



**THURBER** ENGINEERING LTD.

**FINAL  
FOUNDATION INVESTIGATION REPORT  
CULVERT SITE 27-361/C  
HIGHWAY 417, CASSELMAN ON**

**G.W.P. 451-98-00**

Geocres No.: 31G-270

Report to:

**Ainley Group**

Latitude: 45.304244  
Longitude: -75.078180

November 2018  
Thurber File: 18310

## TABLE OF CONTENTS

### PART 1. FACTUAL INFORMATION

1	INTRODUCTION .....	1
2	SITE DESCRIPTION .....	1
3	SITE INVESTIGATION AND FIELD TESTING.....	2
4	LABORATORY TESTING.....	3
5	DESCRIPTION OF SUBSURFACE CONDITIONS .....	3
5.1	Surficial Materials.....	3
5.1.1	Fill: Sand with Gravel .....	3
5.1.2	Fill: Silty Gravel with Sand.....	3
5.1.3	Fill: Silty Sand.....	4
5.2	Clay (Cl to CH).....	4
5.3	Gravel with Silt and Sand (Glacial Till).....	5
5.4	Bedrock.....	5
5.5	Groundwater .....	6
5.6	Analytical Testing.....	6
6	MISCELLANEOUS .....	7

### APPENDICES

Appendix A.	Borehole Location Plan and Stratigraphic Drawings
Appendix B.	Record of Borehole Sheets
Appendix C.	Laboratory Testing
Appendix D.	Site Photographs

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**PART 1. FACTUAL INFORMATION**

**1 INTRODUCTION**

This section of the report presents the factual findings obtained from a foundation investigation completed for Culvert 27-361/C at the E-N/S ramp of the Highway 417 County Road 7 Interchange. The culvert is located approximately 200 m east of County Road 7 East within the Township of Cambridge. Thurber Engineering Limited (Thurber) carried out the current investigation as a sub-consultant to Ainley Graham & Associates Limited (Ainley) under Agreement No. 4016-E-0036.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions influencing design and construction was developed throughout the current investigation. No previous foundation investigation information was available for the subject culvert site within the Geocres Library.

**2 SITE DESCRIPTION**

The existing culvert is a corrugated steel sectional plate arch culvert servicing the Leo Denis Municipal Drain and is understood to have been constructed in 1971. The culvert is reported to be 3.5 m wide by 2.2 m high and approximately 49 m long with a generally north to south alignment. The flow through the culvert is to the south.

At the location of the culvert, The E-N/S ramp is a 4.8 m wide single-lane ramp with a 2.5 m wide paved outside shoulder. The ramp embankment fill height is approximately 2.7 m over the culvert with the road surface at approximate elevation of 66.9 m. The existing embankment side slopes are inclined flatter than 2H:1V. No signs of erosion or slope instability were noted on the existing highway embankments during the field investigation. The roadway surface over the culvert was generally in good condition with no dips or bumps noted during the field investigation. The existing culvert, however, did show minimal signs of corrosion. The land adjacent to the ramp is commercially developed. Traffic volumes are understood to be 1812 AADT (2014).

Photographs showing the existing conditions near the culvert are included in Appendix D for reference.

**FINAL**

### 3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing program was carried out between September 13<sup>th</sup> and 22<sup>nd</sup>, 2017 for the on-road investigation and between June 18<sup>th</sup> and 27<sup>th</sup>, 2018 for the off-road investigation. Drilling consisted of advancing four boreholes identified as 17-1 through 17-4. The drilling was carried out using a track mounted CME 55 drill rig for off-road Boreholes 17-1 and 17-4 and a truck mounted CME 55 drill rig for on-road Boreholes 17-2 and 17-3. Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations.

The northing, easting and elevation of the boreholes from the current investigation are shown on the Borehole Location and Soil Strata Drawing No. 1 in Appendix A, the individual Record of Borehole sheets in Appendix B and are summarized in Table 3-1. The termination depth of each of the boreholes is also provided, below. The borehole elevations were surveyed using geodetic benchmark GBM 00819758419 (elev. 71.241 m) and a Trimble Catalyst with centimetre precision in conjunction with a Nikon-AP-8 with an accuracy of +/- 1.5 mm. Borehole locations were measured off existing site features and translated to northings and eastings based on the available base plans. The site is within MTM Zone 8.

**Table 3-1: Borehole Summary**

<b>Borehole No.</b>	<b>Drilled Location</b>	<b>Northing (m)</b>	<b>Easting (m)</b>	<b>Ground Surface Elevation (m)</b>	<b>Termination Depth (m)</b>
17-1	Near Culvert inlet	5 019 480.4	181 051.3	64.3	10.5
17-2	Shoulder west of Culvert	5 019 471.6	181 039.1	66.7	12.7
17-3	Shoulder east of Culvert	5 019 463.4	181 047.9	66.7	13.1
17-4	Near Culvert outlet	5 019 442.8	181 032.3	64.4	8.6

The boreholes were advanced through soil using hollow stem augers. Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). In-situ shear vane testing was carried out within the cohesive strata using an N-vane. Bedrock was cored with NQ size coring equipment.

The drilling and sampling operations were supervised on a full-time basis by a member of Thurber's technical staff. The drilling supervisor logged the boreholes and processed the recovered soil and rock samples for transport for further laboratory examination and testing.

A 19 mm diameter standpipe piezometer was installed in Borehole 17-1 to allow for measurements of the groundwater level after completion of drilling. The piezometer installation details are illustrated on the Record of Borehole sheet for Borehole 17-1, provided in Appendix B. Following completion of the field investigation the remaining

boreholes were backfilled in accordance with MOE requirements (O.Reg. 903, as amended).

#### **4 LABORATORY TESTING**

The recovered soil samples were subjected to visual identification and to natural moisture content determination. Selected samples were also subjected to gradation analysis (hydrometer and/or sieve) and Atterberg Limit testing. The results of these tests are summarized on the Record of Borehole sheets included in Appendix B. One sample of soil recovered from within the Borehole was selected and submitted for analytical testing of corrosivity parameters and sulphate content. All laboratory test results from the field investigation are provided in Appendix C.

#### **5 DESCRIPTION OF SUBSURFACE CONDITIONS**

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix B and the Borehole Locations and Soil Strata Drawing included in Appendix A. A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over the Soil Strata Drawing and the general description. It must be recognized that the soil and groundwater conditions may vary between and beyond borehole locations.

In general terms, the site was found to be underlain by a granular embankment fill overlying native deposits of clay and glacial till. Bedrock was encountered within the depth of investigation in Boreholes 17-1, 17-2, and 17-3.

##### **5.1 Surficial Materials**

###### **5.1.1 Fill: Sand with Gravel**

A layer of sand with gravel was encountered at surface in Borehole 17-1. The underside of the fill was 0.8 m below the ground surface (elev. 63.5 m). An SPT test conducted in the layer gave an N-value of 6, indicating a loose relative density. A moisture content of 9% was measured on one sample.

###### **5.1.2 Fill: Silty Gravel with Sand**

A layer of silty gravel with sand was encountered below the sand with gravel fill in Borehole 17-1. The layer had a thickness of 2.3 m and an underside elevation of 61.2 m.

SPT tests conducted in the fill gave N-values ranging from 17 to 25 blows, indicating a compact relative density. The recorded moisture contents ranged from 7 to 12%.

Gradation analysis was completed on one sample from this fill layer. The grain size distribution curve is included in Figure C1 of Appendix C. The results of the tests indicated the material to consist of 49% gravel, 38% sand and 13% fines, and are presented on the corresponding Record of Borehole sheet in Appendix B.

### 5.1.3 Fill: Silty Sand

A layer of silty sand with gravel to silty sand was encountered at surface in Boreholes 17-2 through 17-4. The underside of this fill ranged from 3.0 to 5.6 m below the existing roadway surface (elev. 63.7 to 60.6 m).

SPT tests conducted in the fill gave N-values ranging from 3 to 63 blows, indicating a relative density of very loose to very dense, but predominantly compact. The recorded moisture contents ranged from 3 to 22%.

Gradation analyses were completed on five samples from this fill layer. The grain size distribution curves are included in Figure C1 of Appendix C. The results of the tests are summarized in Table 5-1 and are presented on the corresponding Record of Borehole sheets in Appendix B.

**Table 5-1 Gradation Results for Silty Sand with Gravel Fill**

Soil Particle	Percentage (%)
Gravel	1 – 40
Sand	45 -62
Silt	13 – 37
Clay	

## 5.2 Clay (CI to CH)

A layer of native clay was encountered beneath the fill in all boreholes. The thickness of this layer ranged from 1.7 to 5.2 m with base elevations ranging from 58.3 to 59.4 m. It should be noted that the upper 1.4 m of the clay layer in Borehole 17-3 was a firm weathered crust.

In-situ shear vane testing in the clay indicated undrained shear strengths ranging from 30 to 55 kPa, indicating a firm to stiff consistency. The results of the in-situ shear vane tests indicate that the clay exhibits moderate to high sensitivity. SPT tests below the crust gave N-values ranging from Weight of Hammer (WH) to 1 blow.

The moisture content for the samples tested ranged from 30 to 92%. The results of grain size analysis conducted on five samples of this material are summarized in Table 5-2 and are illustrated on Figure C2 in Appendix C.

**Table 5-2 Gradation Results for Clay**

Soil Particle	Percentage (%)
Gravel	0 – 1
Sand	1 – 3
Silt	23 – 64
Clay	35 – 74

The results of Atterberg Limits testing completed on five samples of this material are summarized in Table 5-3 on the Record of Borehole sheets in Appendix B and the Atterberg Limits graph is included as Figure C4 of Appendix C.

**Table 5-3 Atterberg Limits Results for Clay**

Parameter	Value
Liquid Limit	38 – 71
Plastic Limit	17 – 28
Plasticity Index	21 – 43

The laboratory results indicate that the clay has intermediate to high plasticity (CI to CH).

### **5.3 Gravel with Silt and Sand (Glacial Till)**

Below the clay stratum in all boreholes was a deposit of glacial till consisting of a heterogenous mixture of gravel (GW-GM to GP-GM) with silt and sand. The glacial till in Borehole 17-1 transitioned to a mixture consisting of silty sand with gravel with depth. Borehole 17-4 was terminated within the glacial till at a depth of 8.6 m below the existing ground surface (elev. 55.8 m). The thickness of the glacial till in Boreholes 17-1 through 17-3 ranged from 1.5 to 2.0 m with base elevations ranging from 57.0 to 57.9 m.

SPT tests gave N-values ranging from 10 blows for 300 mm of penetration to 100 blows for 200 mm of penetration, indicating a relative density of loose to very dense. Recorded moisture contents ranged from 5 to 14%.

Gradation analyses was conducted on three samples from the glacial till layer. The grain size distribution curves for these samples are included in Figure C3 of Appendix C. The results of the tests are summarized in Table 5-4 and are presented on the corresponding Record of Borehole sheets in Appendix B.

**Table 5-4 Gradation Results for Glacial Till**

Soil Particle	Percentage (%)
Gravel	27 – 56
Sand	34 – 44
Silt	9 – 29
Clay	

Glacial till inherently contains cobbles and boulders.

### **5.4 Bedrock**

Bedrock was proven by coring in Boreholes 17-1 to 17-3, inclusive. Information on the bedrock surface is summarized in Table 5-5.

**Table 5-5 Summary of Bedrock Elevations**

Borehole No.	Depth to Bedrock (m)	Bedrock Elevation (m)
17-1	7.3	57.0
17-2	8.8	57.9
17-3	9.7	57.0

The bedrock encountered within Boreholes 17-1 through 17-3 consisted of fresh limestone with shale partings and calcite nodules. The Total Core Recovery (TCR) ranged from 89 to 100%, the Solid Core Recovery (SCR) ranged from 75 to 100%, and the Rock Quality Designation ranged from 57 to 100%, with one value of 22%. Based on the RQD values, the bedrock is classified as poor to excellent quality, but predominantly excellent.

Unconfined Compressive Strength (UCS) testing was carried out on the bedrock. The results of UCS testing carried out on three samples of the rock core ranged from 134 to 144 MPa, indicating the intact limestone bedrock to be very strong. Photographs of the bedrock core are provided in Appendix C.

## 5.5 Groundwater

The groundwater level measured in the standpipe piezometer in Borehole 17-1 was recorded at a depth of 1.5 m (elev. 62.8 m) on August 3, 2018.

The water level of the Leo Denis Municipal Drain was measured to be at an elevation of 62.3 m on June 22, 2018. It is expected that the groundwater level will likely reflect the water level in the ditch.

These observations are considered short term and it should be noted that the groundwater level at the time of construction may be different and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation.

## 5.6 Analytical Testing

One sample of the native soil was submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, sulphide content, resistivity and conductivity. The analysis results are summarized in Table 5-6.

**Table 5-6 Summary of Analytical Testing**

Borehole (Sample)	Depth (mbgs)	Sulphate (µg/g)	pH (-)	Resistivity (Ohm-cm)	Conductivity (uS/cm)	Chloride (µg/g)	Sulphide (%)
17-1 (SS4)	2.3 – 2.9	93	7.83	1,680	594	229	0.13



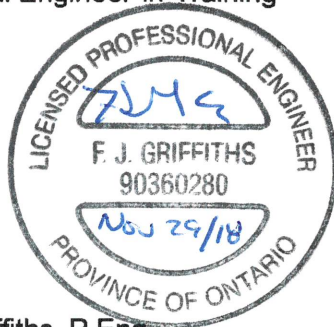
## 6 MISCELLANEOUS

Borehole locations were selected by Thurber relative to existing site features. The as-drilled locations and ground surface elevations were surveyed by Thurber following completion of the field program.

George Downing Estate Drilling Ltd. of Hawkesbury, Ontario supplied and operated the drilling equipment to conduct the drilling, soil sampling, in-situ testing and borehole decommissioning. Beaconlite of Ottawa, Ontario supplied the traffic control equipment and personnel for TL-12 shoulder work required for the on-road boreholes and off-road boreholes in conformance with Ontario Book 7 requirements. The field investigation was supervised on a full time basis by either Mr. Justin Gray, E.I.T. or Miss Katya Edney, P.Eng. of Thurber. Overall supervision of the investigation program was conducted by Dr. Fred Griffiths, P.Eng.

Routine geotechnical laboratory testing was completed by Thurber's laboratory in Ottawa, Ontario. Analytical testing was completed by Paracel Laboratories in Ottawa, Ontario. Interpretation of the factual data and preparation of this report were carried out by Miss Allison Chow and Dr. Fred Griffiths, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng. a Designated Principal Contact for MTO Foundation Projects.

Allison Chow, B.A.Sc.  
Geotechnical Engineer-in-Training



Dr. Fred Griffiths, P.Eng.  
Senior Associate  
Senior Geotechnical Engineer

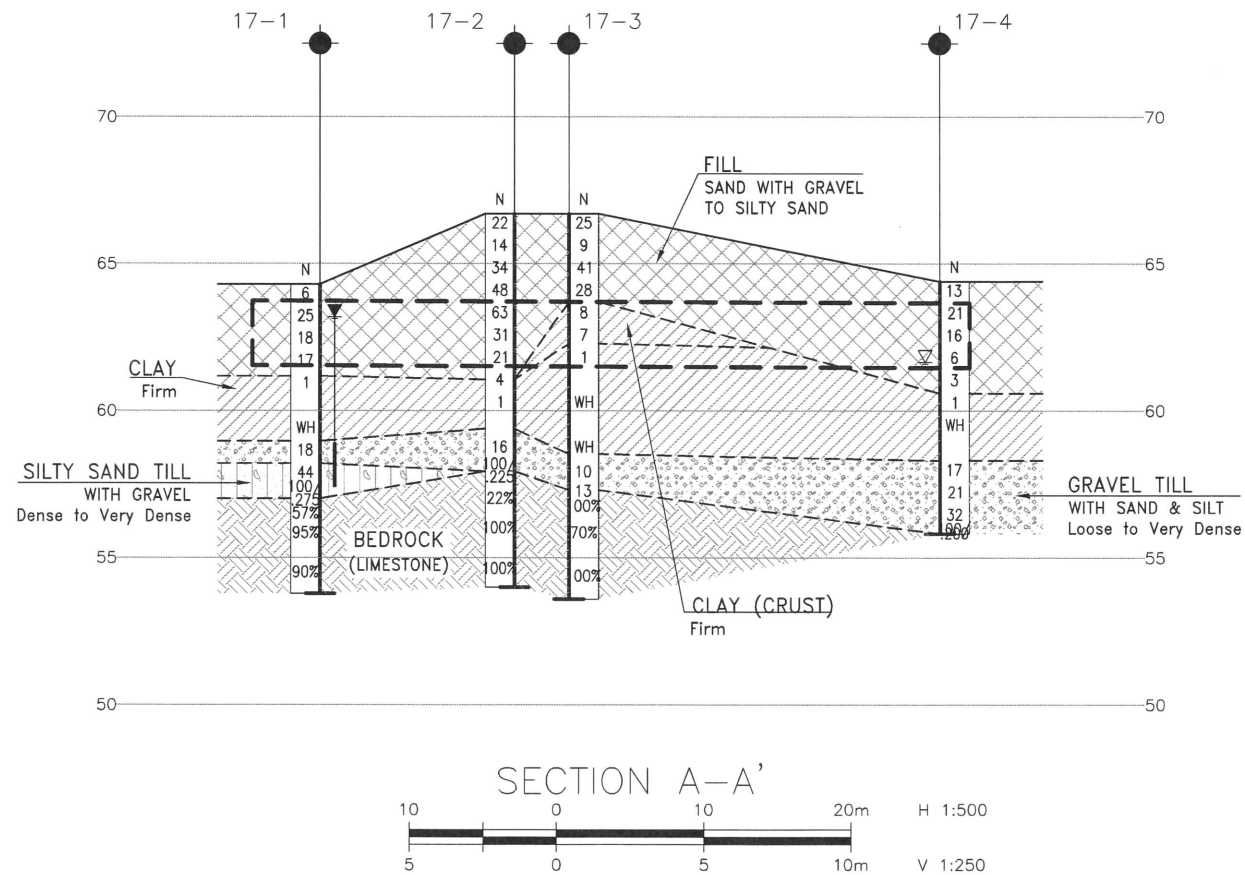
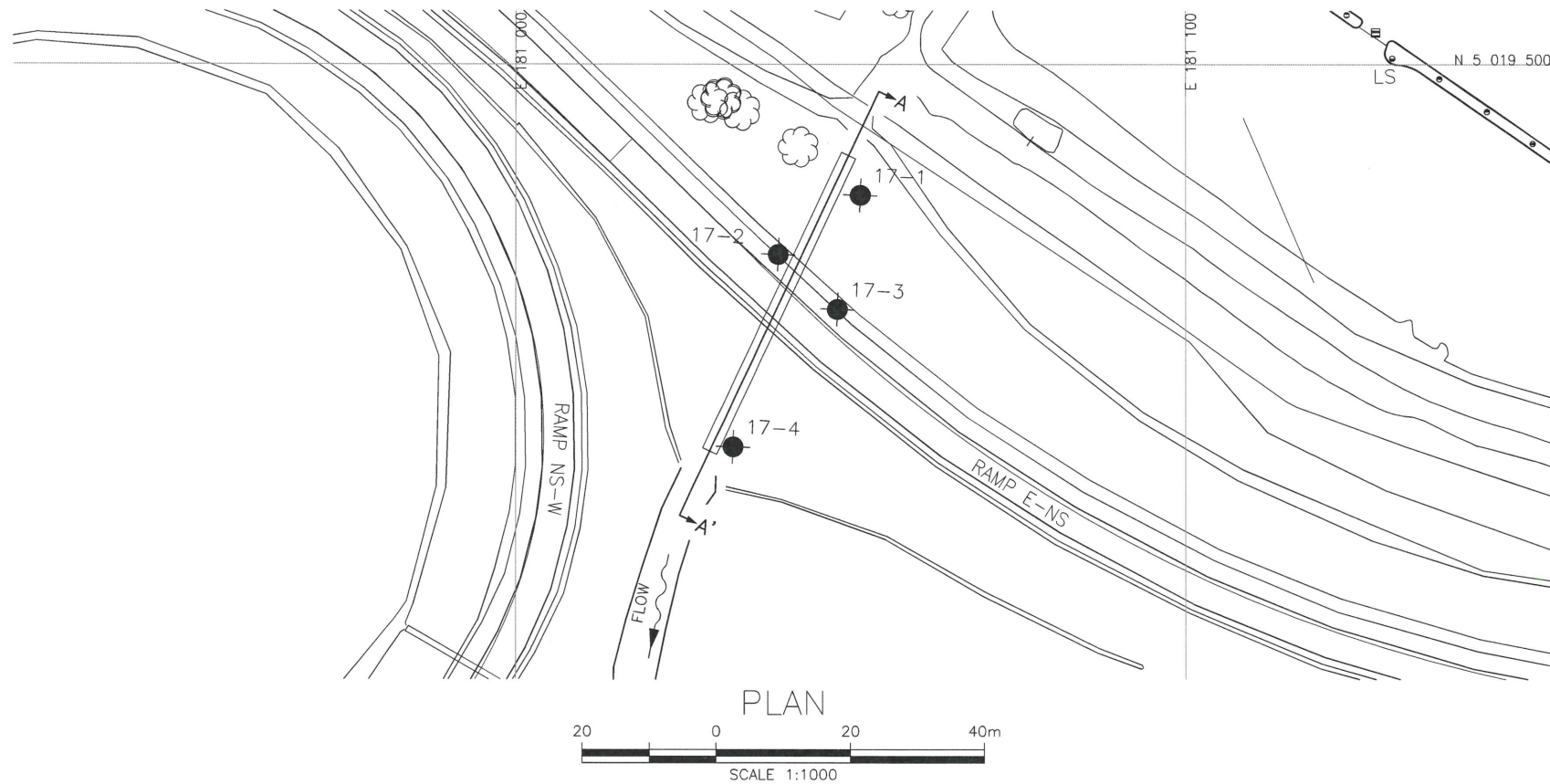


Dr. P.K. Chatterji, P.Eng.  
Review Principal  
Senior Geotechnical Engineer

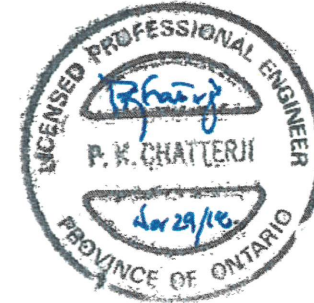
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**Appendix A.**

**Borehole Location Plan and Stratigraphic Drawings**



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



CONT No  
GWP No 451-98-00

HIGHWAY 417  
CULVERT 27-361/C  
REPLACEMENT  
BOREHOLE LOCATIONS AND SOIL STRATA



### 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
▽	Water Level
⊕	Head Artesian Water
⊖	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
17-1	64.3	5 019 480.4	181 051.3
17-2	66.7	5 019 471.6	181 039.1
17-3	66.7	5 019 463.4	181 047.9
17-4	64.4	5 019 442.8	181 032.3

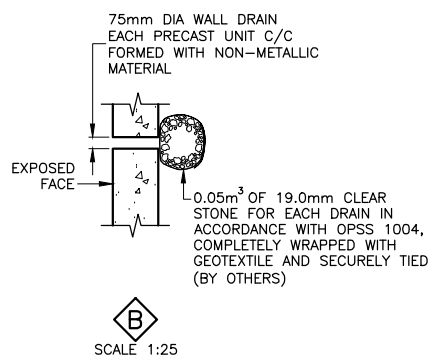
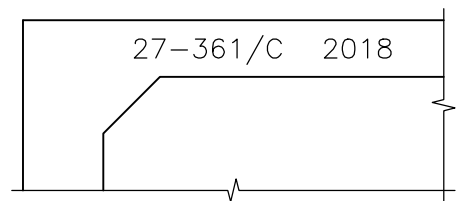
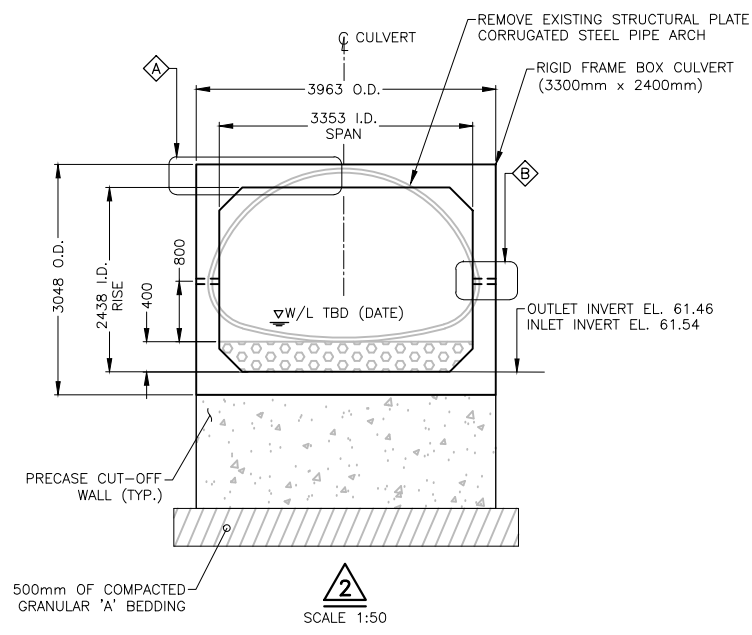
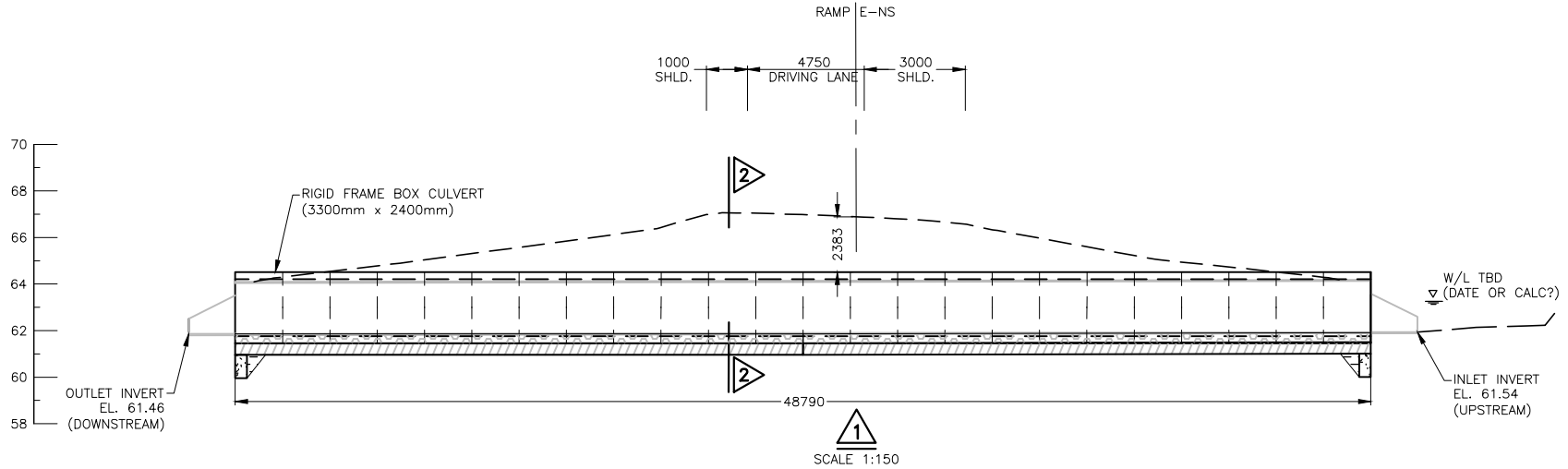
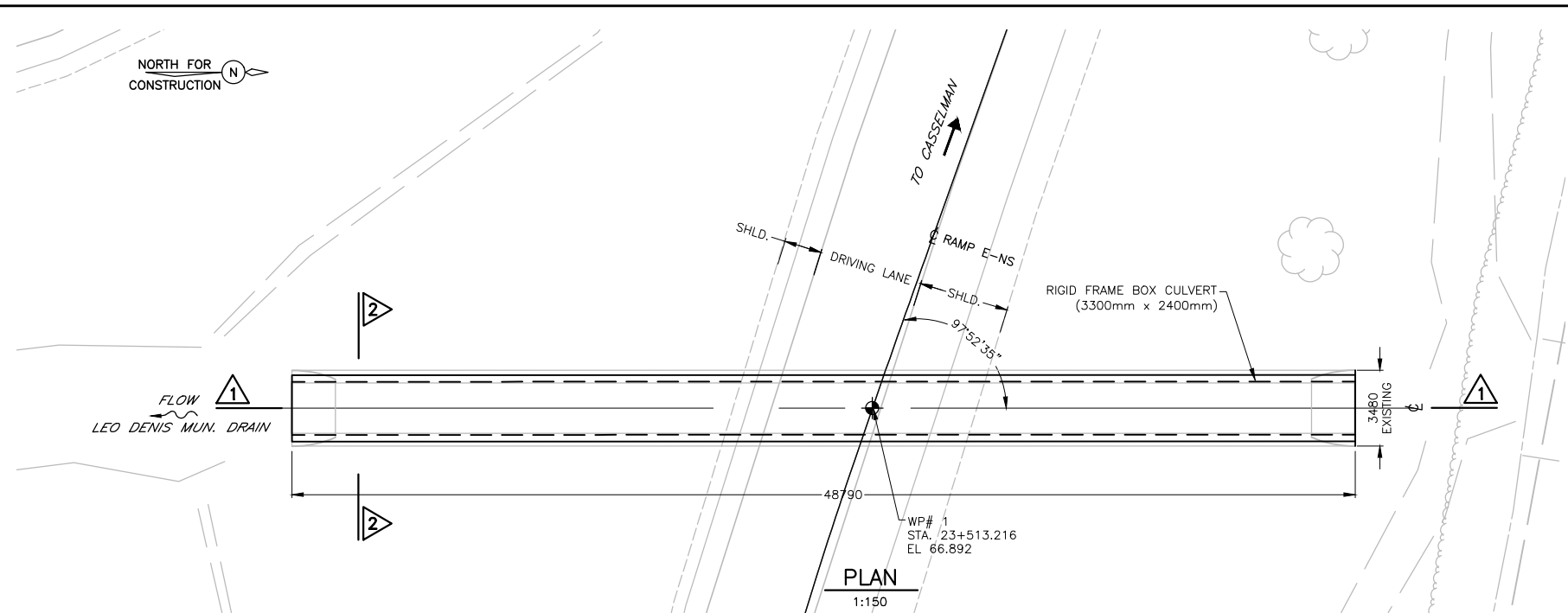
### -NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- 3) Coordinate system is MTM NAD 83 Zone 8.

GEOCRES No. 31G-270

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	KE	CHK	PC
DRAWN	MFA	CHK	KE
CODE	LOAD	DATE	NOV 2018
SITE	STRUCT	DWG	1

DRAWING NAME: K:\MTO\17804 - Highway 417 Reconstruction\451-98-00 Working CT\Structural\17804-1 - Site No. 27-361C - General Arrangement.dwg  
CREATED: 2018-07-13 3:56 PM  
MODIFIED: 2018-07-13  
MINISTRY OF TRANSPORTATION, ONTARIO  
PR-D-707 88-05



FLOW DATA: EXISTING CULVERT

DURATION	PEAK FLOW "Q" (m <sup>3</sup> /S)	WATER LEVEL (m)
2 YR.	1.325	-
5 YR.	2.238	-

- GENERAL NOTES**
- CLASS OF CONCRETE  
35MPa UNLESS OTHERWISE NOTED.
  - CLEAR COVER TO REINFORCING STEEL  
PRECAST CONCRETE 50±10  
ALL EXPOSED CORNERS TO BE CHAMFERED 20mm.
  - REINFORCING STEEL  
REINFORCING STEEL SHALL BE GRADE 400W UNLESS OTHERWISE SPECIFIED.  
UNLESS SHOWN OTHERWISE, TENSION LAP SPLICES SHALL BE CLASS B.  
BAR HOOKS SHALL HAVE STANDARD HOOK DIMENSIONS USING MINIMUM BEND DIAMETERS WHILE STIRRUPS AND TIES SHALL HAVE MINIMUM HOOK DIMENSIONS. ALL HOOKS SHALL BE IN ACCORDANCE WITH THE STRUCTURAL STANDARD DRAWINGS SS12-1, UNLESS INDICATED OTHERWISE.
- CONSTRUCTION NOTES**
- PRECAST END UNITS SHALL BE EQUAL LENGTH. ALL INTERNAL UNITS SHALL BE EQUAL LENGTH.
  - BACKFILL SHALL BE PLACED SIMULTANEOUSLY BEHIND BOTH SIDES OF STRUCTURE KEEPING THE HEIGHT OF THE BACKFILL APPROXIMATELY THE SAME. AT NO TIME SHALL THE DIFFERENCE IN ELEVATION BE GREATER THAN 500mm.
  - NO PRECAST UNIT SHALL BE PLACED UNTIL THE DEPTH OF THE EXCAVATION AND THE CHARACTER OF THE FOUNDATION HAVE BEEN APPROVED BY THE QUALITY VERIFICATION ENGINEER. CARE SHALL BE TAKEN NOT TO DISTURB THE FOUNDING SOILS.
  - DESIGN SOILS BEARING CAPACITIES MUST BE VERIFIED BY THE QUALITY VERIFICATION ENGINEER ON SITE:  
AT SLS = \_\_\_\_ kPa (TBD)  
AT ULS = \_\_\_\_ kPa (ALONG THE JOINTS) (TBD)

- SCOPE OF WORK \***
- INSTALL AND CONTINUOUSLY MONITOR TEMPORARY FLOW PASSAGE SYSTEM AND MANAGE FLOW OF WATER FOR DURATION OF THE WORK.
  - COMPLETE PRECONSTRUCTION SURVEY.
  - REMOVE DEBRIS AND CLEAN CULVERT SURFACES.
  - SUPPLY AND INSTALL RIGID BOX CULVERT AND CUT-OFF WALLS.
- \* NOT INTENDED TO SHOW SEQUENCE OF WORK

- LIST OF ABBREVIATIONS**
- |       |                      |
|-------|----------------------|
| WP#   | WORKING POINT NUMBER |
| EL.   | ELEVATION            |
| TYP.  | TYPICAL              |
| SHLD. | SHOULDER             |
| DIA.  | DIAMETER             |
| STA.  | STATION              |
| W/L   | WATER LEVEL          |
| I.D.  | INNER DIAMETER       |
| O.D.  | OUTTER DIAMETER      |

- LIST OF DRAWINGS**
- GENERAL ARRANGEMENT

DRAWING NOT TO BE SCALED  
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**Appendix B.**

**Record of Borehole Sheets**





## SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

### TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

Topsoil	mixture of soil and humus capable of supporting vegetative growth
Peat	mixture of fragments of decayed organic matter
Till	unstratified glacial deposit which may include particles ranging in sizes from clay to boulder
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 materials, shrinkage cracks, etc.
Fissured	having cracks, and hence a blocky structure
Varved	composed of 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

### RECOVERY:

For soil samples, the recovery is recorded as the length of the soil sample recovered.

### N-VALUE:

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 63.5 kg hammer falling 0.76 m, required to drive a 50 mm O.D. split spoon sampler 0.3 m into undisturbed soil. For samples where insufficient penetration was achieved and N-value cannot be presented, the number of blows are reported over the sampler penetration in millimetres (e.g. 50/75).

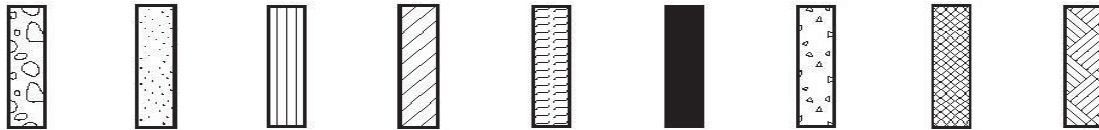
### DYNAMIC CONE PENETRATION TEST (DCPT):

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to an "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 0.3 m into the soil. The DCPT is used as a probe to assess soil variability.



### STRATA PLOT:

Strata plots symbolize the soil and 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      Bedrock

### TEXTURING CLASSIFICATION OF SOILS

Classification	Particle Size
Boulders	Greater than 200 mm
Cobbles	75 – 200 mm
Gravel	4.75 – 75 mm
Sand	0.075 – 4.75 mm
Silt	0.002 – 0.075 mm
Clay	Less than 0.002 mm

### TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

Descriptive Term	Undrained Shear Strength (kPa)
Very Soft	12 or less
Soft	12 – 25
Firm	25 – 50
Stiff	50 – 100
Very Stiff	100 – 200
Hard	Greater than 200

NOTE: Clay sensitivity is defined as the ratio of the undisturbed strength over the remolded strength.

### SAMPLE TYPES

SS	Split spoon samples
ST	Shelby tube or thin wall tube
DP	Direct push sample
PS	Piston sample
BS	Bulk sample
WS	Wash sample
HQ, NQ, BQ etc.	Rock core sample obtained with the use of standard size diamond coring equipment

### TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

Descriptive Term	SPT “N” Value
Very Loose	Less than 4
Loose	4 – 10
Compact	10 – 30
Dense	30 – 50
Very Dense	Greater than 50

### MODIFIED UNIFIED SOIL CLASSIFICATION

Major Divisions		Group Symbol	Typical Description
COARSE GRAINED SOIL	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	SILT AND CLAY SOILS $W_L < 35\%$	ML	Inorganic silts, 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.
		OL	Organic silts and organic silty-clays of low plasticity.
	SILT AND CLAY SOILS $35\% < W_L < 50\%$	MI	Inorganic compressible fine sandy silt with clay of medium plasticity, clayey silts.
		CI	Inorganic clays of medium plasticity, silty clays.
		OI	Organic silty clays of medium plasticity.
	SILT AND CLAY SOILS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy of silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other organic soils.

Note -  $W_L$  = Liquid Limit





## EXPLANATION OF ROCK LOGGING TERMS

### ROCK WEATHERING CLASSIFICATION

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

### 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 0.1 m in length or larger, as a percentage of total core length
Unconfined Compressive Strength: (UCS)	Axial stress required to break the specimen.
Fracture Index: (FI)	Frequency of natural fractures per 0.3 m of core run.

### DISCONTINUITY SPACING

Bedding	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 to 2 m
Medium bedded	0.2 to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 to 60 mm
Laminated	6 to 20 mm
Thinly laminated	Less than 6 mm

### STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)
Extremely Strong	Greater than 250
Very Strong	100 – 250
Strong	50 – 100
Medium Strong	25 – 50
Weak	5 – 25
Very Weak	1 – 5
Extremely Weak	0.25 – 1

# RECORD OF BOREHOLE No 17-1

1 OF 2

METRIC

GWP# 451-98-00 LOCATION Lat: 45.304373°, Long: -75.078018° Culvert Site 27-361/C MTM z8: N 5 019 480.4 E 181 051.3 ORIGINATED BY KE  
HWY 417 BOREHOLE TYPE HSA/NQ coring COMPILED BY AC  
DATUM Geodetic DATE 18.06.2018 - 19.06.2018 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)									
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)								
								○ UNCONFINED	+ FIELD VANE											
													● QUICK TRIAXIAL	× LAB VANE						
64.3						20	40	60	80	100	PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	GR	SA	SI	CL			
0.0	SAND with gravel loose brown FILL		1	SS	6															
63.5																				
0.8	SILTY GRAVEL with sand compact grey FILL		2	SS	25															
			3	SS	18												49	38	13 (SH+CL)	
			4	SS	17															
61.2																				
3.1	CLAY (CH) firm grey		5	SS	1															
			6	SS	WH												0	3	30	67
59.0																				
5.3	GRAVEL with sand TILL compact grey		7	SS	18															
58.2																				
6.1	SILTY SAND (SM) with gravel TILL dense to very dense grey		8	SS	44															
			9	SS	100/ 275 mm															
57.0																				
7.3	BEDROCK LIMESTONE with shale partings and calcite nodules fresh thinly bedded fine to medium grained grey		1	NQ													27	44	29 (SH+CL)	
			2	NQ																

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity 20  
15 10 5  
(%) STRAIN AT FAILURE

DOUBLE LINE SITE 27-361/C.GPJ 2012TEMPLATE(MTO).GDT 14/11/18

## METRIC

[illegible]

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

## METRIC

[illegible]

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

## METRIC

SOIL PROFILE					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES	GROUND WATER CONDITIONS	ELEVATION SCALE
<div>DYNAMIC CONE PENETRATION RESISTANCE PLOT</div> <div>SHEAR STRENGTH kPa</div> <div>○ UNCONFINED + FIELD VANE</div> <div>● QUICK TRIAXIAL × LAB VANE</div> <div>WATER CONTENT (%)</div> <div>PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT</div> <div>w p w w L</div> <div>UNIT WEIGHT γ</div> <div>REMARKS &amp; GRAIN SIZE DISTRIBUTION (%)</div> <div>GR SA SI CL</div>					
Continued From Previous Page					
54.0	BEDROCK LIMESTONE grey fresh strong		2 NQ		56
12.7	End of Borehole		3 NQ		55
					54

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No 17-3

1 OF 2

METRIC

GWP# 451-98-00 LOCATION Lat: 45.304219°, Long: -75.078057° Culvert Site 27-361/C MTM z8: N 5 019 463.4 E 181 047.9 ORIGINATED BY JG  
HWY 417 BOREHOLE TYPE HSA/NQ coring COMPILED BY JG  
DATUM Geodetic DATE 22.09.2017 - 22.09.2017 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)		
								20 40 60 80 100											
								○ UNCONFINED    + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE											
66.7	Gravel Shoulder																		
0.0	SILTY SAND with gravel compact grey FILL		1	SS	25											32 52 16 (SI+CL)			
66.2																			
0.5	SILTY SAND some gravel loose to dense brown FILL		2	SS	9											10 56 34 (SI+CL)			
			3	SS	41														
			4	SS	28														
63.7	gravel layer from 2.8 m to 3.0 m																		
3.0	CLAY (CI) (crust) firm grey		5	SS	8														
			6	SS	7														
62.3																			
4.4	CLAY (CH) firm grey		7	SS	1														
			8	SS	WH														
			9	SS	WH														
58.5																			
8.2	GRAVEL with sand and silt TILL loose to compact grey		10	SS	10														
	LIMESTONE		11	SS	13														
57.0																			
9.7	BEDROCK		1	NO															

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

DOUBLE LINE SITE 27-361C.GPJ 2012TEMPLATE(MTO).GDT 14/11/18

## METRIC

[illegible]

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No 17-4

1 OF 1

METRIC

GWP# 451-98-00 LOCATION Lat: 45.304031°, Long: -75.078251° Culvert Site 27-361/C MTM z8: N 5 019 442.8 E 181 032.3 ORIGINATED BY SOB  
 HWY 417 BOREHOLE TYPE HSA COMPILED BY AC  
 DATUM Geodetic DATE 27.06.2018 - 27.06.2018 CHECKED BY FG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								WATER CONTENT (%)						
64.4														
0.0	SILTY SAND with gravel very loose to compact brown FILL		1	SS	13									
			2	SS	21									
			3	SS	16									40 47 13 (SI+CL)
			4	SS	6									
			5	SS	3									
60.6			6	SS	1									
3.8	CLAY (CH) firm grey		7	SS	WH									0 3 23 74
58.3			8	SS	17									
6.1	GRAVEL (GP-GM) with silt and sand TILL compact to very dense grey		9	SS	21									56 34 10 (SI+CL)
			10	SS	32									
			11	SS	100/									
55.8														
8.6	End of Borehole Water level during drilling operations at 2.7 mgbs (elev. 61.7 m)				200 mm									

DOUBLE LINE SITE 27-361/C.GPJ 2012TEMPLATE(MTO).GDT 14/11/18

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE



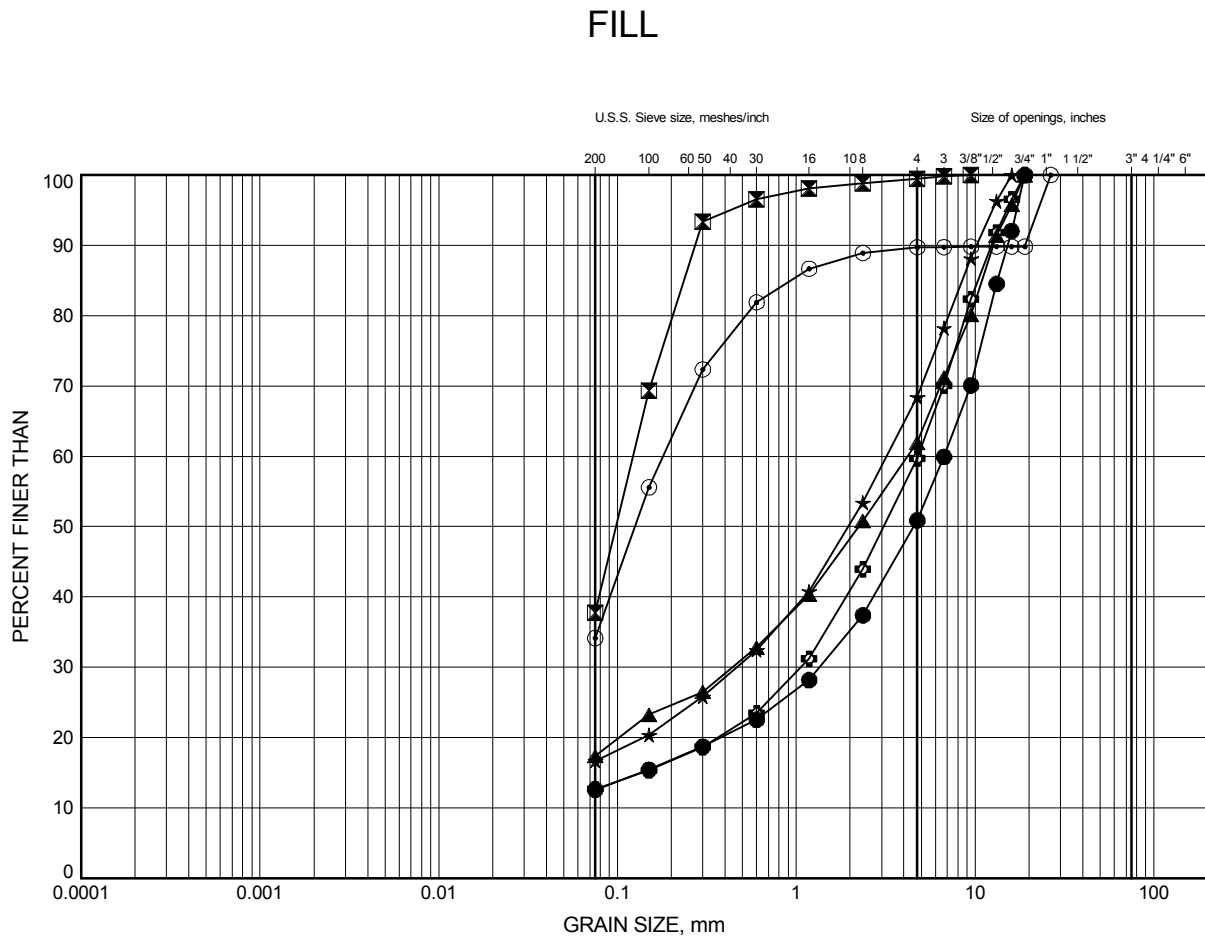
**Appendix C.**  
**Laboratory Testing**

**Appendix C.1**  
**Particle Size Analysis Figures**

# Site 27-361/C

## GRAIN SIZE DISTRIBUTION

FIGURE C1



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-1	1.8	62.5
⊠	17-2	1.8	64.9
▲	17-2	3.4	63.3
★	17-3	0.2	66.5
⊙	17-3	1.1	65.6
⊕	17-4	1.8	62.6

Date November 2018

GWP# 451-98-00



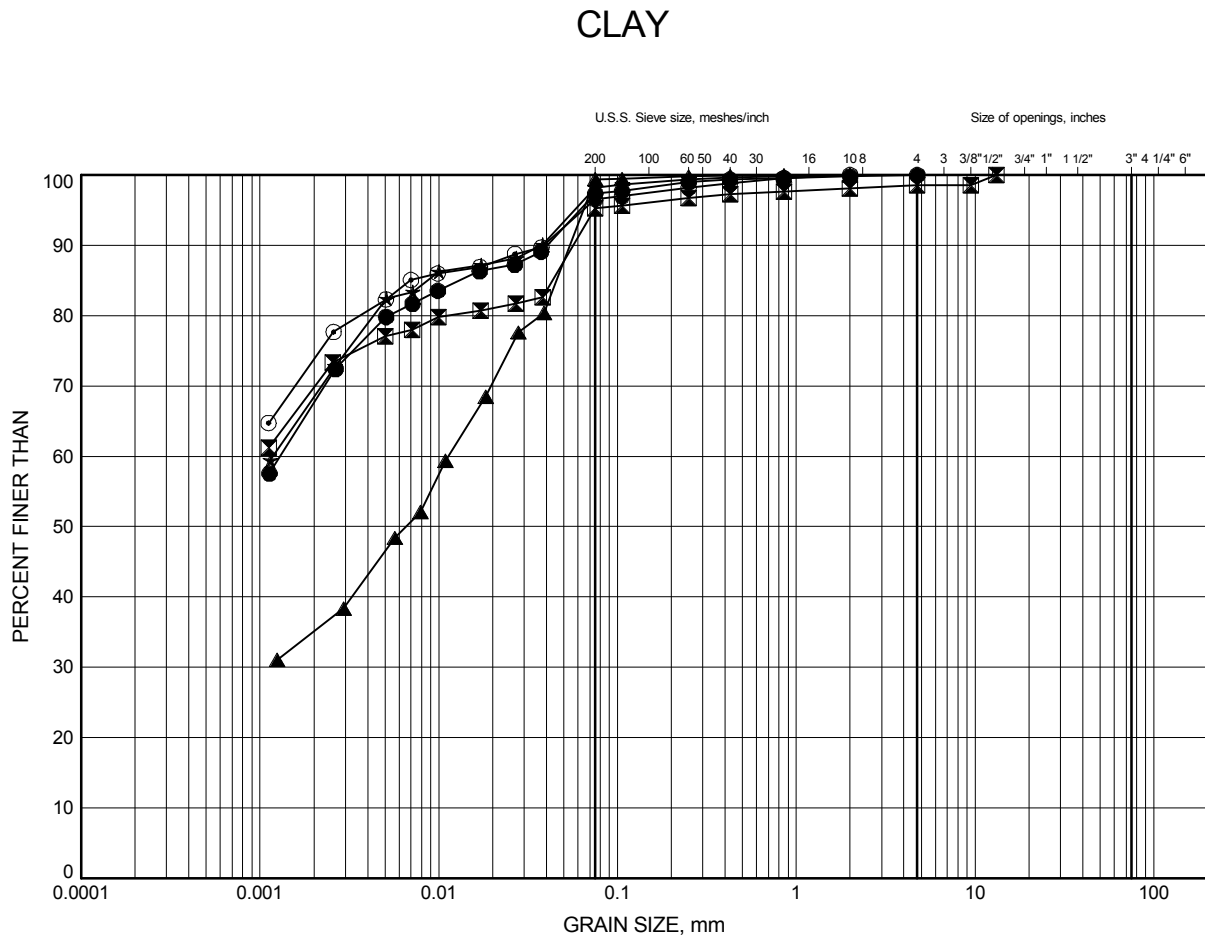
Prep'd KE

Chkd. FG

# Site 27-361/C

## GRAIN SIZE DISTRIBUTION

FIGURE C2



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-1	4.9	59.4
⊠	17-2	6.4	60.3
▲	17-3	4.1	62.6
★	17-3	7.9	58.8
⊙	17-4	4.9	59.5

Date November 2018

GWP# 451-98-00



Prep'd KE

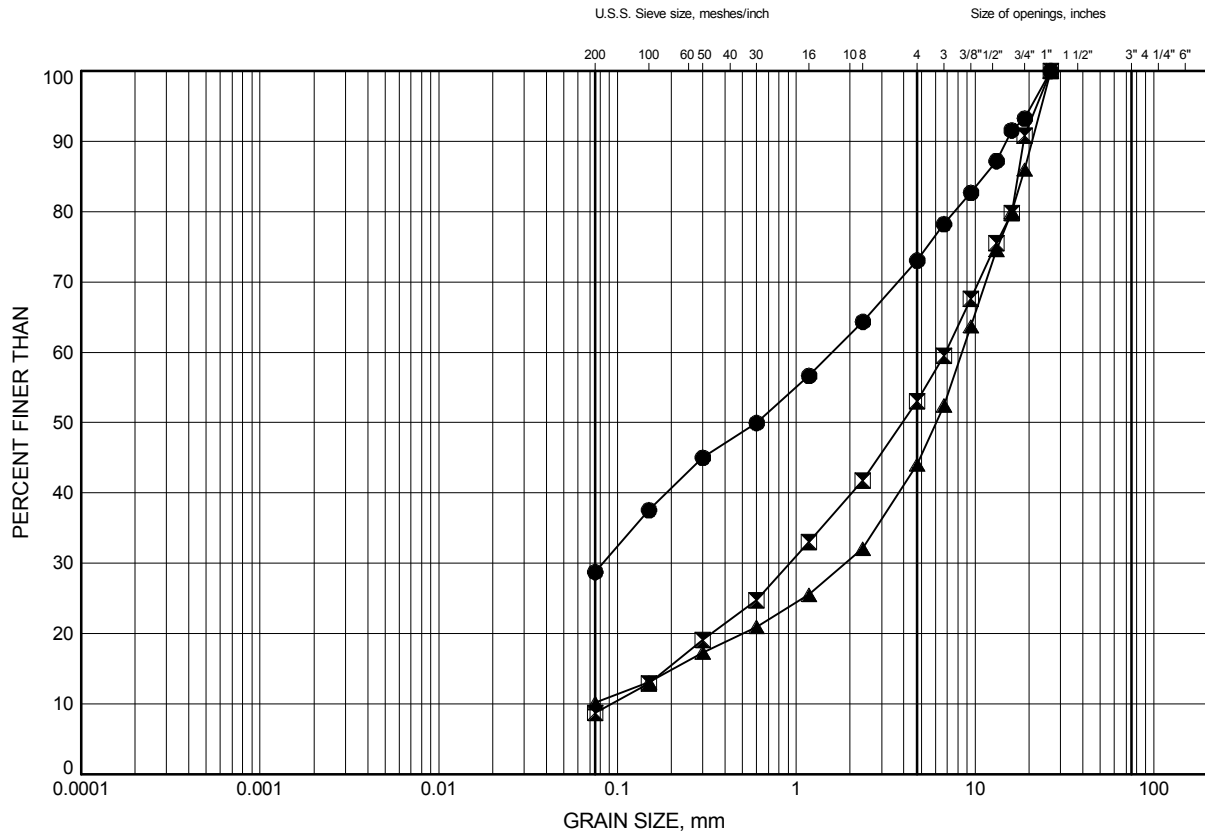
Chkd. FG

Site 27-361/C

# GRAIN SIZE DISTRIBUTION

FIGURE C3

## Gravel with Silt and Sand (GLACIAL TILL)



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-1	7.1	57.2
⊠	17-2	7.9	58.8
▲	17-4	7.2	57.2

Date November 2018  
GWP# 451-98-00



Prep'd KE  
Chkd. FG

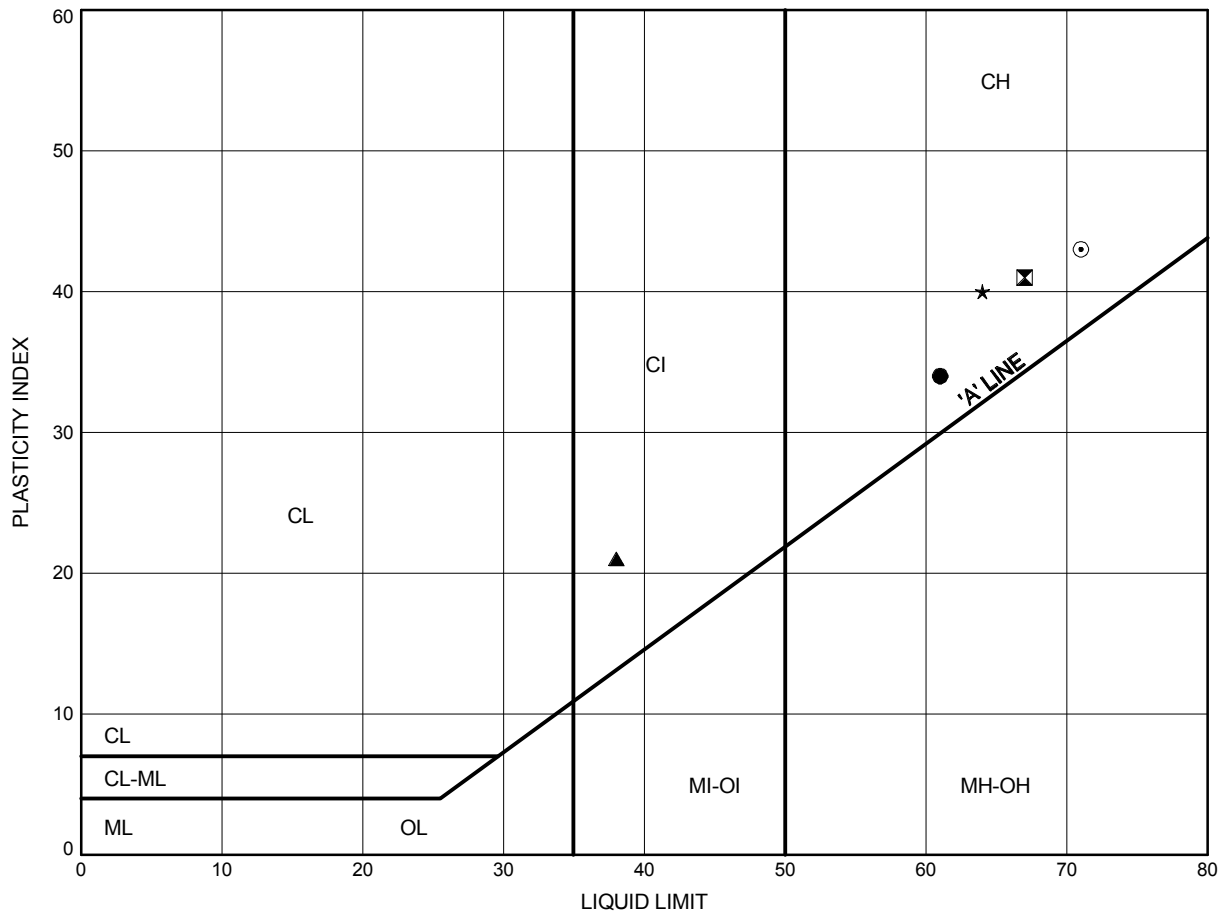
**Appendix C.2**  
**Atterberg Limits Figure**

Site 27-361/C

# ATTERBERG LIMITS TEST RESULTS

FIGURE C4

## CLAY



### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-1	4.9	59.4
⊠	17-2	6.4	60.3
▲	17-3	4.1	62.6
★	17-3	7.9	58.8
⊙	17-4	4.9	59.5

Date November 2018  
GWP# 451-98-00



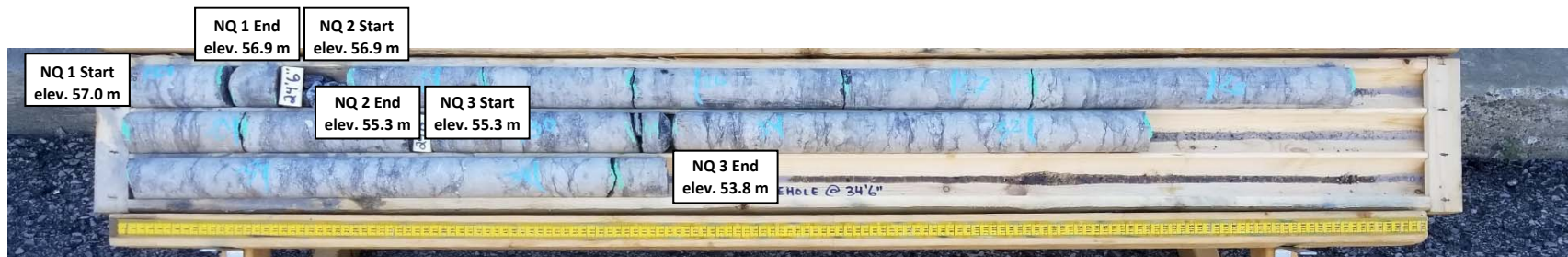
Prep'd KE  
Chkd. FG

### **Appendix C.3**

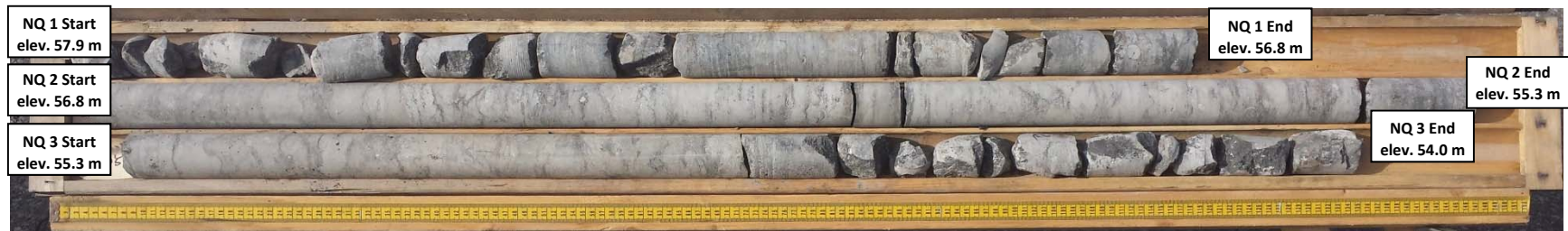
#### **Rock Core Photos and Testing Results**



**Borehole 17-1**  
**Run 1 to 3 (of 3)**  
**Elevation 57.0 m to 53.8 m**



**Borehole 17-2**  
**Run 1 to 3 (of 3)**  
**Elevation 57.9 m to 54.0 m**



**THURBER** ENGINEERING LTD.

**Foundation Investigation**  
**Highway 417 Interchange 27-361/C**  
**Foundations**

**GWP: 451-98-00**

**Project No.: 18310**

**Borehole 17-3**  
**Run 1 to 3 (of 3)**  
**Elevation 57.0 m to 53.6 m**



**THURBER** ENGINEERING LTD.

**Foundation Investigation**  
**Highway 417 Interchange 27-361/C**  
**Foundations**

**GWP: 451-98-00**

**Project No.: 18310**



**Stantec**

**Stantec Consulting Ltd**  
2781 Lancaster Rd, Suite 100 A&B  
Ottawa, ON K1B 1A7  
Tel: (613) 738-6075  
Fax: (613) 722-2799

July 11, 2018  
File: 122410864

**Attention: Thurber Engineering Ltd., File #18310**

**Reference: ASTM D7012, Method C, Unconfined Compressive Strength of Intact Rock Core**

The table below summarizes five (5) rock core unconfined compressive strength results.

Location	Sample Depth	Compressive Strength (MPa)	Description of Break
17-1	Run 2 @ 22'4"	143.6	Well-formed cone on one end
17-5	Run 2 @ 36'4"	138.0	Well-formed cone on one end
17-10	Run 2 @ 53'7"	98.0	Reasonably well-formed cones on both ends
17-11	Run 3 @ 51'10"	127.4	Vertical cracking through both ends
17-13	Run 2 @ 23'10"	140.4	Specimen shattered

Sincerely,

**Stantec Consulting Ltd**

Denis Rodriguez  
Laboratory Technician  
Tel: 613-738-6075  
[denis.rodriquez@stantec.com](mailto:denis.rodriquez@stantec.com)



**Stantec**

**Stantec Consulting Ltd**  
2781 Lancaster Rd, Suite 100 A&B  
Ottawa, ON K1B 1A7  
Tel: (613) 738-6075  
Fax: (613) 722-2799

November 6, 2017  
File: 122410864

**Attention: Thurber Engineering Ltd., File #18310**

**Reference: ASTM D7012, Method C, Unconfined Compressive Strength of Intact Rock Core**

The table below summarizes six rock core unconfined compressive strength results.

Location	Sample Depth	Compressive Strength (MPa)	Description of Break
BH17-2 Run-2	35'9"	134.1	Two well-formed cones on either end
BH17-3 Run-2	33'6"	133.5	Two well-formed cones on either end
BH17-6 Run-3	41'2"	104.5	Well-formed cone on bottom, vertical cracks through top
BH17-7 Run-2	32'8"	152.7	Well-formed cone on bottom, vertical cracks through top
Bh17-14 Run-3	36'10"	105.2	Two well-formed cones on either end
BH17-15 Run-2	32'5"	107.5	No well-formed cones, cracks throughout core

Sincerely,

**Stantec Consulting Ltd**

*Brian Prevost*

Brian Prevost  
Laboratory Supervisor  
Tel: 613-738-6075  
[brian.prevost@stantec.com](mailto:brian.prevost@stantec.com)

**Appendix C.4**  
**Analytical Testing Results**

## Certificate of Analysis

**Thurber Engineering Ltd.**

2460 Lancaster Rd, Suite 104  
Ottawa, ON K1B 4S5  
Attn: Justin Gray

Client PO: 18310  
Project: Site 27-361/c  
Custody: 39852

Report Date: 28-Jun-2018  
Order Date: 25-Jun-2018

**Order #: 1826161**

This Certificate of Analysis contains analytical data applicable to the following samples as submitted:

Paracel ID	Client ID
1826161-01	17-1, SS4, 7'6"-9'6"

Approved By:



Dale Robertson, BSc  
Laboratory Director

Certificate of Analysis  
Client: Thurber Engineering Ltd.  
Client PO: 18310

Report Date: 28-Jun-2018  
Order Date: 25-Jun-2018  
Project Description: Site 27-361/c

### Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	27-Jun-18	27-Jun-18
Conductivity	MOE E3138 - probe @25 °C, water ext	27-Jun-18	27-Jun-18
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	26-Jun-18	27-Jun-18
Resistivity	EPA 120.1 - probe, water extraction	27-Jun-18	27-Jun-18
Solids, %	Gravimetric, calculation	27-Jun-18	27-Jun-18



Certificate of Analysis  
**Client: Thurber Engineering Ltd.**  
**Client PO: 18310**

Report Date: 28-Jun-2018

Order Date: 25-Jun-2018

**Project Description: Site 27-361/c**

<b>Client ID:</b>	17-1, SS4, 7'6"-9'6"	-	-	-
<b>Sample Date:</b>	06/18/2018 09:00	-	-	-
<b>Sample ID:</b>	1826161-01	-	-	-
<b>MDL/Units</b>	Soil	-	-	-

**Physical Characteristics**

% Solids	0.1 % by Wt.	89.2	-	-	-
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**General Inorganics**

Conductivity	5 uS/cm	594	-	-	-
pH	0.05 pH Units	7.83	-	-	-
Resistivity	0.10 Ohm.m	16.8	-	-	-

**Anions**

Chloride	5 ug/g dry	229	-	-	-
Sulphate	5 ug/g dry	93	-	-	-

Certificate of Analysis  
**Client: Thurber Engineering Ltd.**  
**Client PO: 18310**

Report Date: 28-Jun-2018  
 Order Date: 25-Jun-2018  
**Project Description: Site 27-361/c**

**Method Quality Control: Blank**

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
<b>Anions</b>									
Chloride	ND	5	ug/g						
Sulphate	ND	5	ug/g						
<b>General Inorganics</b>									
Conductivity	ND	5	uS/cm						
Resistivity	ND	0.10	Ohm.m						

Certificate of Analysis  
Client: Thurber Engineering Ltd.  
Client PO: 18310

Report Date: 28-Jun-2018  
Order Date: 25-Jun-2018  
Project Description: Site 27-361/c

**Method Quality Control: Duplicate**

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
<b>Anions</b>									
Chloride	265	5	ug/g dry	282			6.1	20	
Sulphate	146	5	ug/g dry	151			3.0	20	
<b>General Inorganics</b>									
Conductivity	293	5	uS/cm	290			1.1	6.2	
pH	7.89	0.05	pH Units	7.83			0.8	10	
Resistivity	34.1	0.10	Ohm.m	34.5			1.1	20	
<b>Physical Characteristics</b>									
% Solids	84.4	0.1	% by Wt.	85.3			1.0	25	

Certificate of Analysis  
Client: Thurber Engineering Ltd.  
Client PO: 18310

Report Date: 28-Jun-2018  
Order Date: 25-Jun-2018  
Project Description: Site 27-361/c

**Method Quality Control: Spike**

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
<b>Anions</b>									
Chloride	374	5	ug/g	282	92.2	78-113			
Sulphate	254	5	ug/g	151	104	78-111			

Certificate of Analysis  
Client: Thurber Engineering Ltd.  
Client PO: 18310

Report Date: 28-Jun-2018  
Order Date: 25-Jun-2018  
Project Description: Site 27-361/c

**Qualifier Notes:**

***Login Qualifiers :***

Received at temperature > 25C  
*Applies to samples: 17-1, SS4, 7'6"-9'6"*

**Sample Data Revisions**

None

**Work Order Revisions / Comments:**

None

**Other Report Notes:**

n/a: not applicable  
ND: Not Detected  
MDL: Method Detection Limit  
Source Result: Data used as source for matrix and duplicate samples  
%REC: Percent recovery.  
RPD: Relative percent difference.

Soil results are reported on a dry weight basis when the units are denoted with 'dry'.  
Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.

## Subcontracted Analysis

**Thurber Engineering Ltd.**

2460 Lancaster Rd, Suite 104  
Ottawa, ON K1B 4S5  
Attn: Justin Gray

Tel: (613) 408-6795  
Fax: (613) 247-2185

Paracel Report No **1826161**  
Client Project(s): **Site 27-361/c**  
Client PO: **18310**  
Reference: **Standing Offer**  
CoC Number: **39852**

Order Date: 25-Jun-18  
Report Date: 05-Jul-18

Sample(s) from this project were subcontracted for the listed parameters. A copy of the subcontractor's report is attached

Paracel ID	Client ID	Analysis
1826161-01	17-1, SS4, 7'6"-9'6"	Sulphide, solid

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.  
Lakefield - Ontario - K0L 2H0  
Phone: 705-652-2000 FAX: 705-652-6365

**Paracel Laboratories**

Attn : Dale Robertson

300-2319 St.Laurent Blvd.  
Ottawa, ON  
K1G 4K6,

Phone: 613-731-9577  
Fax:613-731-9064

05-July-2018

**Date Rec. :** 27 June 2018  
**LR Report:** CA12931-JUN18  
**Reference:** Project#:1826161

**Copy:** #1

## CERTIFICATE OF ANALYSIS

### Final Report

Sample ID	Sample Date & Time	Sulphide %
1: Analysis Start Date		05-Jul-18
2: Analysis Start Time		10:43
3: Analysis Completed Date		05-Jul-18
4: Analysis Completed Time		13:06
5: QC - Blank		<0.02
6: QC - STD % Recovery		85%
7: QC - DUP % RPD		11%
8: RL		0.02
9: 17-1, SS4, 7'6"-9'6"	18-Jun-18	0.13

RL - SGS Reporting Limit

Kimberley Didsbury  
Project Specialist  
Environmental Services, Analytical

## **Appendix D.**

### **Site Photographs**





**Photo 1. Looking southwest at culvert inlet**



**Photo 2. Looking northwest at culvert crossing**





**Photo 3. Looking southwest along culvert alignment**



**Photo 4. Looking north east at culvert outlet**