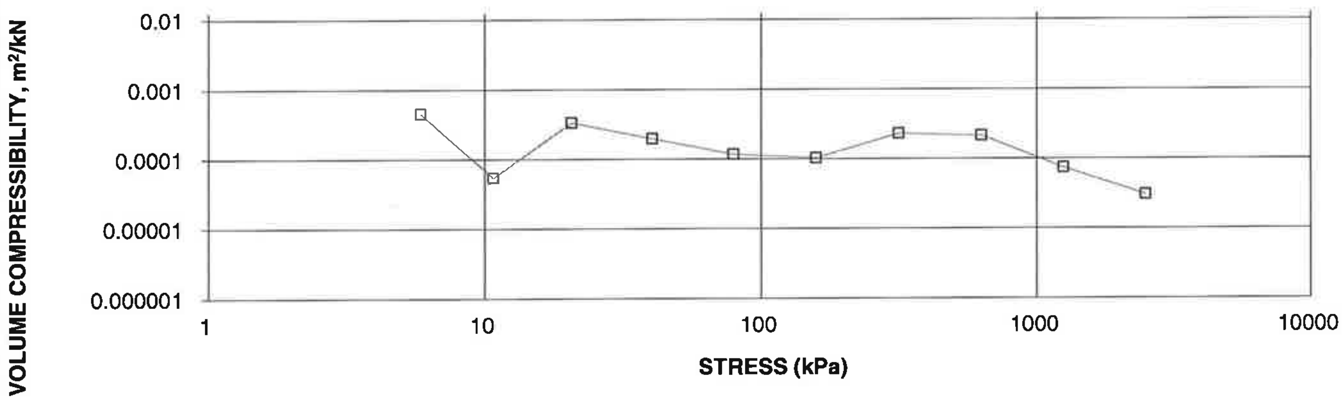
CONSOLIDATION TEST SUMMARY

FIGURE

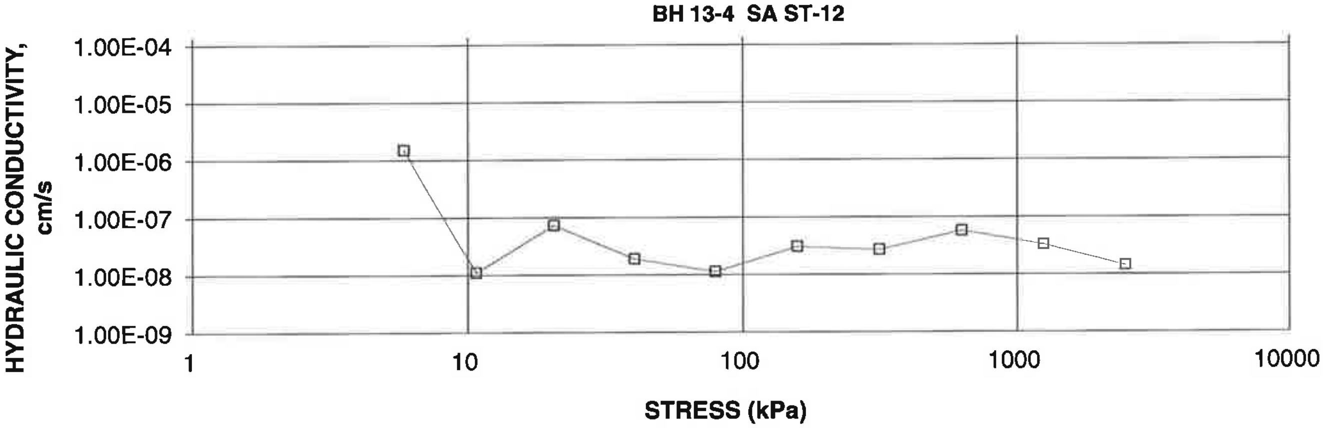
CONSOLIDATION TEST
CV cm²/s VS STRESS (kPa)
BH 13-4 SA ST-12



CONSOLIDATION TEST
MV m²/kN vs STRESS (kPa)
BH 13-4 SA ST-12



CONSOLIDATION TEST
HYDRAULIC CONDUCTIVITY vs STRESS
BH 13-4 SA ST-12



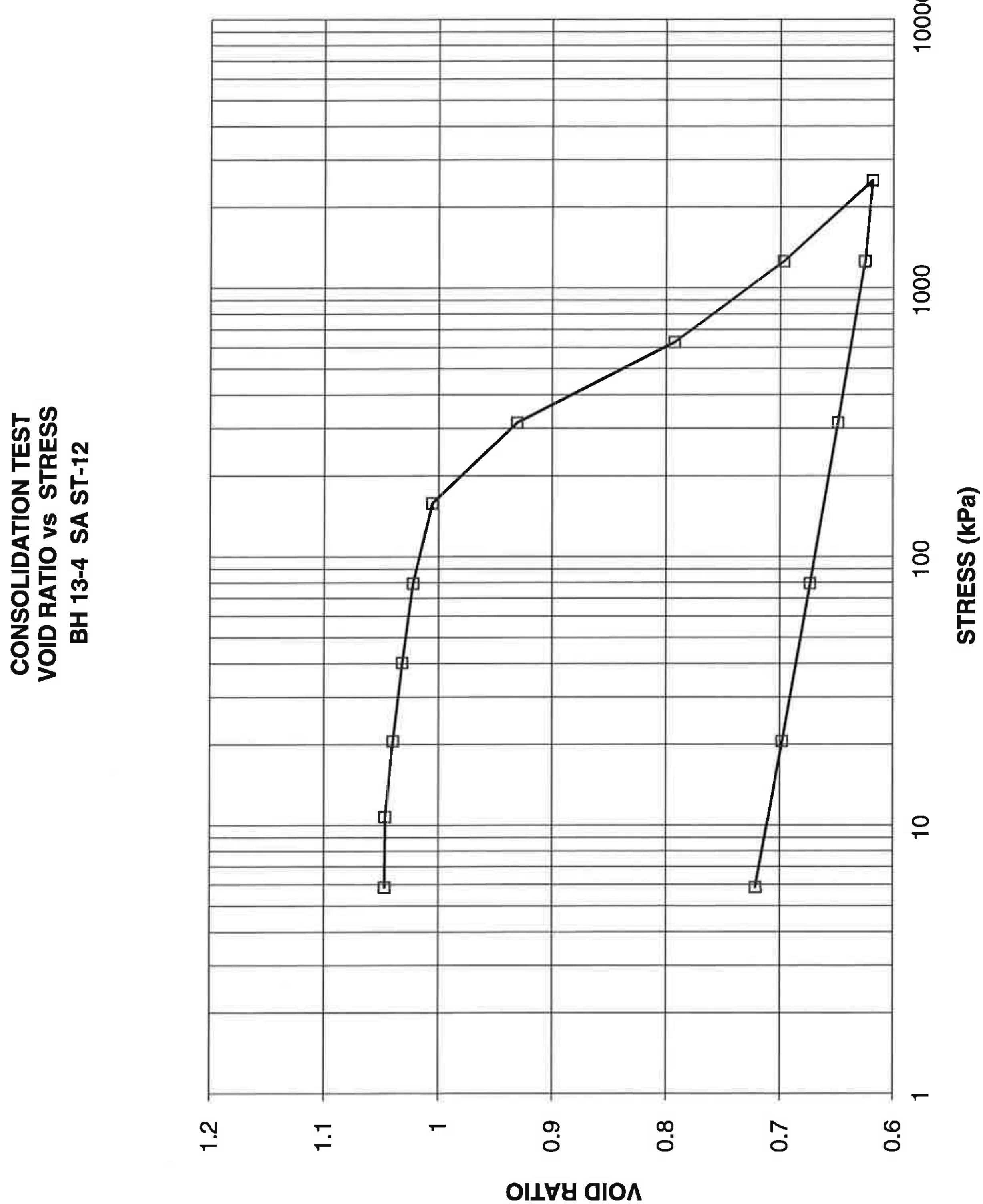
Project No. 13-1183-0112
Prepared By: LG

Golder Associates

Checked By: [signature]

CONSOLIDATION TEST
VOID RATIO VS LOG STRESS

FIGURE



Project No. 13-1183-0112

Prepared By: LG

Golder Associates

Checked By:

CONSOLIDATION TEST SUMMARY

FIGURE

SAMPLE IDENTIFICATION

Project Number	13-1183-0112	Sample Number	ST-16
Borehole Number	13-4	Sample Depth, m	18.3-18.9

TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	8		
Date Started	11/12/2013		
Date Completed	11/28/2013		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.90	Unit Weight, kN/m^3	18.10
Sample Diameter, cm	6.30	Dry Unit Weight, kN/m^3	13.01
Area, cm^2	31.19	Specific Gravity, measured	2.74
Volume, cm^3	59.27	Solids Height, cm	0.920
Water Content, %	39.05	Volume of Solids, cm^3	28.70
Wet Mass, g	109.36	Volume of Voids, cm^3	30.56
Dry Mass, g	78.65	Degree of Saturation, %	100.5

TEST COMPUTATIONS

Stress kPa	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv. cm^2/s	mv m^2/kN	k cm/s
0.00	1.900	1.065	1.900				
6.42	1.897	1.062	1.899	15	5.10E-02	2.13E-04	1.06E-06
11.33	1.893	1.057	1.895	163	4.67E-03	4.39E-04	2.01E-07
21.23	1.890	1.054	1.892	154	4.93E-03	1.75E-04	8.47E-08
40.93	1.880	1.043	1.885	178	4.23E-03	2.67E-04	1.11E-07
80.23	1.865	1.026	1.872	386	1.93E-03	2.08E-04	3.92E-08
158.63	1.842	1.002	1.853	358	2.03E-03	1.52E-04	3.02E-08
316.36	1.796	0.952	1.819	404	1.74E-03	1.53E-04	2.61E-08
629.55	1.654	0.798	1.725	540	1.17E-03	2.38E-04	2.73E-08
1257.77	1.552	0.686	1.603	304	1.79E-03	8.58E-05	1.51E-08
2514.07	1.468	0.596	1.510	184	2.63E-03	3.50E-05	9.01E-09
1257.77	1.476	0.604	1.472				
316.36	1.503	0.633	1.489				
80.23	1.534	0.667	1.519				
21.23	1.568	0.704	1.551				
6.42	1.589	0.727	1.579				

Note:
Consolidation loading and unloading schedule assigned by the client.
Specimen taken 8 to 17cm from bottom of the tube.
k calculated using cv based on t_{90} values.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

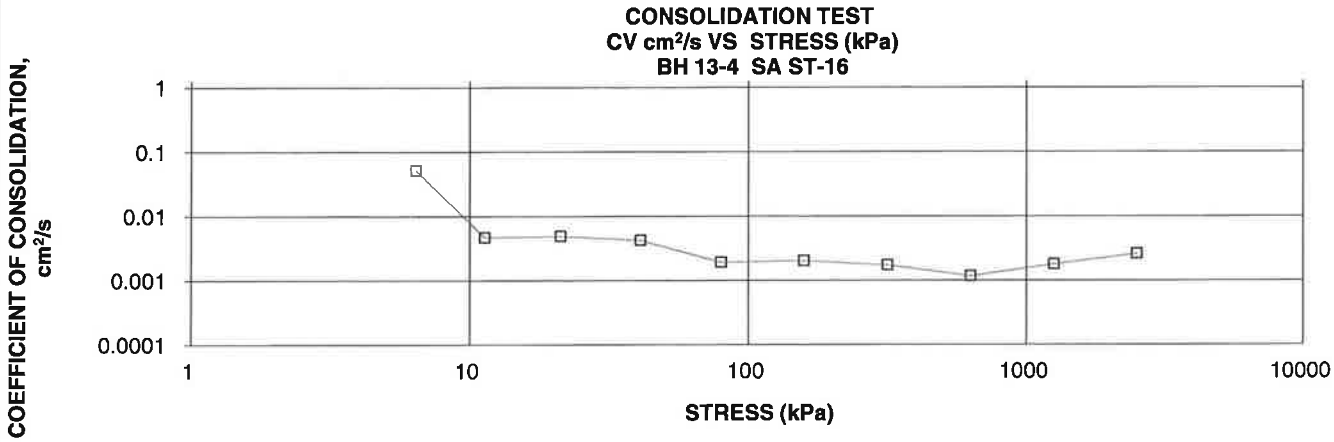
Sample Height, cm	1.59	Unit Weight, kN/m^3	20.38
Sample Diameter, cm	6.30	Dry Unit Weight, kN/m^3	15.56
Area, cm^2	31.19	Specific Gravity, measured	2.74
Volume, cm^3	49.56	Solids Height, cm	0.920
Water Content, %	30.96	Volume of Solids, cm ^{3}	28.70
Wet Mass, g	103.00	Volume of Voids, cm ^{3}	20.86
Dry Mass, g	78.65		

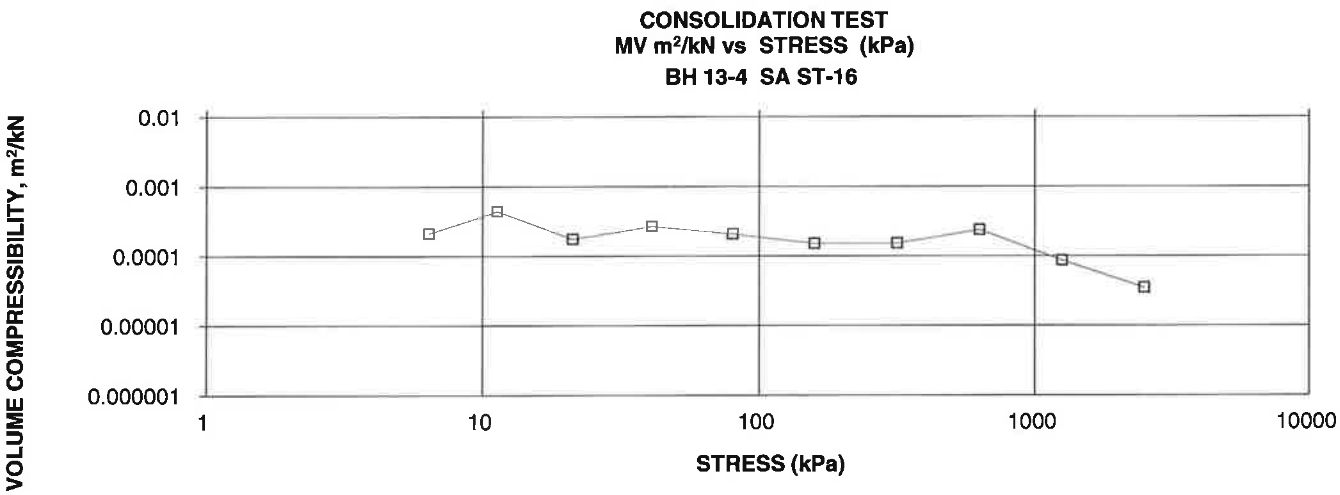
Prepared By: LG

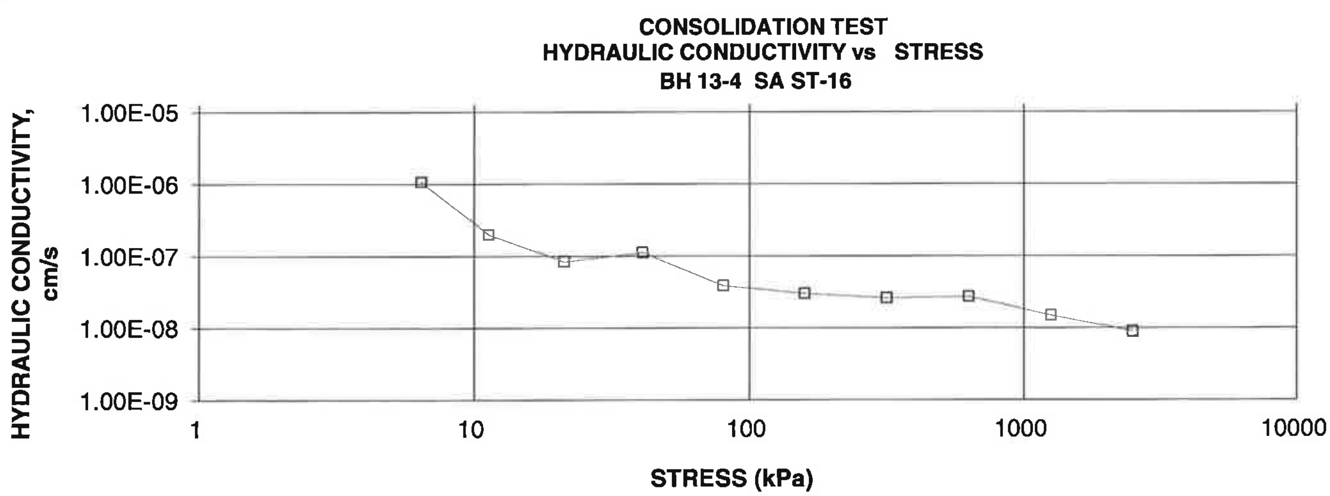
Golder Associates

Checked By: [signature]

CONSOLIDATION TEST SUMMARY	FIGURE







Project No. 13-1183-0112

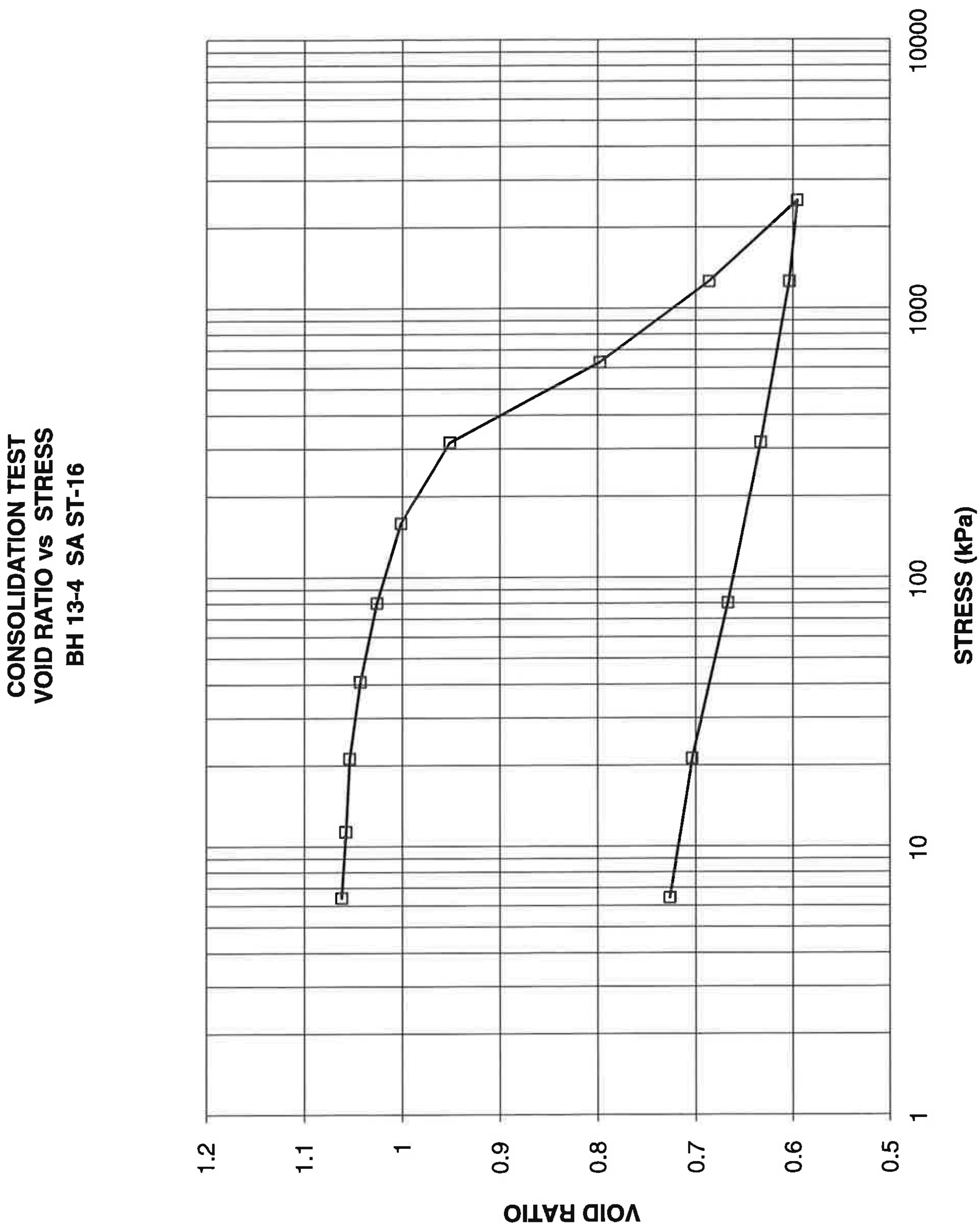
Prepared By: LG

Golder Associates

Checked By:

CONSOLIDATION TEST
VOID RATIO VS LOG STRESS

FIGURE



Project No. 13-1183-0112

Prepared By: LG

Golder Associates

Checked By: [illegible]

SPECIFIC GRAVITY TEST RESULTS

ASTM D 854-06 TEST METHOD A

PROJECT NUMBER	13-1183-0112
PROJECT NAME	Stantec / Testing / 165000836-307
DATE TESTED	November, 2013

Borehole No.	Sample No.	Specific Gravity
13-3	ST-9	2.73
13-3	ST-14	2.72
13-4	ST-12	2.73
13-4	ST-16	2.74

Note: Test carried out on soil particles <2.00mm using distilled water.

Checked By: [signature]

Golder Associates

APPENDIX D

Geophysics GPR International Inc. Report – Geophysical Investigation for the Highway 17B Duchesnay Creek Crossing, North Bay, Ontario

Geophysical Investigation for the Highway 17B Duchesnay Creek Crossing, North Bay, Ontario

Presented to:

Stantec Consulting Ltd.
400 - 1331 Clyde Avenue
Ottawa, Ontario,
K2C 3G4

Presented by:

Geophysics GPR International Inc.
6741 Columbus Road. Unit 14
Mississauga, Ontario
L5T 2G9

June 2015 T15767

Geophysical Investigation for the Highway 17B Duchesnay Creek Crossing, North Bay, Ontario

Presented to:

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K2C 3G4

Presented by:

Geophysics GPR International Inc.
6741 Columbus Road. Unit 14
Mississauga, Ontario
L5T 2G9

June 2015 T15767

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1.0 INTRODUCTION

Geophysics GPR International Inc. was requested by Stantec Consulting Ltd to carry out a geophysical investigation at the Highway 17B crossing of Duchesnay Creek, North Bay, Ontario (Figure 1).

The goal of this investigation was to interpret the bedrock surface profiles from refraction seismic data and the bathymetry and composition of the overburden, specifically the presence of cobbles and boulders, with the use of ground penetrating radar.

The geophysical fieldwork was carried out on May 13th to May 15th, 2015. The location of the survey lines are indicated in Figure 2.

The following report describes the survey design, the geophysical methods, the methodology for interpreting the data and finally a culmination of the interpretations in the form of a bedrock profile with overburden interpretation.

2.0 METHODOLOGY

2.1 Positioning and Topography

The investigated site is located along Highway 17B at Duchesnay Creek, North Bay, Ontario. Figures 1 and 2 show the location of the site and the surveyed profile lines respectively.

Positioning data of the survey lines was provided by the client.

Topography data were collected by GPR personnel using a standard survey level. The levelling data were tied to elevation data provided by the client.

The coordinate system is MTM zone 10.

All measurements are in SI units.

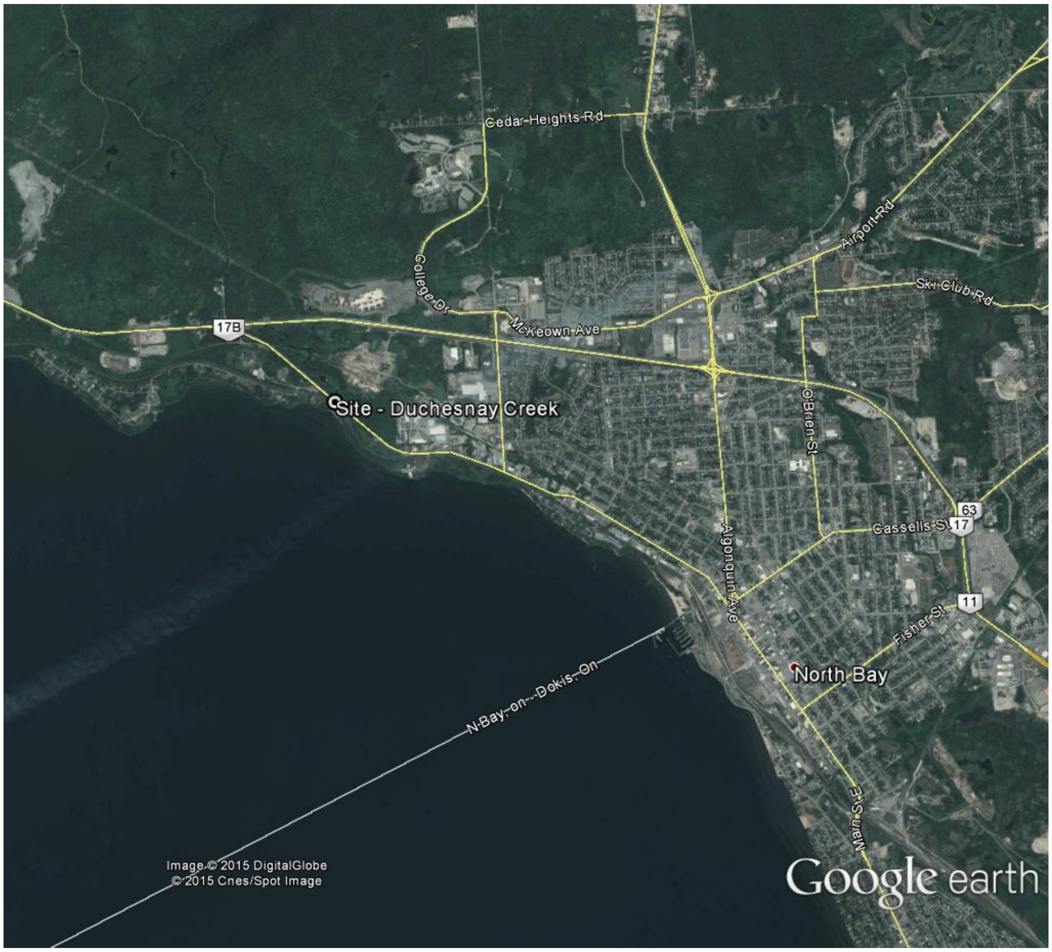

Figure 1: Site: Highway 17B Crossing of Duchesnay Creek, North Bay, Ontario

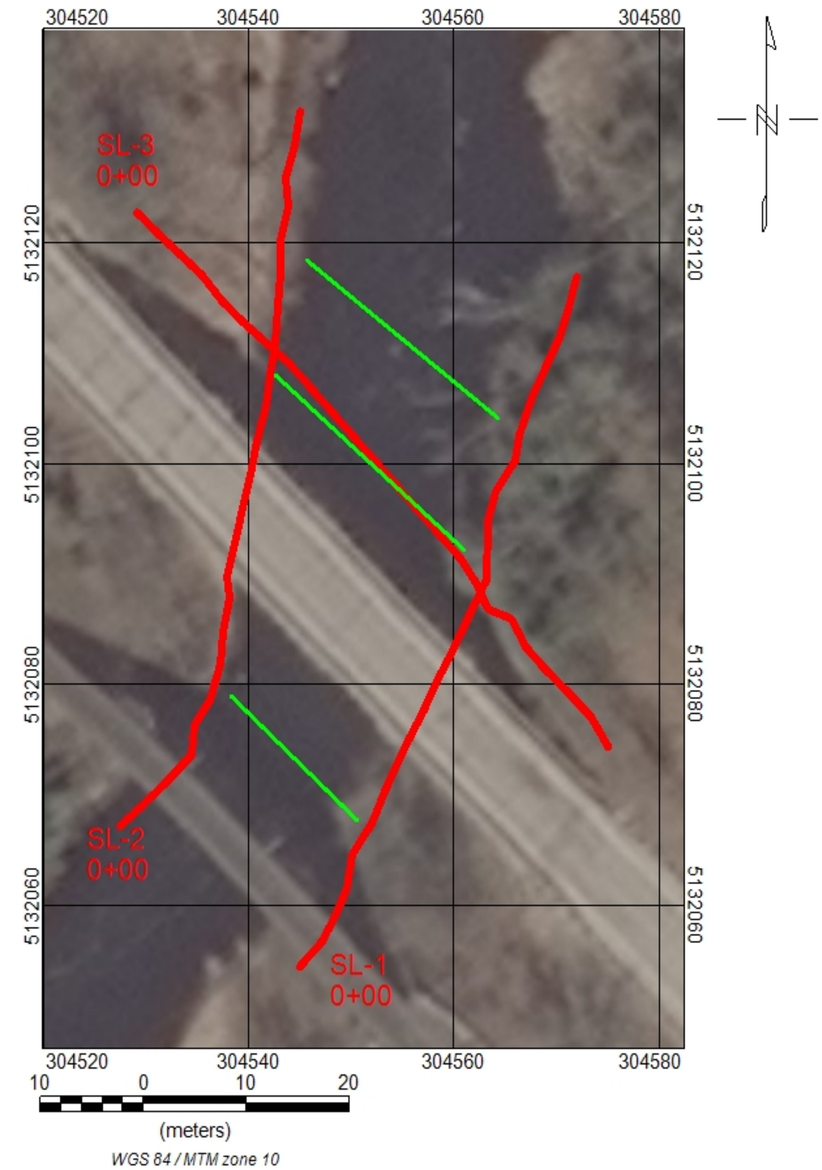

Figure 2: Seismic (red) and Georadar (green) profile locations

2.2 Seismic Refraction Profiling

Basic Theory

The seismic refraction method relies on measuring the transit time of the wave that takes the shortest time to travel from the impact point (shot-point) to a series of receivers (geophones/hydrophones). The fastest seismic waves are the compressional (P) or acoustic waves, where displaced particles oscillate in the direction of wave propagation. The energy that follows this first arrival, such as reflected waves and transverse (S) waves, is not considered under routine seismic refraction interpretation. A more detailed description of the theory can be found in Appendix B.

Survey Design

A seismic spread typically consists of 12 or more vibration monitoring devices (hydrophones/geophones) connected in line (spread) to a seismograph (ABEM Terraloc Mark 6) by connector cables. Seismic pulses (shots) are then generated at various locations with respect to the spread. The majority of profiles for this seismic investigation used a spacing of three metres between hydrophones and five metres between geophones. Typically seven or more shots are executed per seismic spread: three to five shots within the profile to obtain the lateral velocity variation in the overburden and two shots on either side of the spread to provide the true velocity of the bedrock surface.

For this project, a Buffalo gun source was used to generate the seismic signal.

Interpretation Method and Accuracy of Results

The preferred technique for interpretation of seismic refraction data is Hawkins' method. Hawkins' method allows the computation of rock depth at every geophone. This method provides information on the thickness of the various overburden layers, depth to bedrock and rock quality. It is based on the closure times of the inner shots. It can calculate the true velocities of the rock using the apparent velocities, measured with information provided by the outer shots. A full description of the strengths and limitations of refraction seismic method is presented in Appendix A. A basic description of Hawkins' method can also be found in the article Seismic Refraction Surveys for Civil Engineering by L. Hawkins (1961).

Critical distance calculations were done at suitable shot locations along SL-1, SL-2 and SL-3. Critical distance calculations allow determination of the depth to bedrock below the shot point. Critical distance calculations are not suitable for areas with large topography variations and/or variations in bedrock depth.

Accuracy of Results and Limitations

The Hawkins' seismic refraction method typically allows the determination of the bedrock profile with a precision of 10% or better for depths greater than 10 m and a precision of 1 m for depths less than 10 m. The precision in the determination of rock velocities is plus or minus 3%. The vertical contacts (lateral velocity change), usually associated with faults and deep valleys, are generally accurate to within 5 m in width; although, this is somewhat site specific.

The two most significant problem areas for refraction mapping are the "hidden" layer and effect of velocity inversions.

A "hidden" layer or "blind zone" is a stratigraphic layer that is not possible to discern from the arrival time data due to insufficient velocity variation or thickness. The unknown presence of a hidden layer has the effect of making the interpreted bedrock depth too shallow. The presence of a "hidden" layer is typically revealed through borehole or test-pit data and calculations can be made to compensate for the presence of such a layer. At this particular site, the presence of a "hidden" layer could be present if the material beneath the creek bed is significantly different in composition or density than the material encountered in the boreholes.

Velocity inversions occur when the velocity does not increase with depth. The velocity inversion can result from the presence of a low or high velocity layer. Refractions from low-velocity layers cannot be determined from the arrival time data. The unknown presence of a low velocity layer has the effect of making the interpreted depths deeper than actual depths. At this particular site, the presence of a velocity inversion is unlikely.

Along with hidden layers and velocity inversions, other inherent limitations of the seismic refraction method are approached as the depth to bedrock decreases. This is especially apparent with higher velocity overburden material. Identification and interpretation of vertical and lateral velocity variations and the time spent in each layer is critical to accurate interpretations. Irregularities in the bedrock surface and weathered bedrock at shallow depths will also have a more pronounced effect on accuracy than irregularities at greater depths.

2.3 Ground Penetrating Radar(Georadar)

Basic Theory

Georadar uses radar technology to obtain a near continuous profile of the subsurface. The basic principle is to send an electromagnetic impulse into the ground. This pulse will travel through the earth and reflect off boundaries of differing dielectric constants. A reflected pulse returns to the surface and is recorded by a receiver. Examples of boundaries included air/water (water table); water/earth (bathymetry); earth/metal, PVC, or concrete (pipe locating); and differing earth materials (stratigraphic profiles, including bedrock profiles). Only by moving the antennas along a profile directly over the targets can the locations and depths be determined. All data are generated in real time and recorded digitally. The 400 MHz antenna was used for this survey. This particular antenna is most appropriate for relatively shallow depth penetration and resolution of near surface geology, pipes and voids.

Interpretation Method

The vertical scale on all radar images is essentially a time scale. It is the time it takes for a radar pulse to travel down and back to the receiver. In order to convert the time scale to a depth scale, we must apply a velocity at which the pulse travels through the various layers. This velocity will vary with the type of material.

At this particular site, the primary goal of the georadar was for bathymetry. A secondary goal was mapping the content of the overburden, the depth of targets was of less importance.

Interpretation of the data is based primarily on the qualitative analysis of three characteristics of radar reflections: continuity, amplitude and texture. Cobbles and boulders will produce hyperbolas or arcs, often very tiny arcs. If there is a multitude of boulders then there will be likewise a congestion of arcs that will produce a radar image texture often referred to as 'mottled'.

3.0 RESULTS

Seismic Interpretation

The results of the seismic refraction investigation are presented in drawing T-15767_A1 and as a plan view contour plot in Figure 3. The drawings present the interpreted bedrock elevation based on the refracted P-wave arrival times.

Based on the interpreted seismic data, the depth to bedrock along Line 1 ranged from approximately 5.8 to 16.1 m. The interpreted bedrock elevation ranged from approximately 180.6 to 189.8 m.

For Line 2, the depth to bedrock ranged from approximately 4.4 to 11.0 m. The interpreted bedrock elevation ranged from approximately 185.3 to 191.3 m.

For Line 3, the depth to bedrock ranged from approximately 2.3 m to 19.3 m. The interpreted bedrock elevation ranged from approximately 180.7 to 193.2 m.

The depth and elevation to competent bedrock is typically accurate to +/- 1m for depths less than 10 m and +/- 10% for depths greater than 10 m. At this particular site, the presence of the ice layer and varying water column increases the estimate error as it is more difficult to measure the velocity of the bottom sediments accurately.

The general seismic compressional (P) wave velocity model consists of three layers.

The upper layer, with a velocity range of 400 to 500 m/s, is interpreted to represent loose to compact unsaturated overburden material.

The second layer, with a velocity of 1450 to 1550 m/s is interpreted to represent water saturated overburden material.

The third layer, with a velocity of 5000 to 5400 m/s, is interpreted to represent the bedrock. This velocity is typical for competent rock. There was no evidence of low velocity zones that could indicate the presence of fault or fracture zones. The vertical contacts (lateral velocity change), usually associated with faults and deep valleys, are generally accurate to within 5 m in width; although, this is somewhat site specific.

Georadar Interpretation

Interpretation of the radar data is based primarily on the qualitative analysis of three characteristics of radar reflections: continuity, amplitude and shape. The interpretation identifies reflectors and textures within the radar records that represent subsurface contacts, objects or zones. The true nature of the interpreted features can only be assumed without corroborating evidence.

Interpreted radar comments are included on the line profiles in drawing T-15767_A1. Figures 4 through 6 present the radar cross-section images.

The depth scale of the georadar images is based on the velocity of the signal in water and only the water. Once the radar pulse enters the saturated soil the pulse will move much faster so the scale no longer applies. There is a large variation in velocities between dry sediments, saturated sediments and water. With that in mind, zones of increased reflectors have been interpreted to represent increased boulder material. There remains the potential to encounter boulders outside of these zones.

Georadar data was collected at three cross-sections. The maximum water depths were 2.4m, 1.6m and 1.5m for the lines from north to south respectively. The southern most line appears to have a higher concentration of boulder material and thinner bottom sediments.

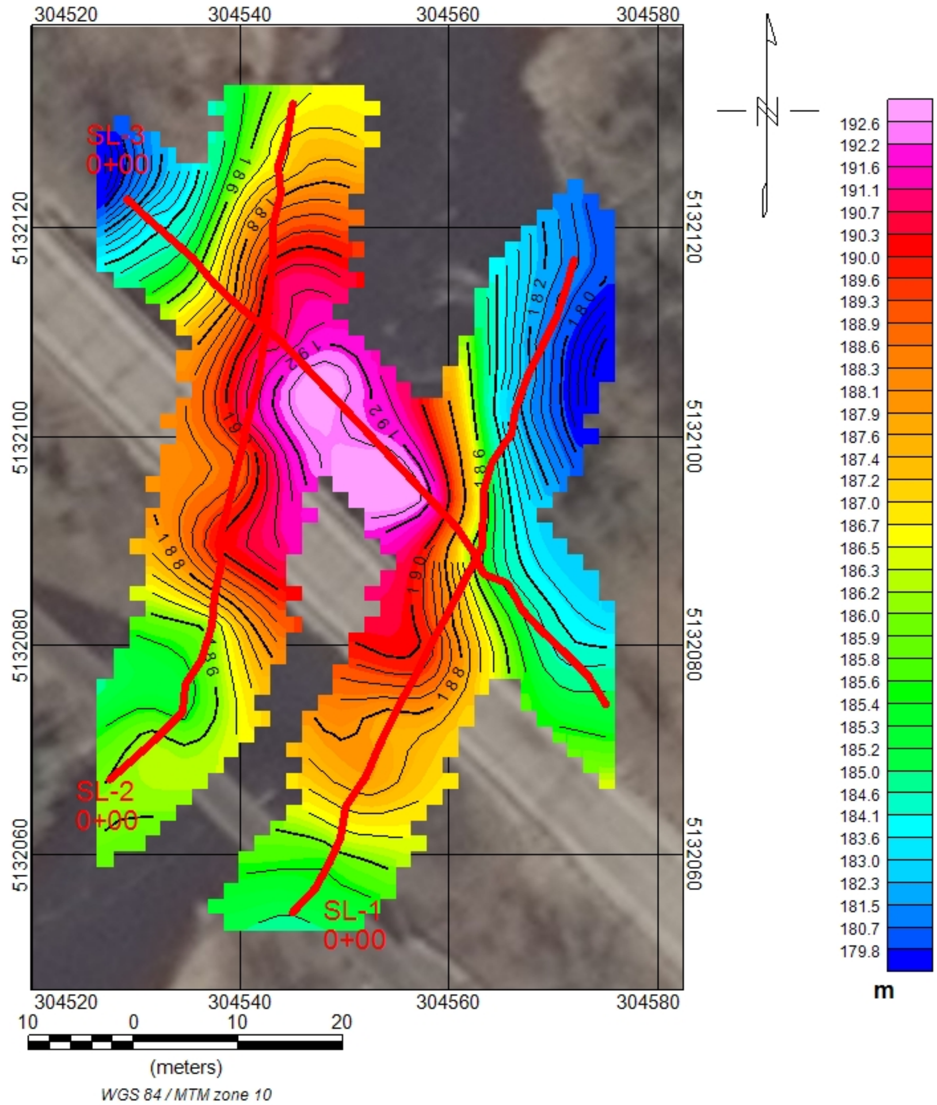

Figure 3: Bedrock elevation contour plot from interpreted seismic data

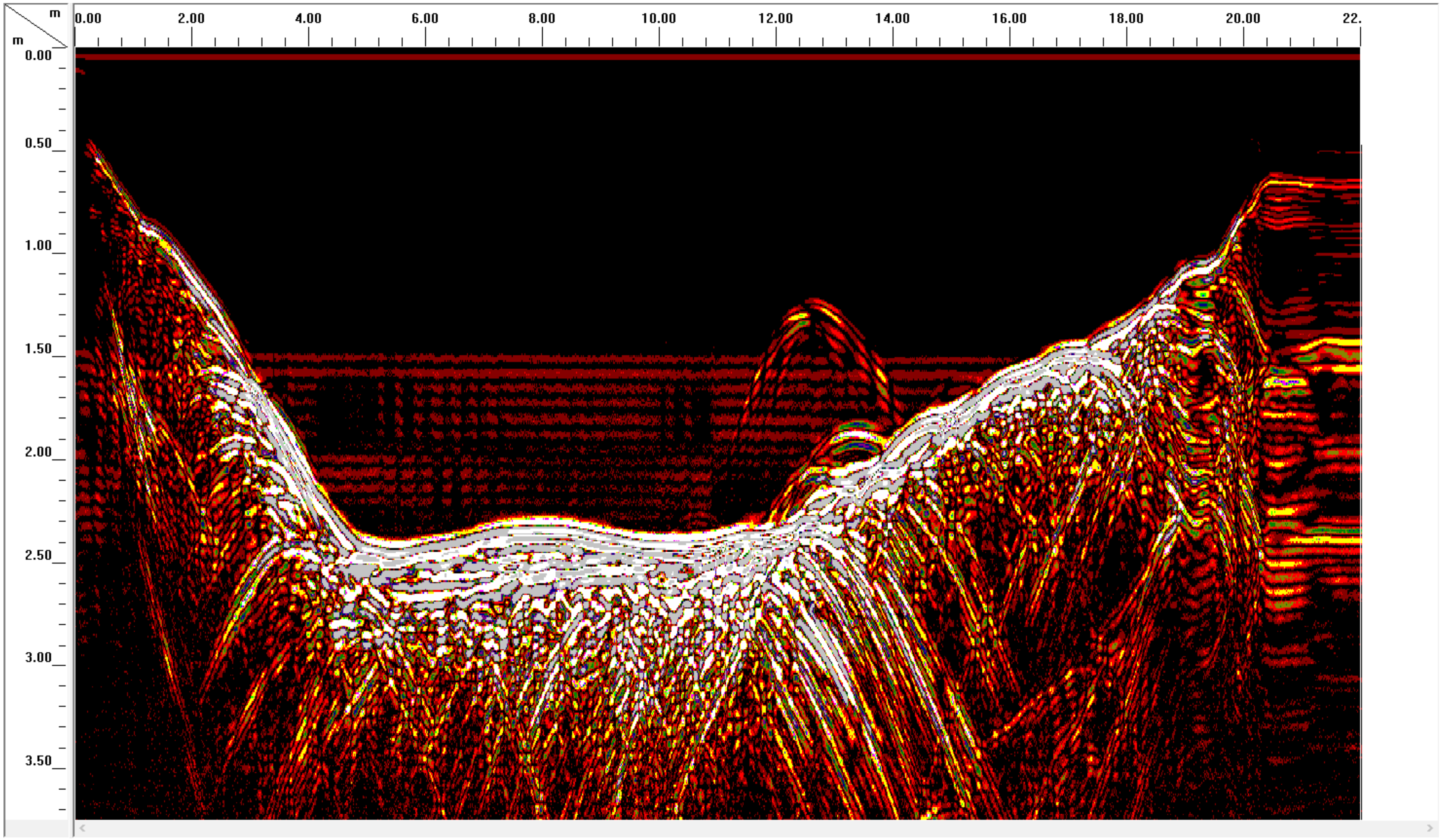

Figure 4: Georadar bathymetry profile northern most crossing, west to east

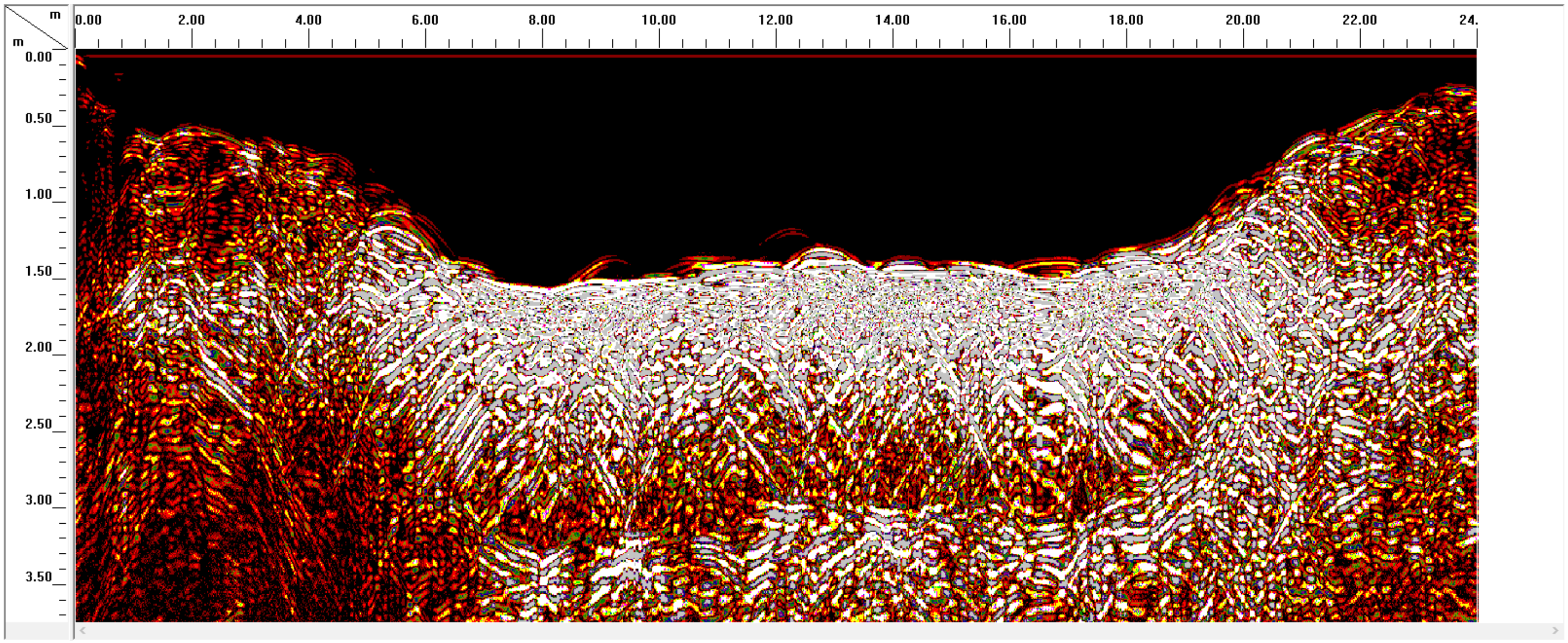

Figure 5: Figure 3: Georadar bathymetry profile, central crossing (SL-03), west to east

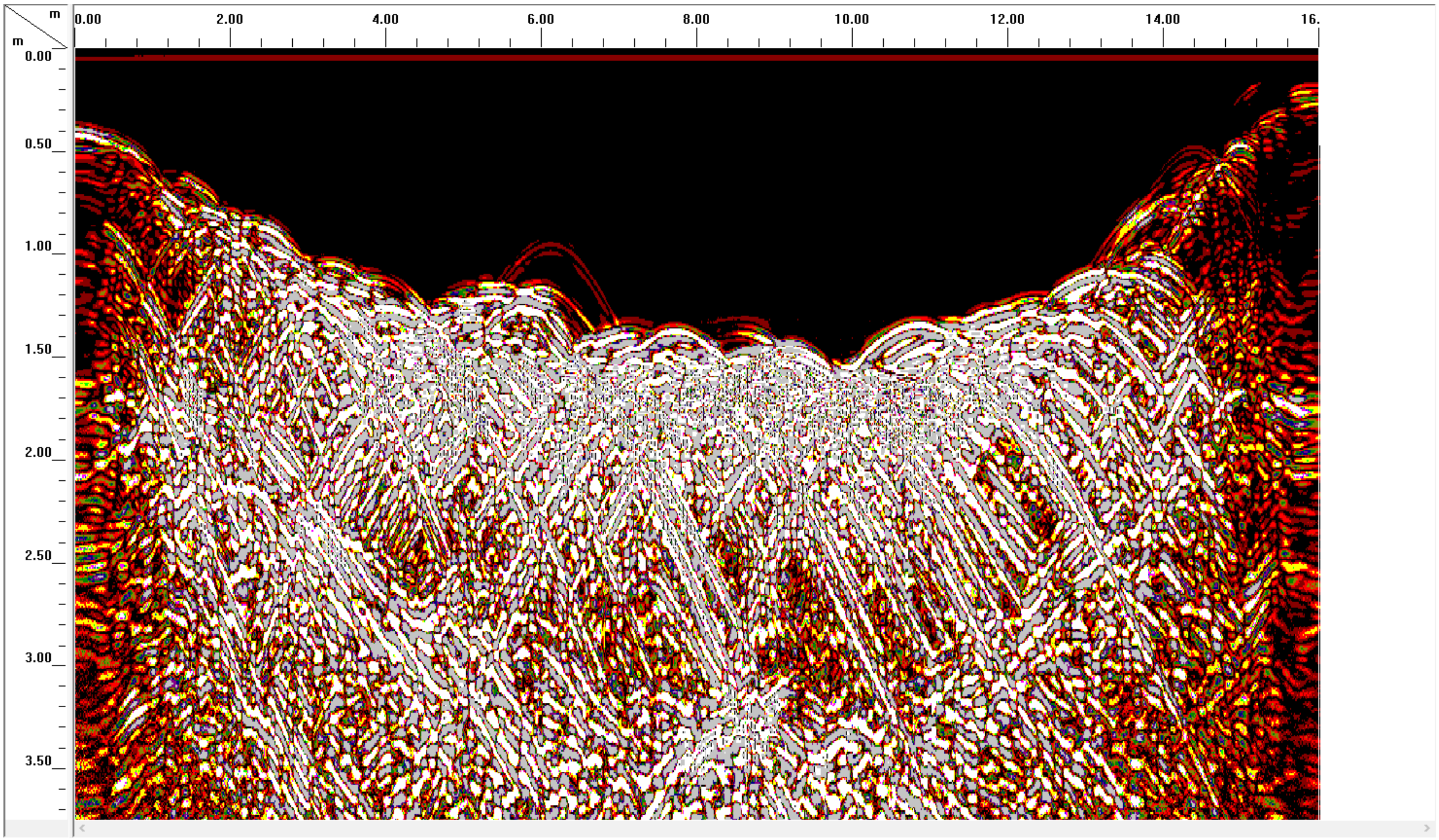

Figure 6: Georadar bathymetry profile southern most crossing, west to east

4.0 CONCLUSIONS AND RECOMMENDATIONS

A geophysical investigation involving seismic and georadar methodologies was carried out adjacent to the Highway 17B crossing of Duchesnay Creek, North Bay, Ontario.

The seismic refraction method was applied along three alignments to map the depth to bedrock. The results of the refraction survey are presented in drawings T-15767_A1. A plan-view contour plot of the data are presented in Figure 3.

The interpretation was done with the aid of boreholes provided by the client at the approximate locations indicated on the drawings. If additional borehole data becomes available the information can be incorporated into the interpretation.

Based on the interpreted seismic data, the depth to bedrock along Line 1 ranged from approximately 5.8 to 16.1 m. The interpreted bedrock elevation ranged from approximately 180.6 to 189.8 m.

For Line 2, the depth to bedrock ranged from approximately 4.4 to 11.0 m. The interpreted bedrock elevation ranged from approximately 185.3 to 191.3 m.

For Line 3, the depth to bedrock ranged from approximately 2.3 m to 19.3 m. The interpreted bedrock elevation ranged from approximately 180.7 to 193.2 m.

The depth and elevation to competent bedrock is typically accurate to +/- 1m for depths less than 10 m and +/- 10% for depths greater than 10 m. Inherent limitations of the seismic refraction method are approached as the depth to bedrock decreases. This is especially apparent with higher contrasts in overburden velocity. Identification and interpretation of vertical and lateral velocity variations and the time spent in each layer is critical to accurate interpretations. Irregularities in the bedrock surface and weathered bedrock at shallow depths will also have a more pronounced effect on accuracy than irregularities at greater depths.

The bedrock P-wave velocity along the alignments was measured as 5000 to 5400 m/s. This range is typical for competent rock. There was no evidence of low velocities zones within the bedrock that could indicate the presence of fault, shear, fracture or high permeability zones.

Based on the georadar images, zones of potentially increased concentrations of boulder material have been indicated on drawing T-15767_A1. The radar images indicate that isolated boulders may still be encountered outside of these zones. As is typical for radar images, it is difficult to identify zones clear of boulders and/or other features below boulders due to signal reflection and diffraction.

Georadar data was collected at three cross-sections. The maximum water depths were approximately 2.4m, 1.6m and 1.5m for the lines from north to south respectively. The southern most line appears to have a higher concentration of boulder material and thinner bottom sediments.

The lowest bottom elevations were approximately 193.2, 193.9m and 194.0m for the lines from north to south respectively. This suggests that the bottom elevation may be controlled by the interpreted bedrock ridge.

A seismic line collected to the north of Hwy 17B would better define the shape and slope of the interpreted bedrock ridge. The radar data suggests however that there may be significant boulder material within the bottom sediments and/or shallow bedrock.

Interpretation of the seismic data has been performed by Ben McClement, P.Eng. The ground radar interpretation has been performed by Ben McClement, P.Eng and Milan Situm, P.Geo. This report has been written by Ben McClement, P.Eng. And reviewed by Milan Situm, P.Geo.

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APPENDIX A

SITE PHOTOS


Photo 1: SL-01, looking north

Photo 2: SL-02, looking south


Photo 3: SL-03, looking east

APPENDIX B

Equipment and Information Sheets

TERRALOC MK6 FEATURES

Great features in a small seismograph

The Terraloc mark 6 is a high-resolution multi-channel seismograph with an 18-bit A/D converter and 3-bit instantaneous floating point (IFP) amplifier. Overall resolution is thus 21 bits. Its dynamic range, 126 dB, eliminates all gain setting hassles and satisfies the most stringent shallow reflection requirements.

8,4" full colour daylight-visible backlit display with VGA resolution
Armoured glass LCD protection
Sealed, Rugged aluminium case protects against weather and rough handling
Sealed 60 GB 2.5" EIDE drive
Numeric keyboard
Command keyboard

Key Features

Key features of Terraloc are not only reliability and field worthiness but also to offer you a powerful seismograph that has advantages as:

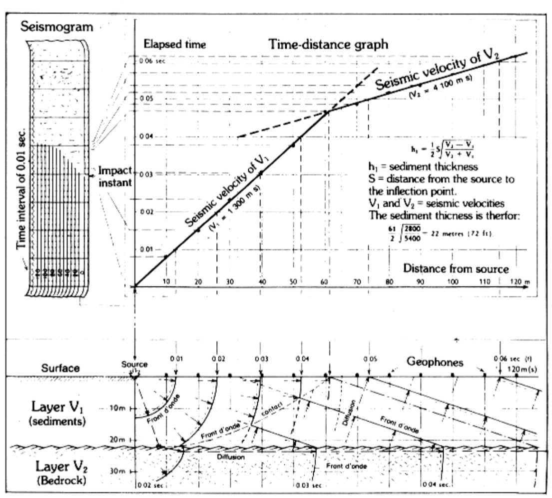
- Wide range of sampling rates, from 25 µs to 2 ms. Fast enough for crosshole surveys
- Record lengths ranging from 3.2 ms to 32.7 seconds. Long enough for Moho studies
- On-site geophone and cable testing. Enhances in the field QC
- Real time noise monitoring. Measure at optimum conditions
- Wide choice of multi- or single- trace view modes. Fast and detailed analysis
- Frequency spectrum analysis. Allows you to check where your filters should be set.
- Refractor velocity indication. Quick check of target velocities found
- And much more. Check the manufacturer website for ore details.

GEOPHYSICS G P R INTERNATIONAL INC.

SEISMIC REFRACTION

Seismic refraction consists of recording the length of time taken for an artificially provoked surface vibration to propagate through the earth. By processing the data, the seismic velocities and depths of the underlying rock layers can be determined. These velocities are characteristic of the nature and quality of the bedrock; a fissured, fractured or sheared rock will be characterized by reduced seismic velocities.

The method is generally used to obtain a better geological analysis of the sub-surface and to determine the following characteristics: the quality, profile and depth of bedrock, its nature, degree of alteration and any other physical contrasts. Seismic refraction ensures that maximum information may be gained from geological field work, and that direct investment costs (drilling, excavation), will be reduced.



PRINCIPLE OF SEISMIC REFRACTION

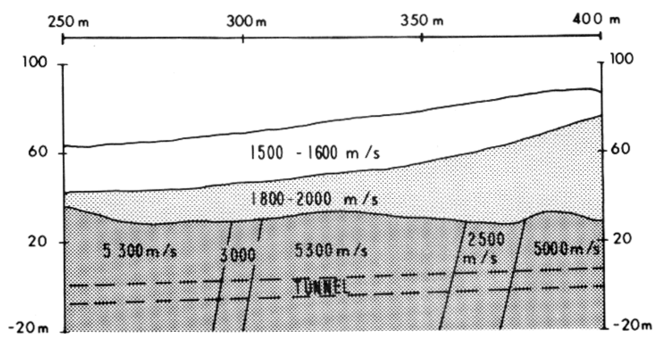
FEATURES

- Precise determination of soil thickness .
- Precise determination of the seismic velocities (rock type and quality).
- Localization and identification of geological units.
- Detailed analysis of soil.
- Year-round use.
- Sea and land surveys (above and below ground).
- Great accessibility possible to rough terrain and remote regions.

AREAS OF APPLICATION

Civil Engineering/Mining Exploration - Exploitation/Petroleum and Gas Sectors/ Geotechnology/Geology/ Hydrology.

- Identification of faults, fractures, shear zones.
- Detection of rock differences (veins, dykes, cavities, etc.).
- Determination of rock topography.
- Evaluation of volume of soil present or to be excavated.
- Excellent complement to geological mapping.
- Recognition of geophysical anomalies such as VLF, gravimetry, etc.
- Drill site selection, better target identification.
- Evaluation of the size, thickness and condition of surface shafts (mining exploitation).
- Mass Rock Quality Determination (MRQD).
- Detection of rock irregularities and breaks.
- Hydrogeology (detection of water tables, veins, reservoirs).
- Excellent complement to any geological analysis.



Interpretation results of a seismic profile

ADDITIONAL REMARKS

Geophysics GPR International Inc. has been recognized for the past fifteen years as a leader in both the application and the development of seismic methods. Seismic refraction is currently used in both civil and mining engineering; the use of lighter high-performance equipment and better tomographical interpretation of the results have contributed to its growing popularity.

GEOPHYSICS G P R INTERNATIONAL INC.

SEISMIC VELOCITIES VERSUS GEOLOGICAL MATERIALS

The seismic refraction differentiates the overburden layers from the bedrock. In general, a layer of overburden material, with associated velocities of 300 - 500 m/sec is seen followed by a second layer under the water table with a velocity corresponding to an impermeable material 1400 - 1600 m/sec.

In some cases, certain limitations may arise, such as differentiation between two different layers having approximately the same velocity. As an example:

- A contact within sand under the water table
- A contact between till and sand, under the water table (both at 1500 m/sec)

As a guideline, the following figure shows a classification of geological material by seismic velocities.

Seismic velocities in the overburden

Variations in the overburden layer can vary over a wide range as a function of its age, its depth of burial, differences in the granular state, degree of porosity, and whether water or air fills the voids (Telford 1976).

Seismic velocities in bedrock

A significant variation in seismic velocities for a particular rock mass may be caused by several factors. These factors include a change in the rock quality when the rock is weathered, sheared, faulted or fractured, a radical topographic change or a rock type change. Other features, such as the distribution of rock types, mineral content, the bonding of the minerals, joints opening, rock pressure, saturation and chemical composition of the minerals may all affect the velocities to some degree, explaining the differences of velocities in sound rock.

Rock type or change in bedrock quality

A rock type change will generally result in a different velocity because of differences in crystallization, mineralization or other physiochemical properties.

In the same way, a change in rock quality such as the presence of large open joints or several small open joints will undoubtedly bring about a velocity change for the same type of rock. Features such as a weathered, sheared, fractured or faulted rock will cause a drop in the velocity.

Faults, deep valleys

A radical topographic change in the bedrock profile may also cause a drop in the measured velocity. The cause of this is geometric and the use of specialized interpretative methods permits an estimation of the true depth of bedrock. A fault will also cause a similar velocity anomaly in the bedrock.

These anomalies may be due to either a deep valley or a cavity like feature (which may be water or sediment filled), or a physical feature in the rock such as a fault or open joints. Since the analysis of the time distance curve does not allow the differentiation of the anomalies, the two possible interpretations are presented on the drawings. In such a case, borehole data gives the best information to assess the true nature of the anomaly.

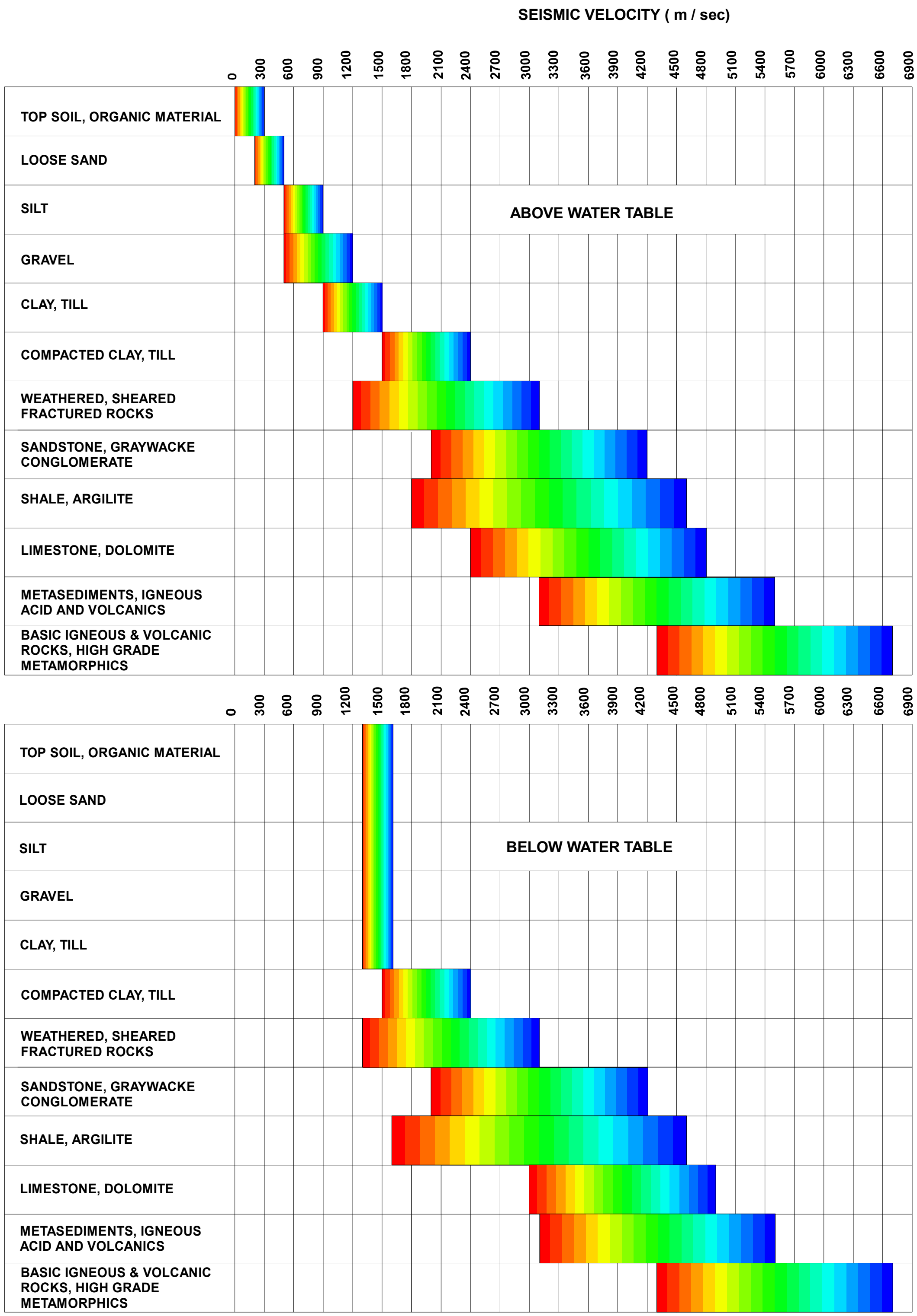


FIGURE B-2

CLASSIFICATION OF GEOLOGICAL MATERIALS BY SEISMIC VELOCITIES

CAUSES OF LATERAL VELOCITY ANOMALIES IN BEDROCK

Velocity changes in rock may represent a change in rock quality, a radical topographic effect or a rock type change. We will discuss each possibility in turn using figure B-3 as a reference.

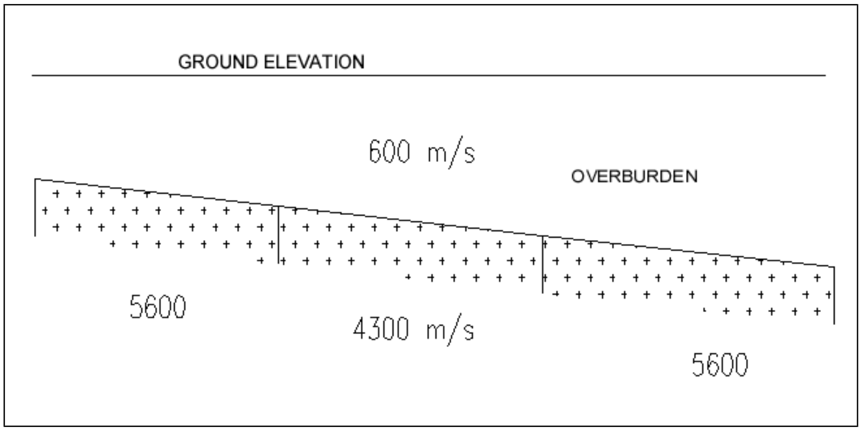


Figure B-3

In the above case, a survey was done using a geophone spacing of 7,5 metres. A zone whose velocity is 4 300 m/sec was measured between the two zones of sound bedrock with a seismic velocity of 5 600 m/sec.

Case 1 – Rock Type Change

A rock type change will result in a velocity change. For example, a sandstone resting on a gneissic rock may bring about the case shown in figure B-4. In this case, the rock may be of good quality, however, the lower velocity represents a physiochemical difference.

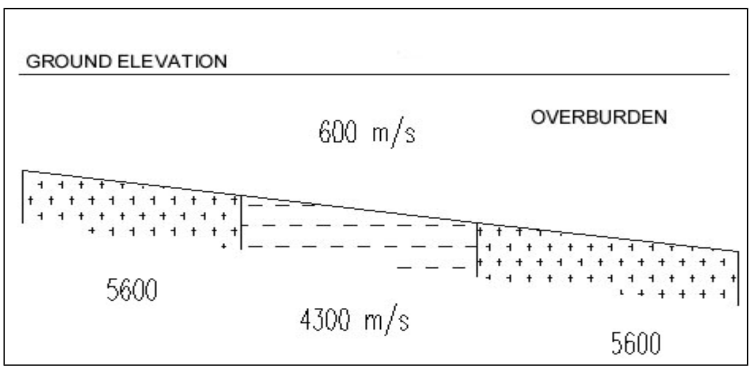
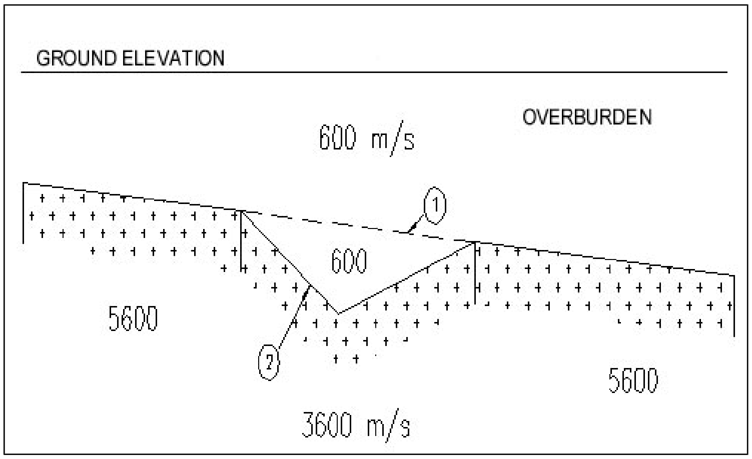


Figure B-4

Case 2 – Topographic effects

A radical topographic change in the bedrock profile, such as a fault with a vertical displacement or a buried valley may bring about a velocity change. The cause of this is geometric and the use of specialized interpretative methods will permit the determination of the true velocity, as seen in figure B-5.



(1) Topography before correction
(2) Topography after correction

Figure B-5

Case 3 – Rock quality change

A change in rock quality will also bring about a velocity change as illustrated in the following cases:

a) Open joint
The presence of a large open joint will bring about a velocity change. Using a 7,5 metres geophone spacing, the zone may appear to be 15 metres large, (as shown). However, in reality, the joint is 4,7 metres large with a velocity of 2 500 m/sec (Figure B-6).

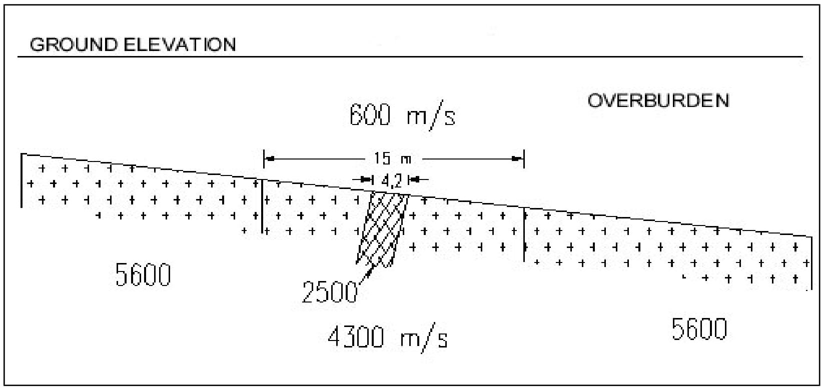


Figure B-6

b) Several small open joints

An important number (6) of small joints, 0,7 metres in width, having a velocity of 2 500 m/sec will cause the velocity to drop as seen in figure B-7.

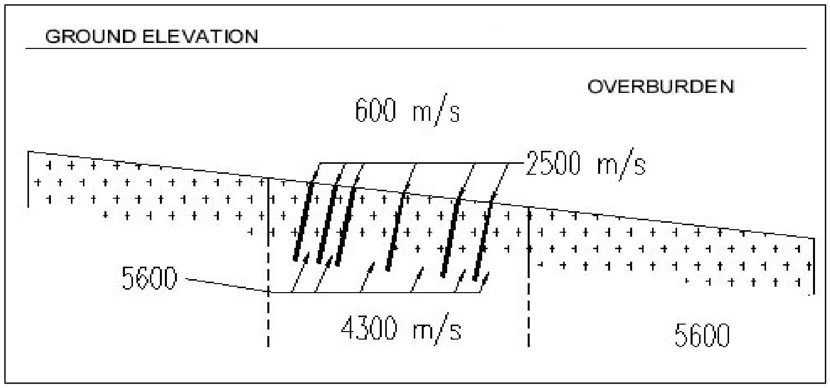


Figure B-7

c) Healed Faults

A healed fault of a zone of filled fractures will also show the same aspect, figure B-8.

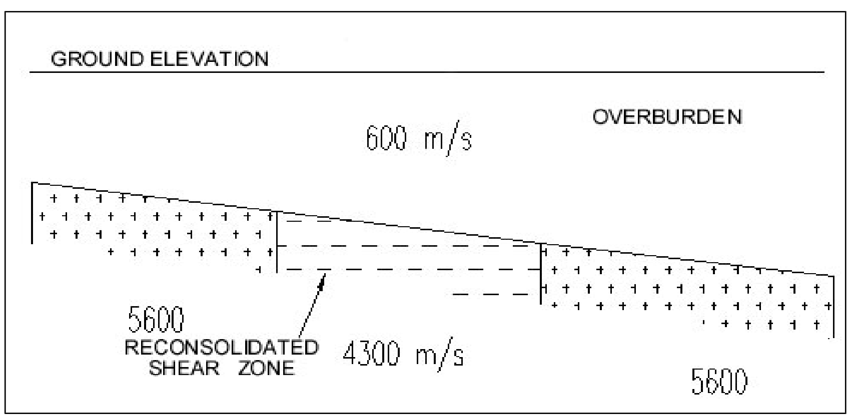


Figure B-8

More important weathered zone

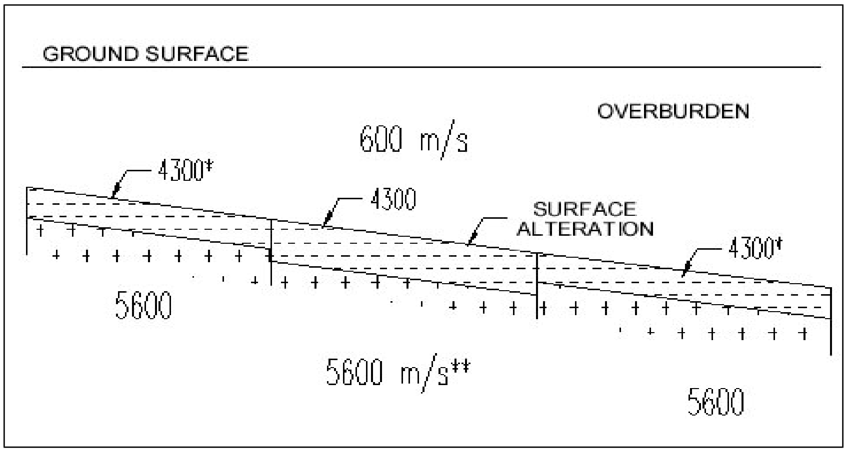


Figure B-9

* These rock weathered zones are not to be identified if too thin

** The 5 600 m/s seismic velocity is not measured if the width of the zone is too small

DESCRIPTIVE CLASSIFICATION OF BEDROCK

SEISMIC VELOCITIES WITH RQD VALUES

Seismic velocities depend on a wide variety of parameters and it is always difficult to relate them to borehole logging. However, there is a way which involves measuring compressional wave velocities in the field and in the laboratory.

The field and laboratory velocities are different. The field velocity is measured on a large scale and depends on the bedrock type and its fracturing degree. The laboratory velocity is measured on a small core sample and depends more on the microscopic features of the bedrock. From these velocities, one can define the velocity index.

The classification of Coon and Merritt is based upon the velocity index property of in-situ rock which is a measure of the discontinuities in the rock mass. According to Coon and Merritt, the velocity index is defined as the square of the ratio of seismic field velocity to laboratory compressional wave velocities, measured on a core sample, representative of a sound rock. The field seismic velocities are normalized by the laboratory results in order to minimize the influence of lithology. Hence as the number of joints decreases, the ratio of the velocities will approach 1. This ratio is then squared to make the velocity index equivalent to the ratio of dynamic module.

The following table is extracted from a study by Coon and Merritt (ASTM STP 477) and illustrates the relationship of the velocity index versus the RQD values (Rock Quality Designation).

We must keep in mind that the seismic refraction usually measures the velocity of the bedrock as is shallow (0 - 100 metres in depth).

TABLE B-1

ENGINEERING CLASSIFICATION FOR IN SITU ROCK (1)			
RQD (%)	VELOCITY INDEX	DESCRIPTION	SEISMIC DESCRIPTION
0 - 25	0.00 - 0.20	Very poor	Low velocity
25 - 50	0.20 - 0.40	Poor	Low velocity
50 - 75	0.40 - 0.60	Fair	Intermediate
75 - 90	0.60 - 0.80	Good	Sound rock
90 - 100	0.80 - 1.00	Excellent	Sound rock

(1) Taken and adapted from: Coon,R.F. and Merritt,A.H.,**Predicting in-situ Modulus of Deformation using Rock Quality Indexes**, Determination of the in-situ modulus of deformation of rock, ASTM STP 477, American Society for testing and materials 1970, pp. 154-173.

It is important to note that the RQD can be affected by the drilling, whereas the velocity measurements are not. The relation between the RQD values and the seismic velocities has always been a concern of geologists and geophysicists. This empirical relation could, thus, be useful. The only additional data needed to compute the velocity index, would be the core laboratory seismic velocity.

Without laboratory calibration, we used one of the highest seismic velocity measured on both sites as reference (6100 m/s), which lead to:

For a geophysical (seismic) appreciation:

$V_p \geq 4800$ m/s → Sound rock
$3900 \leq V_p < 4800$ m/s → Intermediate
$V_p < 3900$ m/s → Low velocity

Or, for an equivalent geotechnical classification:

$V_p \geq 5550$ m/s → Excellent
$4800 \leq V_p < 5549$ m/s → Good
$3900 \leq V_p < 4799$ m/s → Fair
$2800 \leq V_p < 3899$ m/s → Poor
$V_p < 2800$ m/s → Very poor

HIDDEN LAYER AND SEISMIC VELOCITY INVERSION

For seismic refraction surveys for assistance to the geotechnical investigations, relatively simple geological models are considered. These basic models, used for the interpretation of the seismic data must respect some assumptions relating to the overburden laying on the rock:

- The different overburden layers are sub-parallels to the surface;
- These layers presents increasing seismic velocities with depth;
- The seismic velocities are considered constant enough over short lateral distances within the layers;
- The thickness of each layer should be sufficient to permit its detection.

When one or several of these hypotheses are transgressed importantly, some errors may be induced within the calculations results relatively to the thickness of the layers in cause. These errors are then due to the attribution of seismic wave delay time to a seismic erroneous mean velocity. This mean seismic velocity might be under-evaluated if a subjacent layer of a higher seismic velocity could not be detected and by the fact even sees itself neglected. This can occur when a thick layer of overburden covers one second thin layer. One speaks then about "**hidden layer**". The opposite case is also possible, where the average seismic speed of the layers of materials is overestimated being given the absence of critical refraction of the seismic wave necessary to detection of a subjacent layer. This phenomenon occurs when a layer of material presents a seismic velocity lower than that of the layer of material covering it. It is the case known under the name of "**velocity inversion**".

The hidden layer effect results with an under-estimation of the overburden thickness laying on the rock.

"The most important source of uncertainty, at the time of seismic calculation, comes from the grounds which one cannot detect. In the presence of three grounds, when the second is thin, it is possible that the waves refracted with the roof of the third marker arrive at the geophones before those which are refracted with the roof of the second" (p.24).[1]

The phenomenon of *hidden layer* is related to the limitation of the seismic refraction to detect a layer of material associated with a too weak seismic velocity contrast and/or with a too low thickness of the layer. The existence of the aforementioned "*hidden layer*" not being recognized, the time of course of the seismic wave in the *hidden layer* and the layer of material which is overlying of it is attributed to the only layer of material covering the hidden layer, faster seismically. The thickness of the overlying stratum to the hidden layer is then exaggerated, but remains lower than the thicknesses sum of the two layers joined together. Thus, the rock substrate will appear less deep than it is really. The B-10 figure illustrates the evolution of an acoustic wave in a geological medium implying a *hidden layer*.

1 Denis-Jacques Dion
« La méthode sismique réfraction appliquée au génie géologique, notions d'interprétation »
DV-8506
M.E.R.Q., 1986

The phenomenon of *hidden layer* generally arises on banks of lakes or rivers where the thickness of the saturated movable deposits decreases gradually towards the firm ground, and also in the case of deposits strong thickness where the materials are increasing in density with depth.

<u>The seismic velocity inversion</u> produces an over-estimate thickness of a layer of material by neglecting the existence of a layer subjacent slower, which leads to an exaggeration real depth of the rock.

In seismic refraction, only the first arrivals of the acoustic waves are usually considered for calculations. These arrivals can come from direct waves (surfacing) or from refracted waves. These last ones are the product of the phenomenon of critical refraction obeying to the law of Snell-Descartes. There cannot however be critical refraction when a seismic wave passes from a material of seismic speed higher than the one of the layer of subjacent material. Thus, this seismically slower layer could not be detected even if the total time of the way of the seismic wave in were affected (figure B-11). The ignorance of the existence of this second inserted slow layer will carry the attribution of the time of course of the seismic wave of the fast layer and the slow layer subjacent with the only fast layer. The thickness calculated for the fast layer thus appears higher than the real total thickness of this layer and the subjacent slow layer, both will be joined together. There cannot however be critical refraction when a seismic wave passes from a material seismic velocity higher than that of the layer of subjacent material. The phenomenon of *velocity inversion* is rather rare in the cases of shallow seismic refraction. One meets it most of the time in tropical areas and Northern areas with permafrost and/or temporarily thick frozen upper part of overburden. The velocity inversion is most often associated the presence of a hardened soil horizon or a suspended ice lens (permafrost, intermittent permafrost).

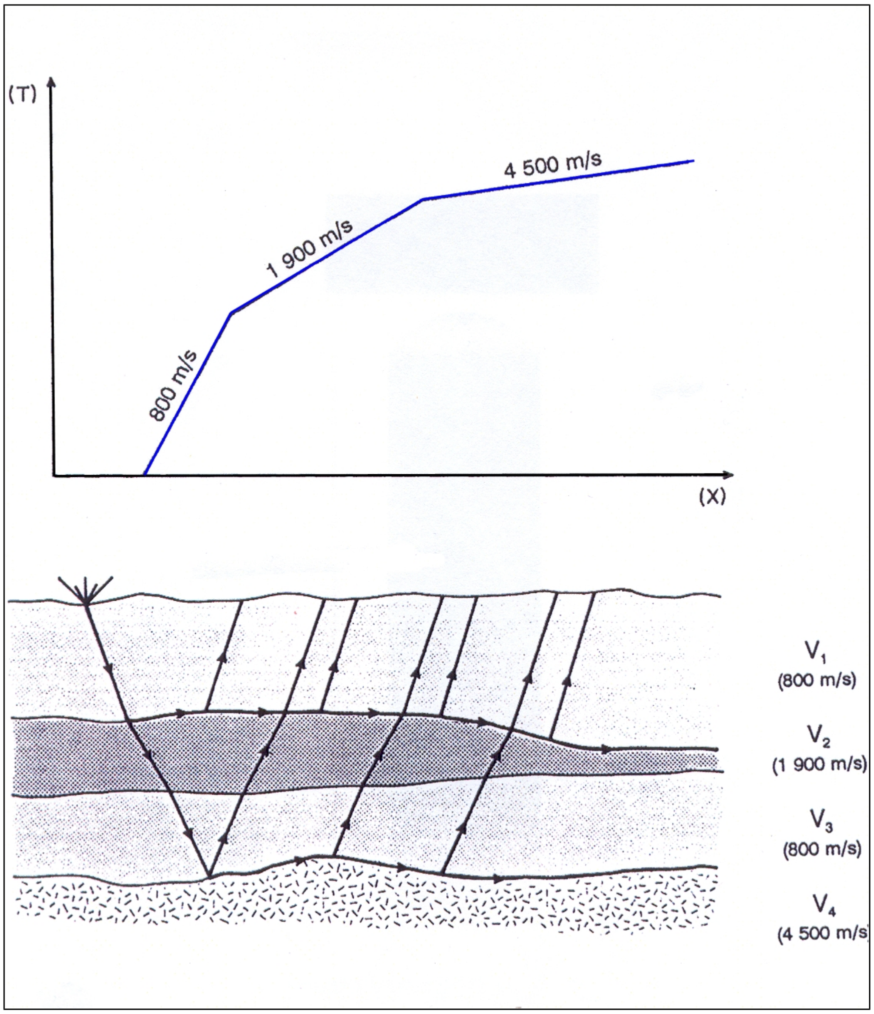


FIGURE B-10

Hidden layer

An overburdens *hidden layer* is said *hidden* when the refracted seismic waves from this layer arrive after those refracted from the roof of the subjacent material.

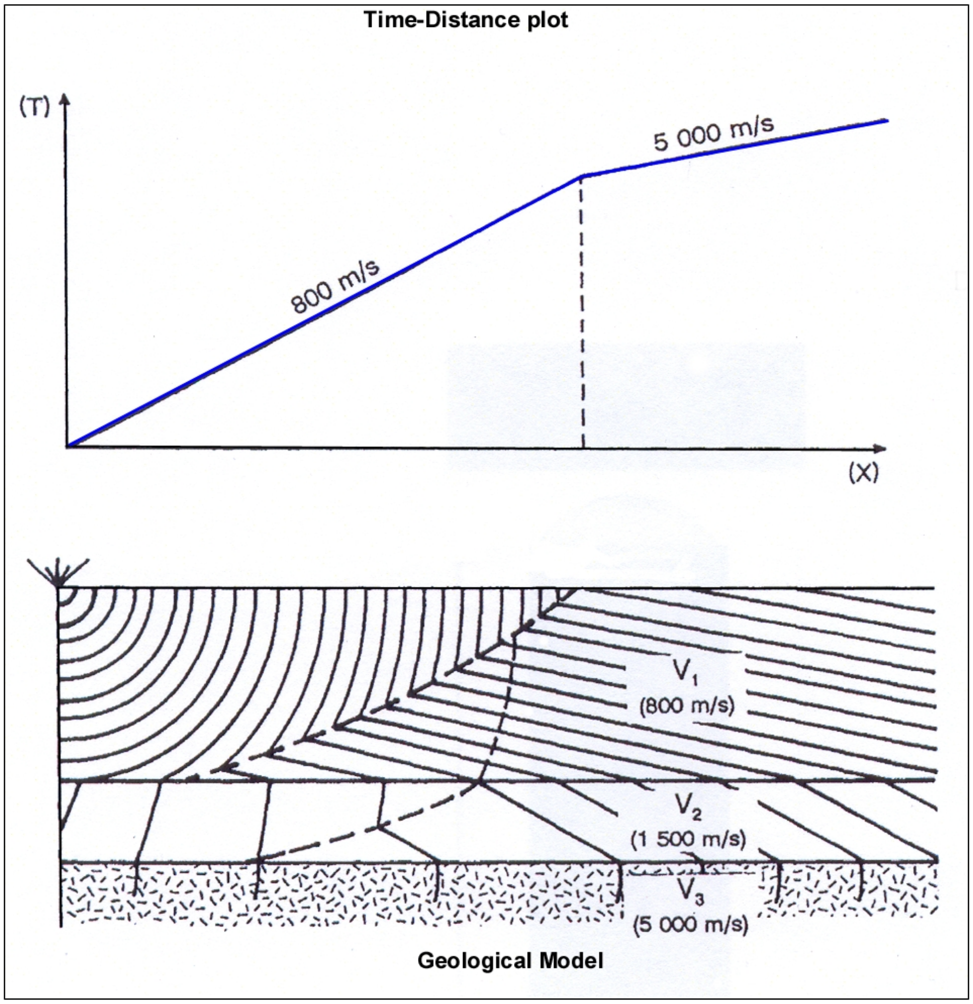


FIGURE B-11
Seismic velocity inversion

The absence of critical refraction of the seismic wave with the roof of the layer "V3", preventing its detection on the Time-Distance plot.

The existence of a case of ***hidden layer*** or a case of seismic ***velocity inversion*** can be revealed by boreholes or by seismic reflection and can be seen specified by seismic surveys "up-hole". When these phenomena are identified, one can consider the geological condition of the investigated site for the seismic calculations.

The seismic profile is then calibrated compared to the results of drillings. This makes it possible to obtain an approximate topography of the rock but the precision for its depth can be seen reduced, particularly when the geological conditions are variable. In spite of the mathematical artifices, the calibration can not allow a complete seismic recognition of the stratigraphy since a layer of materials could not be detected.

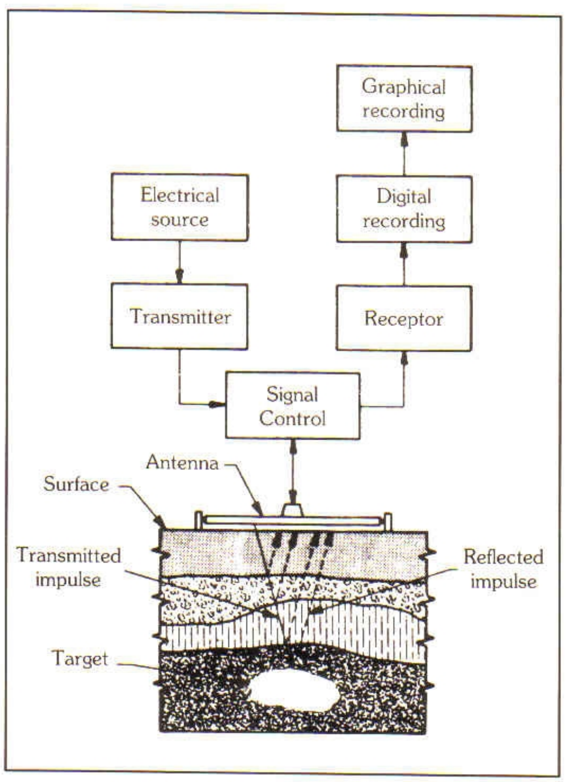
The cases of *hidden layer* and seismic *velocity inversion* cause problems for calculations depth of the rock but do not affect the precision of the seismic velocity in the rock, which can be used to evaluate its quality.

Ground Penetrating Radar(Georadar)

GEOPHYSICS G P R INTERNATIONAL INC.

GEORADAR

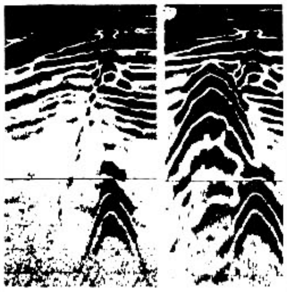
As indicated by its name, georadar combines high resolution radar with geology. The underlying principle is based on the propagation of electromagnetic wave impulses (VHF) that are reflected by anomalies in the terrain (joints, irregularities, interfaces, etc.) at different depths, and then captured by the antenna. The georadar records the time taken by each transmitted signal to complete the cycle in order to calculate the depth of the anomaly. The result is similar to a seismic reflection profile where all the reflections are displayed graphically. This technique is used to solve problems for which there had previously been no practical solution.



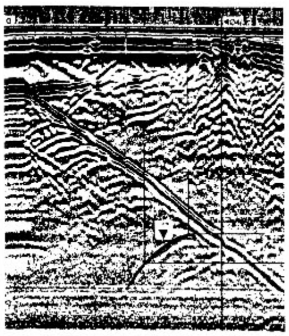
PRINCIPLES OF GEORADAR

FEATURES

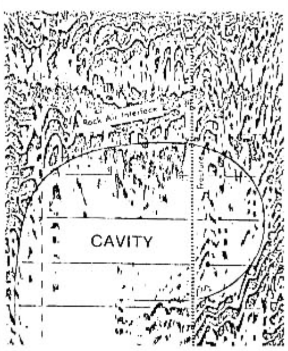
- Penetration of more than 20 metres in certain materials (penetration being inversely proportional to conductivity).
- Surveying in continuous mode.
- Identification of objects measuring only a few centimeters.
- Light and manoeuvrable equipment.
- Detection of conductivity, open spaces and/or holes (cavities).
- Detection of breaks: faults, fractures, joints, cavities.
- Results similar to seismic reflection: continuous underground profile.
- Results available immediately.
- Can be used in land, sea or airborne surveys.



PIPES



JOINTS



CAVITIES

FIELDS OF APPLICATION

Civil Engineering / Mining Exploration-Exploitation / Research / Archaeology / Environment

- Geotechnology: investigation of soils and surface deposits.
- Optimal selection of anchor bolts in mines and quarries.
- Detection of buried pipes before beginning excavation.
- Detection of liquid or gas leakage in soils.
- Detection of cracks in concrete structures.
- Checking material homogeneity.
- Detection of cavities beneath road pavement.
- Determination of water saturation level.
- Detection of girders in reinforced concrete.
- Detection of pollutant leakage in water bodies.
- Inspection of buried disposal sites and or dangerous deposits.
- Continuous measurement of ice thickness.
- Archaeological research: ancient foundations, artifacts.
- Non-destructive method for measuring road pavement thickness.
- Localization and measurement of soil's thickness (swamps, peat bogs).
- Determination of rock beddings (location and thickness).
- Bathymetric studies (depth sounding).
- Calculation of the thickness of permafrost and ice.
- Geotechnical studies for the installation of aqueducts.

SPECIAL FEATURES

The equipment is practical, easy to manoeuvre, and multi-faceted. The field of application of georadar continues to expand in various sectors, particularly in geotechnology (aqueducts), civil engineering (excavation, structures) and mining (structures).

APPENDIX C

Drawings T15767_A1

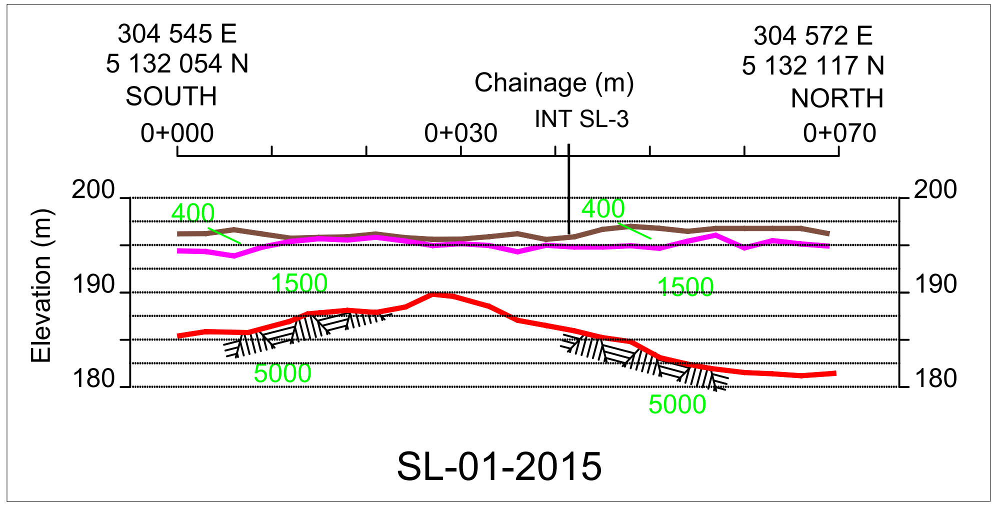
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

PLATE No
CONT
WP 5120–07–00

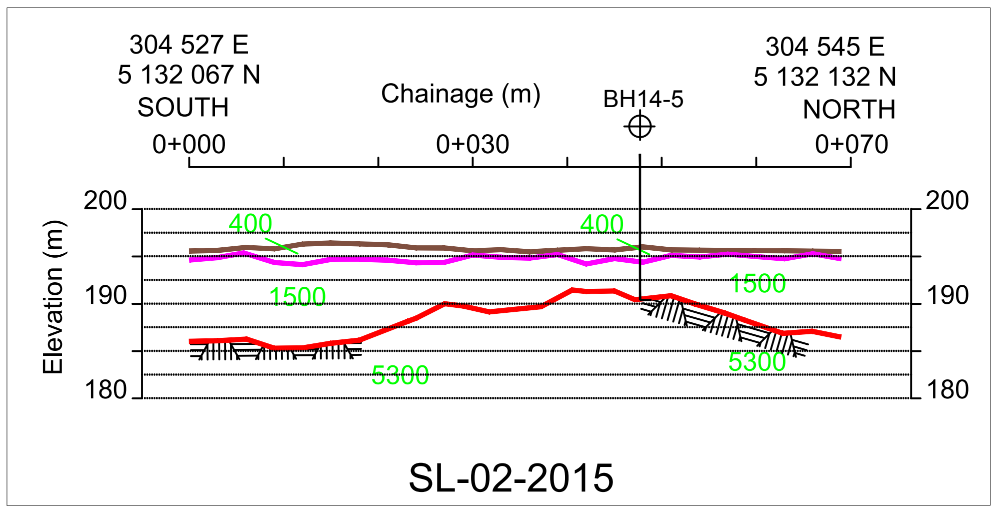
SHEET

HIGHWAY 17B, SITE 43–067
DUCHESNAY CREEK CROSSING
INTERPRETED SEISMIC & RADAR PROFILES

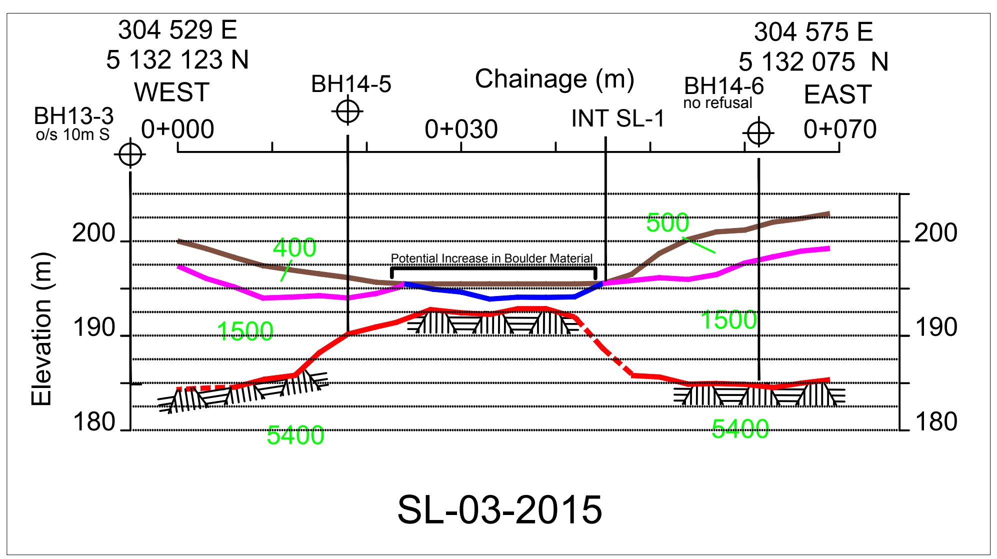
GEOPHYSICS GPR INTERNATIONAL INC.



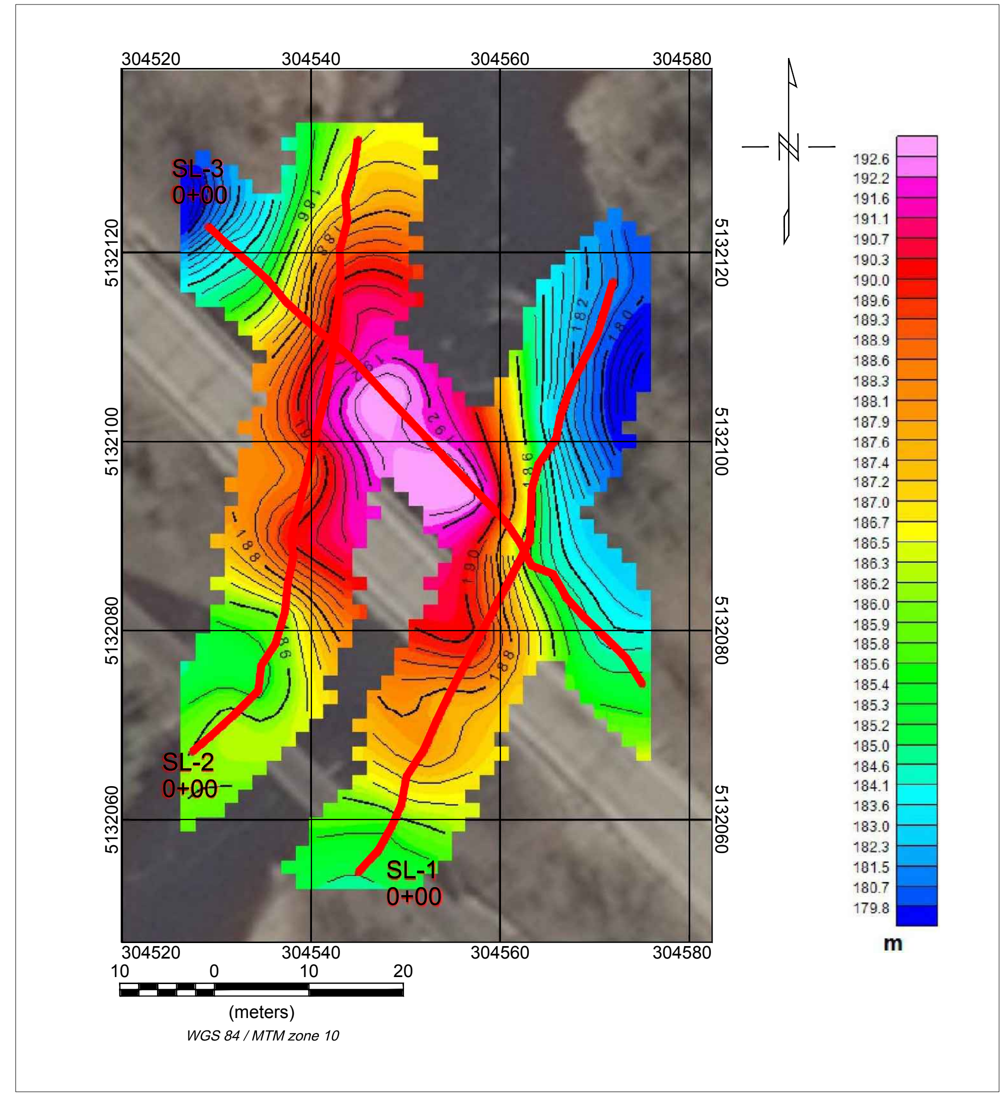
SL-01-2015



SL-02-2015



SL-03-2015



LEGEND

	Interpreted Bedrock
5200	Seismic P–wave Velocity
	Topography
	Water table
	Bathymetry (River Bottom)
	Borehole

DRAFT

NOTES

Not Valid for Construction

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102–2 of Form 100.

1	THE GEOPHYSICAL SURVEY WAS EXECUTED BY GEOPHYSICS GPR INTERNATIONAL INC. MAY 2015
2	COORDINATE SYSTEM: MTM ZONE 10N
3	ELEVATION AND POSITIONING DATA PROVIDED BY CLIENT
4	REFER TO THE FULL REPORT FOR A DISCUSSION OF METHODOLOGY, RESULTS, ACCURACIES AND LIMITATIONS

REVISIONS | DATE | BY | DESCRIPTION

GEOCRES No

HWY No 17B | DIST
SUBM'D ZP | CHECKED | DATE 2015–06–11 | SITE 43–067
DRAWN GBB | CHECKED | APPROVED | DWG 2

MINISTRY OF TRANSPORTATION, ONTARIO PR–D–707 88–05

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