

**FOUNDATION INVESTIGATION REPORT
HIGHWAY 58
PINE STREET UNDERPASS REPLACEMENT
(SITE 34-179)
CITY OF THOROLD, ONTARIO
G.W.P. 2365-09-00, W.P. 2367-09-01
P.O. 2010-E-0073**

GEOCRES No. 30M3-275

Report to

**McCormick Rankin,
a member of MMM Group Limited**

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation carried out at the location of the proposed replacement of the Pine Street Underpass at Highway 58 in the City of Thorold, Ontario. This investigation was carried out as part of a consolidated assignment to rehabilitate or replace six (6) bridge structures at five (5) site locations in Thorold and St. Catharines, Ontario.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide borehole location plan and soil strata drawings with stratigraphic profiles and cross-sections, records of boreholes, laboratory test results and written descriptions of the subsurface conditions. A model of the subsurface conditions was developed for the site based on the data obtained from the present investigation.

Thurber carried out the investigation as a foundation sub-consultant to McCormick Rankin, a member of MMM Group (MRC) under MTO Purchase Order No. 2010-E-0073.

The following MTO document has been referenced in the preparation of this report:

- Department of Highways Ontario (DHO) drawing titled "Pine Street Underpass, King's Highway 58 (Prop.), Welland Co., Thorold Twp., General Layout", Site No. 34-179, W.P. No. 10.65 dated November 1965 (Reference 1).

2 PROJECT AND SITE DESCRIPTION

The existing Pine Street Bridge is a double span bridge carrying Pine Street over Highway 58 in the City of Thorold, The Regional Municipality of Niagara. The lands surrounding the bridge site are primarily occupied with light residential dwellings. In the general vicinity of the bridge, Highway 58 has been constructed in a cut and the Pine Street grade appears to be at the original ground surface.

From published geological information, the bridge site is located within the physiographic region known as the Iroquois Plain. The bridge site is also located in the vicinity of the Niagara Escarpment, which is located to the south of the City of St. Catharines. In this area, a deposit of silty clay to clayey silt till overlies dolostone bedrock of the Lockport Formation.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project was carried out in two phases. The first phase involved drilling and sampling Boreholes PS-04 and PS-05 at Highway 58 grade on April 16 and 17, 2012, respectively. The second phase consisted of drilling and sampling Boreholes PS-01 to PS-03 and PS-06 to PS-08 on May 28 and 29, 2012 at Pine Street grade.

Boreholes PS-01 and PS-07 were drilled at the north and south approaches, respectively. Boreholes PS-02 and PS-03 were drilled near the north abutment, Boreholes PS-04 and PS-05 near the Pier, and Boreholes PS-06 and PS-08 near the south abutment. The borehole depths ranged from 2.2 to 11.2 m (Elevations 167.6 to 172.3 m).

There is no GEOCRETS report for this site, however simplified plots of two boreholes (#1031 and #1032) are shown on a Department of Highways Ontario drawing for the existing bridge (Reference 1). The subsurface information shown on these simplified plots does not include SPT 'N' values or any other indication of soil strength and density/consistency, nor groundwater conditions.

Solid stem augers and coring techniques were used to advance the current boreholes through soil and bedrock. Overburden samples were obtained using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Boreholes PS-02, PS-05, and PS-08 were advanced a minimum of 3.0 m into bedrock by NXL size diamond coring. The remaining boreholes were terminated upon auger and/or split spoon refusal on probable bedrock or boulders.

Groundwater conditions in the open boreholes were observed upon completion of drilling. A standpipe piezometer, consisting of 19 mm diameter Schedule 40 PVC pipe with a 1.5 m long slotted screen, was installed in Boreholes PS-03 and PS-06. The installation details for the piezometers are summarized below along with the backfill details for other boreholes without piezometer installation.

Borehole Number	Piezometer Tip Depth / Elevation (m)	Completion Details
PS-01	None installed	Backfilled with bentonite holeplug and cuttings to 0.6 m, dry concrete from 0.6 m to 0.15 m, then asphalt coldpatch to surface.
PS-02	None installed	Backfilled with bentonite holeplug and cuttings to 0.6 m, dry concrete from 0.6 m to 0.15 m, then asphalt coldpatch to surface.

Borehole Number	Piezometer Tip Depth / Elevation (m)	Completion Details
PS-03	6.6 / 171.6	Filter sand from 6.6 m to 3.4 m, then bentonite holeplug from 3.4 m to 0.15 m. Flushmount protector installed at surface.
PS-04	None installed	Backfilled with bentonite holeplug and cuttings to 0.6 m, dry concrete from 0.6 m to 0.15 m, then asphalt coldpatch to surface.
PS-05	None installed	Backfilled with bentonite holeplug and cuttings to 0.6 m, then asphalt coldpatch to surface.
PS-06	7.3 / 170.9	Filter sand from 7.3 m to 3.4 m, then bentonite holeplug from 3.4 m to 0.15 m. Flush mount protector installed at surface.
PS-07	None installed	Backfilled with bentonite holeplug and cuttings to 0.6 m, dry concrete from 0.6 m to 0.15 m, then asphalt coldpatch to surface.
PS-08	None installed	Backfilled with bentonite holeplug and cuttings to 0.7 m, dry concrete from 0.6 m to 0.15 m, then asphalt coldpatch to surface.

A member of Thurber's technical staff supervised the drilling and sampling operations on a full time basis. The supervisor logged the boreholes, processed the soil and rock core samples in labelled containers and wooden core boxes, respectively, for transport to Thurber's laboratory for further examination and testing.

All rock cores were logged, and properties including the Total Core Recovery (TCR), Rock Quality Designation (RQD) and the Fracture Indices (FI) were determined.

4 LABORATORY TESTING

All recovered soil samples were subjected to visual identification and to natural moisture content determination. The results of this testing are summarized on the Record of Borehole sheets included in Appendix A. At least 25% of the recovered soil samples were subjected to grain size distribution analysis. Atterberg Limits tests were carried out on selected samples of silty clay till and clayey silt till to determine the plasticity characteristics. The results of these tests are plotted on the figures included in Appendix B.

Point load testing was carried out on selected rock cores retrieved from Boreholes PS-02, PS-05, and PS-08. The results of these tests are presented on the Record of Borehole sheets (as estimated UCS) included in Appendix A.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference should be made to the Record of Borehole sheets included in Appendix A. Details of the encountered soil and rock stratigraphy are presented in these records and on the “Borehole Locations and Soil Strata” drawings included in Appendix C. General descriptions of the stratigraphy based on boreholes drilled during the current investigation are given in the following paragraphs. It should be noted that the factual information presented in the Record of Borehole sheets governs any interpretation of site conditions.

In general, the subsurface stratigraphy at the site consists of a pavement structure of asphalt or concrete underlain by gravelly sand to sand and gravel fill with silty clay fill and silty sand fill encountered locally in Borehole PS-04. The fill typically overlies native silty clay till. Silty sand till was encountered locally in Borehole PS-08 below the silty clay to clayey silt till. The above soils are underlain by dolostone bedrock of the Lockport Formation.

5.1 Pavement Structure

Pavement structure consisting of asphalt overlying granular fill materials was encountered in the two boreholes drilled on Highway 58 (Boreholes PS-04 and PS-05). The thickness of the asphalt ranged from 175 to 210 mm.

The six boreholes drilled on Pine Street (Boreholes PS-01 to 03 and PS-06 to 08) encountered concrete with rebar at the surface overlying granular fill materials. The concrete was 125 mm thick in all six boreholes.

The granular fill consisted of gravelly sand to sand and gravel in all boreholes except Borehole PS-04 which encountered 1.3 m of silty clay fill overlying 0.7 m of silty sand fill. The thickness of the granular fill ranged from 0.7 to 2.2 m, with the lower boundary of the granular fill encountered at depths of 0.8 to 2.3 m (Elevations 178.1 to 170.7 m).

SPT ‘N’ values recorded in the granular fill ranged from 2 to 38 blows for 0.3 m penetration, indicating a variable relative density from very loose to dense. An SPT ‘N’ value of 50 blows for 0.1 m penetration was recorded in Borehole PS-05 at the fill-bedrock interface. In Borehole PS-04, the measured ‘N’ values of 12 and 10 blows indicate a stiff consistency and a compact relative density for the silty clay fill and silty sand fill, respectively. The moisture content of samples of the fill ranged from 8 to 20%.

5.2 Silty Clay Till

Silty clay till was encountered below the granular fill in Boreholes PS-01 to PS-03 and PS-06 to PS-08. This cohesive till typically contained trace sand and was brown in colour becoming grey with increasing depth.

Boreholes PS-01, PS-03, PS-06, and PS-07 were all terminated upon auger refusal. In these boreholes, the till was 5.7 to 6.7 m thick and the boreholes were terminated at depths of 6.6 to 7.5 m (Elevations 171.6 to 170.7 m). The silty clay till was fully penetrated in Boreholes PS-02 and PS-08 and was found to be 4.7 to 6.1 m thick. In these boreholes, the lower boundary of the cohesive till was encountered at depths of 6.9 to 7.0 m (Elevations 171.2 to 171.3 m).

SPT 'N' values recorded in the silty clay till ranged from 8 to 26 blows for 0.3 m penetration, indicating a stiff to very stiff consistency. The measured moisture content of samples of the silty clay till ranged from 20 to 28%.

Selected samples of silty clay till were subjected to gradation analysis and Atterberg Limits testing. The results of these tests are summarized in the tables below as well as on the Record of Borehole sheets included in Appendix A. Figures B1 and B2 present the grain size distribution curves for these samples, and Figures B3 and B4 illustrate the results of the Atterberg Limits tests on plasticity charts.

Soil Particles	Percentage
Gravel	0 to 3
Sand	0 to 16
Silt	43 to 73
Clay	23 to 57

Soil Particles	Percentage
Liquid Limit	27 to 51
Plasticity Index	12 to 28

The results of the Atterberg Limits tests indicate that the silty clay till has a variable plasticity, ranging from low plastic (CL) to high plastic (CH) and generally has an intermediate plasticity (CI). It should be noted that glacial tills inherently contain cobbles and boulders.

5.3 Silty Sand Till

Silty sand till was encountered locally in Borehole PS-08 below the silty clay till. The silty sand till was grey in colour and contained some gravel and some clay.

The silty sand till was 1.2 m thick with a lower boundary encountered at a depth of 8.2 m (Elevation 170.0 m). A single SPT 'N' value of 65 blows for 0.3 m penetration was recorded in the silty sand till indicating a very dense relative density. The moisture content of the silty sand till was measured to be 8 % in one sample. It should be noted that glacial tills inherently contain cobbles and boulders.

5.4 Bedrock

The soils described above are underlain by bedrock which was proven by coring in Boreholes PS-02, PS-05, and PS-08. The remaining five boreholes were terminated upon auger and/or split spoon refusal on probable bedrock or boulders. The following table summarizes the depths and elevations of bedrock or auger refusal encountered at the borehole locations.

Proposed Foundation Element	Borehole Number	Depth to Bedrock or Auger Refusal (m)	Elevation of Top of Bedrock or Auger Refusal (m)
North Approach	PS-01	6.6	171.6
North Abutment	PS-02*	6.9*	171.3*
	PS-03	6.6	171.6
Pier	PS-04	2.2	170.2
	PS-05*	1.6*	170.7*
South Abutment	PS-06	7.3	170.9
	PS-08*	8.2*	170.0*
South Approach	PS-07	7.5	170.7

* Bedrock proven by coring

Boreholes 1032 and 1031 (Reference 1) indicate that the bedrock is at Elevations 171.8 and 170.9 m near the north and south abutments, respectively.

Based on the rock cores from the current investigation, the bedrock was described as thinly bedded, grey, dolostone. The bedrock was typically in a moderately to slightly weathered state. Occasional joints and vugs were observed in the bedrock cores.

Total Core Recovery (TCR) of the bedrock ranged from 95 to 100%. The Rock Quality Designation (RQD) values generally ranged from 75 to 98%, indicating a fair to excellent rock quality. Lower RQD values of 46% and 61% were recorded for the rock cores retrieved from Borehole PS-05, drilled on Highway 58. The Fracture Index (FI) of the rock, expressed as fractures or joints per 0.3 m of core, was generally less than 5, except for a highly fractured zone encountered near the bedrock surface at the location of Borehole PS-05.

Point load tests were carried out at regular intervals on selected rock cores. The estimated Unconfined Compressive Strength (UCS) of the bedrock as inferred from the point load tests ranged from 133 to 185 MPa, indicating a very strong intact rock strength.

5.5 Water Levels

Standpipe piezometers were installed in selected boreholes to facilitate monitoring of groundwater levels. The water levels observed in the open boreholes on completion of

drilling are summarized below along with the groundwater levels measured in the standpipe piezometers.

Borehole	Date	Water Levels		Comment
		Depth (m)	Elevation (m)	
PS-01	May 29, 2012	DRY		Open borehole
PS-02	May 28, 2012	DRY		Open borehole
PS-03	July 16, 2012	5.5	172.7	Piezometer
PS-04	April 16, 2012	2.1	170.3	Open borehole
PS-05	April 17, 2012	DRY		Open borehole
PS-06	May 29, 2012	DRY		Open borehole
	July 16, 2012	7.1	171.1	Piezometer
PS-07	May 29, 2012	DRY		Open borehole
PS-08	May 28, 2012	DRY		Open borehole

All groundwater observations at this site are short term and the levels are expected to fluctuate seasonally and after severe climatic events.

Once groundwater monitoring is completed, all piezometer installations will be decommissioned shortly in accordance with Ministry of the Environment Regulation 903 and its Amendments (the water well regulation under the OWRA).

6 MISCELLANEOUS

Borehole locations were established in the field relative to the location of the existing structure. The ground surface elevations and coordinates at all borehole locations were established by surveyors arranged by MRC upon completion of drilling. Underground utility clearances were obtained for the borehole locations prior to drilling.

Elite Drilling Services of St. Catharines, Ontario supplied a truck-mounted CME-75 drill rig and conducted the drilling, sampling and in-situ testing operations.

The field investigation was supervised by Mr. Ryan Kromer, E.I.T. and Mr. Dave Ametrano of Thurber. Geotechnical laboratory testing was carried out in Thurber's Toronto Area laboratory.

Overall planning and supervision of the field program was conducted by Mr. Luke Gilarski, E.I.T. and Mr. Sydney Pang, P.Eng. Interpretation of the data and preparation of this report was carried out by Ms. Lindsey Blaine, E.I.T.

The report was reviewed by Messrs. Sydney Pang, P.Eng. and P.K. Chatterji, P.Eng., who is a Designated Principal Contact for MTO Foundations Projects.

THURBER ENGINEERING LTD.

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Jan. 28/13

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Appendix A

Record of Borehole Sheets

19-1351-221

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT ⁽¹⁾ 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT value
- 5) Pocket Penetrometer

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
	TW Thin Wall Shelby Tube Sample	TP Thin Wall Piston Sample	
	PH Sampler Advanced by Hydraulic Pressure	PM Sampler Advanced by Manual Pressure	
	WH Sampler Advanced by Self Static Weight	RC Rock Core	SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$



Water Level

C_{pen}


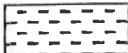



Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS $W_L < 50\%$	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. ($W_L < 30\%$).
		CI	Inorganic clays of medium plasticity, silty clays. ($30\% < W_L < 50\%$).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION		SYMBOLS	
Fresh (FR)	No visible signs of weathering.		
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.		CLAYSTONE
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.		SILTSTONE
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.		SANDSTONE
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.		COAL
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.		Bedrock (general)

DISCONTINUITY SPACING		STRENGTH CLASSIFICATION			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
			(MPa)	(psi)	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m				
Very thinly bedded	20 to 60mm	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Laminated	6 to 20mm				
Thinly Laminated	Less than 6mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
		Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
		Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
		Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

TERMS	
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length.
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.

RECORD OF BOREHOLE No PS-01

1 OF 1

METRIC

2365-09-00 LOCATION Pine St. Underpass N 4 775 226.1 E 329 010.1 ORIGINATED BY RK
HWY 58 BOREHOLE TYPE Solid Stem Augers/CME 75 COMPILED BY AN
DATUM Geodetic DATE 2012.05.29 - 2012.05.29 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
178.2													
0.0	CONCRETE with rebar: (125mm)												
0.1	SAND and GRAVEL Brown Moist (FILL)						178						
177.4													
0.8	Silty CLAY, trace sand Stiff to Very Stiff Brown (TILL)		1	SS	18		177						
			2	SS	19		176						0 3 50 47
			3	SS	12		175						
			4	SS	23		174						
			5	SS	17		173						
	Becomes grey		6	SS	18		172						0 7 52 41
171.6													
6.6	END OF BOREHOLE AT 6.6m UPON AUGER REFUSAL. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.6m, DRY CONCRETE TO 0.15m, THEN ASPHALT COLDPATCH TO SURFACE.												

ONTMT4S 1221.GPJ 1/3/13

METRIC

[illegible]

+ 3, × 3: Numbers refer to Sensitivity

METRIC

[illegible]

RECORD OF BOREHOLE No PS-03

1 OF 1

METRIC

2365-09-00 LOCATION Pine St. Underpass N 4 775 184.2 E 329 022.1 ORIGINATED BY RK
 HWY 58 BOREHOLE TYPE Solid Stem Augers/CME 75 COMPILED BY AN
 DATUM Geodetic DATE 2012.05.29 - 2012.05.29 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	
178.2													
0.0	CONCRETE with rebar. (125mm)												
0.1	Gravelly SAND Brown Moist (FILL)						178						
177.3													
0.9	Silty CLAY, trace sand Stiff to Very Stiff Brown (TILL)		1	SS	10		177						
			2	SS	19								
			3	SS	15		176						
			4	SS	12		175						
							174						
	Becomes grey		5	SS	12		173						
	Some sand, trace gravel		6	SS	24		172						
171.6													
6.6	END OF BOREHOLE AT 6.6m UPON AUGER REFUSAL. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Jul. 16/12 5.5 172.7												

ONTMT4S 1221.GPJ 1/3/13

RECORD OF BOREHOLE No PS-04

1 OF 1

METRIC

2365-09-00

LOCATION

Pine St. Underpass N 4 775 160.0 E 329 004.7

ORIGINATED BY DA

HWY 58

BOREHOLE TYPE Solid Stem Augers/CME 75

COMPILED BY AN

DATUM Geodetic

DATE

2012.04.16 - 2012.04.16

CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)						
172.4								20	40	60	80	100	w _p	w	w _L		
0.0	ASPHALT: (175mm)																
0.2	Silty CLAY, some sand, trace gravel Stiff Brown (FILL)						172										
			1	SS	12												
170.9							171										
1.5	Silty SAND, trace to some gravel Compact Brown Moist (FILL)		2	SS	10												
170.2			3	SS	50/												
2.2	END OF BOREHOLE AT 2.2m UPON AUGER REFUSAL. WATER LEVEL AT 2.1m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.6m, DRY CONCRETE TO 0.15m, THEN ASPHALT COLDPATCH TO SURFACE.				0.075												

RECORD OF BOREHOLE No PS-05

1 OF 1

METRIC

W.P. 2365-09-00 LOCATION Pine St. Underpass N 4 775 159.8 E 329 028.0 ORIGINATED BY DA
HWY 58 BOREHOLE TYPE Solid Stem Augers/CME75/NXL Coring COMPILED BY AN
DATUM Geodetic DATE 2012.04.17 - 2012.04.17 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
172.3								20 40 60 80 100						
0.0	ASPHALT: (210mm)							20 40 60 80 100						
0.2	SAND and GRAVEL, trace silt, trace clay Dense Brown Moist (FILL)		1	AS			172							
			1	SS	38									
170.7			2	SS	50/		171							
1.6	Moderately weathered, thinly bedded, grey, very strong, DOLOSTONE BEDROCK Broken cores at 1.7m, 1.8m Vertical joint from 1.8m to 1.9m Horizontal joints at 2.4m, 3.4m, 3.5m Calcite interbed (25mm thick) at 4.5m		1	RUN	0.100		170							
			2	RUN										
			3	RUN			169							
											</			

+ 3, X 3: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No PS-06

1 OF 1

METRIC

2365-09-00 LOCATION Pine St. Underpass N 4 775 131.2 E 329 010.7 ORIGINATED BY RK
HWY 58 BOREHOLE TYPE Solid Stem Augers/CME 75 COMPILED BY AN
DATUM Geodetic DATE 2012.05.29 - 2012.05.29 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
178.2													
0.0	CONCRETE with rebar (125mm)												
0.1	Gravelly SAND												
177.4	Brown												
0.8	Moist (FILL)												
	Silty CLAY, trace sand		1	SS	19								
	Very Stiff to Stiff												
	Brown		2	SS	20								0 0 43 57
	(TILL)												
			3	SS	13								
			4	SS	13								
	Becomes grey												
			5	SS	8								
			6	SS	13								0 3 52 45
170.9													
7.3	END OF BOREHOLE AT 7.3m UPON AUGER REFUSAL. BOREHOLE OPEN AND DRY UPON COMPLETION. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.												
	WATER LEVEL READINGS: DATE DEPTH (m) ELEV. (m) Jul. 16/12 7.1 171.1												

ONTMT4S 1221.GPJ 1/3/13

+ 3, x 3 Numbers refer to
Sensitivity 20 15 10 5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No PS-07

1 OF 1

METRIC

2365-09-00 LOCATION Pine St. Underpass N 4 775 103.2 E 329 023.2 ORIGINATED BY RK
HWY 58 BOREHOLE TYPE Solid Stem Augers/CME 75 COMPILED BY AN
DATUM Geodetic DATE 2012.05.29 - 2012.05.29 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
178.2													
0.0	CONCRETE with rebar (125mm)												
0.1	SAND and GRAVEL Brown Moist (FILL)						178						
177.4													
0.8	Silty CLAY, trace sand Very Stiff Brown (TILL)		1	SS	21		177						
			2	SS	22								
			3	SS	26		176						
			4	SS	23		175						
							174						
	Becomes grey		5	SS	16		173						0 4 53 43
							172						
	Becomes stiff		6	SS	13								
170.7							171						
7.5	END OF BOREHOLE AT 7.5m UPON AUGER REFUSAL. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.6m, DRY CONCRETE TO 0.15m, THEN ASPHALT COLDPATCH TO SURFACE.												

+ 3, x 3: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

METRIC

SOIL PROFILE			SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI C	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa		WATER CONTENT (%)			
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE	w _p			w
178.2 0.0 0.1	CONCRETE: (125mm) Gravelly SAND Loose to Very Loose Brown Wet (FILL) Silty clay layer from 0.9m to 1.2m		1	SS	8								
			2	SS	2								
175.9 2.3	Silty CLAY Stiff to Very Stiff Brown (TILL) Becomes grey Some sand, trace gravel		3	SS	11							0 0 58 4	
			4	SS	17								
			5	SS	8								
			6	SS	15							0 11 60 2	
171.2 7.0	Silty SAND, some gravel, some clay Very Dense Grey Moist (TILL) Auger refusal at 8.2m		7	SS	65								
170.0 8.2	Slightly weathered, thinly bedded, grey, very strong, DOLOSTONE BEDROCK Sub-horizontally joints		1	RUN							FI	RUN #1 TCR=100% SCR=100% RQD=90% UCS=156MPa (Average)	
											1		
											1		
											3		
											0		
											0		
											2	RUN #2 TCR=95%	

ONTMT4S 1221.GPJ 1/3/13

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

RECORD OF BOREHOLE No PS-08

2 OF 2

METRIC

2365-09-00 LOCATION Pine St. Underpass N 4 775 131.0 E 329 023.2 ORIGINATED BY RK
 HWY 58 BOREHOLE TYPE Solid Stem Augers/CME 75/NXL Coring COMPILED BY AN
 DATUM Geodetic DATE 2012.05.28 - 2012.05.28 CHECKED BY LPG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
	Continued From Previous Page							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
								PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT w _p w w _L WATER CONTENT (%) 20 40 60						
167.0			2	RUN			168							SCR=90% RQD=75% UCS=185MPa (Average)
11.2	END OF BOREHOLE AT 11.2m. BOREHOLE OPEN AND DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.7m, DRY CONCRETE TO 0.15m, THEN ASPHALT COLDPATCH TO SURFACE.													

Appendix B

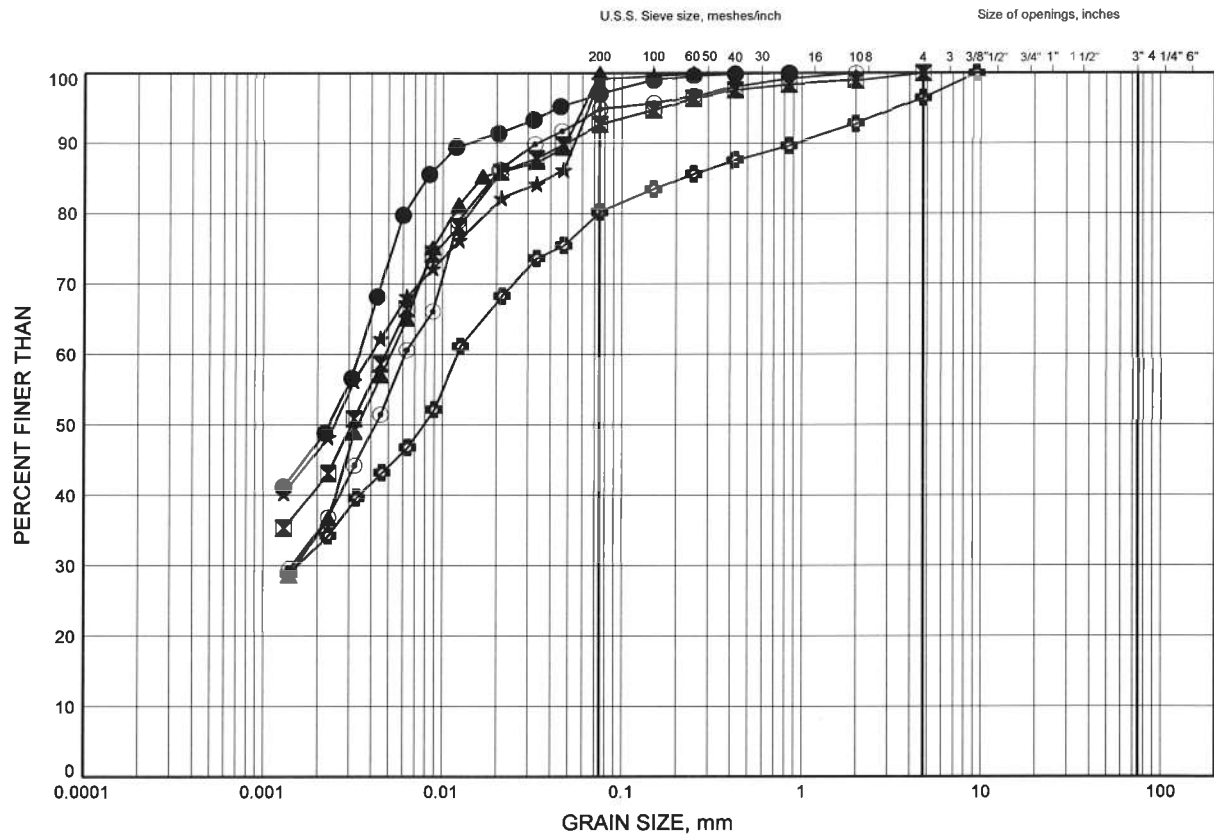
Laboratory Test Results

19-1351-221

5 Bridges, Welland and St. Catharines
GRAIN SIZE DISTRIBUTION

FIGURE B1

SILTY CLAY TILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND			GRAVEL		SIZE

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PS-01	1.83	176.37
⊠	PS-01	6.32	171.88
▲	PS-02	2.59	175.61
★	PS-02	4.88	173.32
⊙	PS-03	3.35	174.85
⊕	PS-03	6.40	171.80

Date November 2012
W.P.# 2365-09-00

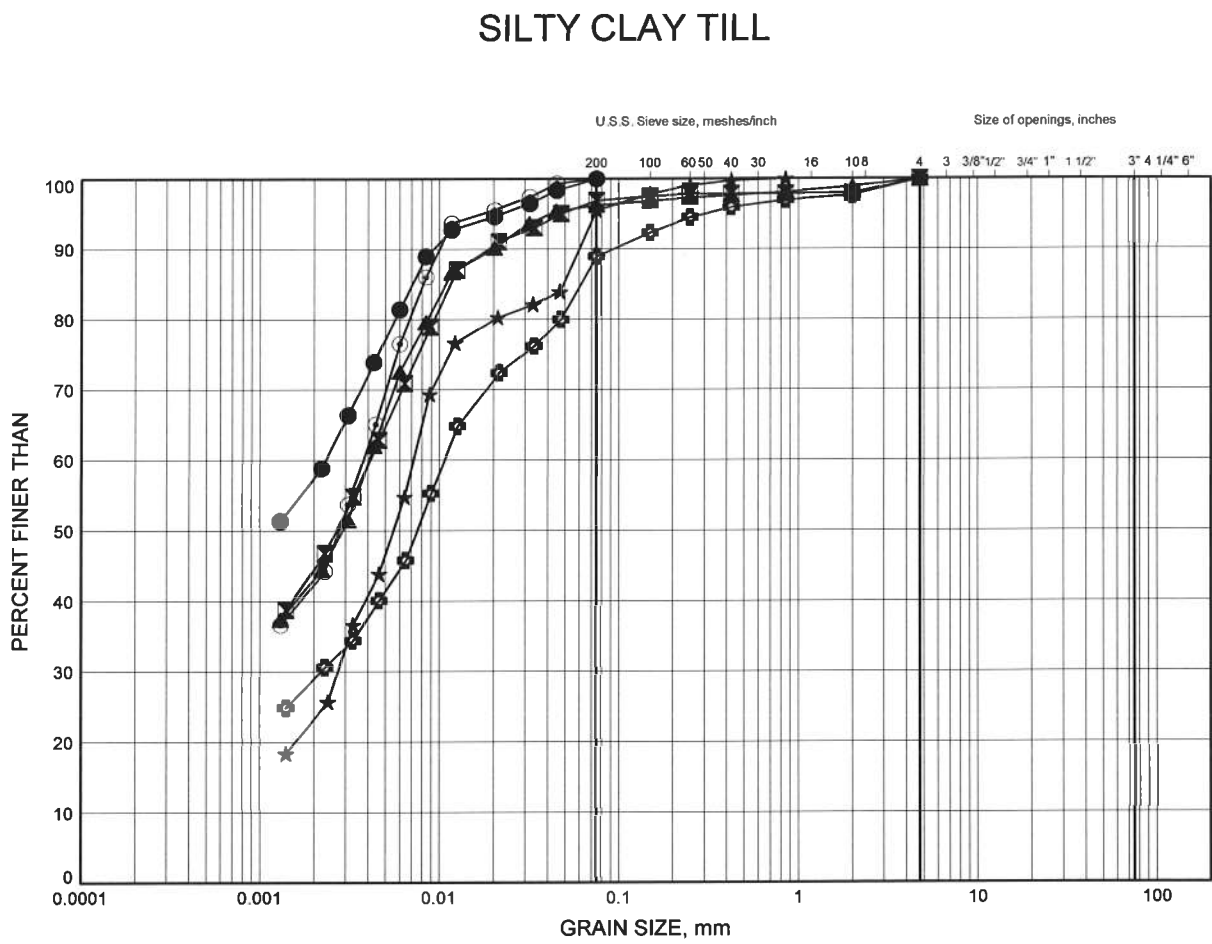


Prep'd AN
Chkd. SKP

5 Bridges, Welland and St. Catharines

GRAIN SIZE DISTRIBUTION

FIGURE B2



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PS-06	1.83	177.05
⊠	PS-06	6.40	172.48
▲	PS-07	2.59	175.61
★	PS-07	4.88	173.32
⊙	PS-08	2.59	175.61
⊕	PS-08	6.40	171.80

GRAIN SIZE DISTRIBUTION - THURBER 1221.GPJ 11/29/12

Date November 2012
W.P.# 2365-09-00

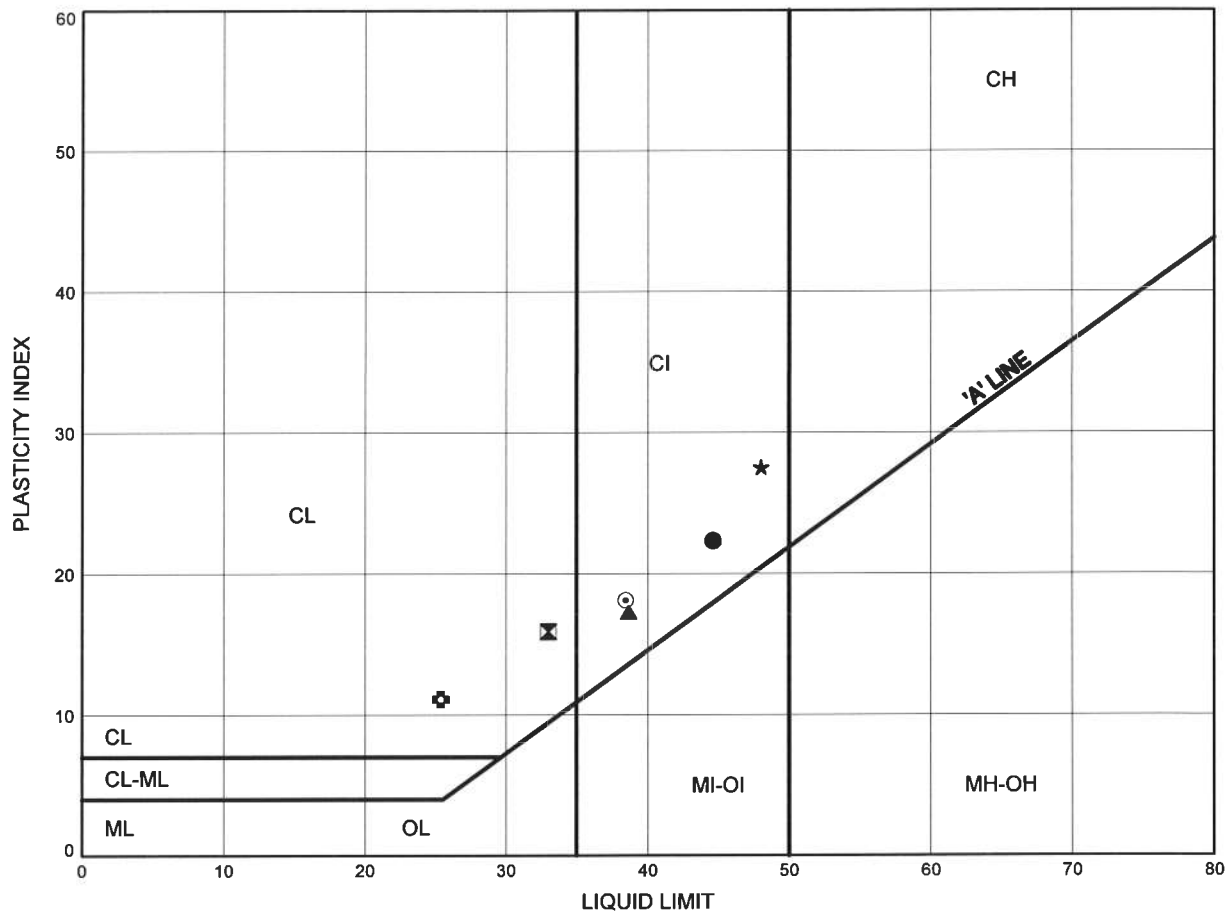


Prep'd AN
Chkd. SKP

5 Bridges, Welland and St. Catharines
ATTERBERG LIMITS TEST RESULTS

FIGURE B3

SILTY CLAY TILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PS-01	1.83	176.37
⊠	PS-01	6.32	171.88
▲	PS-02	2.59	175.61
★	PS-02	4.88	173.32
⊙	PS-03	3.35	174.85
⊕	PS-03	6.40	171.80

Date November 2012

W.P.# 2365-09-00



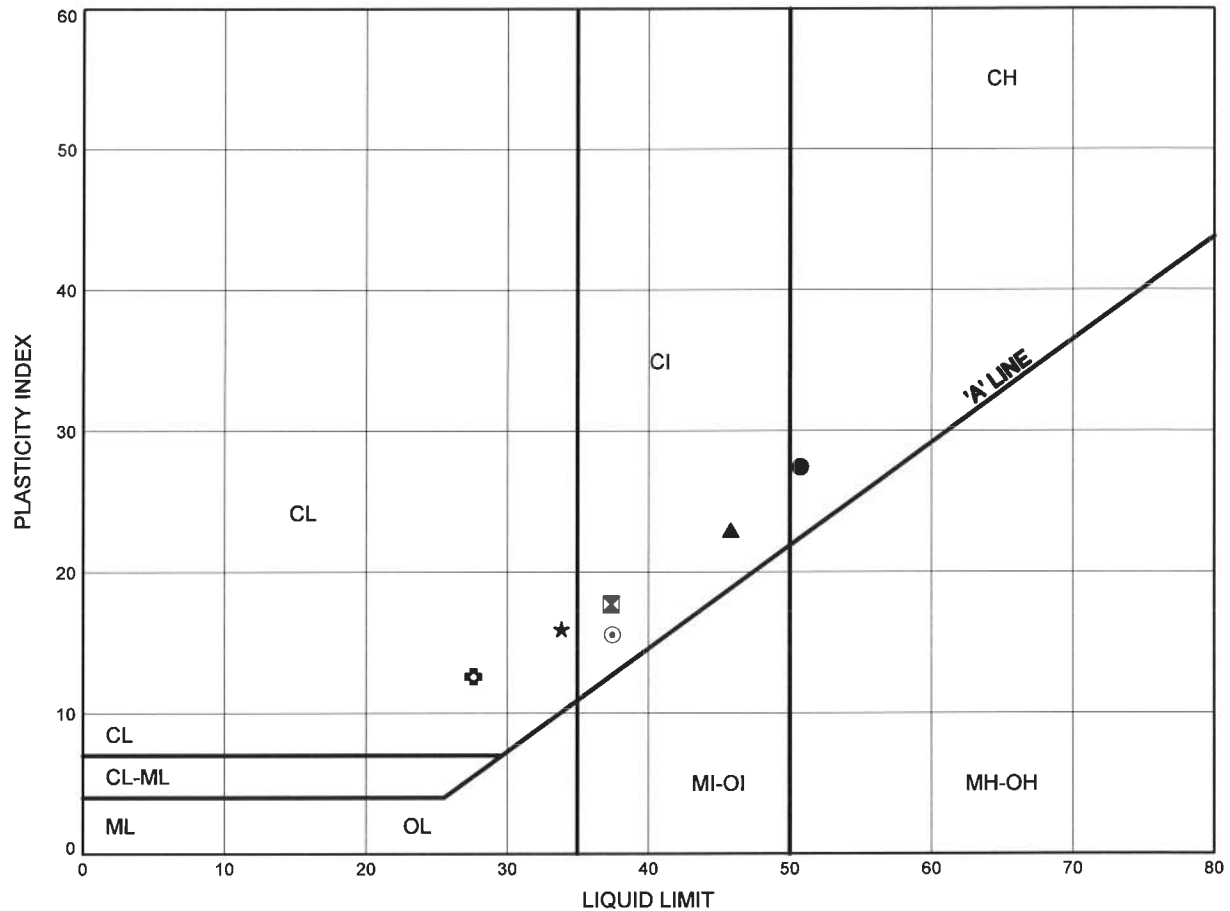
Prep'd AN

Chkd. SKP

5 Bridges, Welland and St. Catharines
ATTERBERG LIMITS TEST RESULTS

FIGURE B4

SILTY CLAY TILL



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	PS-06	1.83	177.05
⊠	PS-06	6.40	172.48
▲	PS-07	2.59	175.61
★	PS-07	4.88	173.32
⊙	PS-08	2.59	175.61
⊕	PS-08	6.40	171.80

Date November 2012

W.P.# 2365-09-00



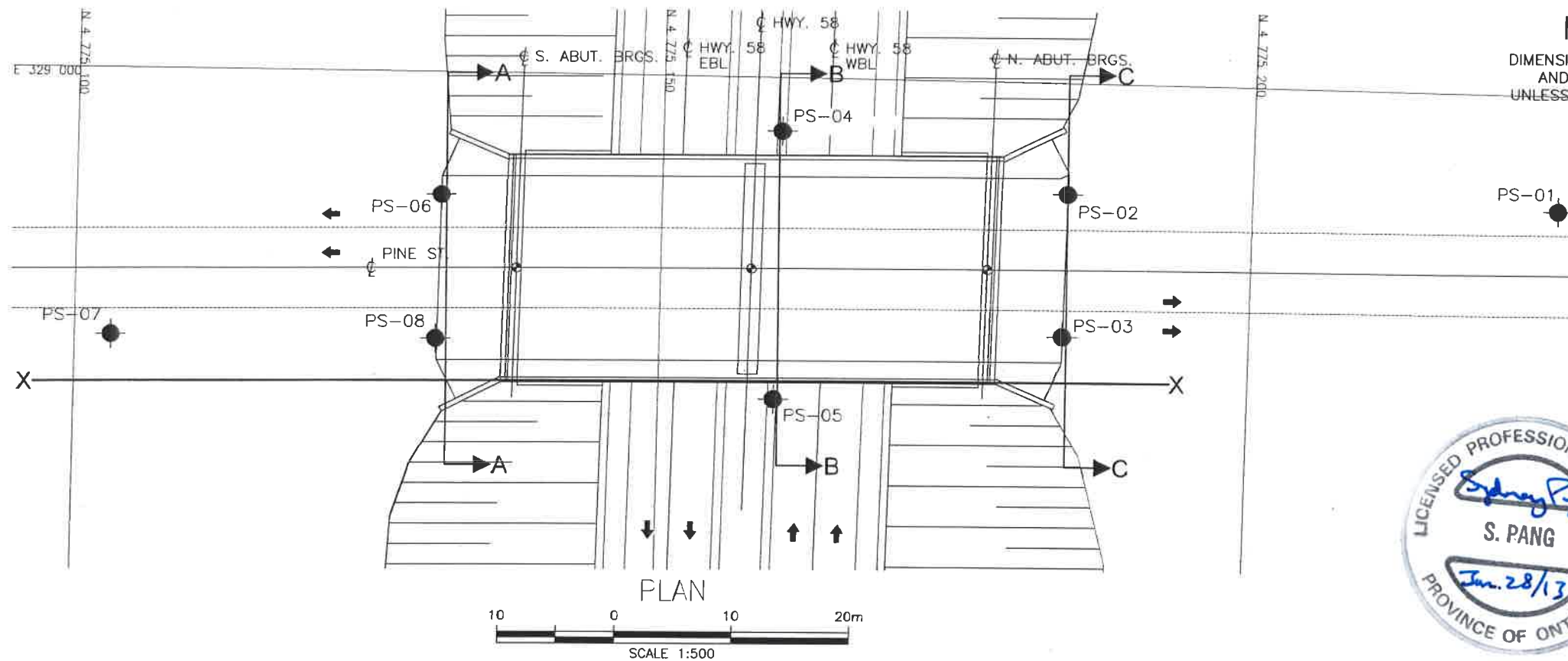
Prep'd AN

Chkd. SKP

Appendix C

Drawings titled “Borehole Locations and Soil Strata”

19-1351-221



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

CONT No
GWP No 2365-09-00
WP No 2367-09-01

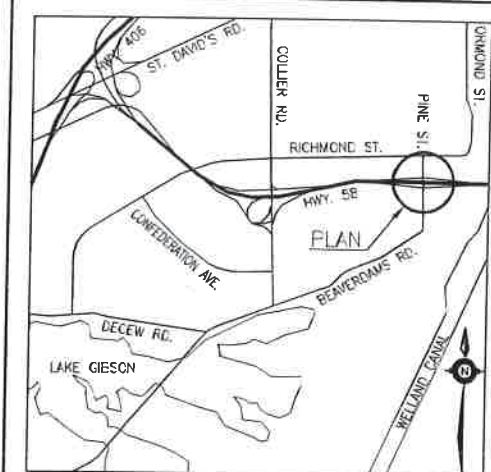


HIGHWAY 58
PINE STREET UNDERPASS
BRIDGE REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET
73

MRC McCORMICK RANKIN
A member of MMM GROUP

THURBER ENGINEERING LTD.



LEGEND

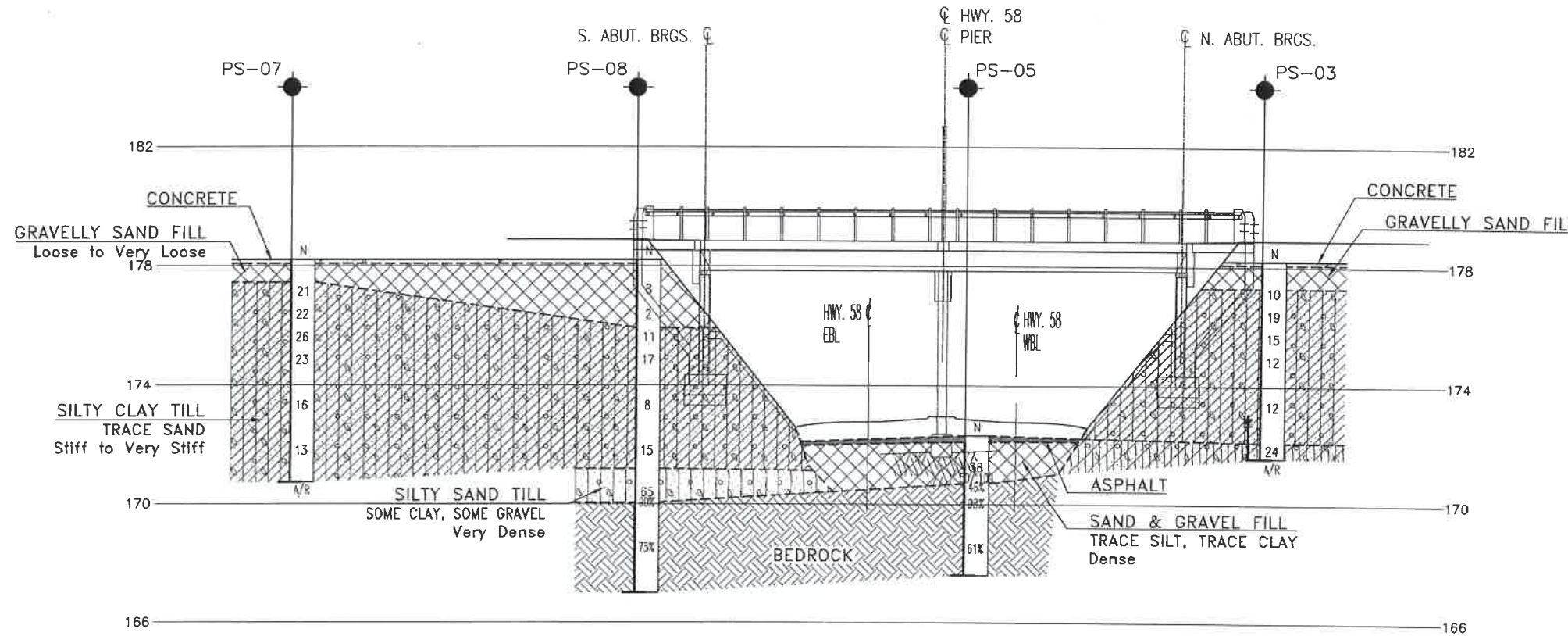
- ◆ Borehole
- ◆ Borehole and Cone
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60' Cone, 475J/blow)
- PH Pressure, Hydraulic
- W Water Level
- W Head Artesian Water
- P Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
PS-01	178.2	4 775 226.1	329 010.1
PS-02	178.2	4 775 184.4	329 009.7
PS-03	178.2	4 775 184.2	329 022.1
PS-04	172.4	4 775 160.0	329 004.7
PS-05	172.3	4 775 159.8	329 028.0
PS-06	178.2	4 775 131.2	329 010.7
PS-07	178.2	4 775 103.2	329 023.2
PS-08	178.2	4 775 131.0	329 023.2

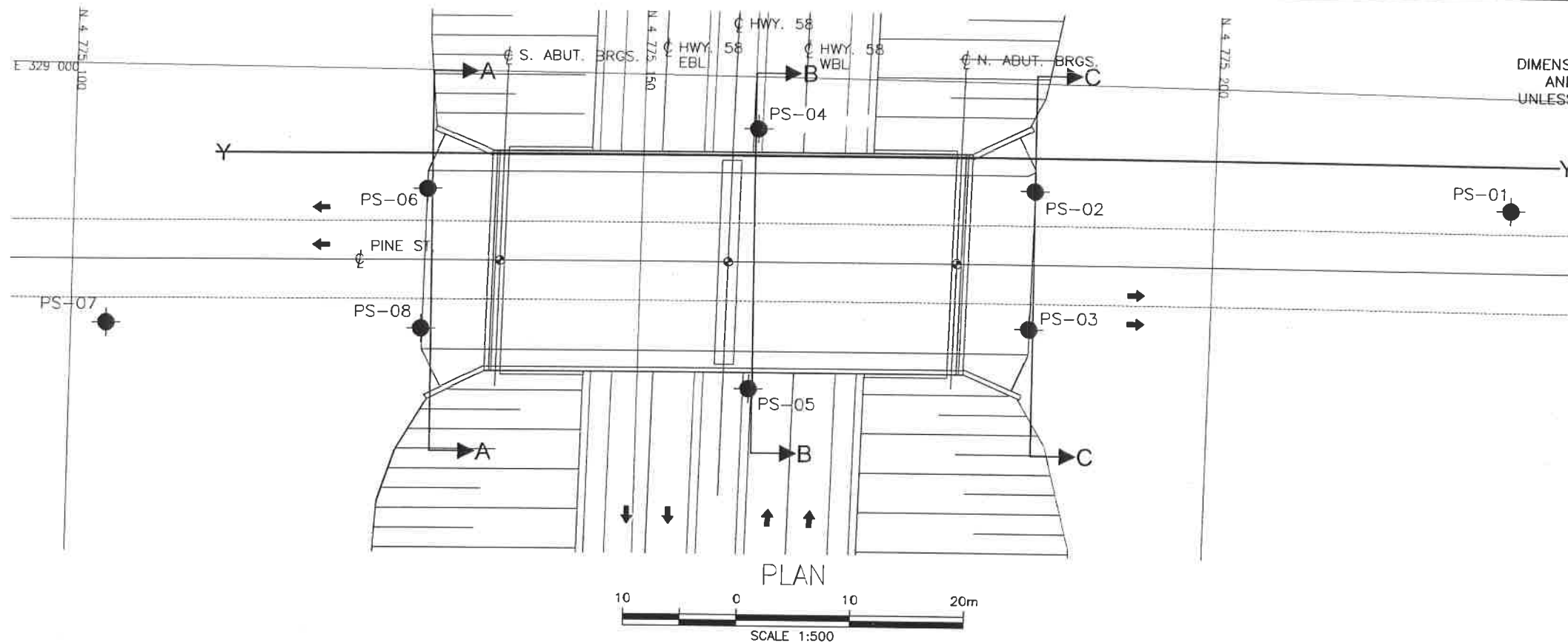
NOTES

- 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.

GEOCRES No. 30M3-275



REVISIONS	DATE	BY	DESCRIPTION
DESIGN LG	CHK SKP	CODE	LOAD
DRAWN MFA	CHK PKC	SITE 34-179	STRUCT DWG 2



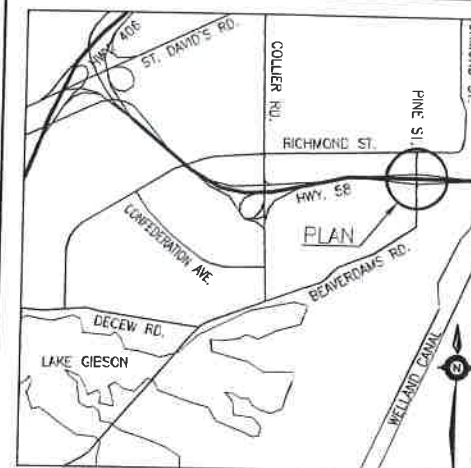
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No
GWP No 2365-09-00
WP No 2367-09-01

SHEET
74

MRC MCCORMICK RANKIN
A member of MRM GROUP

THURBER ENGINEERING LTD.



LEGEND

- ◆ Borehole
- ◆ Borehole and Cone
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60° Cone, 475J/blow)
- PH Pressure, Hydraulic
- W Water Level
- HA Head Artesian Water
- P Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

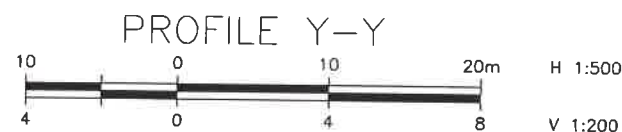
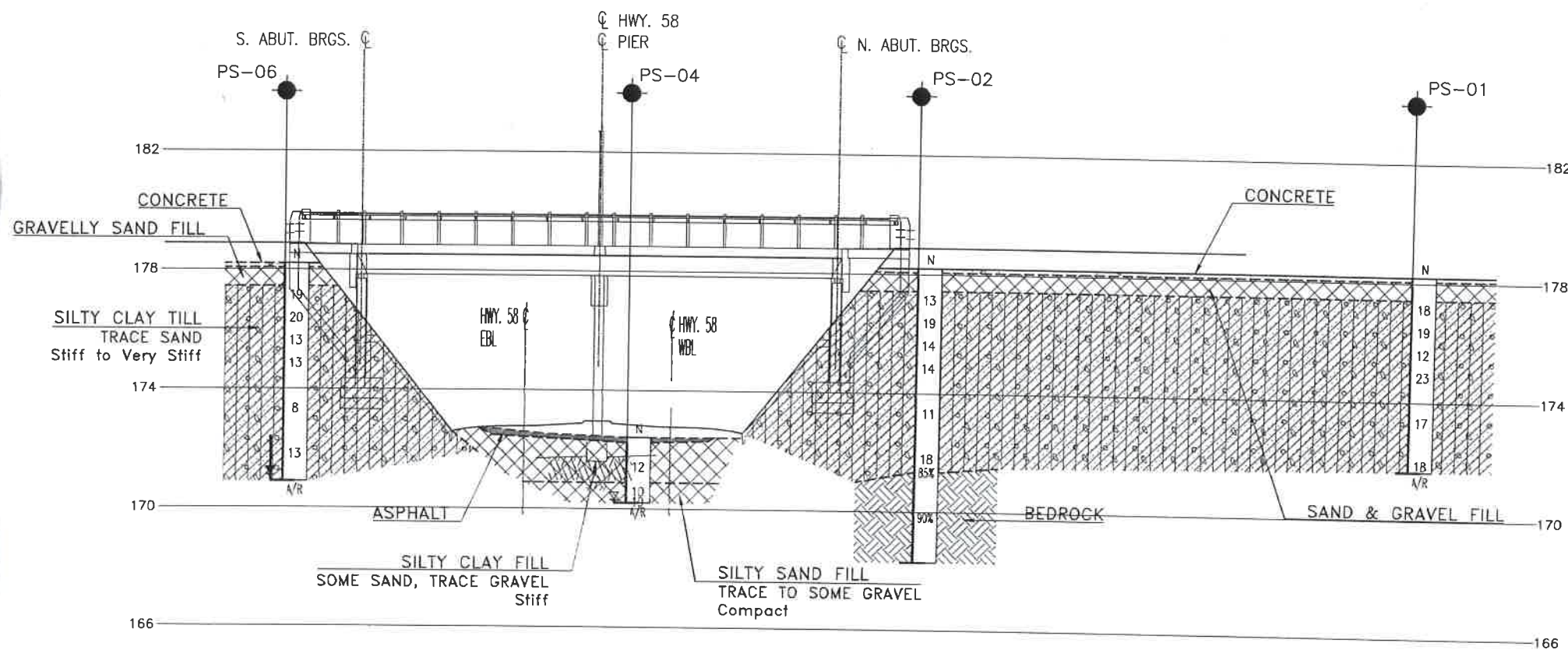
NO	ELEVATION	NORTHING	EASTING
PS-01	178.2	4 775 226.1	329 010.1
PS-02	178.2	4 775 184.4	329 009.7
PS-03	178.2	4 775 184.2	329 022.1
PS-04	172.4	4 775 160.0	329 004.7
PS-05	172.3	4 775 159.8	329 028.0
PS-06	178.2	4 775 131.2	329 010.7
PS-07	178.2	4 775 103.2	329 023.2
PS-08	178.2	4 775 131.0	329 023.2

-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.

GEOCREs No. 30M3-275

DATE	BY	DESCRIPTION
DESIGN LG	CHK SKP	CODE
DRAWN MFA	CHK PKC	SITE 34-179
		STRUCT
		DWG 3
		DATE JAN. 2013



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

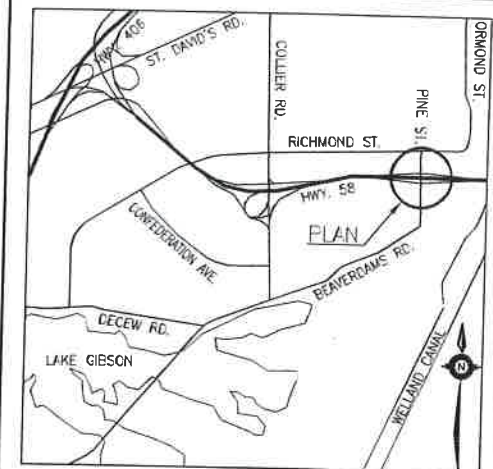
CONT No
GWP No 2365-09-00
WP No 2367-09-01

HIGHWAY 58
PINE STREET UNDERPASS
BRIDGE REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET
75

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THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

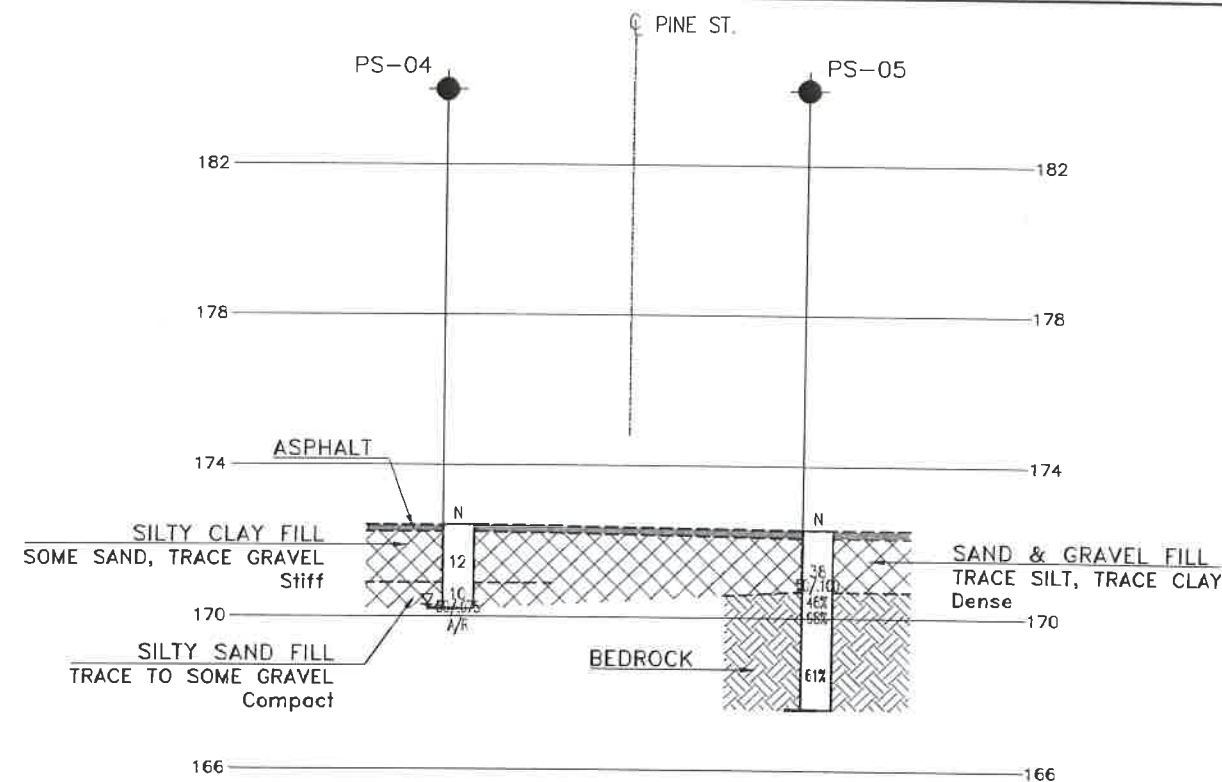
- ◆ Borehole
- ◆ Borehole and Cone
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60° Cone, 475J/blow)
- PH Pressure, Hydraulic
- W Water Level
- HA Head Artesian Water
- P Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
PS-01	178.2	4 775 226.1	329 010.1
PS-02	178.2	4 775 184.4	329 009.7
PS-03	178.2	4 775 184.2	329 022.1
PS-04	172.4	4 775 160.0	329 004.7
PS-05	172.3	4 775 159.8	329 028.0
PS-06	178.2	4 775 131.2	329 010.7
PS-07	178.2	4 775 103.2	329 023.2
PS-08	178.2	4 775 131.0	329 023.2

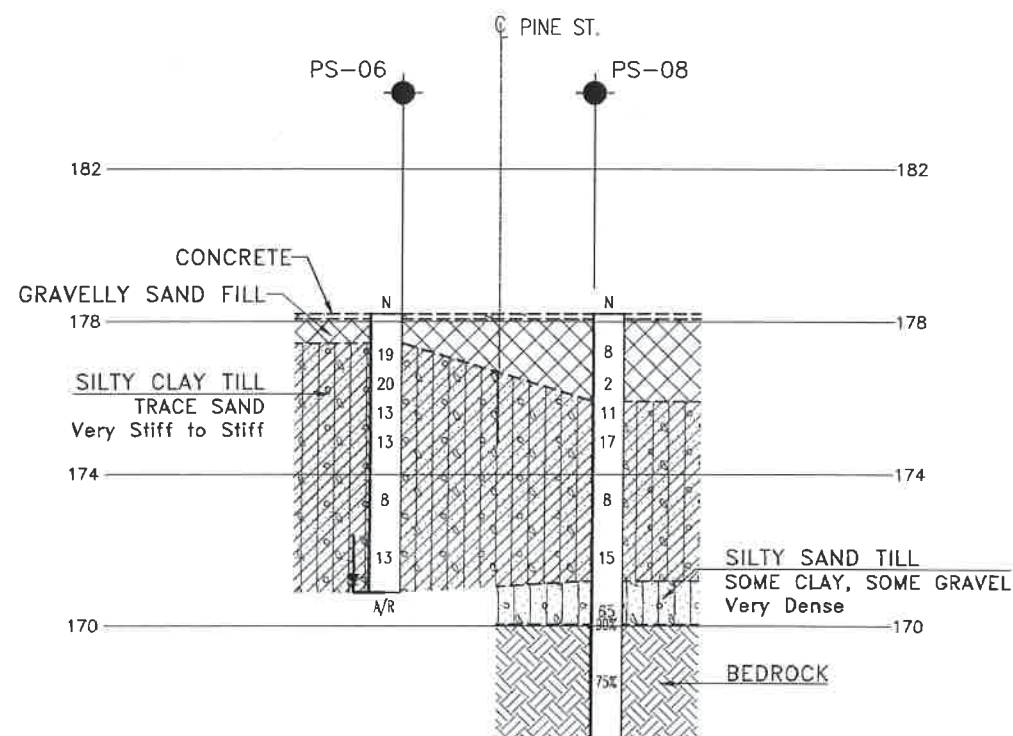
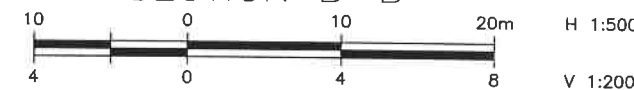
-NOTES-

- 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.

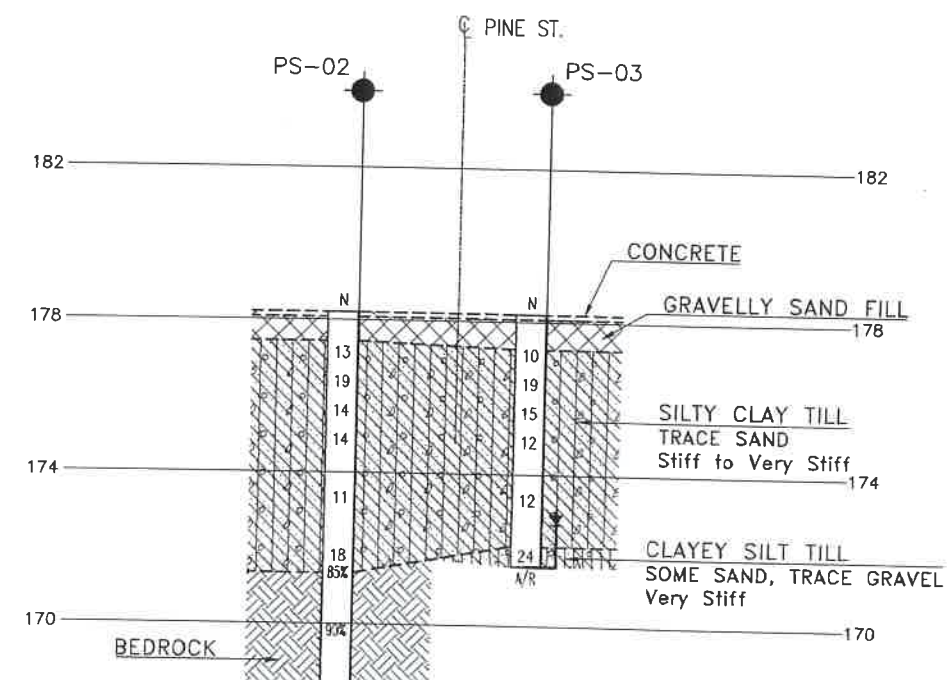
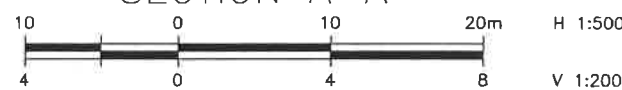
GEOCRES No. 30M3-275



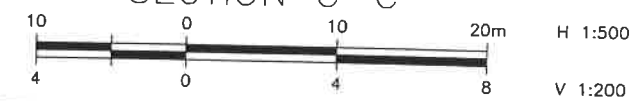
SECTION B-B



SECTION A-A



SECTION C-C



REVISIONS	DATE	BY	DESCRIPTION
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