



December 3, 2014

FOUNDATION INVESTIGATION REPORT

**HIGHWAY 540 KAGAWONG TRIBUTARY CREEK BRIDGE, SITE 49-073
TOWNSHIP OF BILLINGS, MANITOULIN ISLAND, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5057-07-00, WP 5262-10-01**

Submitted to:
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GEOCRES NO. 41G-18

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REPORT





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**FOUNDATION REPORT
HIGHWAY 540 KAGAWONG TRIBUTARY CREEK BRIDGE
SITE 49-073**

PART A

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the replacement of the Kagawong Tributary Creek Bridge (Site 49-073) in the Township of Billings on Manitoulin Island, Ontario. The Key Plan showing the general location of this section of Highway 540 and the location of the investigated area are shown on Drawing 1.

The purpose of this investigation is to establish the subsurface conditions at the location of the bridge by borehole drilling, in situ testing and laboratory testing on selected samples.

2.0 SITE DESCRIPTION

The Kagawong Tributary Creek Bridge is located on Highway 540 in Kagawong, Ontario. The land use in the area is generally rural (i.e., farm land) with a few residences in the vicinity of the site.

In general, the topography in the area of the overall project limits is flat. The banks adjacent to the creek are gently sloping down from the roadway embankment towards the creek and are vegetated with grass. The creek flows from south to north and is approximately 6.5 m wide at the bridge location. A 300 mm diameter steel pipe has been installed along the south side of the bridge, fully spanning the creek. Photographs taken at the site are included following the text of the report.

The existing bridge is 6 m long and 12 m wide and the highway grade at the bridge is at about Elevation 214.1 m. The creek water level was measured by Golder on May 28, 2014 at Elevation 213.0 m.

3.0 INVESTIGATION PROCEDURES

The fieldwork for the investigation was carried out between May 26 and 28, 2014, during which time a total of six boreholes (Boreholes KC-1 to KC-6) were advanced at the locations shown on Drawing 1.

The field investigation was carried out using a truck-mounted CME-55 drill rig supplied and operated by Landcore Drilling of Sudbury, Ontario. The boreholes were advanced through the overburden using 108 mm inside diameter hollow-stem augers. Soil samples were obtained at intervals of depth of about 0.75 m, using a 50 mm outer diameter split-spoon sampler, operated by an automatic hammer on the drill rig, in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586-08a). Samples of the bedrock were obtained using NW casing and 'NQ' size rock core barrels in each of the boreholes. The groundwater levels in the open boreholes were observed during the drilling operations as described on the Record of Borehole sheets in Appendix A. The boreholes were backfilled upon completion in accordance with Ontario Regulation 903 (as amended).

The fieldwork was supervised throughout by a member of our technical staff who: located the boreholes; arranged for the clearance of underground services; supervised the drilling and sampling operations; logged the boreholes; and examined and cared for the soil and bedrock samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Sudbury Geotechnical Laboratory where the samples underwent further visual examination and laboratory testing. Classification testing (water contents and



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grain size distribution) was carried out on selected soil samples. In addition, uniaxial compressive strength (UCS) testing was carried out on selected specimens of the bedrock core recovered from the boreholes. All of the geotechnical laboratory tests were carried out according to MTO LS standards. The results of the laboratory testing are included on the Record of Borehole sheets in Appendix A and on the figures contained in Appendix B.

A sample of the creek water was obtained using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters.

The as-drilled borehole locations and ground surface elevations were measured and surveyed by a member of our technical staff, referenced to stations on the highway. The MTM NAD 83 northing and easting coordinates, ground surface elevations referenced to Geodetic datum and borehole depths at each borehole location are presented on the Record of Borehole sheets in Appendix A and are summarized below.

Borehole	Location (m)		Ground Surface Elevation (m)	Borehole Depth (incl. bedrock core) (m)
	Northing	Easting		
KC-1	5084705.4	323531.7	214.3	3.0
KC-2	5084709.5	323550.3	214.1	4.7
KC-3	5084717.4	323548.1	214.1	4.4
KC-4	5084713.5	323557.5	214.1	4.6
KC-5	5084721.3	323556.1	214.1	4.5
KC-6	5084724.1	323573.7	214.1	3.0

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on surficial geology mapping from the Ministry of Natural Resources¹, the site is located within a glaciolacustrine deposit consisting of silt and clay.

Based on bedrock geology mapping from the Ministry of Natural Resources², the bedrock in the area consists of shale and limestone of the Georgian Bay Formation.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions as encountered in the boreholes advanced for this investigation, together with the results of the laboratory tests carried out on selected soil samples, are given on the attached Record of Borehole and Drillhole sheets in Appendix A. The results of the laboratory testing are provided in Appendix B. The results of the analytical testing on the sample of creek water are summarized in Table B1 in Appendix B. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred

¹ Ministry of Natural Resources, electronic mapping obtained 2014, MRD128, 2007

² Ministry of Natural Resources, electronic mapping obtained 2014, MRD219, 2006



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from non-continuous sampling, observations of drilling progress and the results of SPTs. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations. The inferred soil stratigraphy based on the results of the boreholes is shown in profile on Drawing 1 and in cross-sections on Drawing 2.

A detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Embankment Fill

A 200 mm to 300 mm thick layer of asphalt was encountered at ground surface in each of the boreholes.

Embankment fill between 1.1 m and 1.3 m thick was encountered below the asphalt in each of the boreholes. The embankment fill generally consisted of brown sand and gravel to gravelly sand with a 0.1 m and 0.2 m thick layer of clayey silt fill encountered at the bottom of Boreholes KC-1 and KC-2, respectively.

Standard Penetration Test (SPT) 'N'-values in the embankment fill range between 10 blows and 28 blows per 0.3 m of penetration indicating a compact relative density.

Grain size distribution tests were carried out on five samples of the embankment fill and the results are shown on Figure B1 in Appendix B.

The natural water content measured on samples of the fill is between 2 per cent and 5 per cent.

4.2.2 Bedrock/Refusal

Bedrock was cored in all of the boreholes and the bedrock surface depths and elevations are presented below.

Borehole No.	Depth to Bedrock (m)	Bedrock Surface Elevation (m)	Notes
KC-1	1.5	212.8	Bedrock Cored for 1.5 m
KC-2	1.4	212.7	Bedrock Cored for 3.3 m
KC-3	1.3	212.8	Bedrock Cored for 3.1 m
KC-4	1.5	212.6	Bedrock Cored for 3.1 m
KC-5	1.4	212.7	Bedrock Cored for 3.1 m
KC-6	1.5	212.6	Bedrock Cored for 1.5 m

The retrieved bedrock core is described as a fine grained, slightly weathered, grey, dolomitic limestone, as presented in the Record of Drillhole sheets in Appendix A. Clay/silt seams/lenses up to about 25 mm thick were encountered in Boreholes KC-4 and KC-5 at the depths noted on the drillhole sheets. Photographs of the retrieved bedrock core samples are shown on Figure B2 in Appendix B.

The Total Core Recovery of the bedrock cored in all boreholes is 100 per cent except at the bottom run in Borehole KC-2 which is 48 per cent, attributed to the loss of the lower portion of bedrock due to the presence of



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a 25 mm clay/silt lens at 4.2 m depth. The Rock Quality Designation measured on the core samples ranges from 29 per cent to 80 per cent, indicating a rock mass of poor to good quality as per Table 3.10 of the Canadian Foundation Engineering Manual (CFEM, 2006)³.

Laboratory Uniaxial Compressive Strength (UCS) testing was carried out on four core samples of the bedrock and the laboratory test sheet are presented in Appendix B. The UCS values are presented on the Record of Drillhole sheets and are summarized below and the test results indicate that the bedrock is strong to very strong as per Table 3.5 of the CFEM (2006).

Borehole	Depth/Elevation (m)	UCS (MPa)
KC-2	1.7/212.4	135
KC-3	1.8/212.3	122
KC-4	2.1/212.0	86
KC-5	2.0/212.1	73

4.2.3 Groundwater Conditions

Unstabilized groundwater levels measured in the open boreholes upon completion of drilling are summarized below. The water level in the creek was at Elevation 213.0 m measured on May 28, 2014.

Borehole No.	Depth to Groundwater Level Below Ground Surface (m)	Groundwater Elevation (m)
KC-1	1.3	213.0
KC-2	1.1	213.0
KC-3	1.1	213.0
KC-4	1.2	212.9
KC-5	1.1	213.0
KC-6	1.3	212.8

Groundwater levels in the area are subject to seasonal fluctuations and to fluctuations after precipitation events and snowmelt.

5.0 CLOSURE

The field drilling program was supervised by Mr. Mathew Riopelle and this report was prepared by Mr. André Bom, P.Eng. Mr. Jorge Costa, P.Eng., Golder's Designated MTO Contact for this project, carried out a quality control review and reviewed the technical aspects of the report.

³ Canadian Geological Society, 2003. Canadian Foundation Engineering Manual, 4th Edition.



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SITE 49-073**

Report Signature Page

GOLDER ASSOCIATES LTD.



André Bom, P.Eng., PMP
Geotechnical Engineer

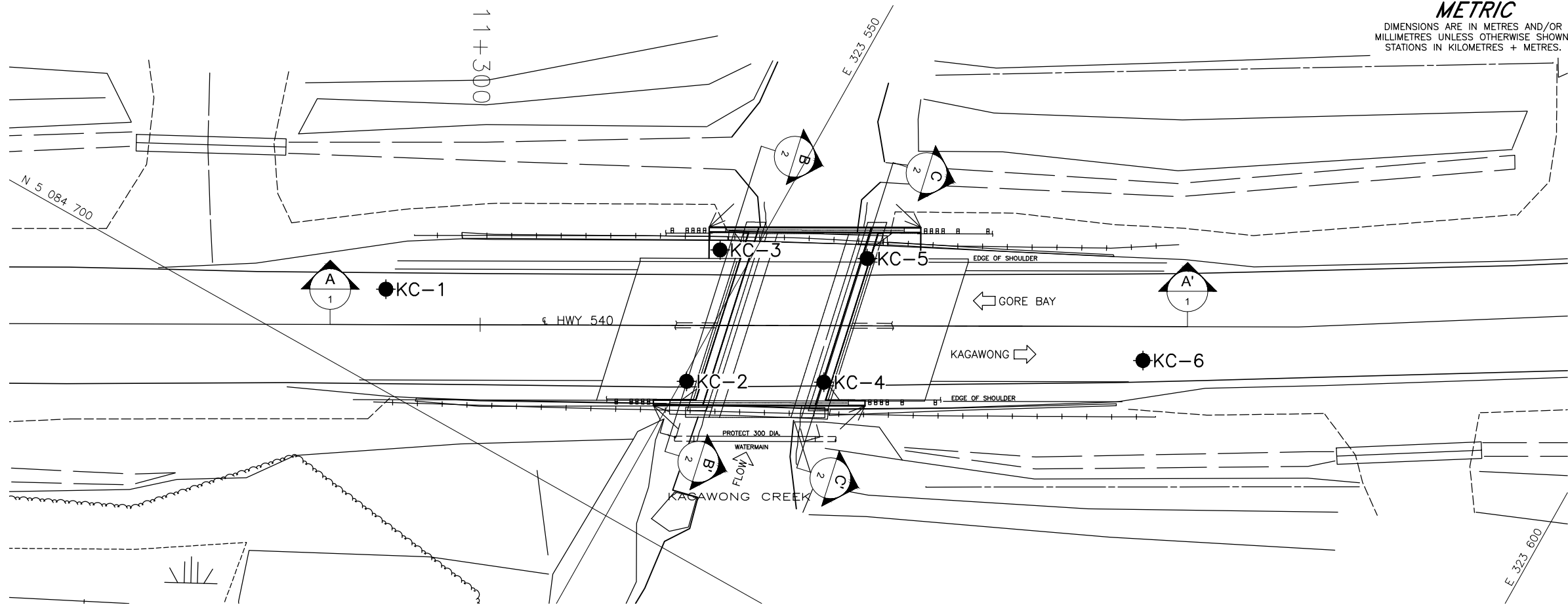


Jorge M.A. Costa, P.Eng.
Designated MTO Contact, Principal

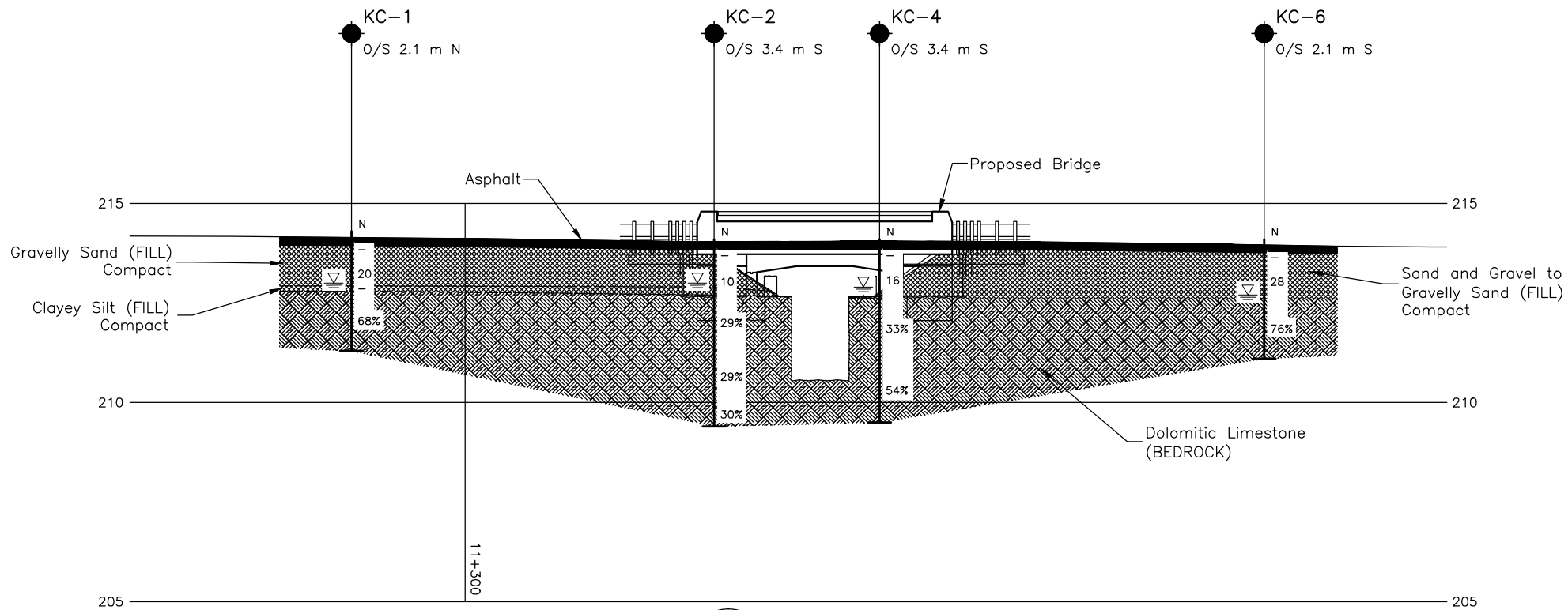
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PLAN
SCALE
3 0 3 6 m



A-A'
1

PROFILE

HORIZONTAL SCALE
3 0 3 6 m
1.5 0 1.5 3 m
VERTICAL SCALE

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

CONT No.
WP No.5262-10-01

HIGHWAY 540
KAGAWONG CREEK BRIDGE
BORE-HOLE LOCATIONS AND SOIL STRATA



KEY PLAN

LEGEND

- Borehole - Current Investigation
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)
- WL upon completion of drilling

BOREHOLE CO-ORDINATES

No.	ELEVATION	NORTHING	EASTING
KC-1	214.3	5084705.4	323531.7
KC-2	214.1	5084709.5	323550.3
KC-3	214.1	5084717.4	323548.1
KC-4	214.1	5084713.5	323557.5
KC-5	214.1	5084721.3	323556.1
KC-6	214.1	5084724.1	323573.7

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

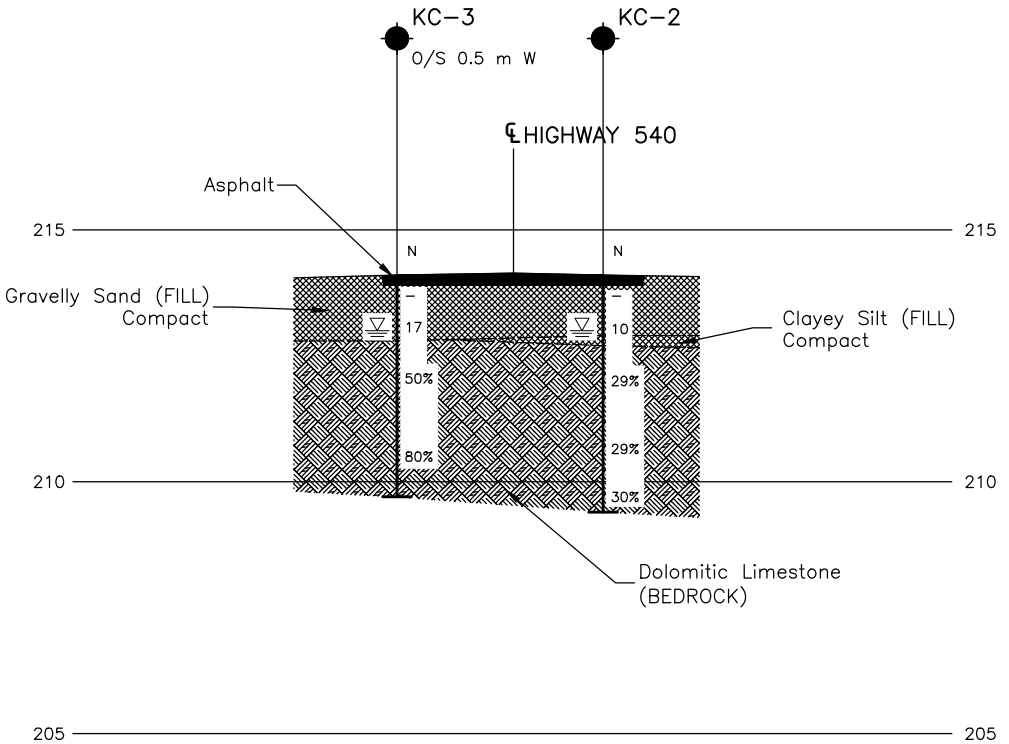
The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

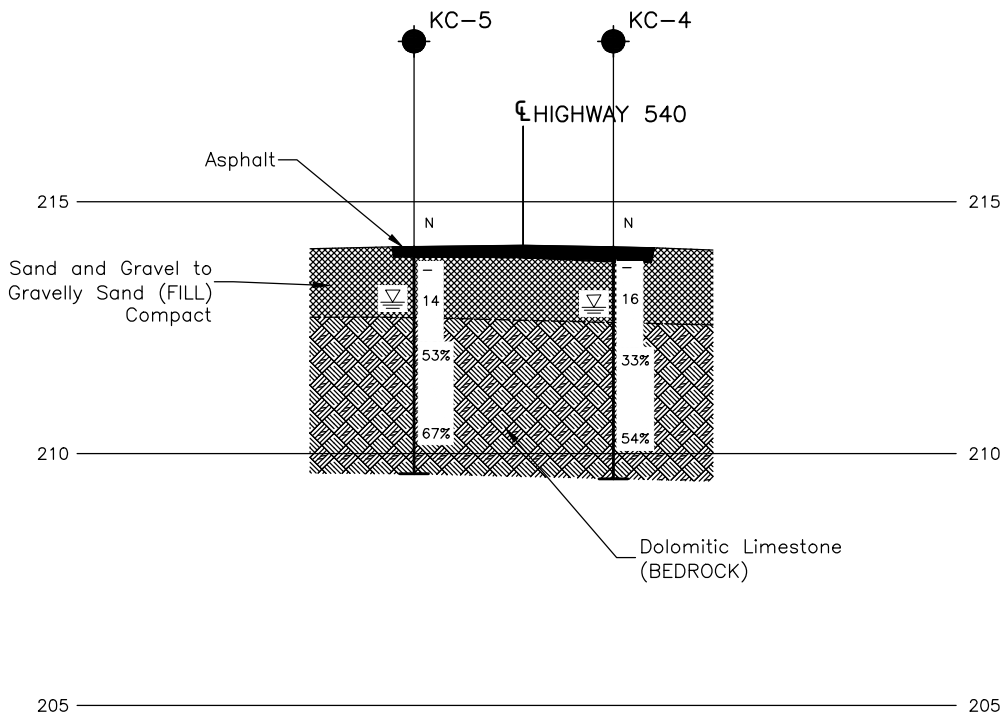
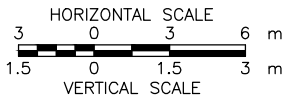
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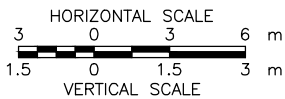
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B-B' WEST ABUTMENT SECTION
1



C-C' EAST ABUTMENT SECTION
1



METRIC
DIMENSIONS ARE IN METRES AND/OR
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STATIONS IN KILOMETRES + METRES.

CONT No.
WP No.5060-07-01

HIGHWAY 540
KAGAWONG CREEK BRIDGE
SOIL STRATA

SHEET



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REFERENCE

Base plans provided in digital format by AECOM, drawing file nos. GWP 5057-07-00.dwg, received AUG 08, 2014 and Kagawong Bridge 49-073.dwg, received NOV 27, 2014.



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Geocres No. 41G-18

HWY. 540	PROJECT NO. 13-1191-0005	DIST.
SUBM'D. AC	CHKD.	DATE: DEC 2014
DRAWN: TB	CHKD. AB	APPD. JMAC
		DWG. 2



SITE PHOTOGRAPHS

Photograph 1: Looking West from North Side of Bridge (May 2014)



Photograph 2: Looking West from South Side of Bridge (May 2014)





APPENDIX A

Record of Boreholes and Drillholes



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
ν	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

(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

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

Notes: 1
2

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$



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, 60° 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 cm² 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	N
Relative Density	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	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



LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERINGS STATE

Fresh: no visible sign of weathering

Faintly weathered: weathering limited to the surface of major discontinuities.

Slightly weathered: penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material.

Moderately weathered: weathering extends throughout the rock mass but the rock material is not friable.

Highly weathered: weathering extends throughout rock mass and the rock material is partly friable.

Completely weathered: rock is wholly decomposed and in a friable condition but the rock and structure are preserved.

BEDDING THICKNESS

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

JOINT OR FOLIATION SPACING

Description	Spacing
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

GRAIN SIZE

Term	Size*
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: * Grains greater than 60 microns diameter are visible to the naked eye.

CORE CONDITION

Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, measured relative to the length of the total core run. RQD varied from 0% for completely broken core to 100% for core in solid sticks.

DISCONTINUITY DATA

Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

Dip with Respect to Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole a discontinuity with a 90° angle is horizontal.

Description and Notes

An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

Abbreviations

JN Joint	PL Planar
FLT Fault	CU Curved
SH Shear	UN Undulating
VN Vein	IR Irregular
FR Fracture	K Slickensided
SY Stylolite	PO Polished
BD Bedding	SM Smooth
FO Foliation	SR Slightly Rough
CO Contact	RO Rough
AXJ Axial Joint	VR Very Rough
KV Karstic Void	
MB Mechanical Break	

PROJECT		13-1191-0005		RECORD OF BOREHOLE No KC-1		1 OF 2 METRIC										
W.P.		5262-10-01		LOCATION		N 5084705.4; E 323531.7										
DIST		HWY 540		BOREHOLE TYPE		108mm ID Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring										
DATUM		GEODETIC		DATE		May 28, 2014										
				ORIGINATED BY		MR										
				COMPILED BY		JLL										
				CHECKED BY		AB										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
214.3	GROUND SURFACE															
0.0	ASPHALT (300 mm)															
0.3	Gravelly sand, some silt (FILL) Compact Brown Moist		1	AS	-											
			2	SS	20											
212.9	Clayey silt, trace sand, trace gravel (FILL) Grey Wet		3	AS	-											24 63 (13)
1.5	DOLOMITIC LIMESTONE (BEDROCK)		1	RC	REC 100%											RQD = 68%
211.3	Bedrock cored from 1.5 m depth to 3.0 m depth.															
3.0	For coring details see Record of Drillhole KC-1. END OF BOREHOLE															
Note: 1. Water level at a depth of 1.3 m below ground surface (Elev. 213.0 m) upon completion of drilling.																

PROJECT: 13-1191-0005

RECORD OF DRILLHOLE: KC-1

SHEET 2 OF 2

LOCATION: N 5084705.4 ;E 323531.7

DRILLING DATE: May 28, 2014

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: —

DRILL RIG: CME 55 Truck Mount

DRILLING CONTRACTOR: Landcore

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	CORING LOG																		NOTES WATER LEVELS INSTRUMENTATION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
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DEPTH SCALE

1 : 50



LOGGED: MR

CHECKED: AB

SUD-RCK 13-1191-0005.GPJ GAL-MISS.GDT 11/09/14 DATA INPUT:

PROJECT 13-1191-0005				RECORD OF BOREHOLE No KC-2				1 OF 2 METRIC									
W.P. 5262-10-01				LOCATION N 5084709.5; E 323550.3				ORIGINATED BY MR									
DIST _____ HWY 540				BOREHOLE TYPE 108mm ID Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring				COMPILED BY JLL									
DATUM GEODETIC				DATE May 27, 2014				CHECKED BY AB									
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
214.1	GROUND SURFACE							20	40	60	80	100					
0.0	ASPHALT (200 mm)						214										
0.2	Gravelly sand, some silt (FILL) Compact Brown Moist		1	AS	-												
212.9			2	SS	10		213										27 61 (12)
1.4	Clayey silt, trace sand, trace gravel (FILL) Grey DOLOMITIC LIMESTONE (BEDROCK) Bedrock cored from 1.4 m depth to 4.7 m depth. For coring details see Record of Drillhole KC-2.		1	RC	REC 100%		212										RQD = 29%
			2	RC	REC 100%		211										RQD = 29%
			3	RC	REC 48%		210										RQD = 30%
209.4	END OF BOREHOLE																
4.7	Note: 1. Water level at a depth of 1.1 m below ground surface (Elev. 213.0 m) upon completion of drilling.																

SUD-MTO 001 13-1191-0005.GPJ GAL-MISS.GDT 11/09/14 DATA INPUT:

PROJECT: 13-1191-0005

RECORD OF DRILLHOLE: KC-2

SHEET 2 OF 2

LOCATION: N 5084709.5 ;E 323550.3

DRILLING DATE: May 27, 2014

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: —

DRILL RIG: CME 55 Truck Mount

DRILLING CONTRACTOR: Landcore

DEPTH SCALE METRES	DRILLING RECORD		DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	JN - Joint FLT - Fault SHR - Shear VN - Vein CJ - Conjugate BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular PO - Polished K - Slickensided SM - Smooth Ro - Rough MB - Mechanical Break BR - Broken Rock <small>NOTE: For additional abbreviations refer to list of abbreviations & symbols.</small>										DISCONTINUITY DATA					HYDRAULIC CONDUCTIVITY k, cm/s				Diametral Point Load Index (MPa)	RMC -Q AVG	NOTES WATER LEVELS INSTRUMENTATION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
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DEPTH SCALE

1 : 50



LOGGED: MR

CHECKED: AB

SUD-RCK 13-1191-0005.GPJ GAL-MISS.GDT 11/09/14 DATA INPUT:

PROJECT		13-1191-0005		RECORD OF BOREHOLE No KC-3		1 OF 2 METRIC							
W.P.		5262-10-01		LOCATION		N 5084717.4; E 323548.1							
DIST		HWY 540		BOREHOLE TYPE		108mm ID Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring							
DATUM		GEODETIC		DATE		May 26, 2014							
ORIGINATED BY		MR		COMPILED BY		JJL							
CHECKED BY		AB											
SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER			TYPE	"N" VALUES						20
214.1	GROUND SURFACE												
0.0	ASPHALT (200 mm)												
0.2	Gravelly sand, some silt (FILL) Compact Brown Moist		1	AS	-								
212.8			2	SS	17								
1.3	DOLOMITIC LIMESTONE (BEDROCK)												
	Bedrock cored from 1.3 m depth to 4.4 m depth.		1	RC	REC 100%								
	For coring details see Record of Drillhole KC-3.												
			2	RC	REC 100%								
209.7													
4.4	END OF BOREHOLE												
	Note: 1. Water level at a depth of 1.1 m below ground surface (Elev. 213.0 m) upon completion of drilling.												

PROJECT: 13-1191-0005

RECORD OF DRILLHOLE: KC-3

SHEET 2 OF 2

LOCATION: N 5084717.4 ;E 323548.1

DRILLING DATE: May 26, 2014

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: —

DRILL RIG: CME 55 Truck Mount

DRILLING CONTRACTOR: Landcore

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	JN - Joint FLT - Fault SHR - Shear VN - Vein CJ - Conjugate BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular PO - Polished K - Slickensided SM - Smooth Ro - Rough MB - Mechanical Break BR - Broken Rock NOTE: For additional abbreviations refer to list of abbreviations & symbols.										NOTES WATER LEVELS INSTRUMENTATION			
							RECOVERY		R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA				HYDRAULIC CONDUCTIVITY k, cm/s	Diametral Point Load Index (MPa)	RMC -Q AVG			
							TOTAL CORE %	SOLID CORE %			B Angle	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn				
		TOP OF BEDROCK		212.8			800000	800000	800000	800000	100	100								
2	NQ	Dolomitic Limestone Fine grained Slightly weathered Grey Very strong All joints irregular an rough.		1.3	1	GREY 100%														UCS = 122 MPa
3	CME 55 NW CASING				2	GREY 100%														
4																				
		END OF DRILLHOLE		209.7																
5				4.4																
6																				
7																				
8																				
9																				
10																				
11																				

DEPTH SCALE

1 : 50



LOGGED: MR

CHECKED: AB

SUD-RCK 13-1191-0005.GPJ GAL-MISS.GDT 11/09/14 DATA INPUT:

PROJECT 13-1191-0005				RECORD OF BOREHOLE No KC-4				1 OF 2 METRIC									
W.P. 5262-10-01				LOCATION N 5084713.5; E 323557.5				ORIGINATED BY MR									
DIST _____ HWY 540				BOREHOLE TYPE 108mm ID Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring				COMPILED BY JJJ									
DATUM GEODETIC				DATE May 27, 2014				CHECKED BY AB									
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
214.1	GROUND SURFACE							20	40	60	80	100					
0.0	ASPHALT (300 mm)						214										
0.3	Gravelly sand, some silt (FILL) Compact Brown Moist		1	AS	-		213										27 60 (13)
212.6			2	SS	16												
1.5	DOLOMITIC LIMESTONE (BEDROCK)						212										RQD = 33%
	Bedrock cored from 1.5 m depth to 4.6 m depth.		1	RC	REC 100%		211										
	For coring details see Record of Drillhole KC-4.		2	RC	REC 100%		210										RQD = 54%
209.5	END OF BOREHOLE																
4.6	Note: 1. Water level at a depth of 1.2 m below ground surface (Elev. 212.9 m) upon completion of drilling.																

SUD-MTO 001 13-1191-0005.GPJ GAL-MISS.GDT 11/09/14 DATA INPUT:

PROJECT: 13-1191-0005

RECORD OF DRILLHOLE: KC-4

SHEET 2 OF 2

LOCATION: N 5084713.5 ;E 323557.5

DRILLING DATE: May 27, 2014

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: —

DRILL RIG: CME 55 Truck Mount

DRILLING CONTRACTOR: Landcore

DEPTH SCALE METRES	DRILLING RECORD		DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	JN - Joint FLT - Fault SHR - Shear VN - Vein CJ - Conjugate										BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage										PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular										PO - Polished K - Slickensided SM - Smooth Ro - Rough MB - Mechanical Break										BR - Broken Rock										NOTES WATER LEVELS INSTRUMENTATION																																																																																																																																																																																																																																																																																																																																																													
								RECOVERY										R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA										HYDRAULIC CONDUCTIVITY										Diametral Point Load Index (MPa)	RMC -Q AVG																																																																																																																																																																																																																																																																																																																																																																														
								FLUSH	TOTAL CORE %	SOLID CORE %	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	k, cm/s																																																																																																																																																																																																																																																																																																																																																																																																								
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2	NQ	TOP OF BEDROCK		212.6	1.5	1	GREY 100%								UCS = 86 MPa																																																																																																																																																																																																																																																																																																																																																																																																								
																3	CME 55 NW CASING	Dolomitic Limestone Fine grained Slightly weathered Grey Strong	Vertical fracture from 2.5 m to 3.1 m, and 3.6 m to 3.8 m.	1	GREY 100%								UCS = 86 MPa																																																																																																																																																																																																																																																																																																																																																																																										
																														4	Clay/silt seams (less than 25 mm) at about 3.9 m, 4.0 m and 4.4 m.	2	GREY 100%								UCS = 86 MPa																																																																																																																																																																																																																																																																																																																																																																														
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DEPTH SCALE

1 : 50



LOGGED: MR

CHECKED: AB

SUD-RCK 13-1191-0005.GPJ GAL-MISS.GDT 11/09/14 DATA INPUT:

PROJECT 13-1191-0005				RECORD OF BOREHOLE No KC-5				1 OF 2 METRIC									
W.P. 5262-10-01				LOCATION N 5084721.3; E 323556.1				ORIGINATED BY MR									
DIST HWY 540				BOREHOLE TYPE 108mm ID Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring				COMPILED BY JLL									
DATUM GEODETIC				DATE May 26, 2014				CHECKED BY AB									
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
214.1	GROUND SURFACE							20	40	60	80	100					
0.0	ASPHALT (200 mm)						214										
0.2	Sand and gravel to gravelly sand, some silt (FILL) Compact Brown Moist		1	AS	-		213										
212.7			2	SS	14												
1.4	DOLOMITIC LIMESTONE (BEDROCK) Bedrock cored from 1.4 m depth to 4.5 m depth. For coring details see Record of Drillhole KC-5.		1	RC	REC 100%		212										RQD = 53%
			2	RC	REC 100%		211										RQD = 67%
209.6							210										
4.5	END OF BOREHOLE Note: 1. Water level at a depth of 1.1 m below ground surface (Elev. 213.0 m) upon completion of drilling.																

PROJECT: 13-1191-0005

RECORD OF DRILLHOLE: KC-5

SHEET 2 OF 2

LOCATION: N 5084721.3 ;E 323556.1

DRILLING DATE: May 26, 2014

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: —

DRILL RIG: CME 55 Truck Mount

DRILLING CONTRACTOR: Landcore

DEPTH SCALE METRES	DRILLING RECORD		DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	JN - Joint FLT - Fault SHR - Shear VN - Vein CJ - Conjugate										BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage										PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular										PO - Polished K - Slickensided SM - Smooth Ro - Rough MB - Mechanical Break										BR - Broken Rock NOTE: For additional abbreviations refer to list of abbreviations & symbols.	NOTES WATER LEVELS INSTRUMENTATION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
								RECOVERY		R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA										HYDRAULIC CONDUCTIVITY		Diametral Point Load Index (MPa)	RMC -Q AVG																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
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DEPTH SCALE

1 : 50



LOGGED: MR

CHECKED: AB

SUD-RCK 13-1191-0005.GPJ GAL-MISS.GDT 11/09/14 DATA INPUT:

PROJECT <u>13-1191-0005</u>		RECORD OF BOREHOLE No KC-6		1 OF 2 METRIC	
W.P. <u>5262-10-01</u>		LOCATION <u>N 5084724.1; E 323573.7</u>		ORIGINATED BY <u>MR</u>	
DIST <u> </u> HWY <u>540</u>		BOREHOLE TYPE <u>108mm ID Continuous Flight Hollow Stem Augers, NW Casing, NQ Coring</u>		COMPILED BY <u>JJL</u>	
DATUM <u>GEODETIC</u>		DATE <u>May 27, 2014</u>		CHECKED BY <u>AB</u>	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE LIQUID CONTENT			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 (%)				
								<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div><div></div><div></div></div>		
214.1	GROUND SURFACE														
0.0	ASPHALT (200 mm)														
0.2	Sand and gravel, some silt (FILL) Compact Brown Moist		1	AS	-										42 46 (12)
			2	SS	28										
212.6															
1.5	DOLOMITIC LIMESTONE (BEDROCK) Bedrock cored from 1.5 m depth to 3.0 m depth. For coring details see Record of Drillhole KC-6.		1	RC	REC 100%										RQD = 76%
211.1															
3.0	END OF BOREHOLE Note: 1. Water level at a depth of 1.3 m below ground surface (Elev. 212.8 m) upon completion of drilling.														

SUD-MTO 001 13-1191-0005.GPJ GAL-MISS.GDT 11/09/14 DATA INPUT:

PROJECT: 13-1191-0005

RECORD OF DRILLHOLE: KC-6

SHEET 2 OF 2

LOCATION: N 5084724.1 ;E 323573.7

DRILLING DATE: May 27, 2014

DATUM: GEODETIC

INCLINATION: -90° AZIMUTH: —

DRILL RIG: CME 55 Truck Mount

DRILLING CONTRACTOR: Landcore

DEPTH SCALE METRES	DRILLING RECORD		DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	COLOUR % RETURN	UN - Joint FLT - Fault SHR - Shear VN - Vein CJ - Conjugate BD - Bedding FO - Foliation CO - Contact OR - Orthogonal CL - Cleavage PL - Planar CU - Curved UN - Undulating ST - Stepped IR - Irregular PO - Polished K - Slickensided SM - Smooth Ro - Rough MB - Mechanical Break BR - Broken Rock NOTE: For additional abbreviations refer to list of abbreviations & symbols.																		NOTES WATER LEVELS INSTRUMENTATION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
								FLUSH	RECOVERY		R.Q.D. %	FRACT. INDEX METRES	DISCONTINUITY DATA						HYDRAULIC CONDUCTIVITY k, cm/s			Diametral Point Load Index (MPa)	RMC -Q AVG																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
									TOTAL CORE %	SOLID CORE %			B Angle	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	Jr	Ja	Jn	10 m	10 m	10 m																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
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DEPTH SCALE

1 : 50



LOGGED: MR

CHECKED: AB

SUD-RCK 13-1191-0005.GPJ GAL-MISS.GDT 11/09/14 DATA INPUT:



**FOUNDATION REPORT
HIGHWAY 540 KAGAWONG TRIBUTARY CREEK BRIDGE
SITE 49-073**

APPENDIX B

Laboratory Test Results



**FOUNDATION REPORT
HIGHWAY 540 KAGAWONG TRIBUTARY CREEK BRIDGE
SITE 49-073**

Table B1 - Summary of Analytical Testing of Creek Water

Parameter	Units	Method Detection Limit	Result
Resistivity	ohm-cm	n/a	2600
Conductivity	µmho/cm	1	390
pH	n/a	n/a	8.30
Sulphate	mg/L	1	Not Detected
Chloride	mg/L	1	2

Notes:

1. Sample obtained May 28, 2014.
2. Analytical testing carried out by Maxxam Analytics Inc.

Prepared by: DAM

Reviewed by: AB

Golder Associates Ltd.
 1010 Lorne Street
 Sudbury, Ontario, Canada P3C 4R9
 Telephone: (705) 524-6861
 Fax: (705) 524-1984



TABLE B2 - SUMMARY OF ROCK CORE TEST DATA

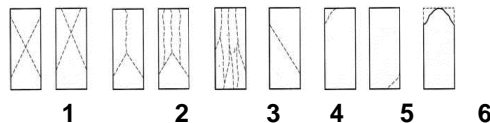
PROJECT NO.: 13-1191-0005
JOB NAME: Kagawong Creek Bridge
TYPE OF UNIT: Bedrock Core

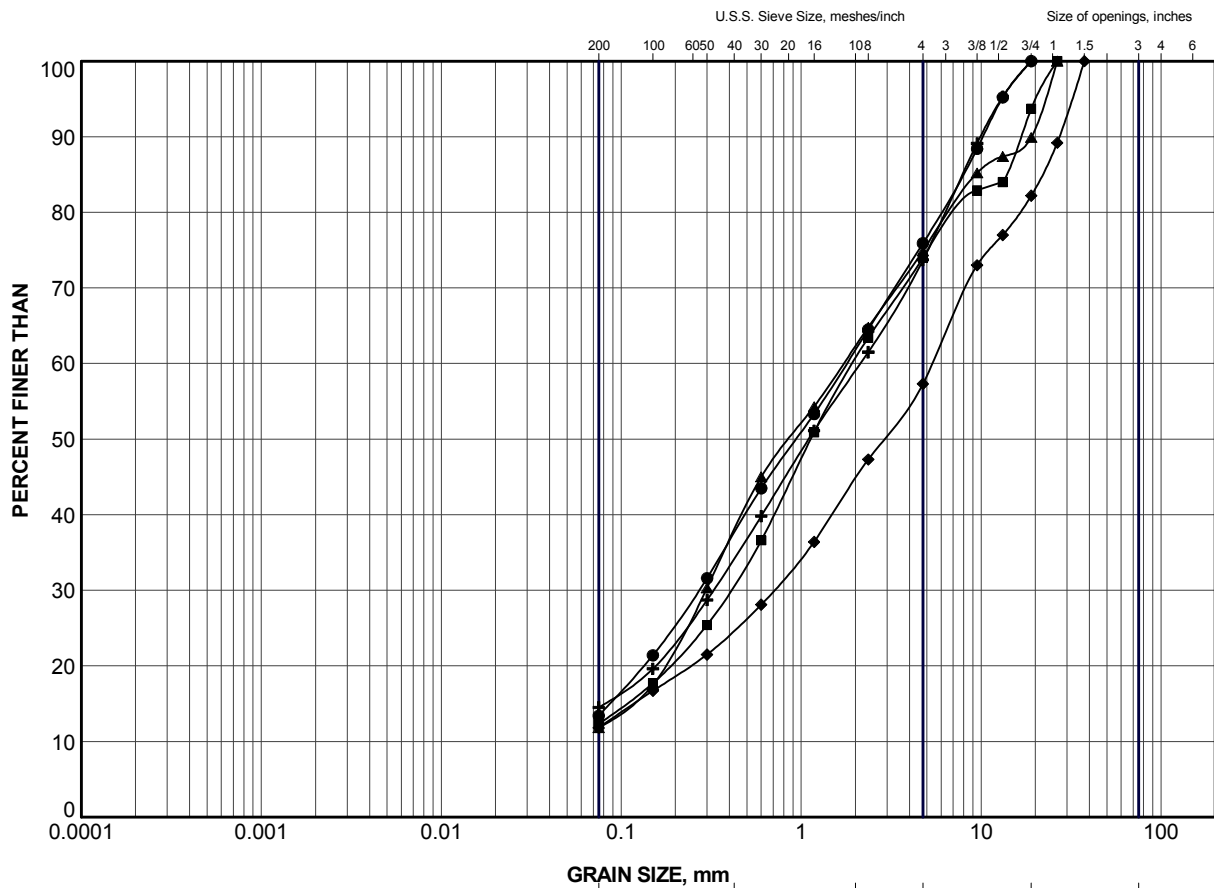
GOLDER LAB NUMBER	GO382	G0383	G0384	G0385
BOREHOLE	KC2	KC3	KC4	KC5
DATE TESTED	June 16, 2014	June 16, 2014	June 16, 2014	June 16, 2014
DEPTH OF TESTED CORE (m)	1.7	1.8	2.1	2.0
LENGTH AS CUT (mm)	97.0	97.0	97.5	98.0
DIAMETER (mm)	47.0	47.0	47.0	47.0
DENSITY (kg/m3)	2832.0	2825	2793	2758
COMPRESSIVE STRENGTH (KN)	233.4	211.7	149.4	127.2
COMPRESSIVE STRENGTH (MPa)	135	122	86	73
TYPE OF FRACTURE	3	3	3	3

Tested by: SA

Type of Fracture

Reviewed by : TG





LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	KC-1	2	213.2
■	KC-2	2	213.0
▲	KC-3	2	213.0
+	KC-4	2	213.0
◆	KC-6	2	213.0

PROJECT

HIGHWAY 540
KAGAWONG CREEK BRIDGE

TITLE

GRAIN SIZE DISTRIBUTION
GRAVELLY SAND to SAND and GRAVEL (FILL)



Golder Associates
SUDBURY, ONTARIO

PROJECT No.	13-1191-0005	FILE No.	13-1191-0005.GPJ
DRAWN	TB	Sep 2014	SCALE N/A
CHECK	AB	Sep 2014	REV.
APPR	JMAC	Sep 2014	

FIGURE B1



Borehole KC-1 and KC-6
Elevation 212.8 m to 211.3 m and 212.6 m to 211.1 m



Borehole KC-2
Elevation 212.7 m to 209.4 m



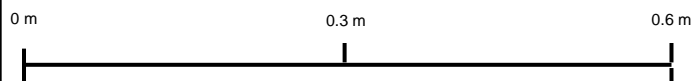
Borehole KC-3
Elevation 212.8 m to 209.7 m




Borehole KC-4
Elevation 212.6 m to 209.5 m



Borehole KC-5
Elevation 212.7 m to 209.6 m



PROJECT		HIGHWAY 11 KAGAWONG CREEK BRIDGE	
TITLE		BEDROCK CORE PHOTOGRAPHS	
	PROJECT No.	13-1191-0005	FILE No. ----
	DESIGN		SCALE AS SHOWN REV.
	CADD	--	
	CHECK	AB	Sept. 2014
	REVIEW		
FIGURE B2			

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

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