



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION REPORT
REPLACEMENT OF STRUCTURAL CULVERT No. 29-146/C
BARBUT CREEK CROSSING OF HIGHWAY 17
RENFREW COUNTY, ON
W.P. 4005-13-01
AGREEMENT NUMBER: 4014-E-0014**

GEOCRES NUMBER: 31L-203

SUBMITTED TO

WSP CANADA

LOCATION:

LATITUDE: 46.26625°

LONGITUDE: -78.35435°

APRIL 2018

19-5161-263



Table of Contents

PART 1: FACTUAL INFORMATION

1	INTRODUCTION	1
2	SITE DESCRIPTION	1
3	SITE INVESTIGATION	2
3.1	Field Investigation	2
3.2	LABORATORY TESTING	3
4	DESCRIPTION OF SUBSURFACE CONDITIONS	3
4.1	Overview / General	3
4.2	Asphalt.....	4
4.3	Topsoil.....	4
4.4	Fill.....	4
4.5	Peat	5
4.6	Silt (ML)	5
4.7	Silty Sand (SM) with Gravel: Till.....	6
4.8	Groundwater	6
5	MISCELLANEOUS	7

APPENDICES

Appendix A	Borehole Locations and Soil Strata Drawings
	Preliminary General Arrangement Drawing
Appendix B	Record of Borehole Sheets
Appendix C	Laboratory Test Results
Appendix D	Site Photographs

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) for the replacement of the Barbut Creek Culvert located on Highway 17, within Renfrew County. Thurber carried out the investigation as a subconsultant to WSP Canada (WSP) as part of Agreement No. 4014-E-0014.

No previous foundation investigation information for the subject culvert was available. A Preliminary General Arrangement (GA) drawing dated March 29, 2018 and base plan mapping were provided by WSP for the preparation of this report.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on this data, provide a borehole location plan, record of boreholes, a stratigraphic profile, laboratory test results and a written description of the subsurface conditions.

2 SITE DESCRIPTION

Culvert 29-146/C is located on Highway 17, approximately 28 km east of Mattawa, Ontario. The location of the culvert is shown on the inset Key Plan on Drawing No. 1 in Appendix A.

It is noted that for project orientation purposes, Highway 17 within the project limits has one through lane in each direction and will be assumed to run west-east. Based on the Preliminary GA drawing the roadway cross-section consists of two, 3.75 m wide lanes with gravel shoulders. Steel beam guide rails are present along both sides of the highway in the vicinity of the culvert.

The existing culvert is a cast-in-place, concrete, open bottom, rigid frame, with an internal height of 2.1 m and span of 6 m that carries creek flow from south to north below the highway. One extension has been added to the north end of the original culvert and two separate extensions have been added to the south end. The extensions are conventional open footing rigid frame culverts. Including the extensions, the total length of the structure is reported to be 40.2 m. The March 2018 Preliminary GA drawing, also provided in Appendix A, indicates that elevation of the top of stream bed ranges from Elevation 151.05 m and 150.28 m at the inlet and outlet respectively.

No settlement or stability issues were noted at the culvert at the time of Thurber's field investigation. Due to the high creek water elevation during the field investigation, inspection for scour and erosion at the founding level at the inlet/outlet was not possible.

The culvert is located within a high fill section. The height of the embankment in the area of the culvert is approximately 7 m. The slopes of the embankment were observed to be covered with a

mix of brush and granular material. Some erosion of the granular slopes on both sides of the highway was noted. The embankment slopes were graded with slopes ranging from approximately 2.2H:1V to 2.8H:1V (Horizontal:Vertical). The elevation of the center line of roadway as reported on the Preliminary GA drawing was 157.6 m and the elevation of the top of the culvert at the inlet and outlet ends are indicated as approximately 153.5 m and 152.9 m providing for 4.1 m to 4.7 m of cover.

The site is located within a physiographic region known as the Algonquin Highlands which is characterized as having soils that are generally shallow overburden deposits with rough relief of rounded knobs and ridges, areas of outwash sand and gravel deposits, and frequently exposed bedrock. (Chapman and Putnam 1984).

The lands surrounding the project limits include forest and swampy areas. The Ottawa River is approximately 150 m north of the culvert site and is approximately parallel to Highway 17. Storm water drainage in the area is to ditches along the highway, and to Barbut Creek which outlets into the Ottawa River.

Site photographs showing the general conditions at the site, along the highway embankment and at the inlet and outlet are presented in Appendix D.

3 SITE INVESTIGATION

3.1 Field Investigation

A field investigation for the proposed culvert replacement was carried out between October 13, 2015 and December 15, 2015, and included advancing four boreholes (Boreholes 501 through 504). Due to the presence of large boulders within the embankment, an additional borehole (designated Boreholes 502C) was advanced in the eastbound lane using telescoping drilling techniques to advance through the existing rock fill.

Based on the September 2017 Preliminary Staging Drawings provided by WSP, a temporary modular bridge (TMB) will be installed along the south side of the highway in order to maintain traffic during construction for replacement of the culvert. A supplementary foundation investigation was carried to support the design of the TMB. The supplemental investigation was carried out between June 29 and June 30, 2017 and included advancing two additional boreholes (Boreholes 505 and 506).

The approximate locations and elevations of the both the original and supplement boreholes are illustrated on Drawing No. 1 provided in Appendix A and are summarized in Table 3-1.

Table 3-1: Borehole Summary

Borehole	Location	Latitude	Longitude	Ground Surface Elevation (m)	Depth (m)
501	Culvert Inlet	46.26611	-78.35431	154.0	4.6
502	Highway 17 EB	46.26629	-78.35430	157.7	5.4
502C	Highway 17 EB	46.26630	-78.35431	157.8	16.0
503	Highway 17 WB	46.26626	-78.35415	157.5	15.3
504	Culvert Outlet	46.26640	-78.35416	154.4	6.0
505	Highway 17 EB	46.26638	-78.35446	157.9	13.8
506	Highway 17 EB	46.26614	-78.35401	157.3	10.9

As a component of our standard procedures and due diligence, Thurber contacted Ontario One Call to provide utility locates/clearances for the intended borehole locations.

The boreholes advanced through the roadway embankment were advanced with either a CME75 truck mounted drill rig equipped with NW size casing or a CME850 truck mounted drill equipped with HW size casing utilizing a telescoping drilling technique. The inlet and outlet boreholes were advanced with portable drilling equipment. Borehole 504 (outlet borehole) was advanced to refusal with Dynamic Cone Penetration Testing (DCPT). The subsurface stratigraphy encountered in the boreholes was recorded in the field by Thurber personnel. Split spoon samples were collected at regular depth intervals in the boreholes via the completion of Standard Penetration Tests (SPT), following the methods described in ASTM Standard D1586-11. All soil samples recovered from the boreholes were placed in moisture-proof containers and the samples were transported to Thurber's Ottawa geotechnical laboratory for further examination and testing.

A 25 mm inside diameter PVC piezometer was installed in Borehole 501 to allow for measurement of the groundwater level at the site. The piezometer construction details are illustrated on the Record of Borehole sheet for Borehole 501, provided in Appendix B. The piezometer was decommissioned on December 15, 2015.

The boreholes without a piezometer were backfilled with a low-permeability mixture of auger cuttings and bentonite pellets in general accordance with the intent of Ontario MOE Regulation 903. Boreholes advanced within paved areas were capped with 150 mm of cold patch asphalt.

The as-drilled locations of the boreholes and ground surface elevations at the borehole locations were surveyed by Thurber. The vertical datum used was a horizontal control point (HCP) identified on base plans provided by WSP as a rock bar with a geodetic elevation of 161.521 m. This HCP is located at Station 13+906, approximately 100 m west of the culvert site and 25 m north of the centerline of Highway 17.

3.2 LABORATORY TESTING

Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all soil samples in accordance with the current MTO standards. Grain size distribution analyses testing was also carried out on selected samples to MTO and ASTM standards. Testing was completed in the Thurber Ottawa laboratory.

The geotechnical laboratory test results are presented on the Record of Borehole sheets in Appendix B and are illustrated on the figures in Appendix C.

Chemical analysis for determination of pH, resistivity, soluble sulphate and chloride concentrations was carried out on one soil sample at Paracel Laboratories Ltd. in Ottawa. A copy of the chemical analysis results is provided in Appendix C.

4 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 Overview / General

Reference is made to the Record of Borehole sheets in Appendix B for details of the soil stratigraphy encountered in the boreholes. A stratigraphic profile along the culvert alignment and along the highway alignment are presented on Drawing No. 1 in Appendix A for illustrative

purposes. An overall description of the stratigraphy is given in the following paragraphs; however, the factual data presented in the Record of Boreholes governs any interpretation of the site conditions.

In general, the stratigraphy beneath Highway 17 in the area of the culvert is characterized by an asphalt pavement structure overlying embankment fill containing rock fill, overlying a glacial till deposit. A buried layer of peat was encountered between the fill and till in Boreholes 504 and 505 and thin layers of silt and peat were encountered between the fill and till in Borehole 506.

More detailed descriptions of the individual strata are presented below.

4.2 Asphalt

Five boreholes were advanced through the Highway 17 pavement structure. The thickness of the asphalt ranged from 100 mm to 120 mm.

4.3 Topsoil

A topsoil layer with a thickness of 25 mm was encountered at surface in Borehole 504 near the culvert outlet.

4.4 Fill

Sand with Gravel Fill

A fill layer consisting predominantly of sand and gravel with varying amounts of silt was encountered below the asphalt in the embankment boreholes, at the ground surface in Borehole 501 and below the topsoil in Borehole 504. The top of this layer ranges from Elevation 157.2 m to 157.8 m. The thickness of the layer ranged from 700 mm to 1.1 m. The SPT 'N' values ranged from 44 to greater than 100 blows; indicating a dense to very dense condition. Cobbles were noted in this layer.

The moisture content of the samples tested ranged from 2% to 10%. The results of a grain size analysis test completed on samples of this material indicated a gravel content ranging from 28% to 39%, sand content ranging from 56% and 63%, and a fines content (combined silt and clay size particles) ranging from 0% to 9%. Grain size analysis results are illustrated on Figure 1 in Appendix C.

Embankment Fill (Rock Fill)

Rock fill was encountered within the core of the embankment beneath the pavement structure in Boreholes 502/502C, 503, 505 and 506. Where encountered, the top of this layer ranges from Elevation 156.1 m to 156.9 m. The thickness of the layer ranged from 4.1 m to 6.7 m. Trace wood pieces were encountered at the base of this layer in Borehole 503.

The rock fill contained frequent cobble and boulder sized particles. Coring techniques were required to advance the boreholes through this layer due to the presence of the cobble and boulder sized material.

Where samples were recovered with a split spoon sampler, the fill consisted predominantly of gravel and sand with trace amounts of silt. The SPT 'N' values ranged from 5 to greater than 100 blows; indicating a loose to very dense condition; but typically compact to dense.

The moisture content for the recovered samples tested ranged from 2% to 21%. The results of grain size analysis conducted on six samples of this material are summarized in Table 4-1 and are illustrated on Figure 2 in Appendix C. It should be noted that the lab testing was carried out on samples recovered from split spoon samplers which did not include the boulders, cobbles and large gravel material present within the rock fill.

Table 4-1: Gradation Results for Rock Fill

Soil Particles	%
Gravel	23 to 62
Sand	35 to 69
Silt and Clay	3 to 9

Sand with Silt and Gravel Fill

A fill layer consisting predominantly of sand and gravel with varying amounts of silt was encountered beneath the topsoil layer in Borehole 504 and at the ground surface of Borehole 501. The top of this layer ranges from Elevation 154.4 m and 154.0 m. The thickness of the layer ranged from 3.0 m and 3.9 m. The SPT 'N' values ranged from 2 to 31; indicating a very loose to dense condition; but typically loose to compact.

The moisture content for the samples tested ranged from 2% to 22%. The results of grain size analysis conducted on samples of this material are summarized in Table 4-2 and are illustrated on Figure 3 in Appendix C.

Table 4-2: Gradation Results for Fill

Soil Particles	%
Gravel	19 to 37
Sand	53 to 76
Silt and Clay	5 to 10

4.5 Peat

Peat with trace to some wood pieces was encountered below the fill material in Boreholes 504 and 505 and between silt layers in Borehole 506. The peat in Borehole 505 was mixed with sand and gravel. The top of the peat ranged from Elevation 150.5 m to 151.2. The thickness of the peat layer ranged from 300 mm to 1.0 m.

The moisture content for the samples tested ranged from 107% to 275%. Test results carried on samples of this material indicated an organic content ranging from 20% to 54%.

4.6 Silt (ML)

A silt deposit was encountered between the fill and the till deposits in Borehole 506. The top of this layer was encountered at Elevation 151.9 m. The overall thickness of the layer was 1.7 m, however, a 300 mm thick layer of peat was encountered in the middle of the silt layer. Trace

organic material was observed throughout the silt both above and below the peat. The SPT 'N' values ranged from 3 to 5; indicating a very loose to loose condition.

The moisture content of the samples tested were 47% and 138%. The results of a grain size analysis test completed on a sample of this material indicated a gravel content of 0%, sand content of 11% a silt content of 69%, and a clay content 20%. Grain size analysis results are illustrated on Figure 4 in Appendix C.

4.7 Silty Sand (SM) with Gravel: Till

A glacial till layer consisting predominantly of silty sand with varying amounts of gravel was encountered in all boreholes. The top of this layer ranges from Elevation 149.6 m to 150.9 m. All boreholes were terminated in this stratum. The SPT 'N' values ranged from 16 to greater than 100 blows; indicating a compact to very dense condition; but typically dense to very dense. Occasional to frequent boulders and cobbles were encountered in this stratum and coring techniques were required to advance through this layer.

The moisture content for the samples tested ranged from was 8% to 20%. The results of grain size analysis conducted on samples of this material are summarized in Table 4-3 and are illustrated on Figures 5 and 6 in Appendix C.

Table 4-3: Gradation Results for Till

Soil Particles	%
Gravel	11 to 28
Sand	50 to 69
Silt and Clay	19 to 36

4.8 Groundwater

The groundwater level was measured in the piezometer installed in Borehole 501 on December 15, 2015, at a depth of 2.1 m; corresponding to an elevation of 151.9 m. The groundwater level was also measured in Borehole 505 during drilling (open borehole) on June 27, 2017, at a depth of 5.65 m; corresponding to an elevation of 152.3 m.

The water level in Barbut Creek was measured at the time of Thurber's field investigations at a depth of 1.3 m below the top of the culvert at the inlet; corresponding Elevation 152.2 m. The groundwater level in the area of the culvert is expected to reflect the creek water level.

These observations are considered short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall.

5 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. Thurber surveyed the borehole locations, and determined the ground surface elevations based on contract drawings provided by WSP Canada. Ohlmann Geotechnical Services (OGS) Inc. of Almonte, Ontario and Downing George Estate Drilling Ltd. of Hawkesbury, Ontario supplied and operated the drilling equipment to carry out the drilling, sampling, and in-situ testing. The drilling, and sampling operations in the field were supervised on a full-time basis by Mr. Simon Paxton and Justin Gray of Thurber. Laboratory testing was carried out by Thurber in its MTO-approved laboratory in Ottawa.

Overall project management and direction of the field program was provided by Paul Carnaffan, P.Eng. Interpretation of the field data and preparation of this report was completed by Kenton Power, P.Eng. The report was reviewed by Paul Carnaffan, P.Eng. and Dr. P.K. Chatterji, P.Eng., the Designated Principal Contact for MTO Foundations Projects.



Kenton C. Power, P.Eng.
Geotechnical Engineer



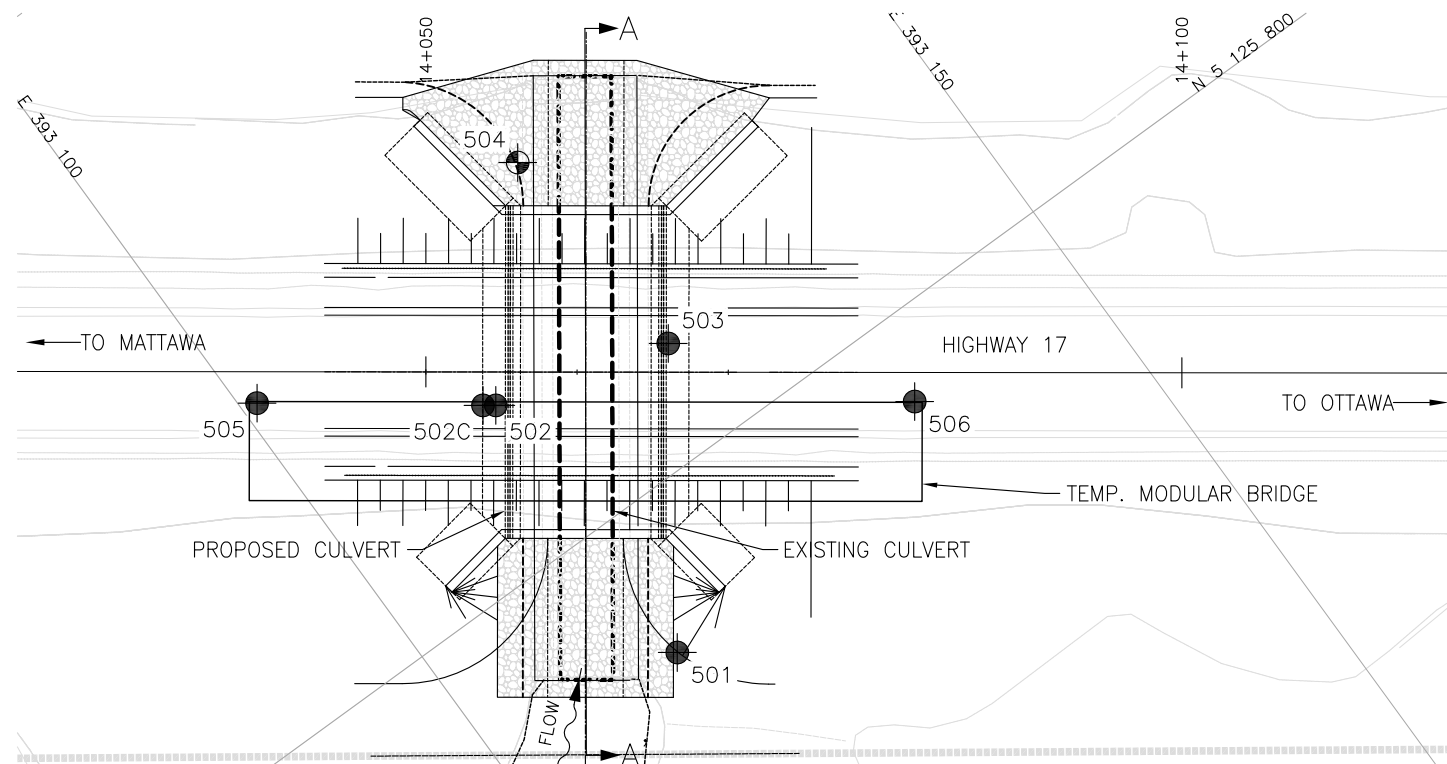
Paul Carnaffan, P.Eng.
Principal, Senior Geotechnical Engineer



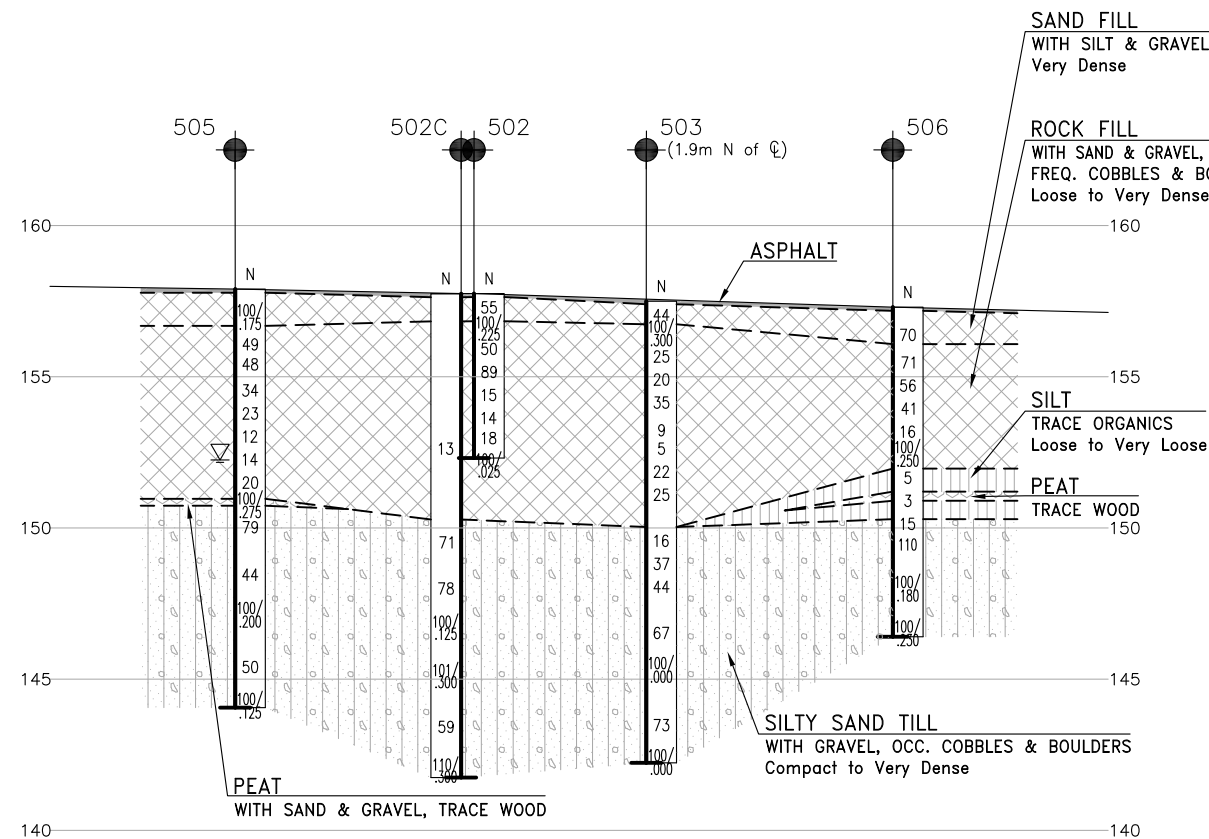
P.K. Chatterji, P.Eng.
Review Principal, Designated MTO Contact

APPENDIX A

BOREHOLE LOCATIONS AND SOIL STRATA DRAWINGS PRELIMINARY GENERAL ARRANGEMENT DRAWING

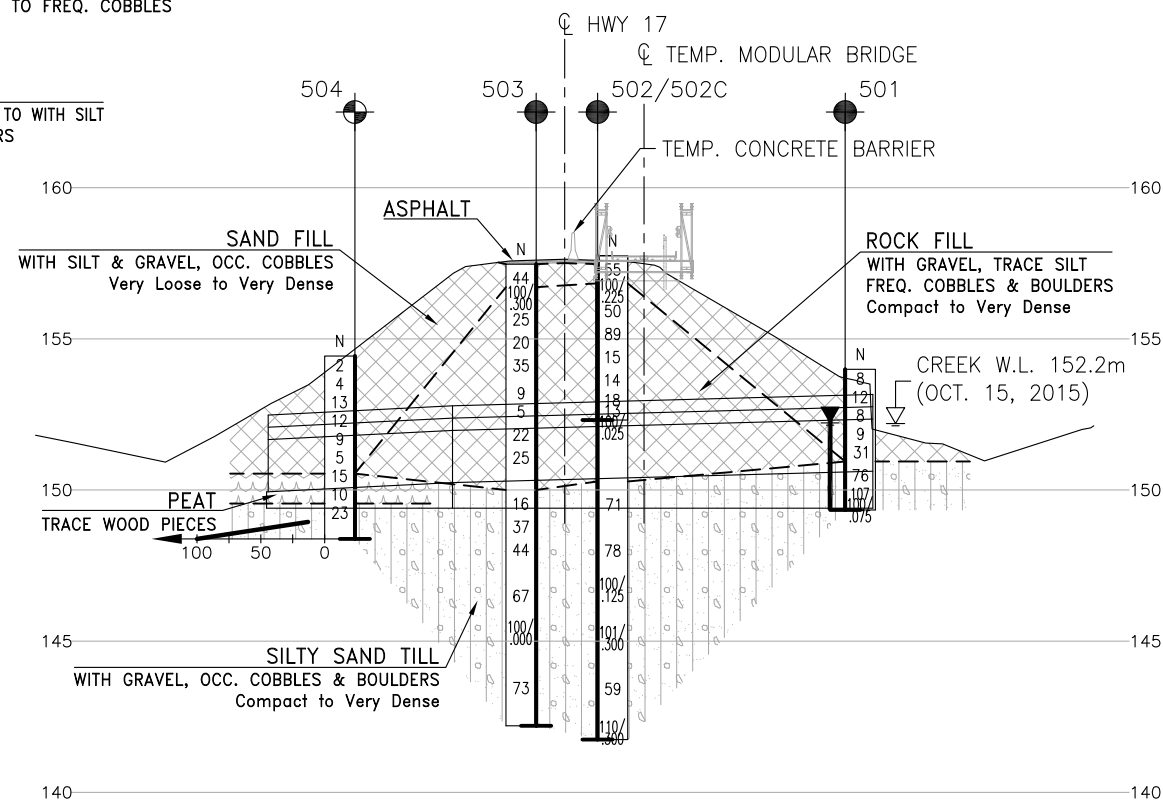


PLAN
SCALE 1:500



PROFILE ALONG CL TEMP. MODULAR BRIDGE

SCALE 1:500
H 1:500
V 1:250



SECTION A-A' ALONG CL CULVERT

SCALE 1:500
H 1:500
V 1:250

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



CONT No
WP No 4005-13-01

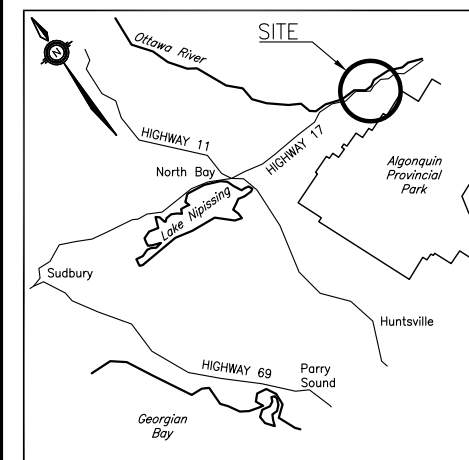
HIGHWAY 17
BARBUT CREEK
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

WSP

THURBER ENGINEERING LTD.



SHEET



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

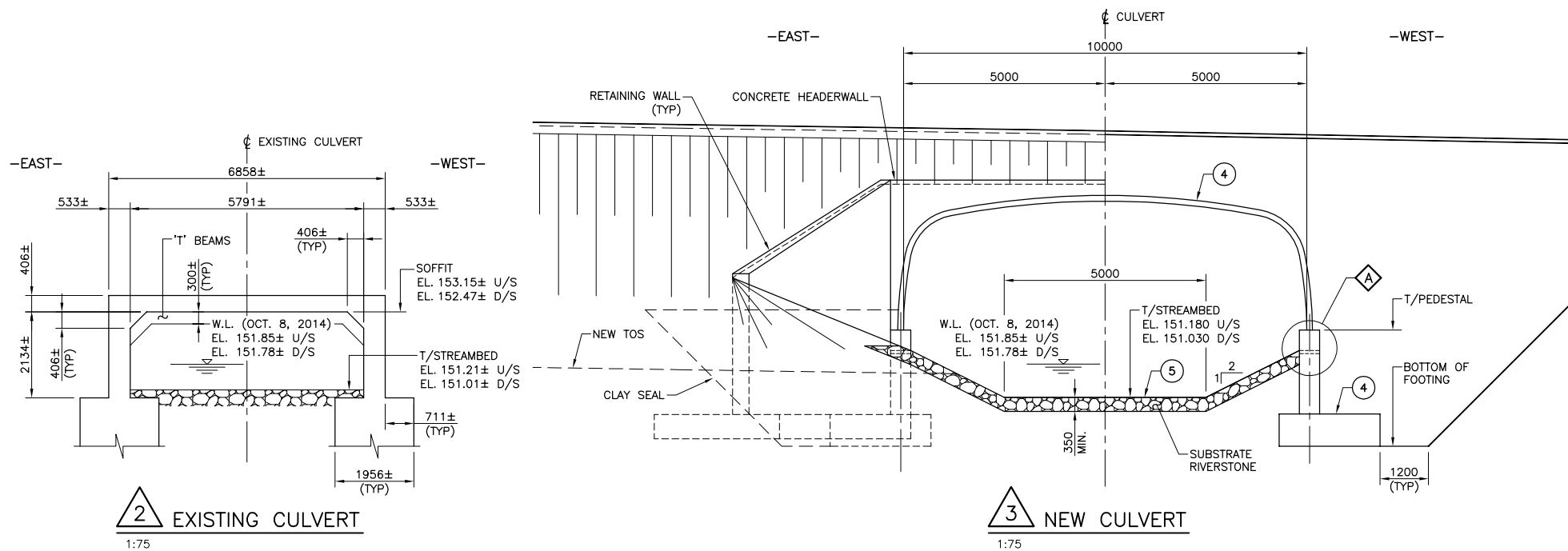
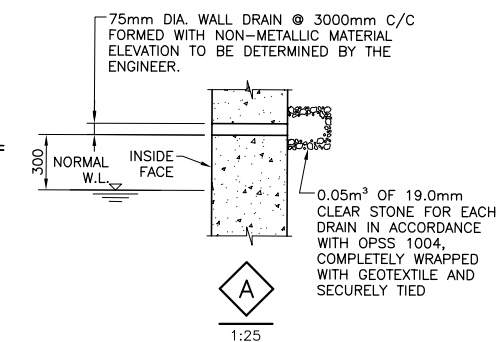
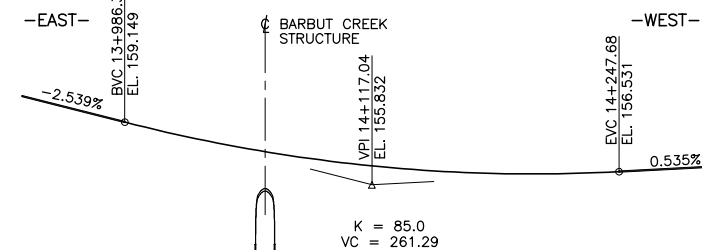
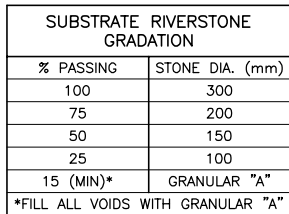
NO	ELEVATION	NORTHING	EASTING
501	154.0	5 125 790.3	393 113.8
502	157.7	5 125 810.6	393 113.7
502C	157.8	5 125 811.1	393 113.0
503	157.5	5 125 807.2	393 125.4
504	154.4	5 125 822.7	393 124.4
505	157.9	5 125 820.0	393 101.0
506	157.3	5 125 794.5	393 136.3

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.
- Borehole locations are shown in MTM Zone 10 coordinates.

GEOCRES No. 31L-203

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	KP	CHK -	CODE
DRAWN	MFA	CHK KP	SITE 29-146/C/STRUCT
DATE	APR 2018	DWG	1



VC = 261.29



0.05m³ OF 19.0mm
CLEAR STONE FOR EACH
DRAIN IN ACCORDANCE
WITH OPSS 1004.
COMPLETELY WRAPPED
WITH GEOTEXTILE AND
SECURELY TIED

PRELIMINARY
2018/03/29
NOT FOR CONSTRUCTION

W.P. No.	NORTHING	EASTING
1	5125799.963	393113.350
2	5125817.733	393126.319

[illegible]

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).

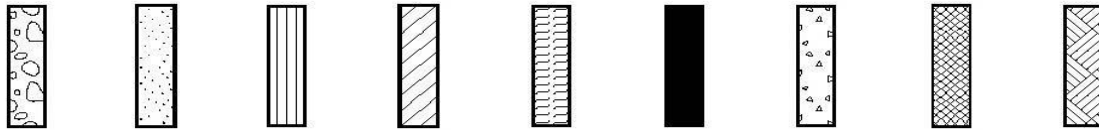
DYNAMIC CONE PENETRATION TEST (DCPT):

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 501

1 OF 1

METRIC

W.P. 4005-13-01 LOCATION 29-146/C Barbut Creek Culvert: MTM Zone 10: N 5 125 790.3 E 393 113.8 ORIGINATED BY SMP
 HWY 17 BOREHOLE TYPE Portable NW Casing COMPILED BY SMP
 DATUM Geodetic DATE 2015.10.27 - 2015.10.27 CHECKED BY KP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
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+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 502

1 OF 1

METRIC

W.P. 4005-13-01 LOCATION 29-146/C Barbut Creek Culvert: MTM Zone 10: N 5 125 810.6 E 393 113.7 ORIGINATED BY CAM
 HWY 17 BOREHOLE TYPE NW Casing COMPILED BY SMP
 DATUM Geodetic DATE 2015.10.15 - 2015.10.15 CHECKED BY KP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL LIMIT MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)						
								○ UNCONFINED + FIELD VANE					W P W W L					
								● QUICK TRIAXIAL × LAB VANE	20	40	60	80	100	20			40	60
157.7																		
0.0	115 mm ASPHALT																	
0.1	Sand with gravel - frequent cobbles Very dense Brown		1	SS	55											37 63 0 (SI+CL)		
156.8	FILL		2	SS	100/ 225mm													
0.9	Gravel with sand trace silt - frequent cobbles and boulders Compact to very dense Brown																	
	ROCK FILL		3	SS	50													
			4	SS	89											60 36 4 (SI+CL)		
			5	SS	15													
			6	SS	14													
			7	SS	18													
152.3			8	SS	100/ 25mm													
5.4	End of Borehole Splitspoon refusal on inferred boulder																	

ONTMT4S 19-5161-263 BARBUT CREEK GPJ 2012TEMPLATE(MTO).GDT 17/1/18

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

ONTMT4S 19-5161-263 BARBUT CREEK.GPJ 2012TEMPLATE(MTO).GDT 17/1/18

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

METRIC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL LIMIT MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	20 40 60 80 100	20 40 60				
157.5 0.0 0.1	100 mm ASPHALT													
156.7 0.8	Sand with gravel - frequent cobbles Very dense Brown FILL		1	SS	44									
	Sand with silt and gravel - frequent cobbles and boulders Loose to very dense Brown ROCK FILL		2	SS	100/ 300mm									
			3	SS	25									
			4	SS	20									
			5	SS	35									
	- Boulders from 3.7 m to 4.0 m		6	SS	9									
			7	SS	5									
			8	SS	22									
			9	SS	25									
	- Boulders from 6.7 m to 7.3 m													
150.0 7.5	- trace wood pieces Silty SAND (SM) with gravel, TILL - occasional cobbles and boulders Compact to very dense Grey		10	SS	16									
			11	SS	37									
			12	SS	44									

+³, ×³: Numbers refer to Sensitivity

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 (%)
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
								SHEAR STRENGTH kPa	WATER CONTENT (%)		
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				
	Continued From Previous Page										

Estimated from previous page																			
142.2 15.3	Silty SAND (SM) with gravel, TILL - occasional cobbles and boulders Compact to very dense Grey		13	SS	67														
			14	SS	100/ 0mm														
			15	SS	73														
			16	SS	100/ 0mm														
			17	SS	100/ 0mm														
147																			
146																			
145																			
144																			
143																			
28	51	21 (SI+CL)																	

ONTMT4S 19-5161-263 BARBUT CREEK.GPJ 2012TEMPLATE(MTO)GDT 17/11/18

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 504

1 OF 1

METRIC

W.P. 4005-13-01 LOCATION 29-146/C Barbut Creek Culvert: MTM Zone 10: N 5 125 822.7 E 393 124.4 ORIGINATED BY SMP
 HWY 17 BOREHOLE TYPE Portable NW Casing COMPILED BY SMP
 DATUM Geodetic DATE 2015/10/26. - 2015/10/26. CHECKED BY KP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W P W W L							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%)							
154.4							20 40 60 80 100												
0.0	25 mm TOPSOIL																		
	Sand with silt and gravel Very loose to compact Brown FILL		1	SS	2														
			2	SS	4														
			3	SS	13								○					33 62 5 (SI+CL)	
			4	SS	12								○						
			5	SS	9														
	- Grey below 3 m		6	SS	5								○						
150.5													○					19 76 5 (SI+CL)	
3.9	PEAT , trace wood pieces Brown to black - saturated		7	SS	15											114 ○			
			8	SS	10											121 ○			
149.6																			
4.9	Silty SAND (SM) with gravel, TILL - occasional cobbles and boulders Compact Grey - Casing refusal on inferred boulder Advanced DCPT from 5.5 m to 6.0 m		9	SS	23								○					12 69 19 (SI+CL)	
148.4	End of Borehole DCPT Resulsal on inferred boulder																		
6.0																			

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

RECORD OF BOREHOLE No 505

1 OF 2

METRIC

W.P. 4005-13-01 LOCATION 29-146/C Barbut Creek Culvert: MTM Zone 10: N 51 258.0 E 3 931.0 ORIGINATED BY JAG
 HWY 17 BOREHOLE TYPE HW Casing COMPILED BY JAG
 DATUM Geodetic DATE 2017.06.26 - 2017.06.27 CHECKED BY KP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								20 40 60 80 100					
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					
				WATER CONTENT (%)				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _p W W _L					
157.9													
0.0	120 mm ASPHALT												
0.1	Sand with silt and gravel - occasional cobbles Very dense Brown FILL		1	AS									28 63 9 (SI+CL)
156.7			2	SS	100/ 175mm								
1.2	Sand with silt and gravel - frequent cobbles and boulders Compact to very dense Brown ROCK FILL		3	SS	49								23 69 8 (SI+CL)
	- switch to HW casing		4	SS	48								
	- cobbles - 240 mm boulder at 2.9 m		5	SS	34								
	- 120 mm cobble at 3.7 m		6	SS	23								
			7	SS	12								
	- cobbles		8	SS	14								
	- 120 mm cobble at 5.8 m		9	SS	20								
151.0													
6.9 150.7	PEAT with sand and gravel, trace wood		10	SS	100/ 275mm							107	27 30 34 9 20% organic content
7.2	Silty SAND (SM) with gravel, TILL - occasional cobbles and boulders Compact to very dense Grey - 210 mm boulder at 7.3 m		11	SS	79								

Continued Next Page

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

ONTMT4S 19-5161-263 BARBUT CREEK GPJ 2012TEMPLATE(MTO).GDT 17/1/18

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 506

1 OF 2

METRIC

W.P. 4005-13-01 LOCATION 29-146/C Barbut Creek Culvert: MTM Zone 10: N 51 258.0 E 3 931.0 ORIGINATED BY JAG
 HWY 17 BOREHOLE TYPE HW Casing COMPILED BY JAG
 DATUM Geodetic DATE 2017.06.27 - 2017.06.28 CHECKED BY KP

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					W P			W			W L			GR	SA	SI	CL																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
157.3																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								</

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE


ONTMT4S 19-5161-263 BARBUT CREEK GPJ 2012TEMPLATE(MTO).GDT 17/1/18

RECORD OF BOREHOLE No 506

2 OF 2

METRIC

W.P. 4005-13-01 LOCATION 29-146/C Barbut Creek Culvert: MTM Zone 10: N 51 258.0 E 3 931.0 ORIGINATED BY JAG
 HWY 17 BOREHOLE TYPE HW Casing COMPILED BY JAG
 DATUM Geodetic DATE 2017.06.27 - 2017.06.28 CHECKED BY KP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
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						
								WATER CONTENT (%) W P W W L 20 40 60						
146.4	Silty SAND (SM) with gravel, TILL - occasional cobbles and boulders Compact to very dense Grey		13	SS	100/		147							
10.9	End of Borehole				230mm									

ONTMT4S 19-5161-263 BARBUT CREEK GPJ 2012TEMPLATE(MTO).GDT 17/1/18

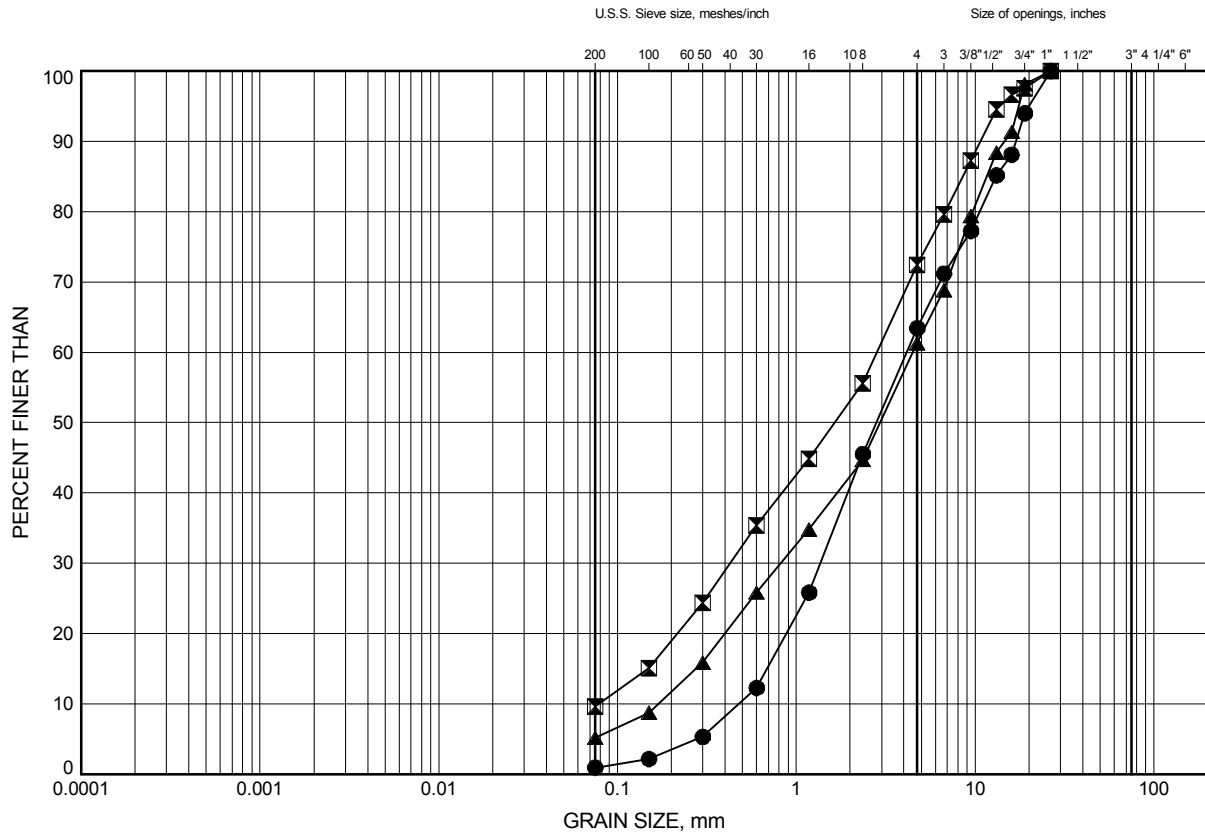
APPENDIX C
LABORATORY TEST RESULTS

Site 29-146/C - Barbut Creek

GRAIN SIZE DISTRIBUTION

FIGURE 1

Fill - Sand with Gravel



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	502	0.24	157.49
◻	505	0.38	157.52
▲	506	0.46	156.81

Date January 2018
W.P. 4005-13-01



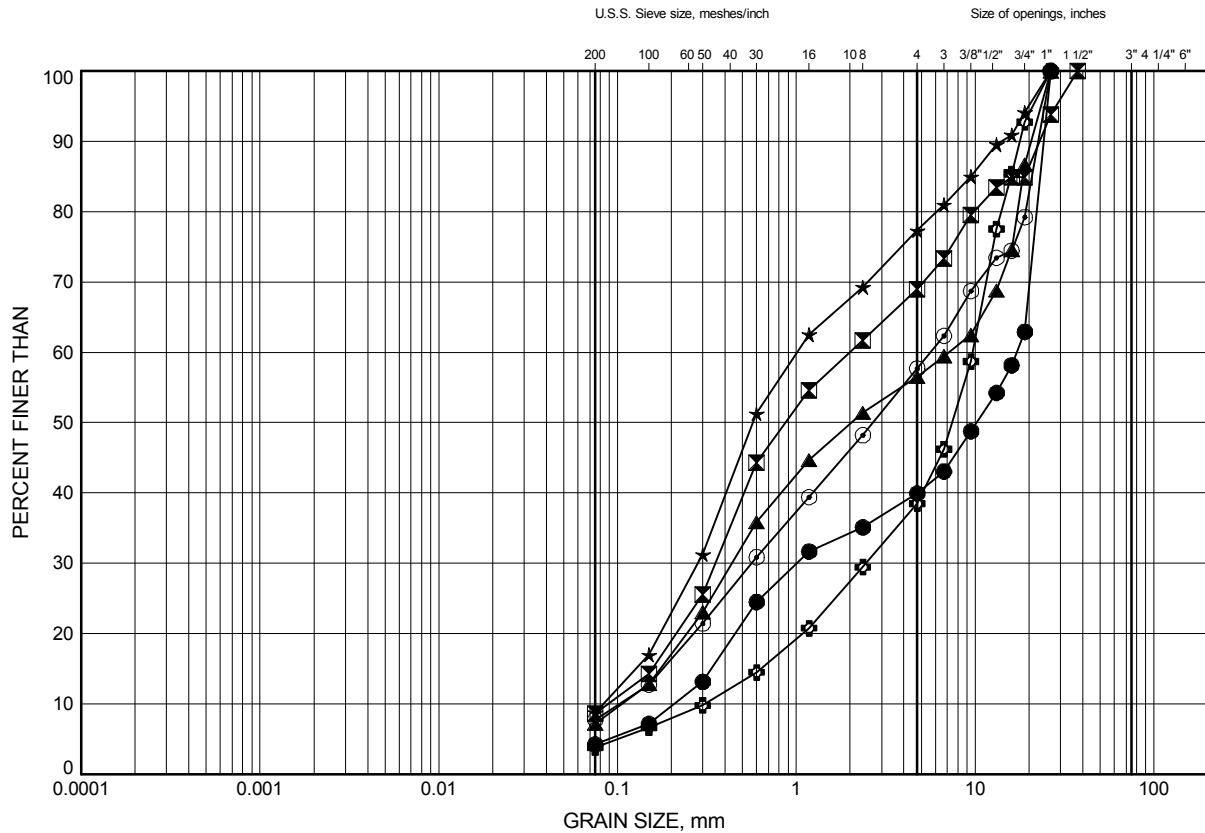
Prep'd KCP
Chkd. PC

Site 29-146/C - Barbut Creek

GRAIN SIZE DISTRIBUTION

FIGURE 2

Embankment Fill (Rock Fill)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	502	2.59	155.14
⊠	503	2.63	154.84
▲	503	6.40	151.07
★	505	1.83	156.07
⊙	506	2.59	154.68
⊕	502C	5.13	152.67

Date January 2018
W.P. 4005-13-01



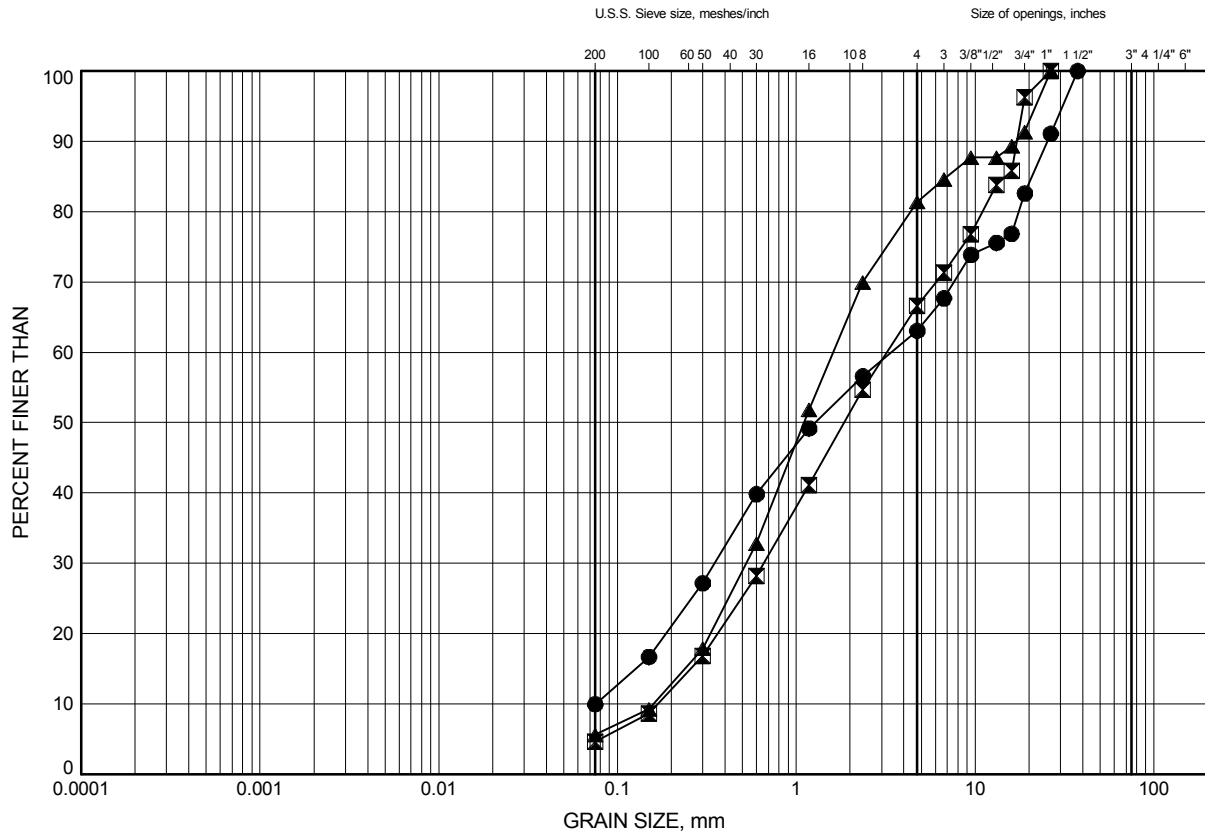
Prep'd KCP
Chkd. PC

Site 29-146/C - Barbut Creek

GRAIN SIZE DISTRIBUTION

FIGURE 3

Fill - Sand with Silt and Gravel



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	501	0.30	153.69
⊠	504	1.52	152.91
▲	504	3.77	150.66

Date January 2018
W.P. 4005-13-01

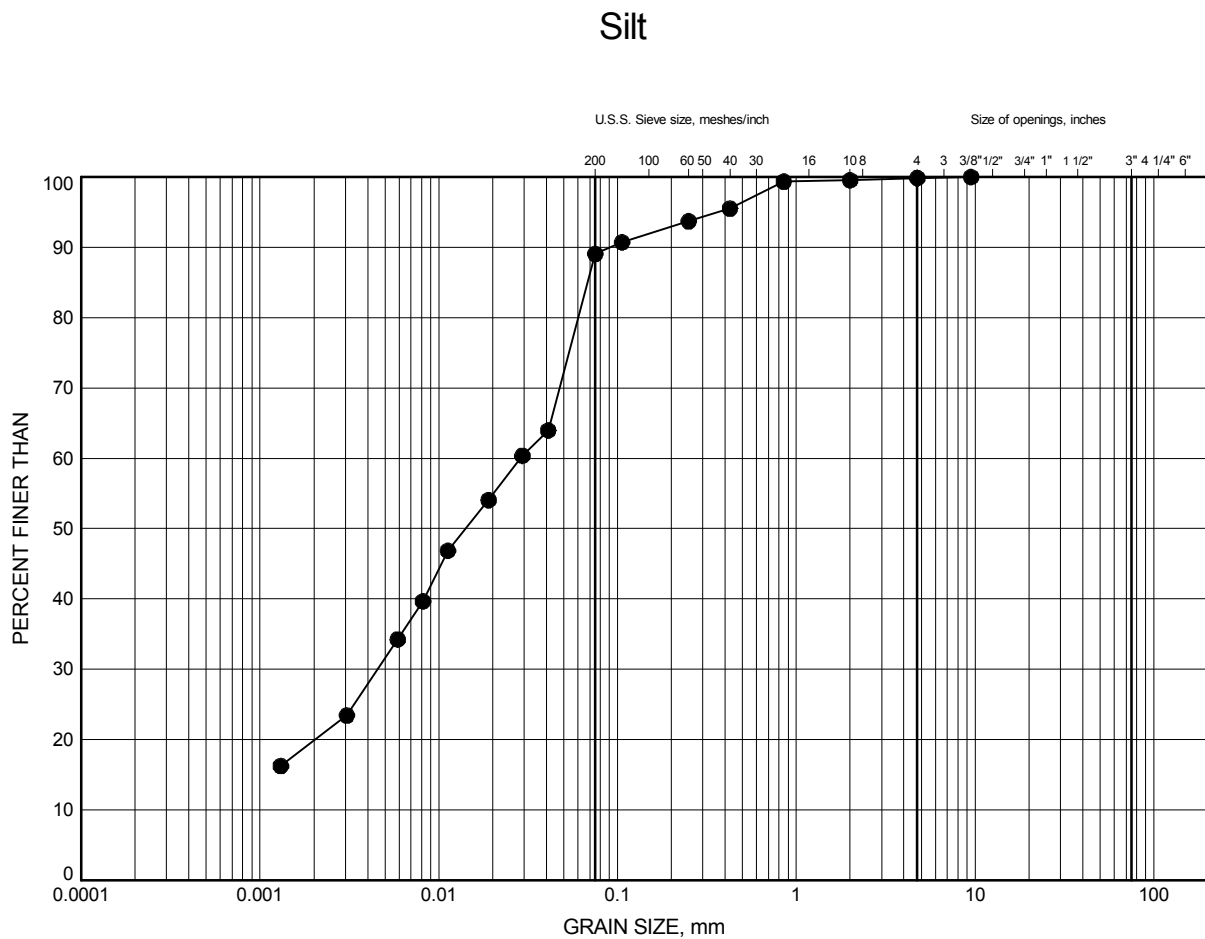


Prep'd KCP
Chkd. PC

Site 29-146/C - Barbut Creek

GRAIN SIZE DISTRIBUTION

FIGURE 4



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	506	5.64	151.63

Date ..September 2017.....
W.P.4005-13-01.....



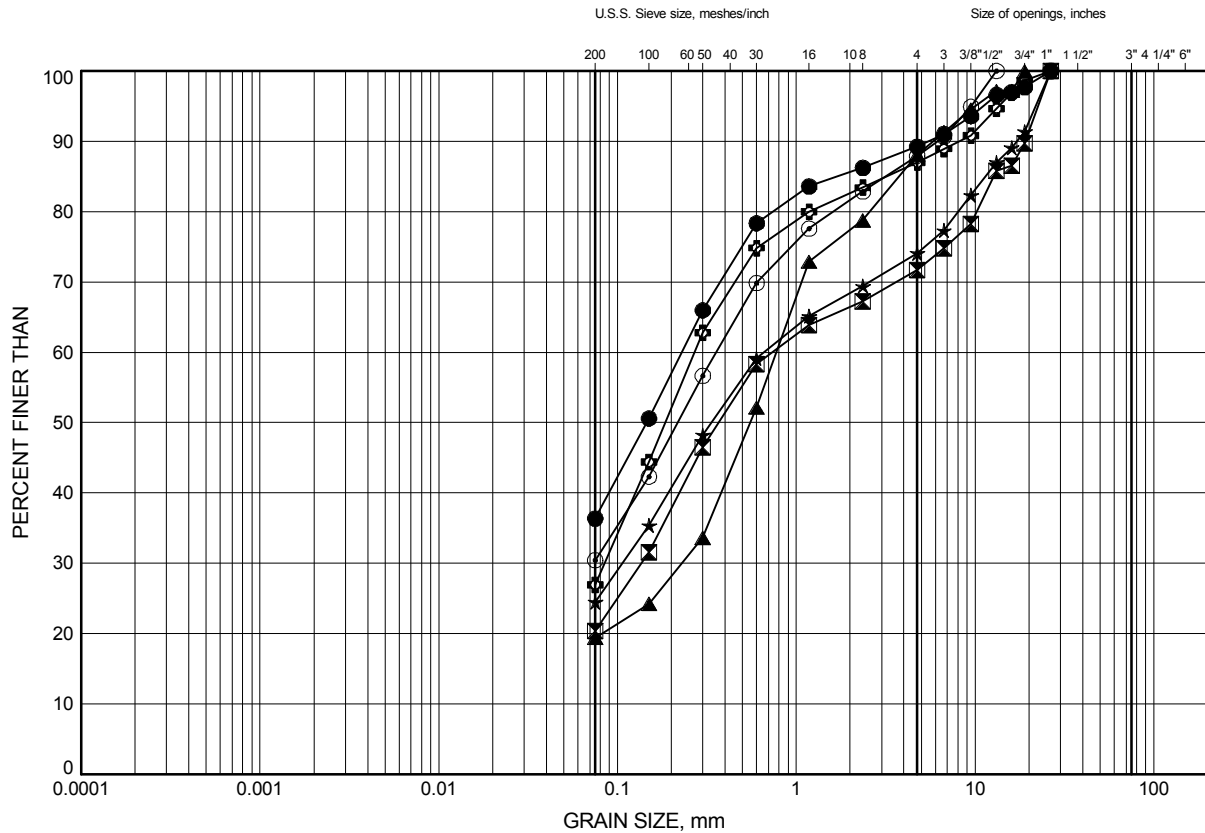
Prep'dKCP.....
Chkd.PC.....

Site 29-146/C - Barbut Creek

GRAIN SIZE DISTRIBUTION

FIGURE 5

Silty Sand with Gravel: Till



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	501	4.11	149.88
⊠	503	10.97	146.50
▲	504	5.18	149.25
★	505	9.45	148.45
⊙	506	7.77	149.50
⊕	502C	9.75	148.05

Date January 2018
W.P. 4005-13-01



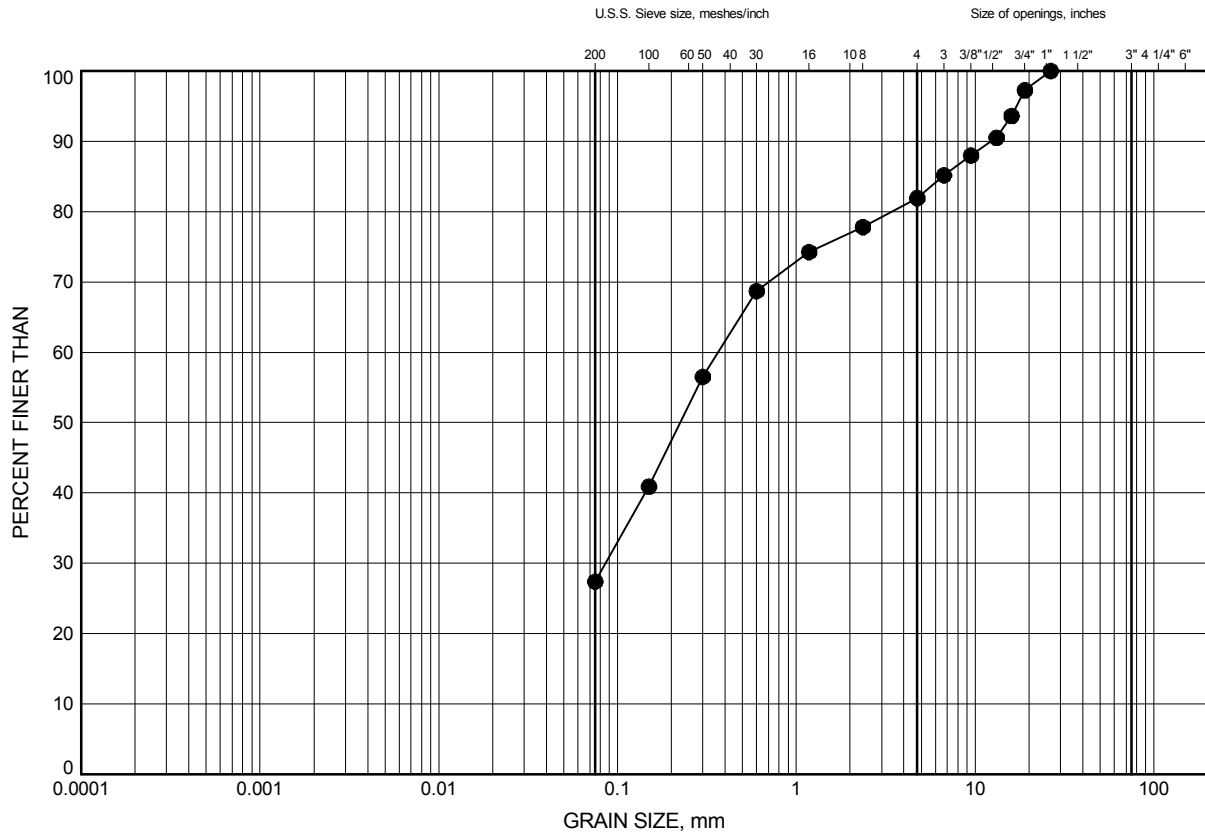
Prep'd KCP
Chkd. PC

Site 29-146/C - Barbut Creek

GRAIN SIZE DISTRIBUTION

FIGURE 6

Silty Sand with Gravel: Till



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	502C	15.77	142.03

Date January 2018
W.P. 4005-13-01



Prep'd KCP
Chkd. PC

Certificate of Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Unit 107
Ottawa, ON K1B4S5
Attn: Kenton Power

Client PO:
Project: 19-5161-263
Custody:

Report Date: 13-Nov-2015
Order Date: 10-Nov-2015

Order #: 1546148

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

Paracel ID	Client ID
1546148-01	BH704 SS4 6' to 8'
1546148-02	BH601 SS4 6' to 8'
1546148-03	BH501 SS6 10.5' to 12.5'

Approved By:



Mark Foto, M.Sc.
Lab Supervisor

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

Project Description: **19-5161-263****Analysis Summary Table**

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	12-Nov-15	12-Nov-15
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	11-Nov-15	11-Nov-15
Resistivity	EPA 120.1 - probe, water extraction	12-Nov-15	12-Nov-15
Solids, %	Gravimetric, calculation	12-Nov-15	12-Nov-15

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

Client PO:

Project Description: 19-5161-263

Client ID:		BH704 SS4 6' to 8'	BH601 SS4 6' to 8'	BH501 SS6 10.5' to 12.5'	-
Sample Date:		22-Oct-15	19-Oct-15	27-Oct-15	-
Sample ID:		1546148-01	1546148-02	1546148-03	-
MDL/Units		Soil	Soil	Soil	-
Physical Characteristics					
% Solids	0.1 % by Wt.	81.9	76.3	91.8	-
General Inorganics					
pH	0.05 pH Units	7.56	7.73	7.99	-
Resistivity	0.10 Ohm.m	25.3	31.2	157	-
Anions					
Chloride	5 ug/g dry	129	70	6	-
Sulphate	5 ug/g dry	27	112	7	-

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

Project Description: **19-5161-263**

Method Quality Control: Blank

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

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

Project Description: **19-5161-263**

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	7.0	5	ug/g dry	7.1			0.5	20	
Sulphate	24.3	5	ug/g dry	25.1			3.6	20	
General Inorganics									
pH	8.11	0.05	pH Units	7.99			1.5	10	
Resistivity	24.8	0.10	Ohm.m	25.3			1.9	20	
Physical Characteristics									
% Solids	78.2	0.1	% by Wt.	77.6			0.7	25	

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

Project Description: **19-5161-263****Method Quality Control: Spike**

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	100	5	ug/g	7.1	93.3	78-113			
Sulphate	104	5	ug/g	25.1	79.1	78-111			

Certificate of Analysis

Client: **Thurber Engineering Ltd.**

Client PO:

Report Date: 13-Nov-2015

Order Date: 10-Nov-2015

Project Description: 19-5161-263

Qualifier Notes:

None

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.

APPENDIX D
SELECTED PHOTOGRAPHS



Figure 1: Roadway Platform at Culvert 29-146/C looking east



Figure 2: Culvert 29-146/C inlet looking north



Figure 3: Looking upstream from Culvert 29-146/C



Figure 4: Culvert 29-146/C outlet looking south



Figure 5: Looking downstream from Culvert 29-146/C



Figure 6: South embankment looking west towards Borehole 501



Figure 7: Erosion of north embankment granular cover