CONTRACT NO. 2017-3003

G.W.P. 3042-11-00

FOUNDATION INVESTIGATION REPORT

HWY 6, PETTIGREW DRAIN CULVERT

(SITE No. 2-448/C)

CONTRACT 4
STRUCTURE REPLACEMENTS
AND REHABILITATIONS

Ministry Of Transportation

Ontario

April 2017

FOUNDATION INVESTIGATION REPORT

Culvert Replacement, Pettigrew Drain Culvert
Site No. 2-448/C, Highway 6
Contract 4 Structure Replacements and Rehabilitation
GWP 3042-11-00
Ministry of Transportation, Ontario, West Region

Submitted to:
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REPORT

Report Number: 12-1132-0163-4000-R04
Geocres No.: 41A-242_____
Distribution:
8 Copies Stantec Consulting Ltd.
1 Copy Golder Associates Ltd.

Golder Associates

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder Associates) was retained by Stantec Consulting Ltd. (Stantec) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out foundation investigations as part of the detail design work for GWP 3042-11-00. The project involves the detailed design of the replacement and rehabilitation of several structures along multiple highways in Southern Ontario. This report addresses the proposed replacement of the Pettigrew Drain culvert (Site 2-448/C) at Station 16+504 on Highway 6 in the Geographic Township of Eastnor in Bruce County, Ontario. The culvert was formerly a part of GWP 3101-10-00 (Contract 1) but has been subsequently included in GWP 3042-11-00 (Contract 4).

The purpose of the foundation investigation was to explore the subsurface conditions at the location of the proposed culvert replacement by drilling boreholes and carrying out in situ testing and laboratory testing on selected samples. The terms of reference for the scope of work are outlined in the MTO's Request for Proposal and in Golder Associates' proposal P2-1132-0163 dated February 25, 2013 and change order 12-1132-0163-4000-CO3 dated September 16, 2016. The work was carried out in accordance with our Quality Control Plan for Foundation Engineering dated March 26, 2013.

2.0 SITE DESCRIPTION

The subject culvert is situated at Station 16+504 on Highway 6, approximately 400 metres north of Little Pike Bay Road in the Township of Eastnor in Bruce County. The town of Lion's Head is located about 7.0 kilometres northeast of the site. The location of the culvert is shown on the Key Plan, Figure 1.

This section of Highway 6 is currently a two lane, undivided highway with gravel shoulders. It is generally oriented north-south in the vicinity of the subject site. Pettigrew Drain flows in the culvert from west to east beneath Highway 6. The existing corrugated steel (C.S.P.) arch culvert was constructed in 1970.

Dimensions (m)	Obvert Elevation (m)		Construction
	Lt[1]	Rt[1]	
4.26 x 2.59 x 25.6	192.28	192.00	C.S.P.

NOTE: 1. When facing the direction of increasing chainage, Lt and Rt are defined as Left and Right of centreline, respectively.

The banks of Pettigrew Drain and the embankments along Highway 6 near the culvert are grass covered. The drain flows through fields on both sides of Highway 6. Site photographs are provided in Appendix B.

2.1 Site Geology

The project area is located within the Bruce Peninsula physiographic region. This region is typically characterized by shallow soils with bare rock exposed in areas. Surficial silt deposits are mapped as covering most of the area in the vicinity of the site.[1] The quaternary geological mapping indicates that surficial soils consist of silt and clay with minor sand deposits.[2] Geological mapping also indicates that the underlying bedrock consists of sandstone, shale, dolostone and siltstone of the Amabel Formation of Lower Silurian age.[3] Based on information provided on nearby water well records available on the Ministry of Environment and Climate Change website, the bedrock surface in the vicinity of the site is at depths ranging from about 17 to 24 metres.

3.0 INVESTIGATION PROCEDURES

Field work for the investigation was carried out on September 20, 2016, during which time three boreholes were drilled at the approximate locations shown on the Borehole Location Plan, Drawing 1.

The boreholes were drilled using track-mounted D50T drilling equipment supplied and operated by a specialist drilling contractor. Samples of the overburden were typically obtained at depth intervals of 0.75 metres using 50 millimetre outside diameter split spoon sampling equipment in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586). Field vane shear testing was carried out in the saturated fine-grained soils encountered at the site in accordance with ASTM D2573.

The recorded SPT N values are noted on the Record of Borehole sheets. The results of the SPT testing, as presented on the Record of Borehole sheets, Drawing 1 and in Section 4.0 of this report, are unmodified (not standardized for hammer efficiency, borehole diameter, rod length, etc.). The samplers used in the investigation limit the maximum particle size that can be sampled and tested to about 40 millimetres. Therefore, particles or objects that may exist within the soils that are larger than this dimension will not be sampled or represented in the grain size distributions. Larger particle sizes, including cobbles and boulders, may be present in the soils at this site.

Groundwater conditions in the boreholes were observed throughout the drilling operations and piezometers were installed in boreholes 401 and 403 as indicated on the corresponding Record of Borehole sheets. The boreholes were backfilled in accordance with current MTO procedures and Ontario Regulation 903 (as amended).

Field work was monitored on a full-time basis by an experienced member of our staff who located the boreholes in the field, obtained utility locates, monitored the drilling, sampling and in situ testing operations and logged the boreholes. The samples were identified in the field, placed in labelled containers and transported to our London laboratory for further examination and testing. Index and classification tests, consisting of water content determinations, grain size distribution analyses and Atterberg limits determinations, were carried out on selected samples. The results of the testing are shown on the Record of Borehole sheets and in Appendix A.

[1] Chapman, L.J., and Putnam, D.F., 1984: Physiography of Southern Ontario; Ontario Geological Survey, Special Volume 2, 270p. Accompanied by Map. P.2715 (coloured), scale 1:600,000.

[2] Barnett, P.J., Cowan, W.R. and Henry, A.P. 1991: Quaternary Geology of Ontario, southern sheet; Ontario Geological Survey, Map 2556, scale 1:1,000,000.

[3] Ontario Geological Survey 2011. 1:250 000 scale bedrock geology of Ontario; Ontario Geological Survey, Miscellaneous Release---Data 126-revision 1.

The as-drilled borehole locations and ground surface elevations at the borehole locations are shown on the Record of Borehole sheets and on Drawing 1. The table below summarizes the coordinates, ground surface elevations and depths of the boreholes.

Borehole	Location (m)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing	Easting		
BH-401	4 978 593	401 682	192.46	10.36
BH-402	4 978 581	401 673	192.66	10.06
BH-403	4 978 579	401 696	191.13	10.36

4.0 SUBSURFACE CONDITIONS

4.1 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes, together with the results of the in situ testing and the laboratory testing carried out on selected samples, are given on the attached Record of Borehole sheets following the text of this report and in Appendix A. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous samples and observations of drilling resistance and, therefore, may represent transitions between soil types rather than exact planes of geological change. Further, the subsurface conditions will vary between and beyond the borehole locations.

The boreholes drilled at the site generally encountered the existing pavement structure or surficial topsoil overlying embankment fill materials, silty sand, sandy silt, silt and silt to clayey silt.

The locations and elevations of the boreholes, together with the interpreted stratigraphic profile, are shown on Drawing 1. Detailed descriptions of the subsurface conditions encountered in the boreholes are provided on the Record of Borehole sheets and summarized in the following sections.

4.2 Soil Conditions

Asphaltic concrete pavement (asphalt) was encountered at the ground surface in borehole 402 and was found to be 50 millimetres thick. Beneath the asphalt in borehole 402, sand and crushed gravel, interpreted to be granular base from visual and textural examination, was encountered and found to be 250 millimetres thick. Below the granular base, a 460 millimetre thick layer of sand and gravel, interpreted to be granular subbase, was encountered.

Topsoil was encountered beneath the fill at elevation 190.3 metres in borehole 401 and was found to be 160 millimetres thick. Variable amounts of topsoil were also encountered in boreholes 402 and 403 in the fill layers. Materials designated as topsoil in this report were classified solely based on visual and textural evidence. Testing of organic content or for other nutrients was not carried out. Therefore, the use of materials classified as topsoil cannot be relied upon for support and growth of landscaping vegetation.

Various layers of very loose to compact fill, ranging from sand to sandy silt, were encountered in boreholes 401 and 403 at the ground surface and in borehole 402 beneath the pavement structure at elevation 191.9 metres. The fill ranged in thickness from 2.1 to 2.6 metres and exhibited standard penetration test (SPT) N[4] values of 2 to 13 blows per 0.3 metres. The water content of a sample of the fill was measured to be about 6 per cent. A grain size analysis carried out on a sample of the fill is presented on Figure A-1 in Appendix A.

Very loose to loose layers of native deposits, ranging from silt to silty sand, were encountered in boreholes 401 to 403 beneath the silt to clayey silt at elevations ranging from 184.0 to 186.8 metres and in borehole 402 beneath the fill at elevation 189.3 metres. The native granular deposits in these boreholes ranged in thickness from 0.7 to 1.1 metres. Borehole 403 was terminated in native granular deposits after exploring them for about 3.2 metres. Standard penetration test N values ranged from 1 to 6 blows per 0.3 metres and water contents ranged from about 21 to 26 per cent. Grain size analyses carried out on samples of silty sand and silt are presented on Figures A-2 and A-3, respectively, in Appendix A.

Layers of very soft to soft silt to clayey silt were encountered in borehole 401 below the topsoil at elevation 190.2 metres, in borehole 402 below the sandy silt at elevation 188.2 metres, in borehole 403 below the fill at elevation 189.0 metres, and in boreholes 401 and 402 below the silty sand at elevations 186.1 and 185.5 metres, respectively. Boreholes 401 and 402 were terminated in the silt to clayey silt after exploring it for 4.0 and 2.9 metres, respectively. Where the layers were fully penetrated they were found to be between 2 and 5 metres thick in the boreholes. Standard penetration test N values ranged from 0 (weight of the hammer) to 6 blows per 0.3 metres. Undrained shear strengths, as measured by field vane shear testing, ranged from about 12 to 65 kilopascals and the sensitivity of the silt to clayey silt ranged from 1.3 to 4.3. Raw field vane shear strength data are presented on the Record of Borehole sheets. Water contents ranged from about 22 to 29 per cent and are above the liquid limit values. Grain size analyses carried out on samples of silt to clayey silt are presented on Figure A-4 in Appendix A. The results of Atterberg limits tests are shown on Figure A-5 and indicate the soil is of low plasticity.

4.3 Groundwater Conditions

Groundwater conditions were observed during and on completion of drilling and sampling and groundwater observation piezometers were installed in boreholes 401 and 403. The installation details are provided on the corresponding Record of Borehole sheets following the text of this report. Groundwater was encountered at depths of 3.0 and 4.6 metres, or at elevations ranging from 188.1 to 187.9 metres during drilling on September 20, 2016. The water level in Pettigrew Drain was measured at 189.50 metres on September 20, 2016. The Preliminary General Arrangement drawing indicated that the water level in Pettigrew Drain was measured at elevation 190.14 metres in June 2013. On October 25, 2016, the water level in the piezometers installed in boreholes 401 and 403 were about 2.16 and 0.61 metres below ground surface or at about elevation 190.30 and 190.52 metres, respectively. On November 11, 2016, the water level in the piezometers installed in boreholes 401 and 403 were about 2.44 and 0.81 metres below ground surface or at about elevation 190.02 and 190.32 metres, respectively. A summary of the encountered and measured groundwater levels is provided in the table below.

[4] The SPT N value is defined as the number of blows required by a 63.5 kilogram hammer dropped from a height of 760 millimetres to drive a split spoon sampler a distance of 300 millimetres into the soil after having first penetrated 150 millimetres.

Borehole	Ground Surface Elevation (m)	Encountered Groundwater Elevation (m)	Measured Groundwater Level (m)	
			October 25, 2016	November 11, 2016
BH-401	192.46	187.9	190.30	190.02
BH-402	192.66	188.1	-	-
BH-403	191.13	188.1	190.52	190.32

The above-noted encountered water levels are not considered to be representative of the long-term, stabilized groundwater conditions. Based on the observed groundwater levels, the change in soil colour from brown to grey and the surrounding topography, the groundwater level is inferred to typically be at about elevation 190.5 metres. The groundwater levels are expected to fluctuate seasonally and are expected to be higher during periods of sustained precipitation or during spring snow melt conditions.

5.0 MISCELLANEOUS

The investigation was carried out using equipment supplied and operated by London Soil Test Ltd., an Ontario Ministry of Environment and Climate Change licensed well contractor. The field operations were supervised by Mr. Daniel Hyland, E.I.T. under the direction of the Field Investigation Manager, Mr. Brett Thorner, P.Eng. The laboratory testing was carried out at Golder Associates' London laboratory under the direction of Mr. Michael Arthur. The laboratory is an accredited participant in the MTO Soil and Aggregate Proficiency Program and is certified by the Canadian Council of Independent Laboratories for testing Types C and D aggregates. This report was prepared by Mr. Daniel Hyland, E.I.T. under the direction of the Project Engineer Ms. Dirka U. Prout, P.Eng. The report was reviewed by Mr. W.M. Kellestine, P.Eng., a Senior Consultant with Golder Associates and Dr. Storer J. Boone, P.Eng, a Principal with Golder Associates. Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment, conducted an independent quality review of the report.

GOLDER ASSOCIATES LTD.

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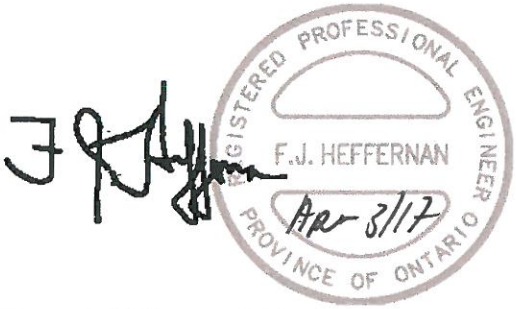

Fintan J. Heffernan, P.Eng.
MTO Designated Contact

DH/DUP/WMK/SJB/FJH/cr

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LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d:

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60º cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

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

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

Density Index / Relative Density	N Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils

Consistency

	c_u, s_u kPa	c_u, s_u psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel / Silty Clay with sand / Clayey Silt with sand

LIST OF SYMBOLS

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

I. GENERAL

π	3.1416
ln x,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

* Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_α	secondary compression index
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
c_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan\delta$
c′	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p′	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes: 1 $\tau = c' + \sigma' \tan\phi'$

2 shear strength = (compressive strength)/2

Golder Associates
London, Ontario

RECORD OF BOREHOLE No BH-401

1 OF 1

METRIC

PROJECT 12-1132-0163
W.P. 3042-11-00
DIST ____ HWY 6
DATUM GEODETIC
LOCATION N 4978592.7 , E 401682.2
BOREHOLE TYPE POWER AUGER, HOLLOW STEM
DATE September 20, 2016
ORIGINATED BY DH
COMPILED BY ZJB/LMK
CHECKED BY ____

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
192.46	GROUND SURFACE					
0.00	FILL, sand, some silt, some gravel Loose Brown	1	SS	8	192	
191.09						
1.37	FILL, silty sand, some gravel Very loose Brown	2	SS	2	191	
190.33						
2.13	TOPSOIL, silty					
2.29	Black	3	SS	3	190	
	SILT to CLAYEY SILT, trace to some sand Very soft to soft Brown to grey at about elev. 189.5m	4	SS	1	189	0 1 86 13
		5	SS	1	188	
186.82						
5.64	SILTY SAND, trace clay Very loose Grey	6	SS	2	187	0 48 45 7
186.12						
6.34	SILT to CLAYEY SILT, some sand Very soft to stiff Grey	7	SS	WH	186	
		8	SS	WH	185	
182.10					184	
10.36	END OF BOREHOLE				183	

Groundwater encountered at about elev. 187.9m during drilling on September 20, 2016.

Water level measured in piezometer at elev. 188.63m on September 20, 2016.

Water level measured in piezometer at elev. 190.30m on October 25, 2016.

Water level measured in piezometer at elev. 190.02m on November 11, 2016.

Granular Bentonite
Cuttings
Filter Sand
Piezometer
Caved Material

DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100)
SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB VANE
(20 40 60 80 100)

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

UNIT WEIGHT γ kN/m³

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

LDN_MTO_06 1211320163-4000.GPJ LDN_MTO.GDT 19/12/16

Golder Associates
London, Ontario

RECORD OF BOREHOLE No BH-402 1 OF 1 METRIC

PROJECT 12-1132-0163 | W.P. 3042-11-00 | DIST ____ HWY 6 | DATUM GEODETIC

LOCATION N 4978580.9 , E 401673.1 | BOREHOLE TYPE POWER AUGER, HOLLOW STEM | DATE September 20, 2016

ORIGINATED BY DH | COMPILED BY ZJB/LMK | CHECKED BY ____

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
192.66	PAVEMENT SURFACE										
0.05	ASPHALT										
0.30	FILL, sand and crushed gravel Brown										
191.90	FILL, sand and gravel, some silt, with cobbles Brown										
0.76			1	SS	12		192				
	FILL, sand, some silt, trace gravel, trace clay, with topsoil pockets Loose to compact Brown		2	SS	13		191		○		3 77 15 5
			3	SS	7		190				
189.31			4	SS	6						
3.35	SANDY SILT, some clay, trace gravel Very loose to loose Brown to grey at about elev 189.0m		5	SS	1		189				
188.24						▽					
4.42	SILT to CLAYEY SILT Very soft to firm Grey		6	SS	1		188		⊢○		0 12 76 12
							187	+ 1.5 + 1.5			
186.26			7	SS	1						
6.40	SILTY SAND, trace clay Very loose Grey						186				
185.50								+ 1.8			
7.16	SILT to CLAYEY SILT, some sand Very soft to stiff Grey		8	SS	WH		185		⊢○		0 10 74 16
							184	+ 2.0 + 1.5			
			9	SS	6		183				
182.60								2.8			
10.06	END OF BOREHOLE Groundwater encountered at about elev. 188.1m during drilling on September 20, 2016.										

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

LDN_MTO_06 1211320163-4000.GPJ LDN_MTO.GDT 19/12/16

Golder Associates
London, Ontario

RECORD OF BOREHOLE No BH-403 1 OF 1 METRIC

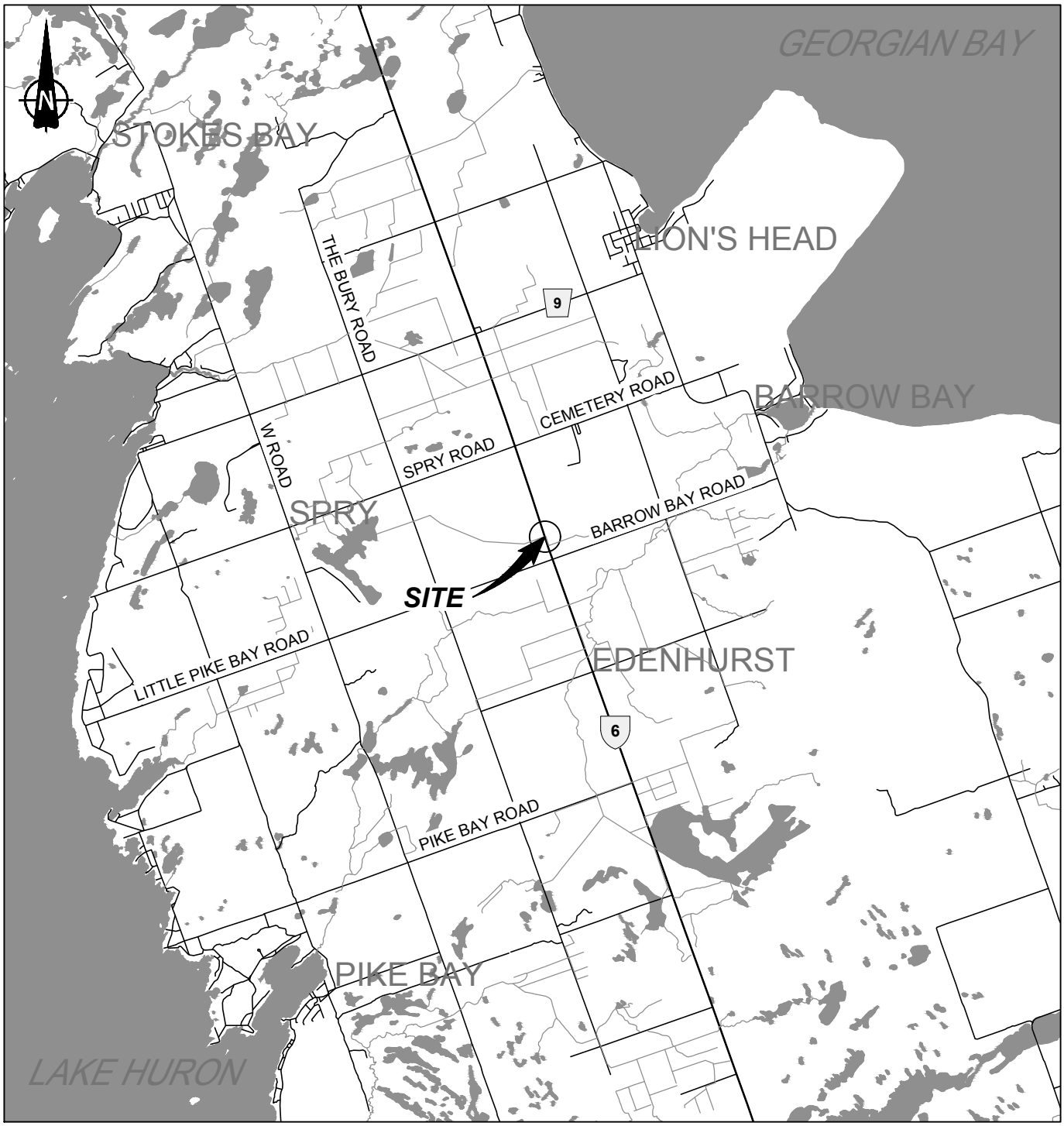
PROJECT 12-1132-0163 | W.P. 3042-11-00 | LOCATION N 4978578.7 , E 401695.7 | ORIGINATED BY DH
DIST ____ HWY 6 | BOREHOLE TYPE POWER AUGER, HOLLOW STEM | COMPILED BY ZJB/LMK
DATUM GEODETIC | DATE September 20, 2016 | CHECKED BY ____

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
191.13	GROUND SURFACE										
0.00	FILL, sandy silt, with topsoil layers Loose Brown and grey		1	SS	8		191				
			2	SS	6						
189.00							189				
2.13	SILT to CLAYEY SILT, trace to some sand, with silty sand layers Very soft to stiff Grey		3	SS	2				o		0 2 71 17
			4	SS	1		188				
							187	1.6, 3.2			
			5	SS	1		186	1.6, 4.3			
			6	SS	1		185				
184.00							184	2.4			
7.13	SILT, trace clay, some sand Very loose Grey		7	SS	1				o		0 14 78 8 (NON-PLASTIC)
182.44							183				
8.69	SILTY SAND, trace clay Loose Grey		8	SS	3		182				
180.77							181				
10.36	END OF BOREHOLE Groundwater encountered at about elev. 188.1m during drilling on September 20, 2016. Water level measured in piezometer at elev. 187.34m on September 20, 2016. Water level measured in piezometer at elev. 190.52m on October 25, 2016. Water level measured in piezometer at elev. 190.32m on November 11, 2016.										

Granular Bentonite
Cuttings
Piezometer
Caved Material

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

LDN_MTO_06 1211320163-4000.GPJ LDN_MTO.GDT 19/12/16



SCALE
0 2000 4000m
1:100,000

REFERENCE

PLAN BASED ON CANMAP STREETFILES V.2008.5.

NOTE

THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ACCOMPANYING TEXT.

PROJECT

PETTIGREW DRAIN CULVERT, SITE 2-448/C
HIGHWAY 6
GWP 3042-11-00

TITLE

KEY PLAN

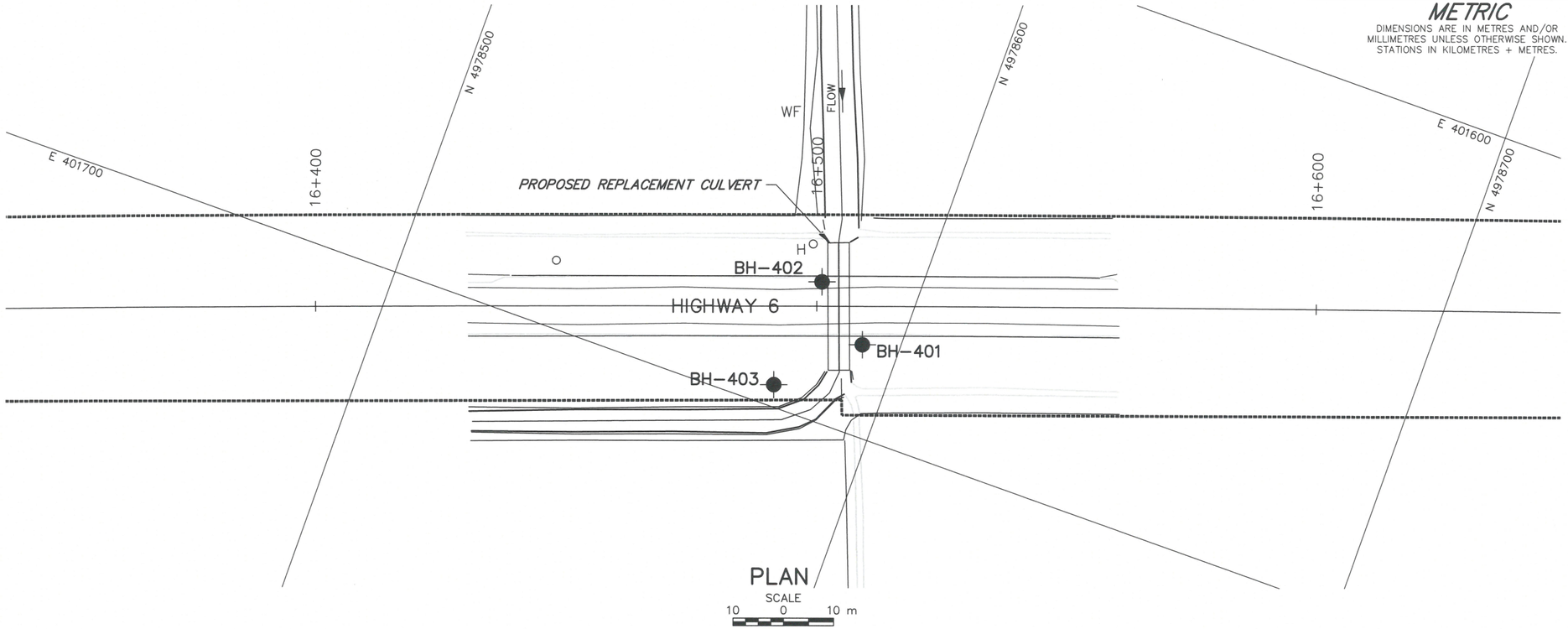
Golder Associates

PROJECT No.		12-1132-0163	FILE No.	1211320163-4000-F04001
			SCALE AS SHOWN	REV. 0
CADD	LMK	Oct. 24/16		
CHECK				

FIGURE 1

Drawing file: 1211320163-4000-F04001.dwg Oct 27, 2016 - 11:16am

MINISTRY OF TRANSPORTATION, ONTARIO



PLAN
SCALE
10 0 10 m

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
WP No. 3042–11–00

SHEET

CULVERT REPLACEMENT

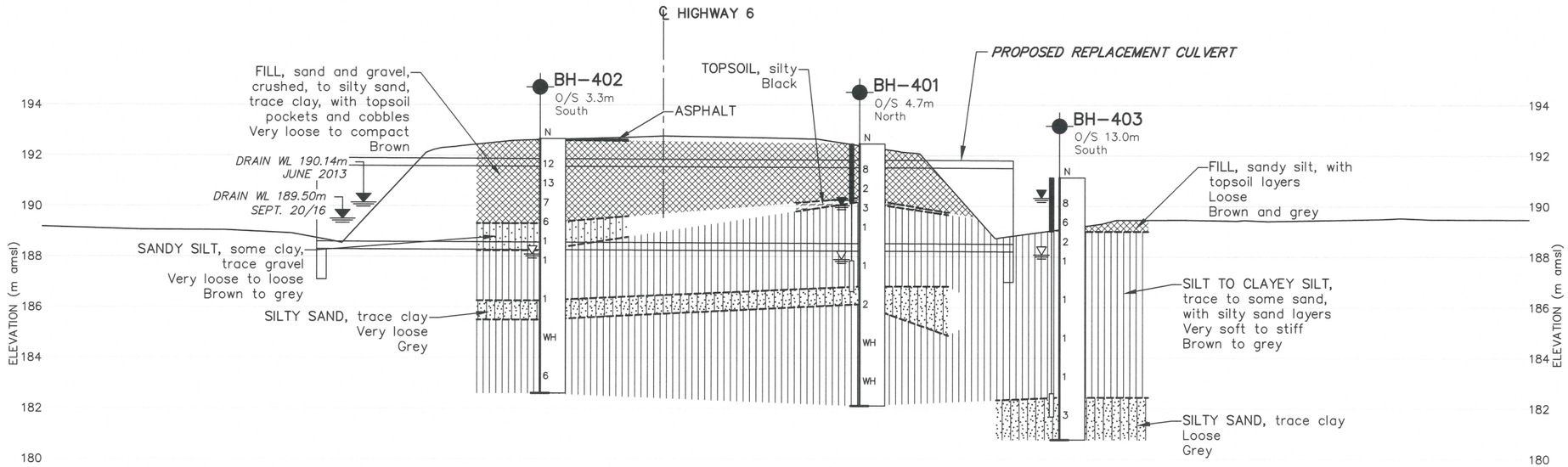
HIGHWAY 6 SITE No. 2–448
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates Ltd.
LONDON, ONTARIO, CANADA

KEY PLAN

LEGEND

- Borehole – Current Investigation
- Seal
- Piezometer
- N — Standard Penetration Test Value
- 16 — Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL measured on November 11, 2016
- WL encountered during drilling



PROFILE ALONG ℄ OF CULVERT
HORIZONTAL SCALE 2 0 2 m
VERTICAL SCALE 2 0 2 m

No.	ELEVATION	CO–ORDINATES (MTM ZONE 10)	
		NORTHING	EASTING
BH–401	192.46	4 978 592.7	401 682.2
BH–402	192.66	4 978 580.9	401 673.1
BH–403	191.13	4 978 578.7	401 695.7

NOTES

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

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

REFERENCE

Base plans provided in digital format by Stantec.

LICENSED PROFESSIONAL ENGINEER D. G. PROUT Mar 31/17 PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER F. J. HEFFERNAN Mar 31/17 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

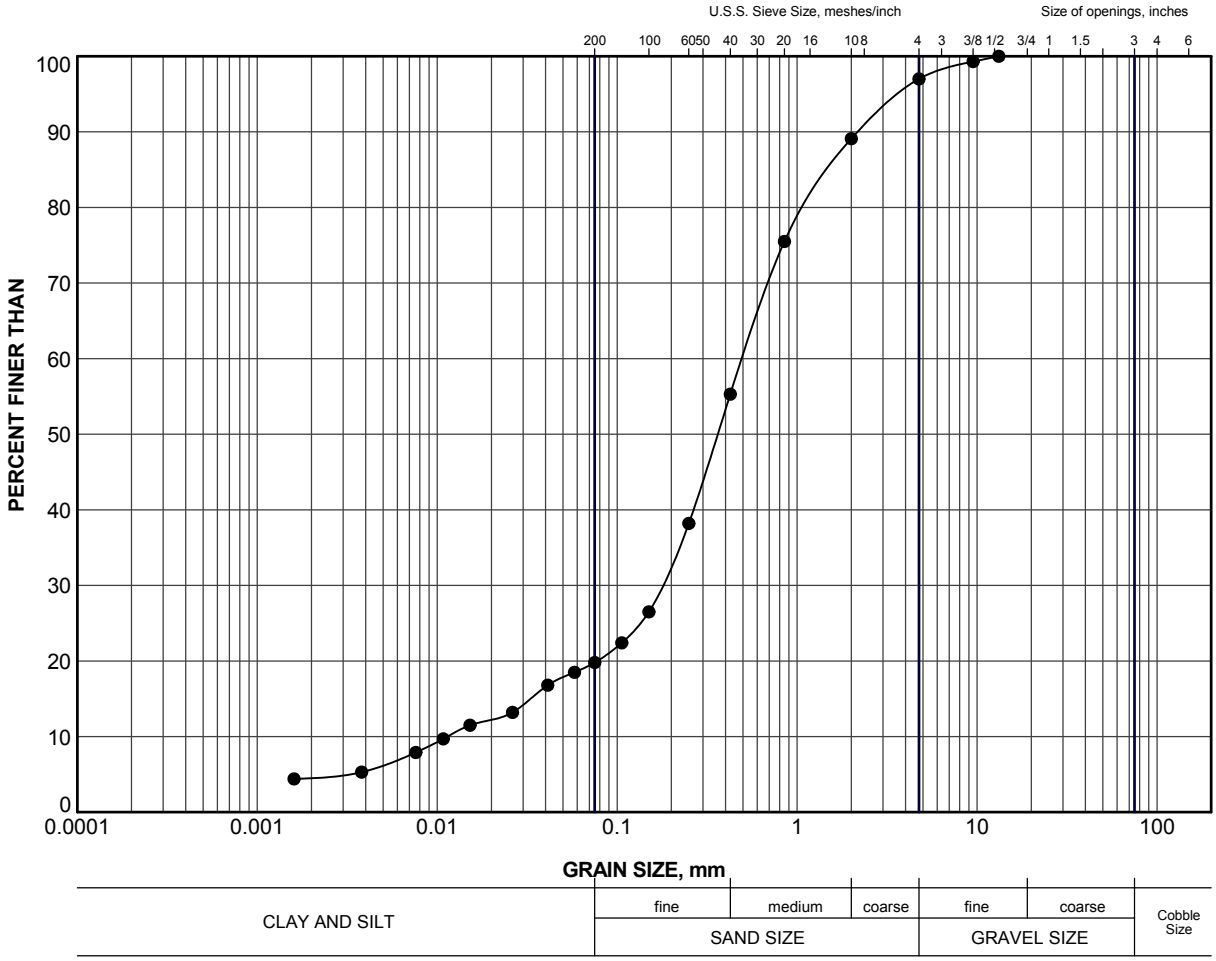
Geocres No. 41A–242

HWY. 6		PROJECT NO. 12–1132–0163	DIST.
SUBM'D. BT	CHKD. DH	DATE: Mar 23/17	SITE: 2–448
DRAWN: LMK	CHKD. DUP	APPD. FJH	DWG. 1

PLOT DATE: March 31, 2017
FILENAME: \\golder.gds\gal\London\active\2012\1132 – Geo\1132–0100\12–1132–0163 STANTEC–FDNS–MEGA CULVERTS–3011–E–0041\Drafting\AutoCAD files\12113201630163–4000–004001.dwg

APPENDIX A

Laboratory Test Data



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-402	2	190.9

PROJECT

PETTIGREW DRAIN CULVERT, SITE 2-448/C
HIGHWAY 6
GWP 3042-11-00

TITLE

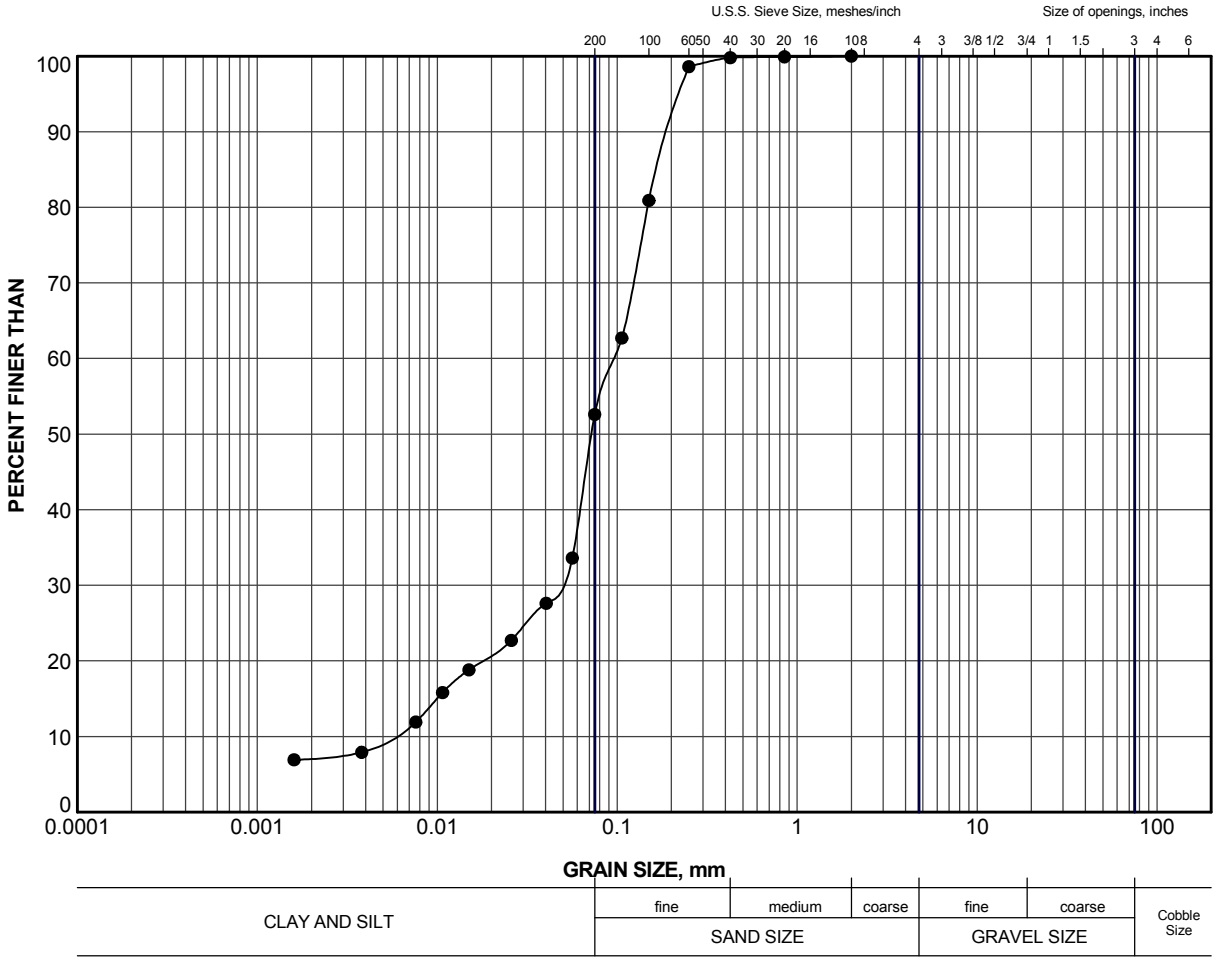
GRAIN SIZE DISTRIBUTION

FILL

Golder Associates

PROJECT No.		12-1132-0163	FILE No.	1211320163-4000-F040A1
			SCALE	N/A REV.
DRAWN	ZJB/LMK	Oct 24/16		
CHECK			**FIGURE**	**A-1**

LDN_MTO_GSD_GLDR_LDN.GDT 18/10/16



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-401	6a	186.2

PROJECT

PETTIGREW DRAIN CULVERT, SITE 2-448/C
HIGHWAY 6
GWP 3042-11-00

TITLE

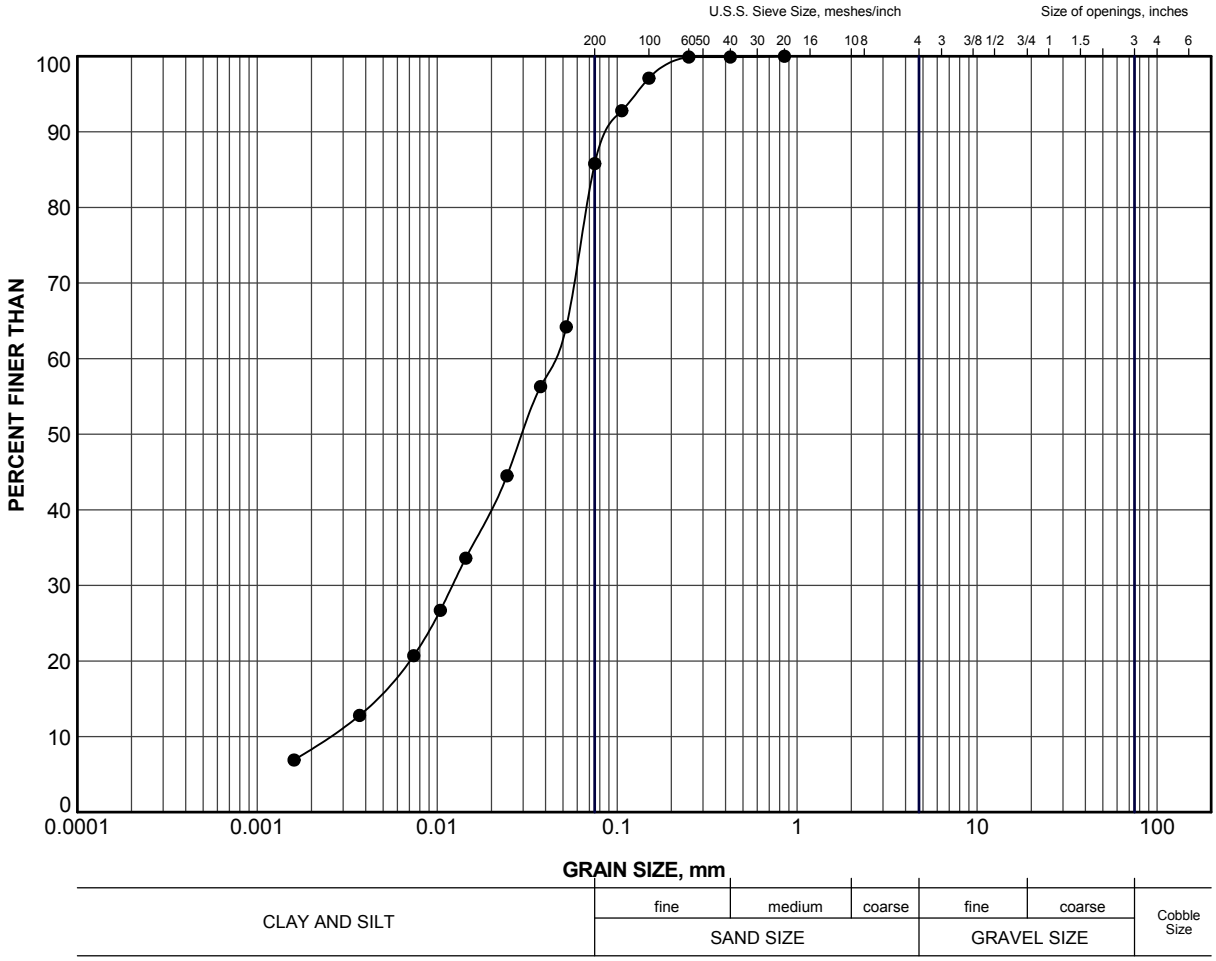
GRAIN SIZE DISTRIBUTION

SILTY SAND

Golder Associates

PROJECT No.		12-1132-0163	FILE No.	1211320163-4000-F040A2
			SCALE	N/A REV.
DRAWN	ZJB/LMK	Oct 24/16		
CHECK			**FIGURE**	**A-2**

LDN_MTO_GSD_GLDR_LDN.GDT 18/10/16



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-403	7	183.3

PROJECT

PETTIGREW DRAIN CULVERT, SITE 2-448/C
HIGHWAY 6
GWP 3042-11-00

TITLE

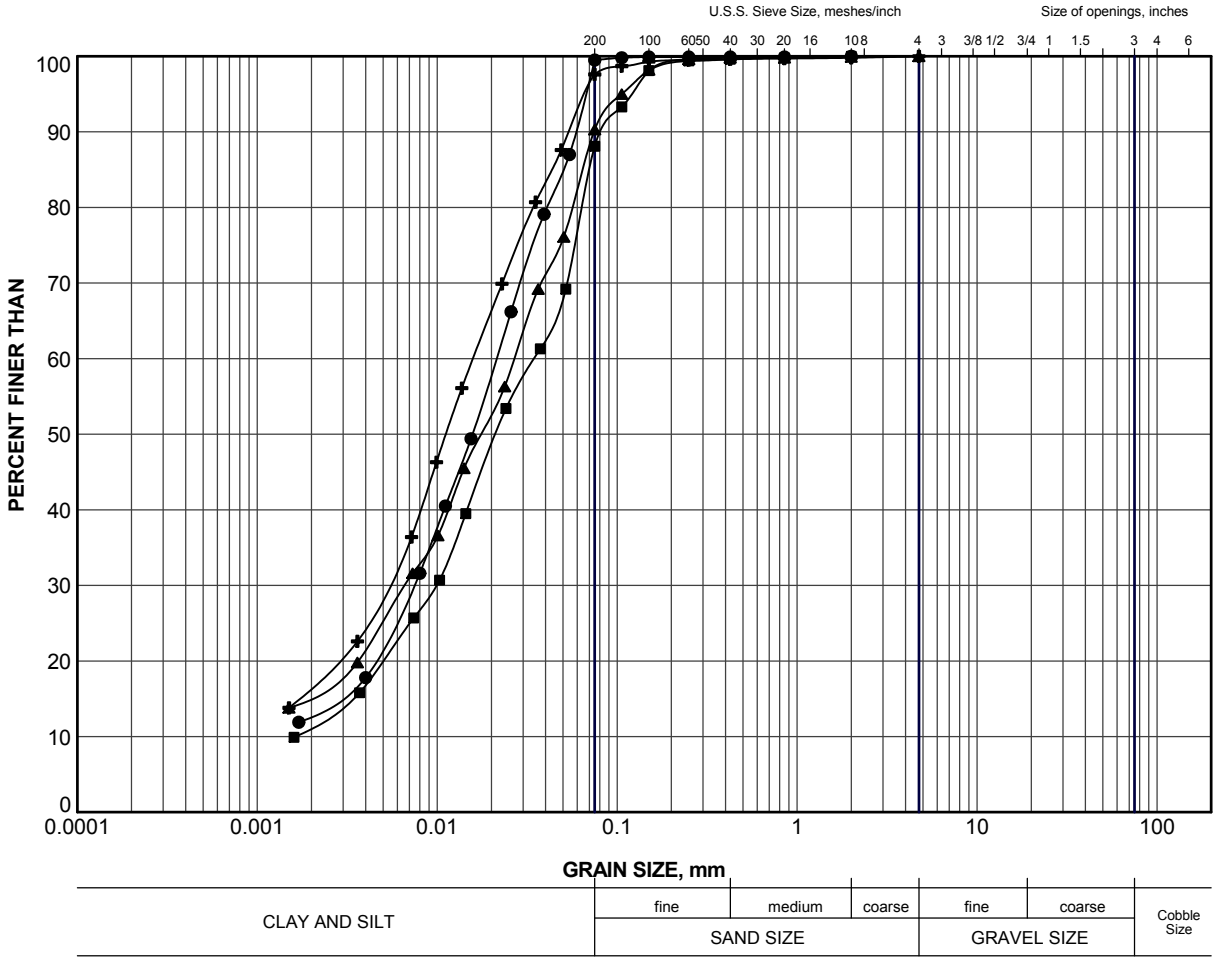
GRAIN SIZE DISTRIBUTION

SILT

Golder Associates

PROJECT No.		12-1132-0163	FILE No.1211320163-4000-F040A3
			SCALE N/A REV.
DRAWN	LMK	Nov 17/16	
CHECK			**FIGURE A-3**

LDN_MTO_GSD_GLDR_LDN.GDT 17/11/16



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	BH-401	4	189.2
■	BH-402	6	187.6
▲	BH-402	8	184.8
✚	BH-403	3	188.8

PROJECT

PETTIGREW DRAIN CULVERT, SITE 2-448/C
HIGHWAY 6
GWP 3042-11-00

TITLE

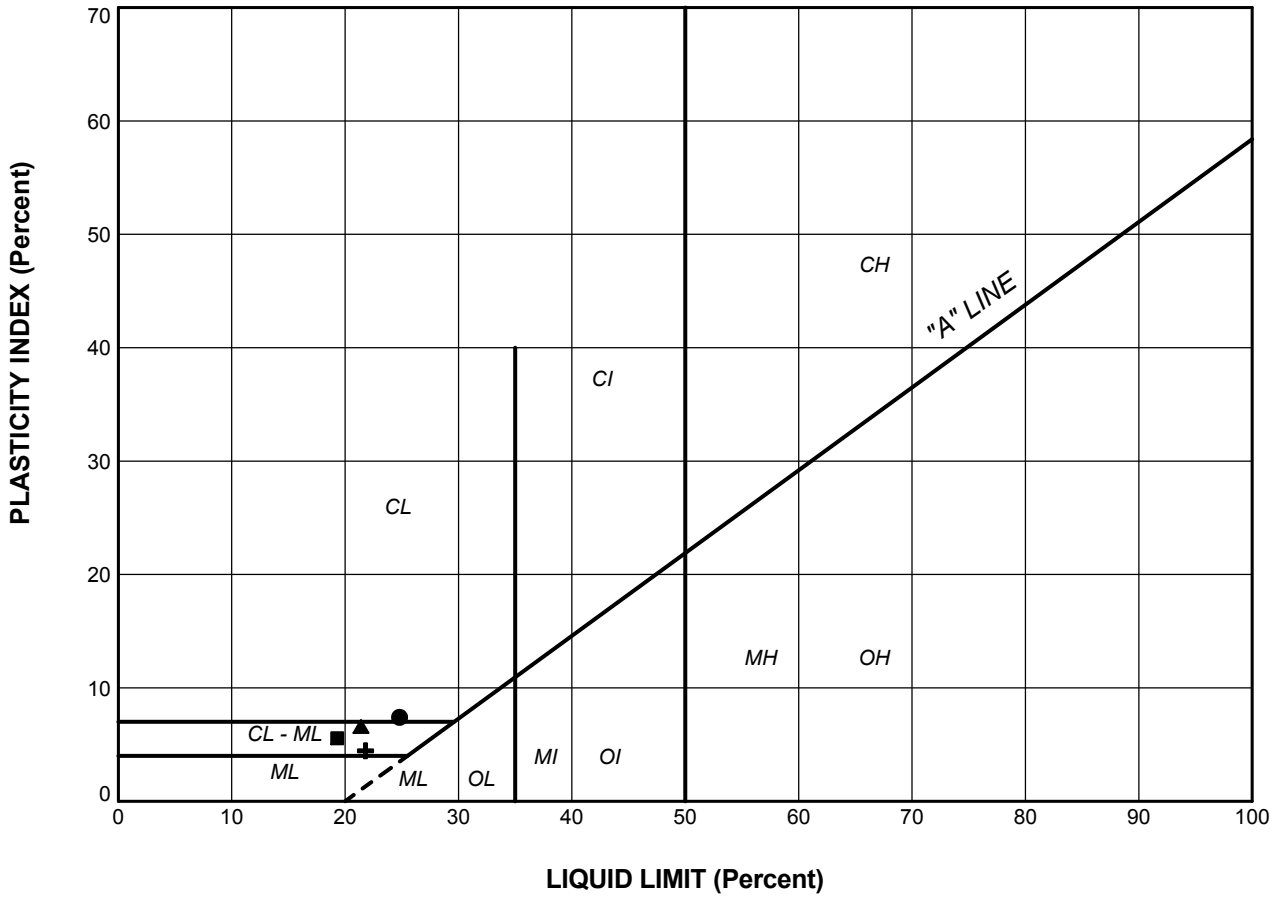
GRAIN SIZE DISTRIBUTION

SILT TO CLAYEY SILT

Golder Associates

PROJECT No.	12-1132-0163		FILE No. 1211320163-4000-F040A4
			SCALE N/A REV.
DRAWN	LMK	Nov 17/16	
CHECK			**FIGURE A-4**

LDN_MTO_GSD_GLDR_LDN.GDT 17/11/16



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
SILT					
●	BH-401	4	24.8	17.4	7.4
■	BH-402	6	19.3	13.8	5.6
▲	BH-402	8	21.4	14.8	6.6
✚	BH-403	3	21.8	17.4	4.5

PROJECT
PETTIGREW DRAIN CULVERT, SITE 2-448/C
HIGHWAY 6
GWP 3042-11-00

TITLE
PLASTICITY CHART

Golder Associates

PROJECT No.	12-1132-0163		FILE No.1211320163-4000-F040A5
			SCALE N/A REV.
DRAWN	ZJB/LMK	Oct 24/16	
CHECK			**FIGURE A-5**

LDN_MTO_PI GLDR_LDN.GDT 18/10/16

APPENDIX B

Site Photographs

Photograph 1: West elevation (inlet) of Culvert Site 2-448/C.

Photograph 2: East elevation (outlet) of Culvert Site 2-448/C.

Photograph 3: Looking north along Highway 6 towards Culvert Site 2-448/C.

n:\active\2012\1132 - geo\1132-0100\12-1132-0163 stantec-fdns-mega culverts-3011-e-0041\ph 4000-gwp 3042-11-00\rpts\r04 2-448-c pettigrew drain\1211320163-4000-r04 apr 3 17 (final) app b - photos.docx

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