APPENDIX A

Statement of General Conditions

STATEMENT OF GENERAL CONDITIONS

USE OF THIS REPORT: This report has been prepared for the sole benefit of the Client or its agent and may not be used by any third party without the express written consent of Stantec Consulting Ltd. and the Client. Any use which a third party makes of this report is the responsibility of such third party.

BASIS OF THE REPORT: The information, opinions, and/or recommendations made in this report are in accordance with Stantec Consulting Ltd.'s present understanding of the site specific project as described by the Client. The applicability of these is restricted to the site conditions encountered at the time of the investigation or study. If the proposed site specific project differs or is modified from what is described in this report or if the site conditions are altered, this report is no longer valid unless Stantec Consulting Ltd. is requested by the Client to review and revise the report to reflect the differing or modified project specifics and/or the altered site conditions.

STANDARD OF CARE: Preparation of this report, and all associated work, was carried out in accordance with the normally accepted standard of care in the state or province of execution for the specific professional service provided to the Client. No other warranty is made.

INTERPRETATION OF SITE CONDITIONS: Soil, rock, or other material descriptions, and statements regarding their condition, made in this report are based on site conditions encountered by Stantec Consulting Ltd. at the time of the work and at the specific testing and/or sampling locations. Classifications and statements of condition have been made in accordance with normally accepted practices which are judgmental in nature; no specific description should be considered exact, but rather reflective of the anticipated material behavior. Extrapolation of in situ conditions can only be made to some limited extent beyond the sampling or test points. The extent depends on variability of the soil, rock and groundwater conditions as influenced by geological processes, construction activity, and site use.

VARYING OR UNEXPECTED CONDITIONS: Should any site or subsurface conditions be encountered that are different from those described in this report or encountered at the test locations, Stantec Consulting Ltd. must be notified immediately to assess if the varying or unexpected conditions are substantial and if reassessments of the report conclusions or recommendations are required. Stantec Consulting Ltd. will not be responsible to any party for damages incurred as a result of failing to notify Stantec Consulting Ltd. that differing site or sub-surface conditions are present upon becoming aware of such conditions.

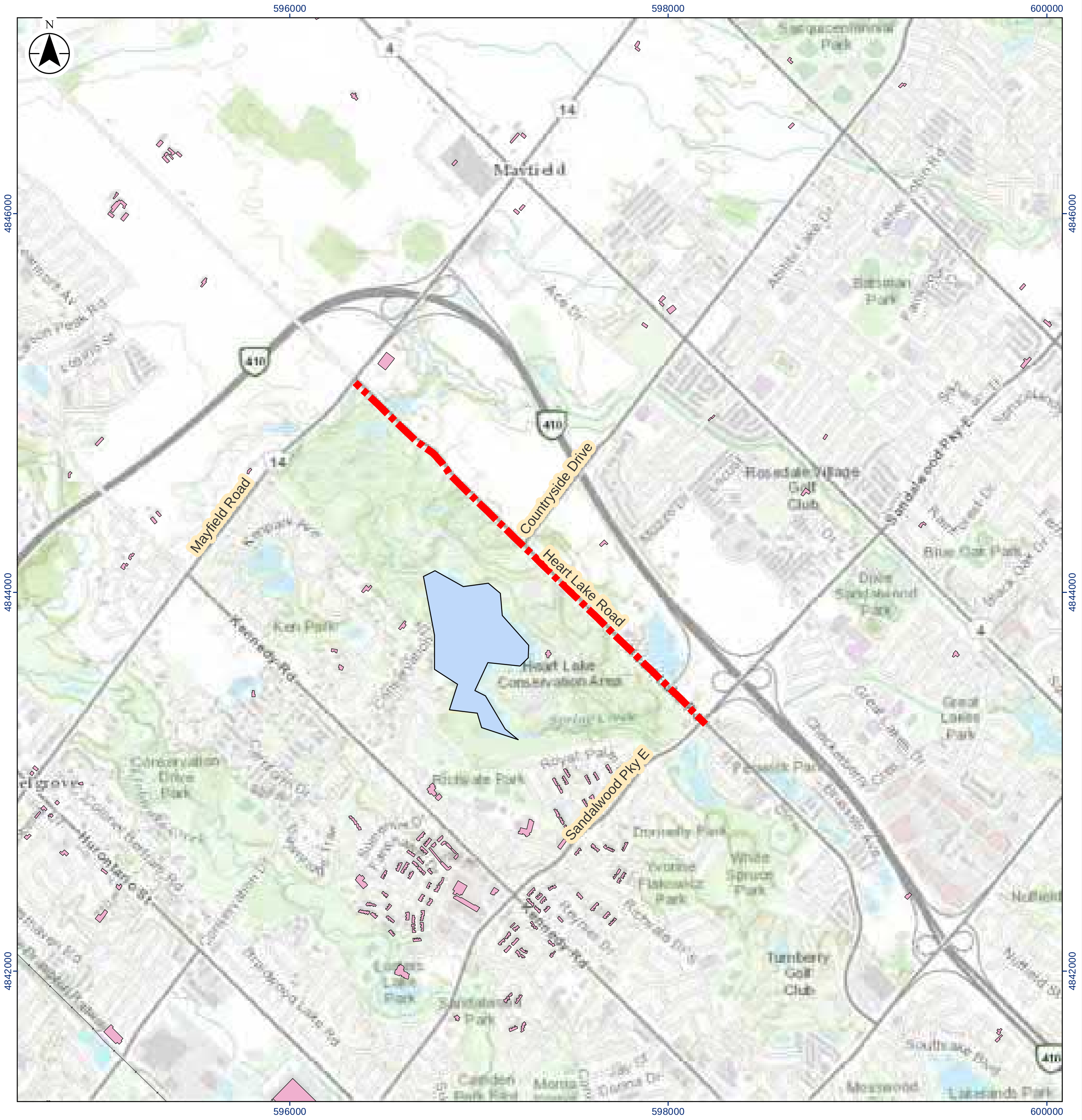
PLANNING, DESIGN, OR CONSTRUCTION: Development or design plans and specifications should be reviewed by Stantec Consulting Ltd., sufficiently ahead of initiating the next project stage (property acquisition, tender, construction, etc), to confirm that this report completely addresses the elaborated project specifics and that the contents of this report have been properly interpreted. Specialty quality assurance services (field observations and testing) during construction are a necessary part of the evaluation of sub-subsurface conditions and site preparation works. Site work relating to the recommendations included in this report should only be carried out in the presence of a qualified geotechnical engineer; Stantec Consulting Ltd. cannot be responsible for site work carried out without being present.

APPENDIX B

Key Plan

Borehole Location Plan

T:\Autocad\Drawings\Project Drawings\2017\165001037\Key Plan (gis)\165001037_Key Plan.mxd Revised: 2017-11-30 By: gbriones



KEY MAP

Legend

🟥 Approximate Site Location

0 400 800
metres
1:30,000 (at original document size of 8.5x11)

Project Location
Heart Lake Road Corridor
Cambridge, Ontario

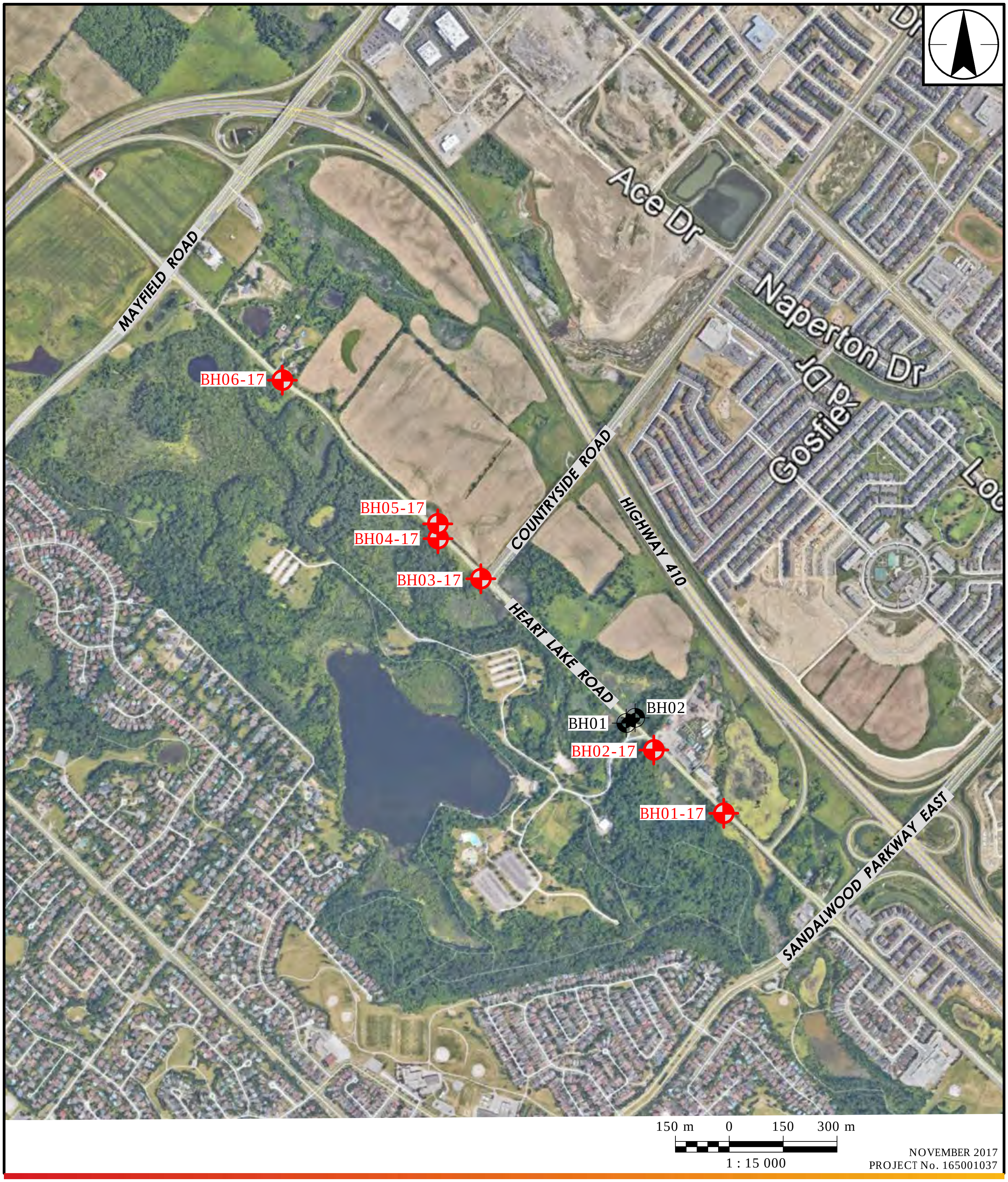
Project No. 165001037
Prepared by Gliceria Briones
on 2017-11-30

Client/Project
CITY OF BRAMPTON
GEOTECHNICAL INVESTIGATION
HEART LAKE ROAD CORRIDOR

Drawing No.
1

Title
Key Plan

Notes
1. Coordinate System: NAD 1983 UTM Zone 17N.
2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2016.
3. Imagery provided by Esri ©2017.



NOVEMBER 2017
PROJECT No. 165001037

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2017/11/30 3:25 PM By: Briones, Gliceria

Stantec

400 - 1331 Clyde Avenue
Ottawa, ON, Canada K2C 3G4
www.stantec.com

LEGEND

⌖ APPROXIMATE BOREHOLE LOCATION (STANTEC, 2017)

⊕ APPROXIMATE BOREHOLE LOCATION (ENGTECH, 2015)

NOTES

1. BASEPLAN: SCREEN SHOT FROM GOOGLE EARTH PRO, 2017.

Client/Project

CITY OF BRAMPTON

GEOTECHNICAL INVESTIGATION
HEART LAKE ROAD CORRIDOR, BRAMPTON, ON

Drawing No.

2

Title

BOREHOLE LOCATION PLAN

APPENDIX C

Symbols and Terms Used on the Borehole Records

Stantec Borehole Records

Engtec Borehole Records

SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT RECORDS

SOIL DESCRIPTION

Terminology describing common soil genesis:

Rootmat	-	vegetation, roots and moss with organic matter and topsoil typically forming a mattress at the ground surface
Topsoil	-	mixture of soil and humus capable of supporting vegetative growth
Peat	-	mixture of visible and invisible fragments of decayed organic matter
Till	-	unstratified glacial deposit which may range from clay to boulders
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 minerals, shrinkage cracks, etc.
Fissured	-	having cracks, and hence a blocky structure
Varved	-	composed of regular 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

Terminology describing soil types:
The classification of soil types are made on the basis of grain size and plasticity in accordance with the Unified Soil Classification System (USCS) (ASTM D 2487 or D 2488) which excludes particles larger than 75 mm. For particles larger than 75 mm, and for defining percent clay fraction in hydrometer results, definitions proposed by Canadian Foundation Engineering Manual, 4th Edition are used. The USCS provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

Terminology describing cobbles, boulders, and non-matrix materials (organic matter or debris):
Terminology describing materials outside the USCS, (e.g. particles larger than 75 mm, visible organic matter, and construction debris) is based upon the proportion of these materials present:

Trace, or occasional	Less than 10%
Some	10-20%
Frequent	> 20%

Terminology describing compactness of cohesionless soils:
The standard terminology to describe cohesionless soils includes compactness (formerly "relative density"), as determined by the Standard Penetration Test (SPT) N-Value - also known as N-Index. The SPT N-Value is described further on page 3. A relationship between compactness condition and N-Value is shown in the following table.

Compactness Condition	**SPT N-Value**
Very Loose	<4
Loose	4-10
Compact	10-30
Dense	30-50
Very Dense	>50

Terminology describing consistency of cohesive soils:
The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by *in situ* vane tests, penetrometer tests, or unconfined compression tests. Consistency may be crudely estimated from SPT N-Value based on the correlation shown in the following table (Terzaghi and Peck, 1967). The correlation to SPT N-Value is used with caution as it is only very approximate.

Consistency	**Undrained Shear Strength**		**Approximate SPT N-Value**
	kips/sq.ft.	**kPa**	
Very Soft	<0.25	<12.5	<2
Soft	0.25 - 0.5	12.5 - 25	2-4
Firm	0.5 - 1.0	25 - 50	4-8
Stiff	1.0 - 2.0	50 – 100	8-15
Very Stiff	2.0 - 4.0	100 - 200	15-30
Hard	>4.0	>200	>30

ROCK DESCRIPTION

Except where specified below, terminology for describing rock is as defined by the International Society for Rock Mechanics (ISRM) 2007 publication "The Complete ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 1974-2006"

Terminology describing rock quality:

RQD	Rock Mass Quality
0-25	*Very Poor Quality*
25-50	*Poor Quality*
50-75	*Fair Quality*
75-90	*Good Quality*
90-100	*Excellent Quality*

Alternate (Colloquial) Rock Mass Quality	
Very Severely Fractured	*Crushed*
Severely Fractured	*Shattered or Very Blocky*
Fractured	*Blocky*
Moderately Jointed	*Sound*
Intact	*Very Sound*

RQD (Rock Quality Designation) denotes the percentage of intact and sound rock retrieved from a borehole of any orientation. All pieces of intact and sound rock core equal to or greater than 100 mm (4 in.) long are summed and divided by the total length of the core run. RQD is determined in accordance with ASTM D6032.

SCR (Solid Core Recovery) denotes the percentage of solid core (cylindrical) retrieved from a borehole of any orientation. All pieces of solid (cylindrical) core are summed and divided by the total length of the core run (It excludes all portions of core pieces that are not fully cylindrical as well as crushed or rubble zones).

Fracture Index (FI) is defined as the number of naturally occurring fractures within a given length of core. The Fracture Index is reported as a simple count of natural occurring fractures.

Terminology describing rock with respect to discontinuity and bedding spacing:

Spacing (mm)	Discontinuities	Bedding
>6000	*Extremely Wide*	-
2000-6000	*Very Wide*	*Very Thick*
600-2000	*Wide*	*Thick*
200-600	*Moderate*	*Medium*
60-200	*Close*	*Thin*
20-60	*Very Close*	*Very Thin*
<20	*Extremely Close*	*Laminated*
<6	-	*Thinly Laminated*

Terminology describing rock strength:

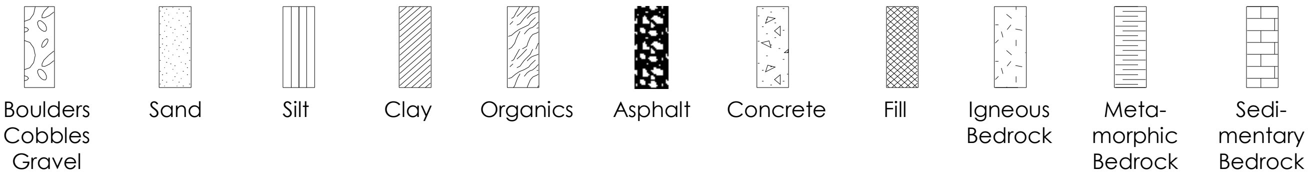
Strength Classification	Grade	Unconfined Compressive Strength (MPa)
Extremely Weak	R0	<1
Very Weak	R1	1 – 5
Weak	R2	5 – 25
Medium Strong	R3	25 – 50
Strong	R4	50 – 100
Very Strong	R5	100 – 250
Extremely Strong	R6	>250

Terminology describing rock weathering:

Term	Symbol	Description
Fresh	W1	No visible signs of rock weathering. Slight discoloration along major discontinuities
Slightly	W2	Discoloration indicates weathering of rock on discontinuity surfaces. All the rock material may be discolored.
Moderately	W3	Less than half the rock is decomposed and/or disintegrated into soil.
Highly	W4	More than half the rock is decomposed and/or disintegrated into soil.
Completely	W5	All the rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact.
Residual Soil	W6	All the rock converted to soil. Structure and fabric destroyed.

STRATA PLOT

Strata plots symbolize the soil or 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.



SAMPLE TYPE

SS	Split spoon sample (obtained by performing the Standard Penetration Test)
ST	Shelby tube or thin wall tube
DP	Direct-Push sample (small diameter tube sampler hydraulically advanced)
PS	Piston sample
BS	Bulk sample
HQ, NQ, BQ, etc.	Rock core samples obtained with the use of standard size diamond coring bits.

WATER LEVEL MEASUREMENT

▼	measured in standpipe, piezometer, or well
▽	inferred

RECOVERY

For soil samples, the recovery is recorded as the length of the soil sample recovered. For rock core, recovery is defined as the total cumulative length of all core recovered in the core barrel divided by the length drilled and is recorded as a percentage on a per run basis.

N-VALUE

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 140 pound (63.5 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (300 mm) into the soil. In accordance with ASTM D1586, the N-Value equals the sum of the number of blows (N) required to drive the sampler over the interval of 6 to 18 in. (150 to 450 mm). However, when a 24 in. (610 mm) sampler is used, the number of blows (N) required to drive the sampler over the interval of 12 to 24 in. (300 to 610 mm) may be reported if this value is lower. For split spoon samples where insufficient penetration was achieved and N-Values cannot be presented, the number of blows are reported over sampler penetration in millimetres (e.g. 50/75). Some design methods make use of N-values corrected for various factors such as overburden pressure, energy ratio, borehole diameter, etc. No corrections have been applied to the N-values presented on the log.

DYNAMIC CONE PENETRATION TEST (DCPT)

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to ‘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 one foot (300 mm) into the soil. The DCPT is used as a probe to assess soil variability.

OTHER TESTS

S	Sieve analysis
H	Hydrometer analysis
k	Laboratory permeability
γ	Unit weight
G_s	Specific gravity of soil particles
CD	Consolidated drained triaxial
CU	Consolidated undrained triaxial with pore pressure measurements
UU	Unconsolidated undrained triaxial
DS	Direct Shear
C	Consolidation
Q_U	Unconfined compression
I_p	Point Load Index (I_p on Borehole Record equals $I_p(50)$ in which the index is corrected to a reference diameter of 50 mm)

↧	Single packer permeability test; test interval from depth shown to bottom of borehole
⌶	Double packer permeability test; test interval as indicated
∘↓	Falling head permeability test using casing
▽↓	Falling head permeability test using well point or piezometer

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BOREHOLE RECORD

BH01-17

Sheet 1 of 1

CLIENT City of Brampton

PROJECT No. 165001037

LOCATION Heart Lake Road, Brampton, ON

DATUM

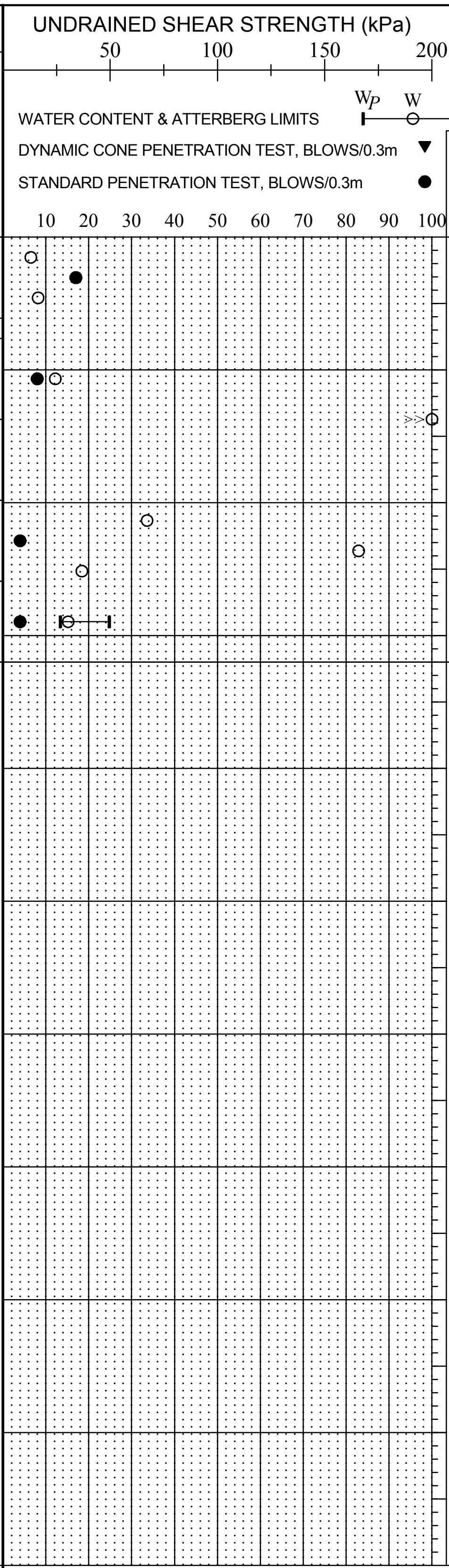
DATES: BORING 11/08/17

WATER LEVEL

TPC ELEVATION

DEPTH (m)	ELEVATION (m)	STRATA DESCRIPTION	STRATA PLOT	WATER LEVEL	DEPTH (ft)
0		**Paved Road**			0
		Asphaltic Concrete 140 mm			
		Granular Fill 220 mm			1
		FILL - brown, SAND (SM) with silt and gravel, dry - grey, sandy silt with gravel, wet			2–4
1					
		PEAT - black, damp - wet sand seam 100 mm - moist			5–7
2					
		Firm, grey, clay (CL) with sand TILL - trace gravel and sand			8–10
3					
		Borehole terminated at 3.2 m depth below existing grade. Borehole was open and dry upon drilling completion.			11

TYPE	NUMBER	RECOVERY (mm) TCR(%) / SCR(%)	N-VALUE OR RQD(%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
SS	1	480/610	17	
SS	2	300/610	8	
ST	3			
SS	4	560/610	4	
SS	5	410/610	4	4 23 41 32



☐ Field Vane Test, kPa

◘ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

Stantec

BOREHOLE RECORD

BH02-17

Sheet 1 of 1

CLIENT City of Brampton
PROJECT No. 165001037
LOCATION Heart Lake Road, Brampton, ON
DATUM
DATES: BORING 11/09/17
WATER LEVEL
TPC ELEVATION

DEPTH (m)	ELEVATION (m)	STRATA DESCRIPTION	DEPTH (ft)	SAMPLES TYPE	NUMBER	RECOVERY (mm) TCR(%) / SCR(%)	N-VALUE OR RQD(%)
0		**Grassed** Topsoil 270 mm	0				
		Firm, grey, silty CLAY (CL) - some sand - moist	1	SS	1	380/610	6
1		Compact, grey, silty SAND (SM) with gravel - moist	3–4	SS	2	380/610	12
2		Stiff, grey, clay (CL) with sand TILL - some sand and gravel	6	SS	3	460/610	10
			8–9	SS	4	430/610	13
3			11	SS	5	330/610	10
4		Borehole terminated at 3.0 m depth below existing grade. Borehole was open and dry upon drilling completion.	12				

UNDRAINED SHEAR STRENGTH (kPa) 50 100 150 200

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC CONE PENETRATION TEST, BLOWS/0.3m ▼

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50 60 70 80 90 100

REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

□ Field Vane Test, kPa
◘ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

Stantec

BOREHOLE RECORD

BH03-17

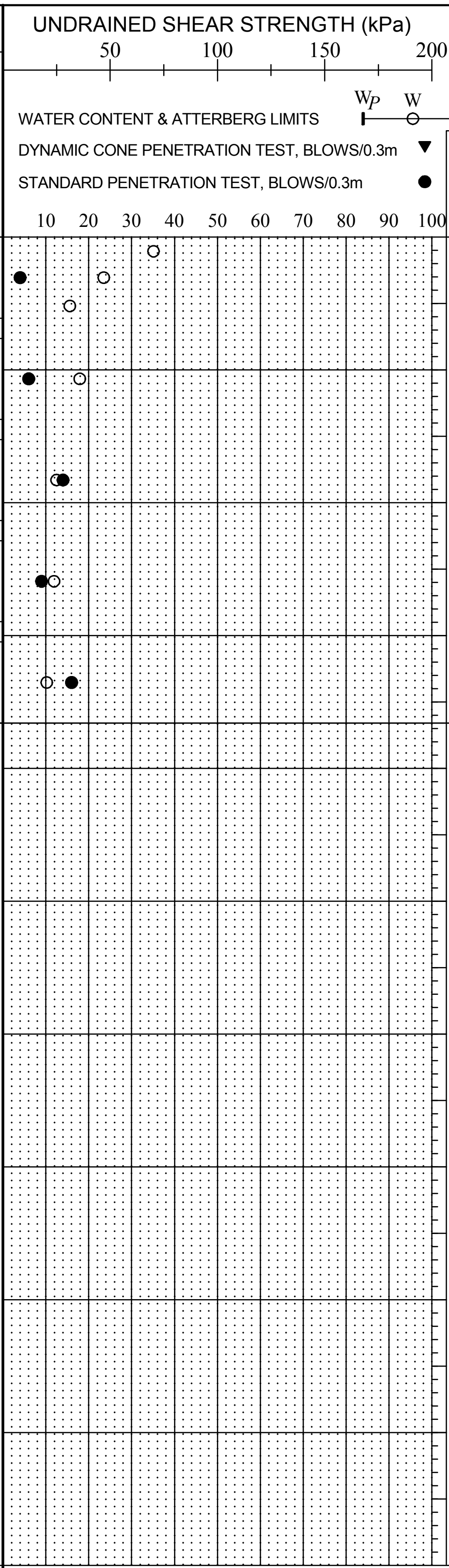
Sheet 1 of 1

CLIENT City of Brampton
PROJECT No. 165001037
LOCATION Heart Lake Road, Brampton, ON
DATUM
DATES: BORING 11/09/17
WATER LEVEL
TPC ELEVATION

DEPTH (m)	STRATA DESCRIPTION
0	**Grassed**
0	Topsoil 280 mm
	Firm, brown, sandy CLAY (CL) - trace organics - possible fill
1	Loose, brown/grey, silty SAND (SM) - some clay - moist - possible fill
2	Stiff, brown/grey, sandy CLAY (CL) - moist to wet - possible fill
3	Compact, brown, silty SAND (SM) with gravel - wet - plastic bag found in spoon
4	Stiff to very stiff, grey, clay (CL) with sand TILL - some gravel
5	Borehole terminated at 3.7 m depth below existing grade.
6	Borehole was open with free groundwater encountered at 2.0 m below existing grade upon drilling completion.

WATER LEVEL: ∇ at approx. 2.0 m (6 ft)

DEPTH (ft)	SAMPLES TYPE	NUMBER	RECOVERY (mm) TCR(%) / SCR(%)	N-VALUE OR RQD(%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	1	510/610	4	
3	SS	2	530/610	6	
6	SS	3	380/610	14	20 56 18 6
8–9	SS	4	410/610	9	
11	SS	5	510/610	16	



☐ Field Vane Test, kPa
◘ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

Stantec

BOREHOLE RECORD

BH04-17

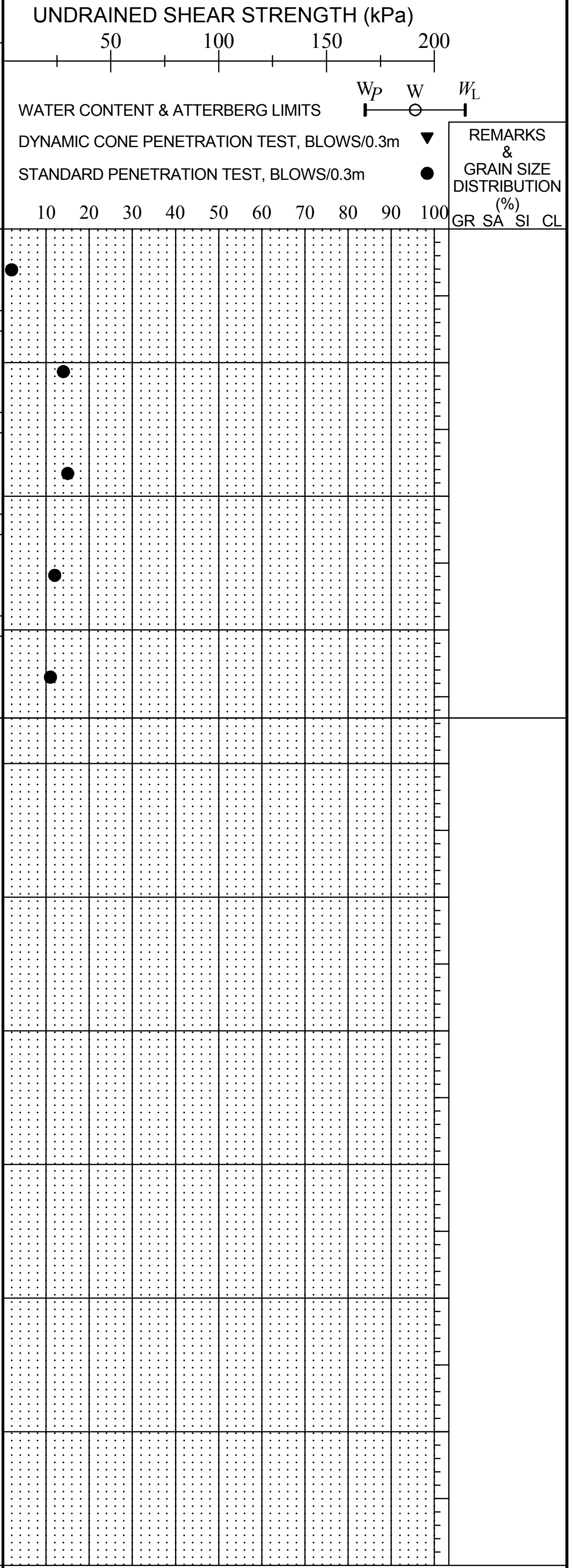
Sheet 1 of 1

CLIENT City of Brampton
PROJECT No. 165001037
LOCATION Heart Lake Road, Brampton, ON
DATUM
DATES: BORING 11/09/17
WATER LEVEL
TPC ELEVATION

DEPTH (m)	ELEVATION (m)	STRATA DESCRIPTION	WATER LEVEL
0		**Grassed** Topsoil 100 mm	
0.1		Stiff to very stiff, brown to brown/grey, silty clay (CL) TILL - trace to some gravel, some sand - moist	
2.3		Stiff, brown/grey, clay (CL) with sand TILL - grey	∇
3.7		Borehole terminated at 3.7 m depth below existing grade. Borehole was open to 3.0 m depth with free groundwater encountered at 2.7 m depth below existing grade upon drilling completion.	

SAMPLES

TYPE	NUMBER	RECOVERY (mm) TCR(%) / SCR(%)	N-VALUE OR RQD(%)
SS	1	250/610	2
SS	2	480/610	14
SS	3	430/610	15
SS	4	510/610	12
SS	5	510/610	11



☐ Field Vane Test, kPa
◘ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

Stantec

BOREHOLE RECORD

BH05-17

Sheet 1 of 1

CLIENT City of Brampton

PROJECT No. 165001037

LOCATION Heart Lake Road, Brampton, ON

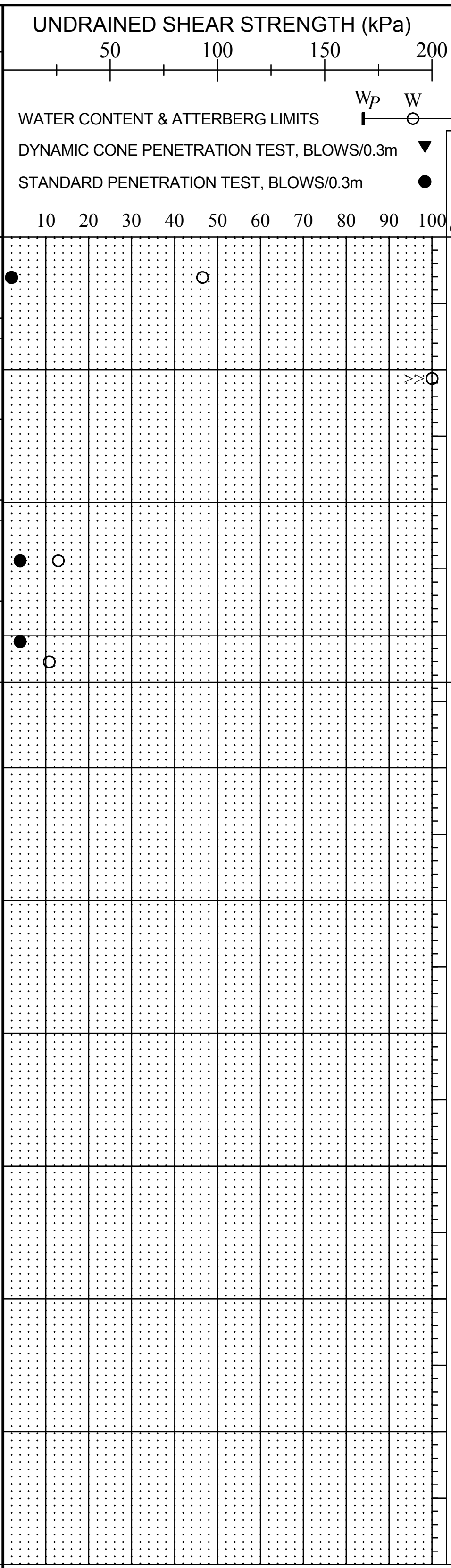
DATUM

DATES: BORING 11/09/17

WATER LEVEL

TPC ELEVATION

DEPTH (m)	ELEVATION (m)	STRATA DESCRIPTION	STRATA PLOT	WATER LEVEL	DEPTH (ft)	TYPE	NUMBER	RECOVERY (mm) TCR(%) / SCR(%)	N-VALUE OR RQD(%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
0		**Grassed** Brown, silty CLAY (CL), organics			0 1 2	SS	1	280/610	2	
1		PEAT			3 4	ST	2			
		Firm, grey, silty CLAY (CL) - some sand			5 6	ST	3			
2				∇	7 8	SS	4	380/610	4	
3					9 10	SS	5	380/610	4	
4 5 6 7 8 9 10		Borehole terminated at 3.4 m depth below existing grade. Borehole was open to 2.7 m depth with free groundwater encountered at 2.6 m depth below existing grade upon drilling completion.			11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32					



□ Field Vane Test, kPa

◘ Remoulded Vane Test, kPa

△ Pocket Penetrometer Test, kPa

BOREHOLE RECORD

BH06-17

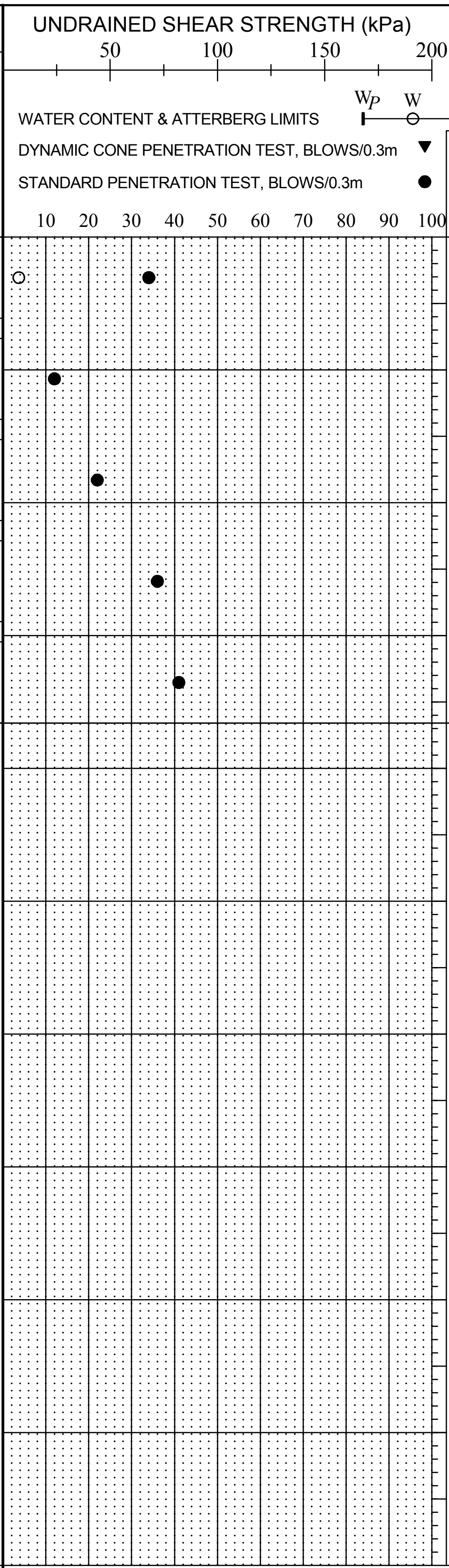
Sheet 1 of 1

CLIENT	City of Brampton	PROJECT No.	165001037
LOCATION	Heart Lake Road, Brampton, ON	DATUM	
DATES: BORING	11/08/17	WATER LEVEL	
		TPC ELEVATION	

STRATA DESCRIPTION	DEPTH (ft)	SAMPLES TYPE	NUMBER	RECOVERY (mm) TCR(%) / SCR(%)	N-VALUE OR RQD(%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
Paved Road						
Asphaltic Concrete 430 mm	1	SS	1	460/610	34	40 51 7 2
FILL - brown, sand with silt and gravel, moist						
Compact, brown, sandy silt (ML) with gravel TILL - moist - sand seam	4	SS	2	460/610	12	
	6	SS	3	510/610	22	
Dense, brown, SAND (SP) - some gravel, trace silt and clay	8.5	SS	4	610/610	36	
Dense, brown, sandy silt (ML) with gravel TILL - some clay - damp	11	SS	5	510/610	41	

Borehole terminated at 3.7 m depth below existing grade.

Borehole was open and dry upon drilling completion.



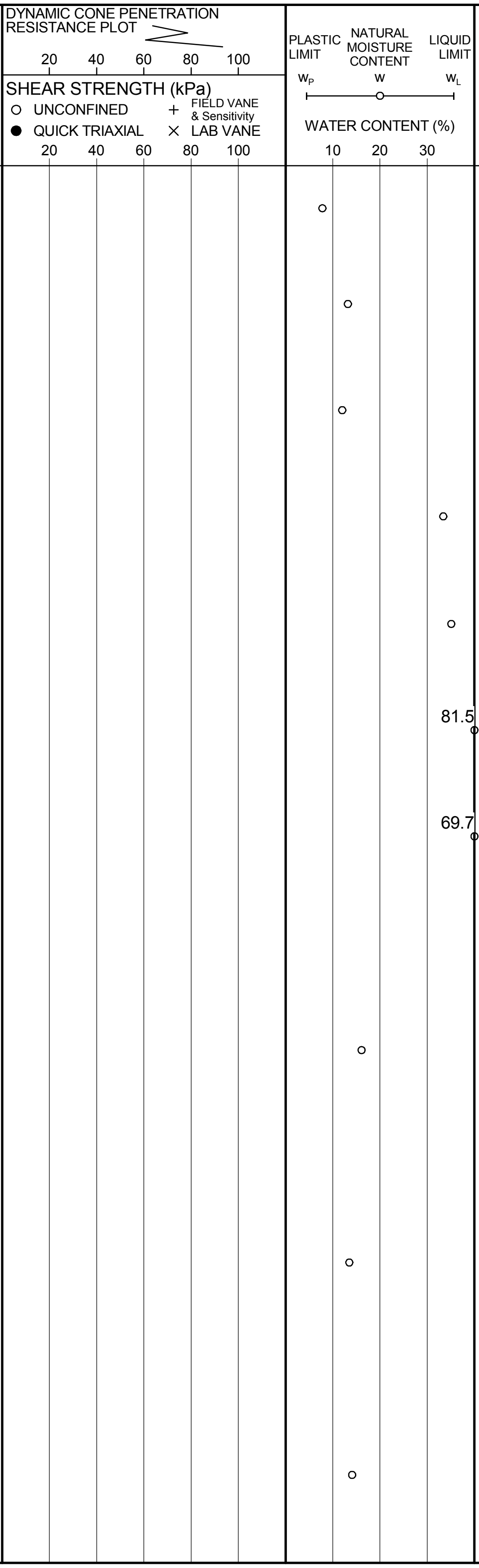
□ Field Vane Test, kPa
◘ Remoulded Vane Test, kPa
△ Pocket Penetrometer Test, kPa

LOG OF BOREHOLE BH1

PROJECT: Geotechnical Investigation for Engtec Heart Lake Road Culvert
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Rd. and Countyside Dr., Brampton, Ontario
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Solid Stem Auger
Diameter: 115 mm
Date: Jul/29/2015
REF. NO.: 15-1026-01
ENCL NO.: 2

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
(m) ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" BLOWS / 0.3 m					
0.0	**GRANULAR BASE:** sand and gravel, brown, moist.	1	SS	25					
0.7	**FILL:** sandy silt, trace gravel, layer of sand, brown to grey, moist, compact to loose.	2	SS	15					
		3	SS	29					
		4	SS	6					
2.6	**PEAT:** fibrous, trace fine silt, layer of dark grey organic silt, trace shell fragments.	1	AS						
3.6	**ORGANIC SILT:** trace fine sand, trace shell fragments, very loose.	5	SS	2					
		6	SS	1					
5.6	**SILTY SAND:** trace gravel, trace clay, grey, wet, very loose to compact.	7	SS	2					
		2	AS	5					
		8	SS	10					



Continued Next Page

GROUNDWATER ELEVATIONS

Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▽ ▼

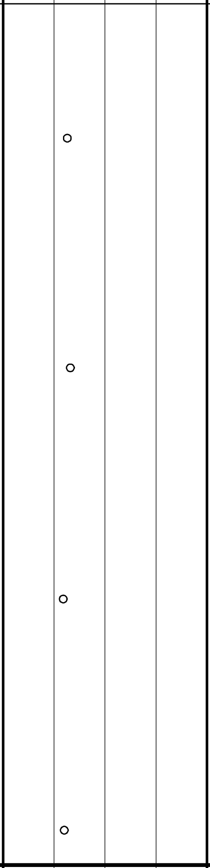
GRAPH NOTES $+^3, \times^3$: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH1

PROJECT: Geotechnical Investigation for Engtec Heart Lake Road Culvert
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Rd. and Countyside Dr., Brampton, Ontario
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Solid Stem Auger
Diameter: 115 mm
Date: Jul/29/2015
REF. NO.: 15-1026-01
ENCL NO.: 2

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● 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	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS / 0.3 m							
	SILTY SAND: trace gravel, trace clay, grey, wet, very loose to compact.(Continued)											
			9	SS	10				○			
			10	SS	10				○			
			11	SS	14				○			
			12	SS	22				○			
15.7	**END OF BOREHOLE** Notes: 1) Water was encountered at a depth of 4.6 m below ground surface during drilling. 2) Water at a depth of 3.35 m below ground surface upon completion of drilling. 3) Borehole caved at a depth of 4.0 m below ground surface upon completion of drilling.											



GROUNDWATER ELEVATIONS

Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▼ ▽

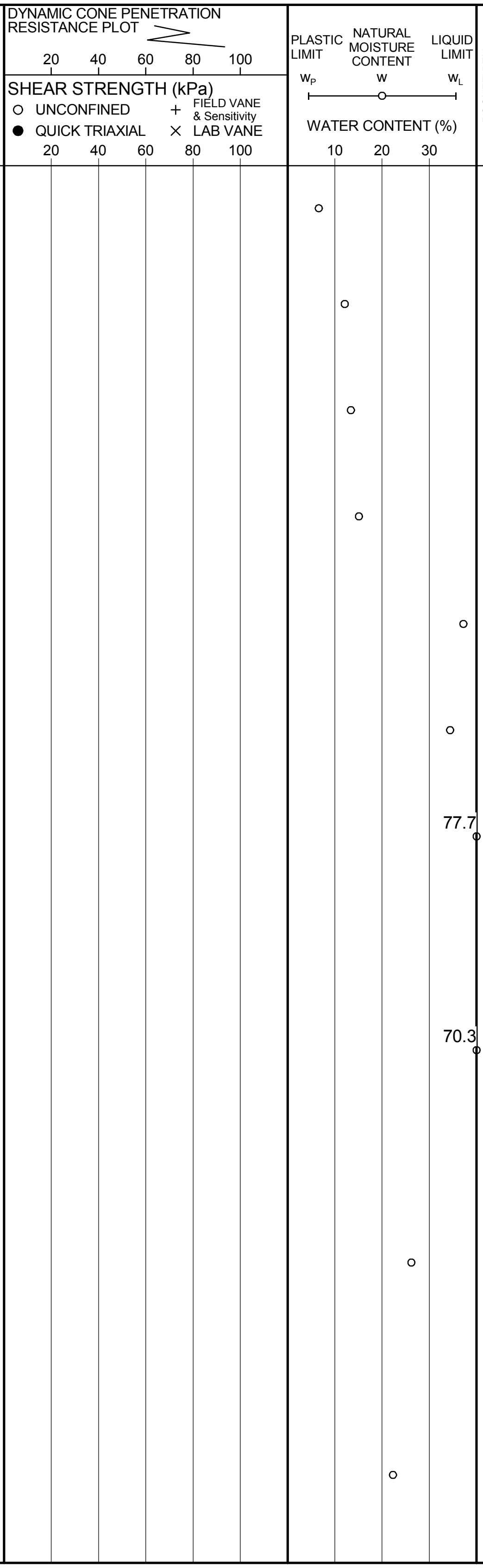
GRAPH NOTES $+^3, \times^3$: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH2

PROJECT: Geotechnical Investigation for Engtec Heart Lake Road Culvert
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Rd. and Countyside Dr., Brampton, Ontario
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Solid Stem Auger
Diameter: 115 mm
Date: Jul/29/2015
REF. NO.: 15-1026-01
ENCL NO.: 3

SOIL PROFILE (m) ELEV DEPTH	DESCRIPTION	SAMPLES NUMBER	TYPE	"N" BLOWS / 0.3 m	GROUND WATER CONDITIONS	ELEVATION	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
0.0	**GRANULAR BASE:** sand and gravel, brown, moist.	1	SS	21					
0.7	**FILL:** sandy silt to silty sand, trace gravel, trace clay, brown, moist, compact to loose.	2	SS	11					
		3	SS	8					
		4	SS	5					
		5	SS	11					
3.3	**PEAT:** fibrous, trace fine silt, layer of dark grey organic silt, trace shell fragments.	6	SS	2					
4.4	**ORGANIC SILT:** trace fine sand, trace shell fragments, very loose.	7	SS	1					
		8	SS	2					
6.5	**SILTY SAND:** trace gravel, trace clay, grey, wet, very loose to compact.	2	SS	4					
		8	SS	10					



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GROUNDWATER ELEVATIONS
Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▽ ▼

GRAPH NOTES
$+^3, \times^3$: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH2

PROJECT: Geotechnical Investigation for Engtec Heart Lake Road Culvert
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Rd. and Countyside Dr., Brampton, Ontario
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Solid Stem Auger
Diameter: 115 mm
Date: Jul/29/2015

REF. NO.: 15-1026-01
ENCL NO.: 3

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● 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	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION					
	SILTY SAND: trace gravel, trace clay, grey, wet, very loose to compact.(Continued)		9	SS	9				○			
11.1	**END OF BOREHOLE** Notes: 1) Water was encountered at a depth of 6.4 m below ground surface during drilling. 2) Water at a depth of 4.9 m below ground surface upon completion of drilling. 3) Borehole caved at a depth of 5.5 m below ground surface upon completion of drilling.											

GROUNDWATER ELEVATIONS

Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▼ ▼

GRAPH NOTES $+^3, \times^3$: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

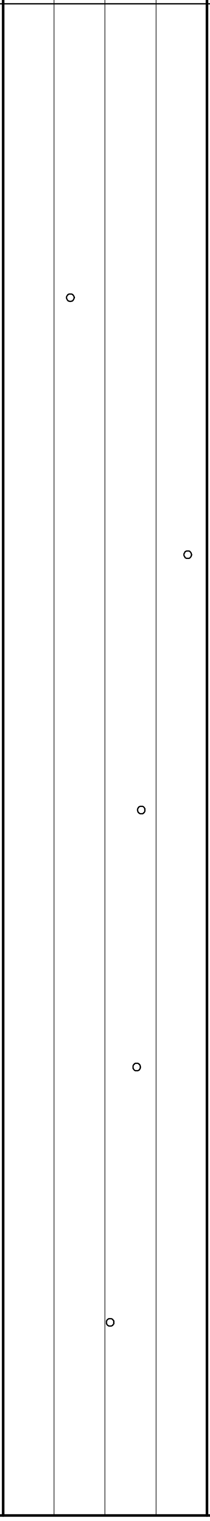
LOG OF BOREHOLE BH101

PROJECT: Geotechnical Investigation for Proposed Culverts
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario
DATUM: N/A
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Continuous Flight Auger - Auto Hammer
Diameter: 115 mm
Date: Nov/06/2015
REF. NO.: 15-1026B-01
ENCL NO.: 2

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH (kPa): ○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE & Sensitivity, × LAB VANE: 20 40 60 80 100
PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L
WATER CONTENT (%): 10 20 30
POCKET PEN. (Cu) (kPa)
NATURAL UNIT WT (Mg/m^3)
REMARKS AND GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

(m) ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION
0.0	**ASPHALT** (240 mm)					
0.2	**GRANULAR BASE:** sand and gravel, brown, moist.					
0.7	**FILL:** sandy silt, trace gravel, trace clay, trace organics, brown to grey, moist, loose.	1	AS			
		2	SS	8		
2.5	**PEAT:** fibrous, trace silt, layer of dark grey organic silt, trace rootlets, dark brown, moist, loose					
		3	SS	6		
4.0	**SILTY SAND:** trace gravel, trace clay, trace rootlets, grey, wet, loose to compact.					
		4	SS	7		
		5	SS	6		
		6	SS	9		



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GROUNDWATER ELEVATIONS
Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▼ ▼

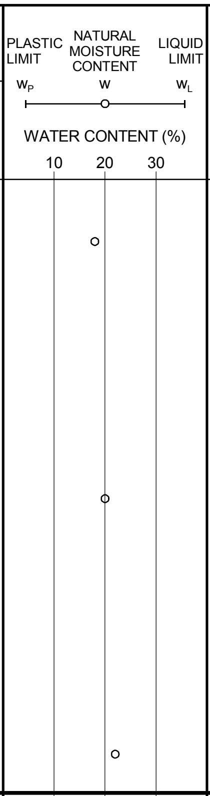
GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH101

PROJECT: Geotechnical Investigation for Proposed Culverts
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario
DATUM: N/A
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Continuous Flight Auger - Auto Hammer
Diameter: 115 mm
Date: Nov/06/2015
REF. NO.: 15-1026B-01
ENCL NO.: 2

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH (kPa)	WATER CONTENT (%)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS 0.3 m							
	SILTY SAND: trace gravel, trace clay, trace rootlets, grey, wet, loose to compact.(Continued)		7	SS	13							
			8	SS	14							
			9	SS	13							
12.7	**END OF BOREHOLE** Notes: 1) Water was encountered at a depth of 4.6 m below ground surface during drilling. 2) Water at a depth of 3.35 m below ground surface upon completion of drilling. 3) Borehole caved at a depth of 3.0 m below ground surface upon completion of drilling.											



Legend: SHEAR STRENGTH (kPa): ○ UNCONFINED; ● QUICK TRIAXIAL; + FIELD VANE & Sensitivity; × LAB VANE

GROUNDWATER ELEVATIONS
Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▽ ▼

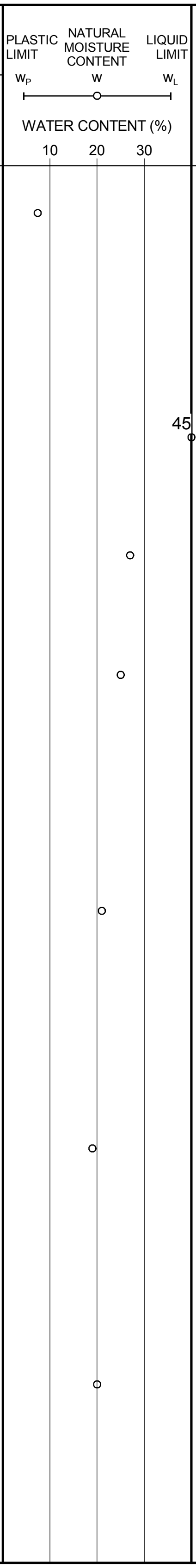
GRAPH NOTES
$+^3, \times^3$: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH102

PROJECT: Geotechnical Investigation for Proposed Culverts
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario
DATUM: N/A
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Continuous Flight Auger - Auto Hammer
Diameter: 115 mm
REF. NO.: 15-1026B-01
Date: Nov/05/2015
ENCL NO.: 3

SOIL PROFILE			SAMPLES									
(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● 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	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
0.0	**GRANULAR BASE (SHOULDER):** sand and gravel, brown, moist.		1	SS	13							
0.3	**FILL:** silty sand, trace gravel, trace clay, brown, moist, compact.											
1.1	**PEAT:** fibrous, trace silt, layer of dark grey organic silt, trace rootlets, dark brown, moist, loose		2	SS	6				45			
1.9	**SILTY SAND:** trace gravel,brown to grey, moist to saturated, loose to compact.		3	SS	13							
			4	SS	8							
			5	SS	10							
			6	SS	10							
			7	SS	9							



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GROUNDWATER ELEVATIONS
Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▽ ▼

GRAPH NOTES
+ 3 , × 3 : Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH102

PROJECT: Geotechnical Investigation for Proposed Culverts
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario
DATUM: N/A
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Continuous Flight Auger - Auto Hammer
Diameter: 115 mm
Date: Nov/05/2015
REF. NO.: 15-1026B-01
ENCL NO.: 3

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● 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	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS / 0.3 m	GROUND WATER CONDITIONS	ELEVATION					
	SILTY SAND: trace gravel,brown to grey, moist to saturated, loose to compact.(Continued)		8	SS	11				○			
9.6	**END OF BOREHOLE** Notes: 1) Water was encountered at a depth of 3.0 m below ground surface during drilling. 2) Water at a depth of 3.35 m below ground surface upon completion of drilling. 3) Borehole caved at a depth of 3.7 m below ground surface upon completion of drilling.											

GROUNDWATER ELEVATIONS
Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▽ ▼

GRAPH NOTES $+^3, \times^3$: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH201

PROJECT: Geotechnical Investigation for Proposed Culverts	**DRILLING DATA**
CLIENT: City of Brampton	Method: Continuous Flight Auger - Auto Hammer
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario	Diameter: 115 mm · REF. NO.: 15-1026B-01
DATUM: N/A	Date: Nov/05/2015 · ENCL NO.: 4
BH LOCATION: See Borehole Location Plan	

SOIL PROFILE (m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	SAMPLES NUMBER	TYPE	"N" BLOWS / 0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● 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	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
0.0	**GRANULAR BASE (SHOULDER):** sand and gravel, brown, moist.											
0.3	**FILL:** silty sand to sandy silt, trace gravel, trace clay, trace organics, brown to grey, moist, loose to compact.		1	SS	15							
			2	SS	7							
			3	SS	14							
2.5	**CLAYEY SILT TILL:** trace to some gravel, trace sand, grey, moist, stiff.											
			4	SS	13							
			5	SS	12							
5.6	**SILTY FINE SAND TO SANDY SILT:** grey, moist to saturated, compact.											
			6	SS	20							
			7	SS	16							

Continued Next Page

GROUNDWATER ELEVATIONS

Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▽ ▼

GRAPH NOTES + ^{3}, × ^{3}: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH201

PROJECT: Geotechnical Investigation for Proposed Culverts
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario
DATUM: N/A
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Continuous Flight Auger - Auto Hammer
Diameter: 115 mm
Date: Nov/05/2015
REF. NO.: 15-1026B-01
ENCL NO.: 4

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● 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	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS / 0.3 m							
	SILTY FINE SAND TO SANDY SILT: grey, moist to saturated, compact.(Continued)		8	SS	12				○			
9.9	**END OF BOREHOLE DUE TO AUGER REFUSAL** Notes: 1) Water was encountered at a depth of 5.1 m below ground surface during drilling. 2) Water at a depth of 3.8 m below ground surface upon completion of drilling. 3) Borehole caved at a depth of 3.9 m below ground surface upon completion of drilling.											

GROUNDWATER ELEVATIONS

Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▽ ▼

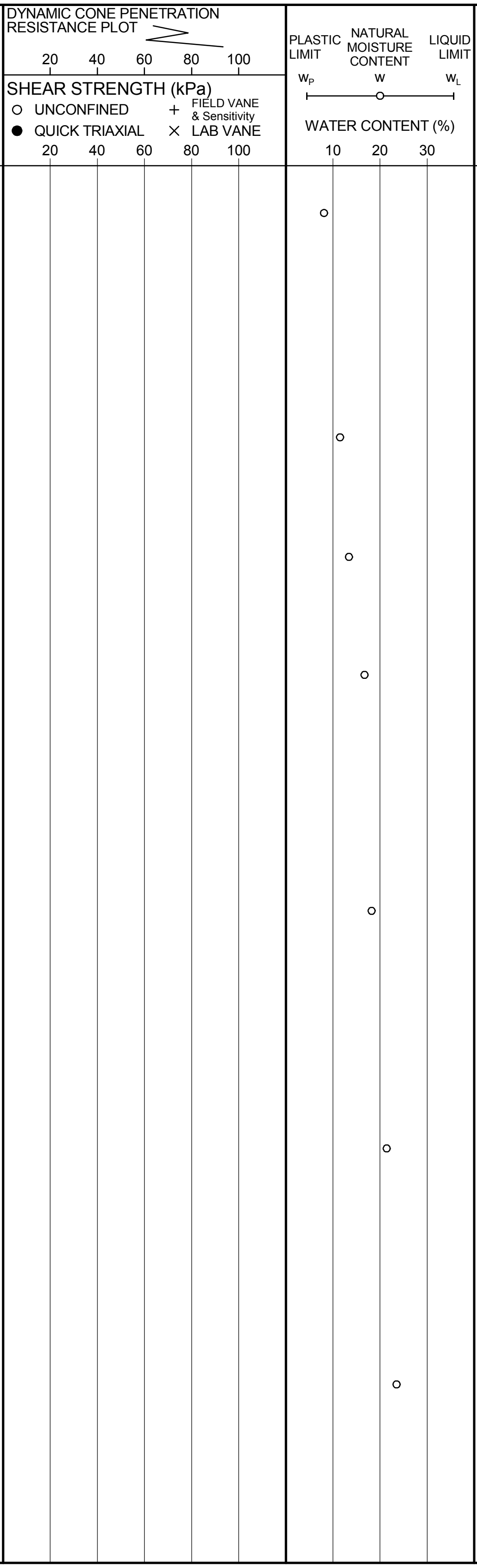
GRAPH NOTES + 3, × 3 : Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH202

PROJECT: Geotechnical Investigation for Proposed Culverts
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario
DATUM: N/A
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Continuous Flight Auger - Auto Hammer
Diameter: 115 mm
Date: Nov/03/2015
REF. NO.: 15-1026B-01
ENCL NO.: 5

(m) ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" BLOWS / 0.3 m	GROUND WATER CONDITIONS	ELEVATION	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
0.0	**GRANULAR BASE (SHOULDER):** sand and gravel, brown, moist.								
0.2	**FILL:** silty sand, trace gravel, trace clay, trace organics, brown to grey, moist, compact.	1	SS	15					
		2	SS	10					
2.1	**SANDY SILT TILL:** trace to some gravel, trace clay, grey, moist, compact.	3	SS	13					
		4	SS	16					
4.0	**SILTY FINE SAND TO SANDY SILT:** grey, moist to saturated, loose to compact.	5	SS	13					
		6	SS	13					
		7	SS	15					



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GROUNDWATER ELEVATIONS

Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▼ ▼

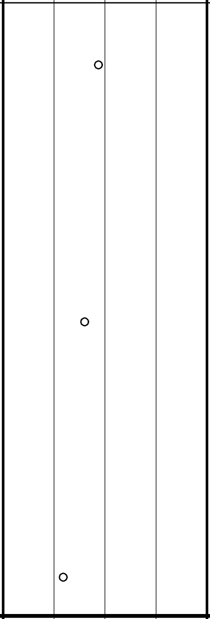
GRAPH NOTES $+^3, \times^3$: Numbers refer to Sensitivity

○ ε=3% Strain at Failure

PROJECT: Geotechnical Investigation for Proposed Culverts
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario
DATUM: N/A
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Continuous Flight Auger - Auto Hammer
Diameter: 115 mm
Date: Nov/03/2015
REF. NO.: 15-1026B-01
ENCL NO.: 5

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● 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	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION					
	SILTY FINE SAND TO SANDY SILT: grey, moist to saturated, loose to compact.(Continued)											
			8	SS	10				○			
			9	SS	8				○			
			10	SS	14				○			
12.7	**END OF BOREHOLE** Notes: 1) Water was encountered at a depth of 3.1 m below ground surface during drilling. 2) Water at a depth of 3.6 m below ground surface upon completion of drilling. 3) Borehole caved at a depth of 3.7 m below ground surface upon completion of drilling.											



GROUNDWATER ELEVATIONS

Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▼ ▽

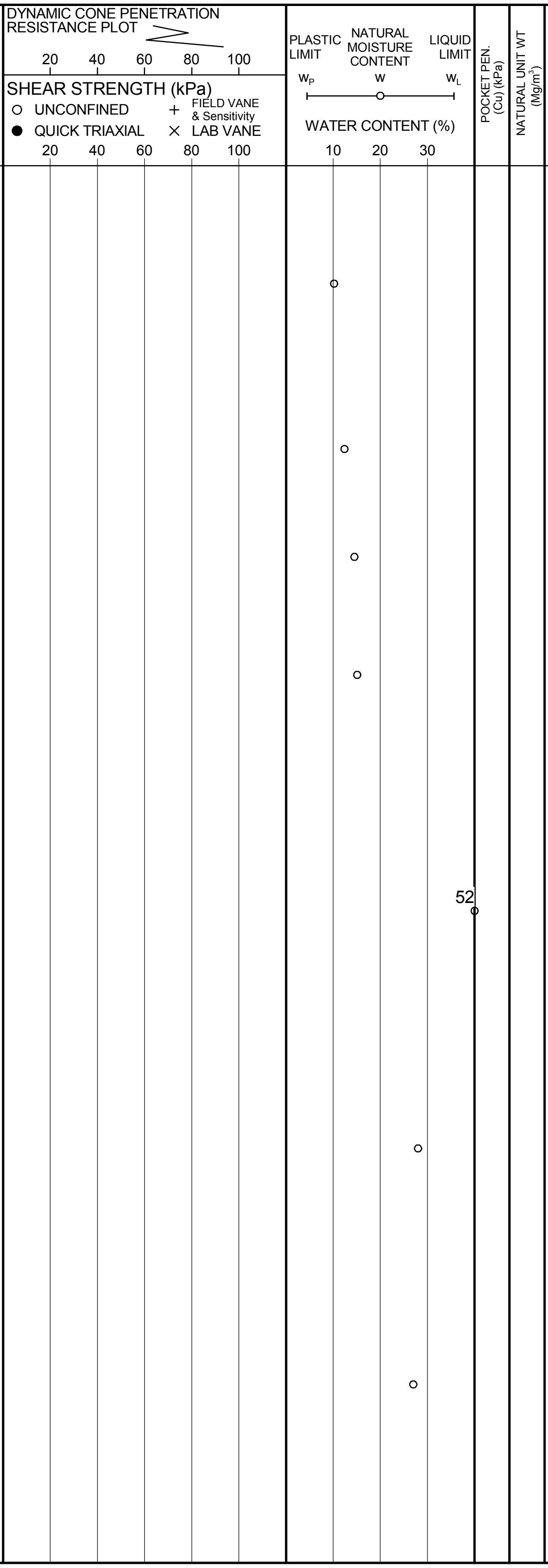
GRAPH NOTES $+^3, \times^3$: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH301

PROJECT: Geotechnical Investigation for Proposed Culverts
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario
DATUM: N/A
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Continuous Flight Auger - Auto Hammer
Diameter: 115 mm
Date: Nov/05/2015
REF. NO.: 15-1026B-01
ENCL NO.: 6

SOIL PROFILE (m) ELEV / DEPTH	DESCRIPTION	SAMPLES NUMBER	TYPE	"N" BLOWS / 0.3 m	GROUND WATER CONDITIONS	ELEVATION	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
0.0	**ASPHALT** (245 mm)						
0.2	**GRANULAR BASE:** sand and gravel, brown, moist.						
0.7	**FILL:** sandy silt, trace gravel, pockets of clayey silt brown, moist to wet, compact to very loose.	1	AS				
		2	SS	17			
		3	SS	7			
		4	SS	3			
4.0	**PEAT:** fibrous, trace silt, layer of dark grey organic silt, trace rootlets, dark brown, moist, very loose.	5	SS	4			
5.6	**SILTY CLAY TO CLAYEY SILT:** trace sand, layer of silt, grey, moist to wet, very soft.	6	SS	1			
		7	SS	1			



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GROUNDWATER ELEVATIONS
Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▼ ▽

GRAPH NOTES $+^3, \times^3$: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH301

PROJECT: Geotechnical Investigation for Proposed Culverts
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario
DATUM: N/A
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Continuous Flight Auger - Auto Hammer
Diameter: 115 mm
Date: Nov/05/2015
REF. NO.: 15-1026B-01
ENCL NO.: 6

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● 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	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS/0.3 m							
	SILTY CLAY TO CLAYEY SILT: trace sand, layer of silt, grey, moist to wet, very soft.(Continued)		8	SS	2				○			
12.4	**SANDY SILT TILL:** trace gravel, trace clay, grey, moist, compact		9	SS	26				○			
12.7	**END OF BOREHOLE** Notes: 1) Water was encountered at a depth of 1.5 m below ground surface during drilling. 2) Water at a depth of 2.0 m below ground surface upon completion of drilling. 3) Borehole caved at a depth of 2.5 m below ground surface upon completion of drilling.											

GROUNDWATER ELEVATIONS

Shallow/ Single Installation ∇ ▼ Deep/Dual Installation ∇ ▼

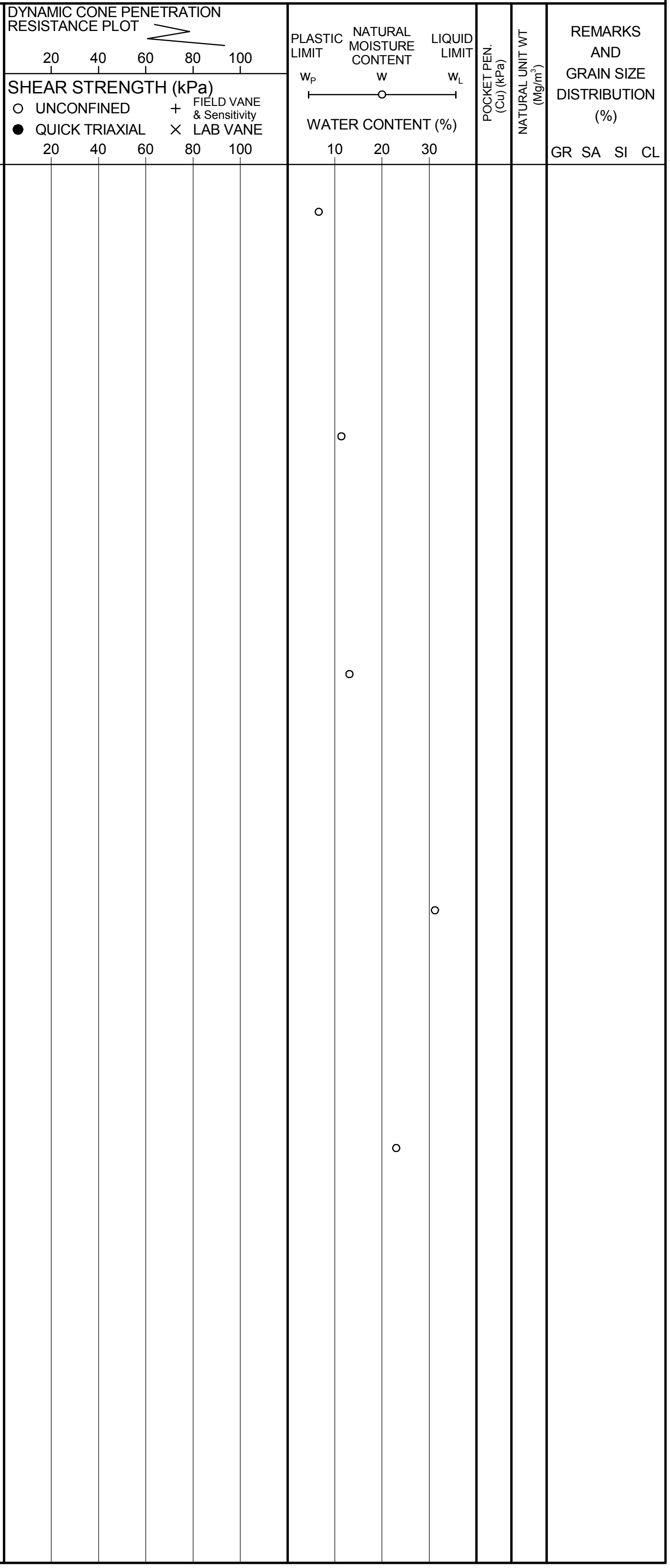
GRAPH NOTES $+^3, \times^3$: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH302

PROJECT: Geotechnical Investigation for Proposed Culverts
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario
DATUM: N/A
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Continuous Flight Auger - Auto Hammer
Diameter: 115 mm
Date: Nov/05/2015
REF. NO.: 15-1026B-01
ENCL NO.: 7

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION
(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS / 0.3 m		
0.0	**GRANULAR BASE (SHOULDER):** sand and gravel, brown, moist.						
0.3	**FILL:** sandy silt, trace gravel, brown, moist to wet, loose to compact.		1	SS	18		
			2	SS	6		
			3	SS	5		
4.7	**PEAT:** fibrous, trace silt, layer of dark grey organic silt, trace rootlets, dark brown, moist, very loose.		4	SS	3		
5.6	**SILTY CLAY TO CLAYEY SILT:** trace sand, layer of silt, grey, moist to wet, very soft.		5	SS	1		



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GROUNDWATER ELEVATIONS

Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▼ ▼

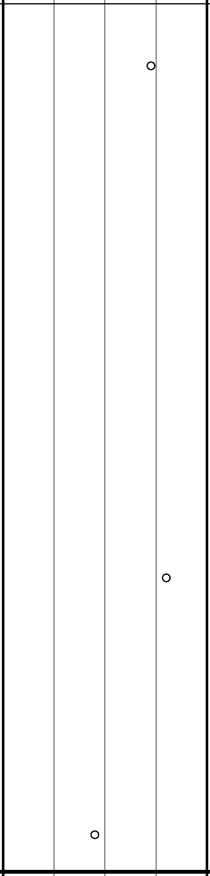
GRAPH NOTES $+^3, \times^3$: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH302

PROJECT: Geotechnical Investigation for Proposed Culverts
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario
DATUM: N/A
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Continuous Flight Auger - Auto Hammer
Diameter: 115 mm
Date: Nov/05/2015
REF. NO.: 15-1026B-01
ENCL NO.: 7

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● 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	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS / 0.3 m	GROUND WATER CONDITIONS	ELEVATION					
	SILTY CLAY TO CLAYEY SILT: trace sand, layer of silt, grey, moist to wet, very soft.(Continued)		6	SS	1				○			
12.4	**SILTY SAND:** trace gravel, grey, moist, compact.		7	SS	1				○			
			8	SS	13				○			
14.2	**END OF BOREHOLE** Notes: 1) Water was encountered at a depth of 2.8 m below ground surface during drilling. 2) Water at a depth of 3.0 m below ground surface upon completion of drilling. 3) Borehole caved at a depth of 3.1 m below ground surface upon completion of drilling.											



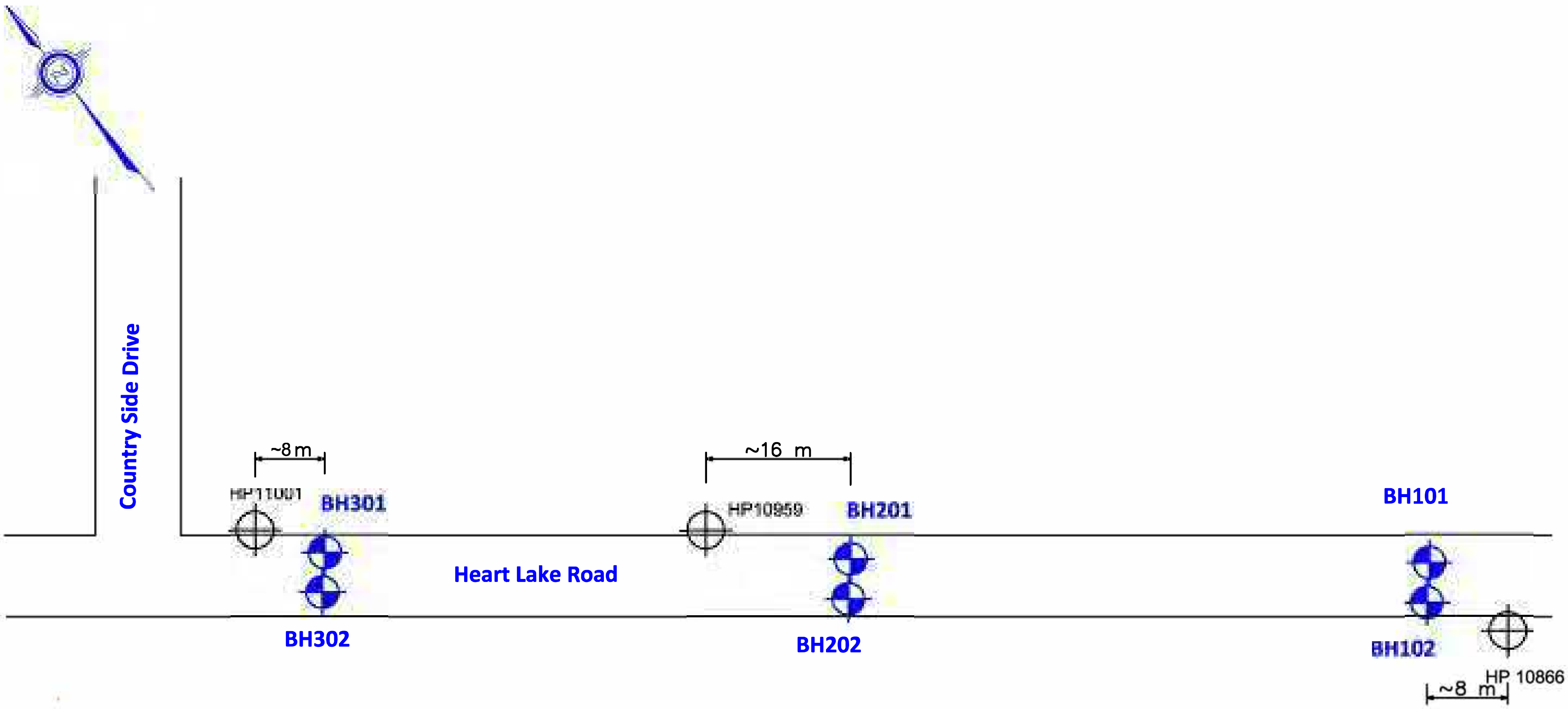
GROUNDWATER ELEVATIONS

Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▽ ▼

GRAPH NOTES
$+^3, \times^3$: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

APPENDIX D

Drawings from Previous Geotechnical Investigation Reports

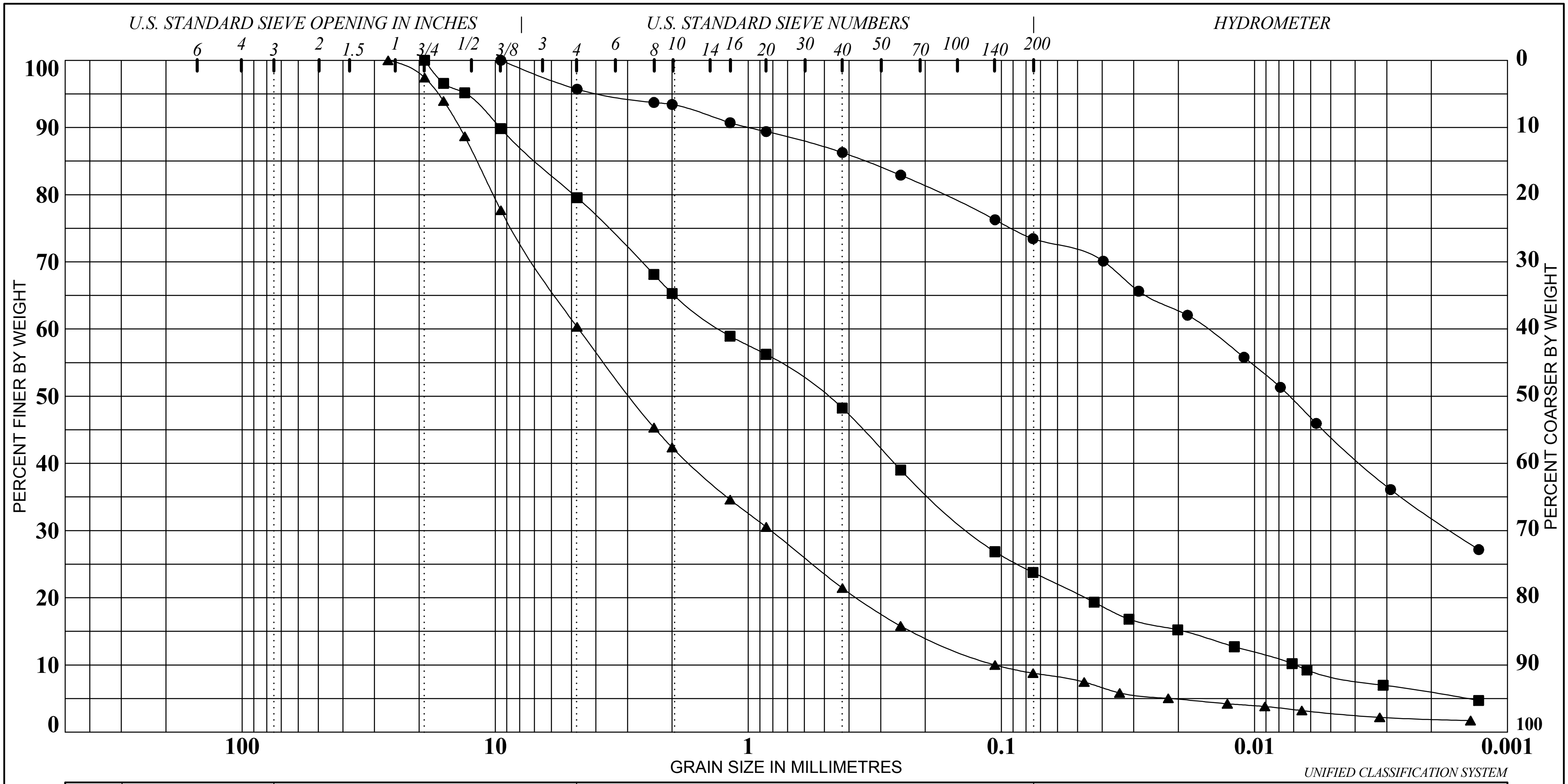


⊕	**BH1**	**Proposed Borehole Location**
⊕	**HP11001**	**Hydro Pole**

Client:	**City of Brampton**			Project No.: **15-1026B-01**	Drawing No.: **1**
Drawn:	**GC**	Approved:	**DL**	Title:	**Borehole Location Plan**
Date:	**October 2015**	Scale:	**N.T.S.**	Project:	**Geotechnical Investigation** **Proposed Culverts** **Heart Lake Road, Brampton, Ontario**
Original Size:	**Letter**	Rev:	**DL**		Engtec Consulting Inc.

APPENDIX E

Laboratory Testing Results



BLDs	COBBLES	GRAVEL		SAND			SILT & CLAY	
		coarse	fine	coarse	medium	fine	SILT	CLAY

Sample		Depth (m)	Description	W%	W_L	W_P	I_P	%Gravel	%Sand	%Silt	%Clay
●	BH01-17	2.9	CLAY with SAND (CL) TILL	15	25	13	12	4	23	41	32
■	BH03-17	1.8	SILTY SAND with GRAVEL (SM)	13				20	56	18	6
▲	BH06-17	0.3	SAND with SILT and GRAVEL (SW-SM)	4				40	51	7	2

Stantec

Project: Heart Lake Road

Location: Heart Lake Road, Brampton, ON

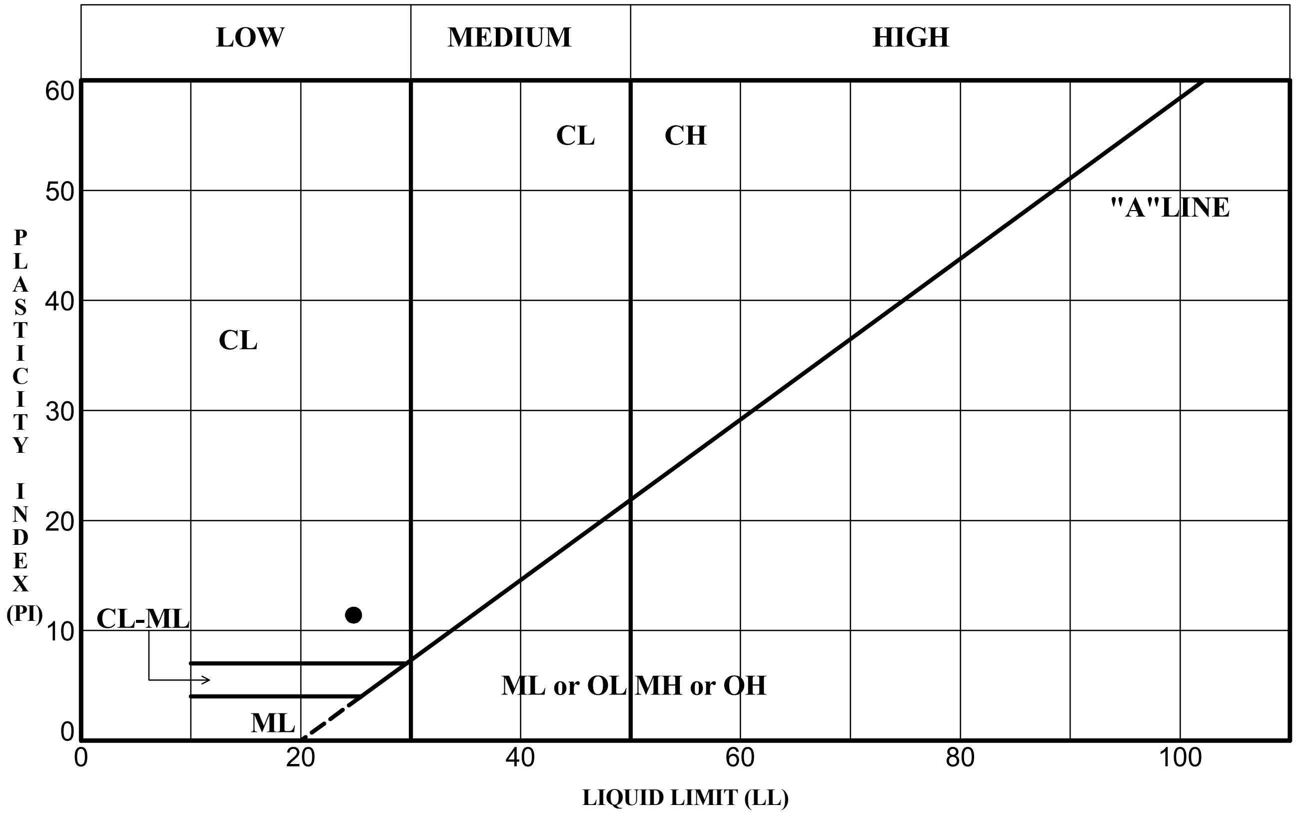
Project No.: 165001037

GRADATION CURVE (ASTM D422)

Figure: 1

Remarks:

PLASTICITY CHART



	Specimen	Depth (m)	LL	PL	PI	Fines	W%	Classification
●	BH01-17	2.9	25	13	12	73	15	CLAY with SAND (CL) TILL

Stantec

Project: Heart Lake Road

Location: Heart Lake Road, Brampton, ON

Project No.: 165001037

ATTERBERG LIMITS
(ASTM D4318)

Figure: 2

Remarks:

STN13-ATTERBERG 165001037.GPJ MM.GDT 12/1/17

CONSOLIDATION TEST SUMMARY

ASTM D2435/D2435M

FIGURE

SAMPLE IDENTIFICATION

Project Number	1776083(7000)	Sample Number	ST2
Borehole Number	5	Sample Depth, m	

TEST CONDITIONS

Test Type	Laboratory Standard	Load Duration, hr	24
Oedometer Number	6		
Date Started	11/17/2017		
Date Completed	11/24/2017		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.90	Unit Weight, kN/m³	10.89
Sample Diameter, cm	6.33	Dry Unit Weight, kN/m³	3.71
Area, cm²	31.50	Specific Gravity, measured	1.797
Volume, cm³	59.84	Solids Height, cm	0.400
Water Content, %	193.74	Volume of Solids, cm³	12.62
Wet Mass, g	66.59	Volume of Voids, cm³	47.33
Dry Mass, g	22.67	Degree of Saturation, %	92.8

TEST COMPUTATIONS

Stress kPa	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv. cm²/s	mv m²/kN	k cm/s
0.00	1.903	3.752	1.903				
6.38	1.901	3.746	1.902				
11.22	1.889	3.717	1.895	60	1.27E-02	1.24E-03	1.55E-06
21.02	1.871	3.672	1.880	97	7.73E-03	9.65E-04	7.31E-07
40.63	1.811	3.521	1.841	231	3.11E-03	1.63E-03	4.98E-07
78.44	1.685	3.207	1.748	305	2.12E-03	1.70E-03	3.54E-07
157.05	1.519	2.790	1.601	279	1.95E-03	1.13E-03	2.16E-07
40.63	1.571	2.923	1.644				
11.22	1.634	3.080	1.603				

Note:

Consolidation loading and unloading schedule assigned by the client.

cv and k are approximate only based on t_{90} estimated from Square Root of Time Method (ASTMD2435/2435M)

Specimen swelled under 6.38kPa.

Specimen taken 8cm from top of the tube.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	1.63	Unit Weight, kN/m³	12.04
Sample Diameter, cm	6.33	Dry Unit Weight, kN/m³	4.32
Area, cm²	31.50	Specific Gravity, measured	1.80
Volume, cm³	51.47	Solids Height, cm	0.400
Water Content, %	178.83	Volume of Solids, cm ³	12.62
Wet Mass, g	63.21	Volume of Voids, cm ³	38.85
Dry Mass, g	22.67		

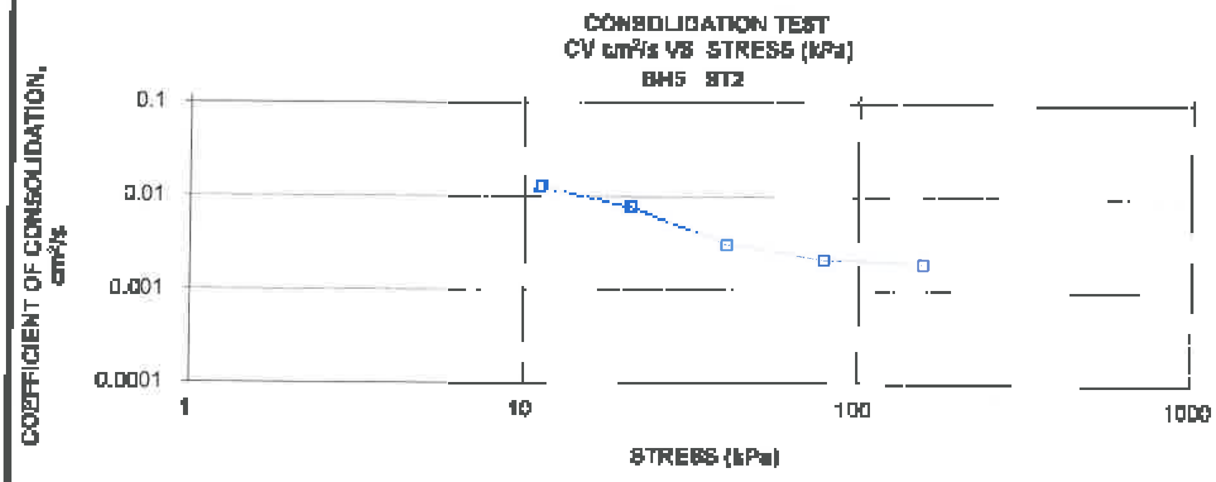
Prepared By:

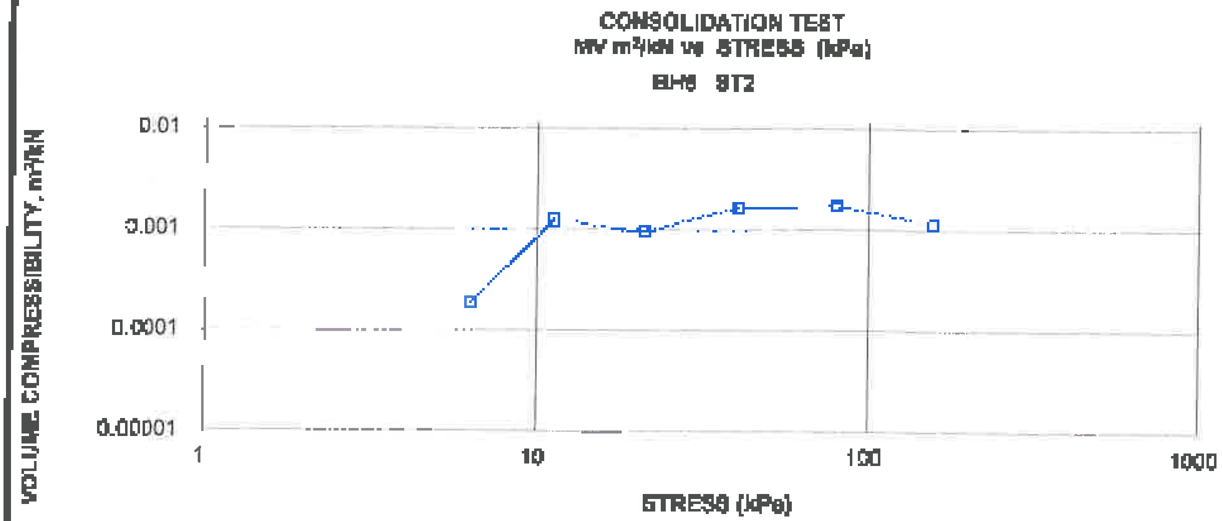
Golder Associates

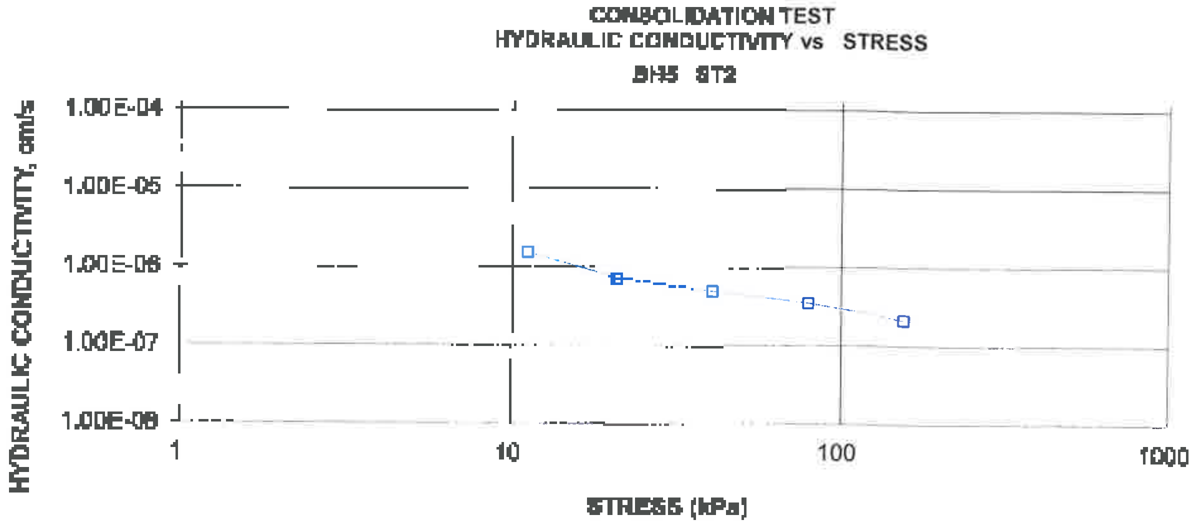
Checked By:

CONSOLIDATION TEST SUMMARY

FIGURE


CONSOLIDATION TEST
CV cm²/s VS STRESS (kPa)
BH5 ST2


CONSOLIDATION TEST
MV m²/kN vs STRESS (kPa)
BH5 ST2


CONSOLIDATION TEST
HYDRAULIC CONDUCTIVITY vs STRESS
BH5 ST2

Project No. 1776093(7000)

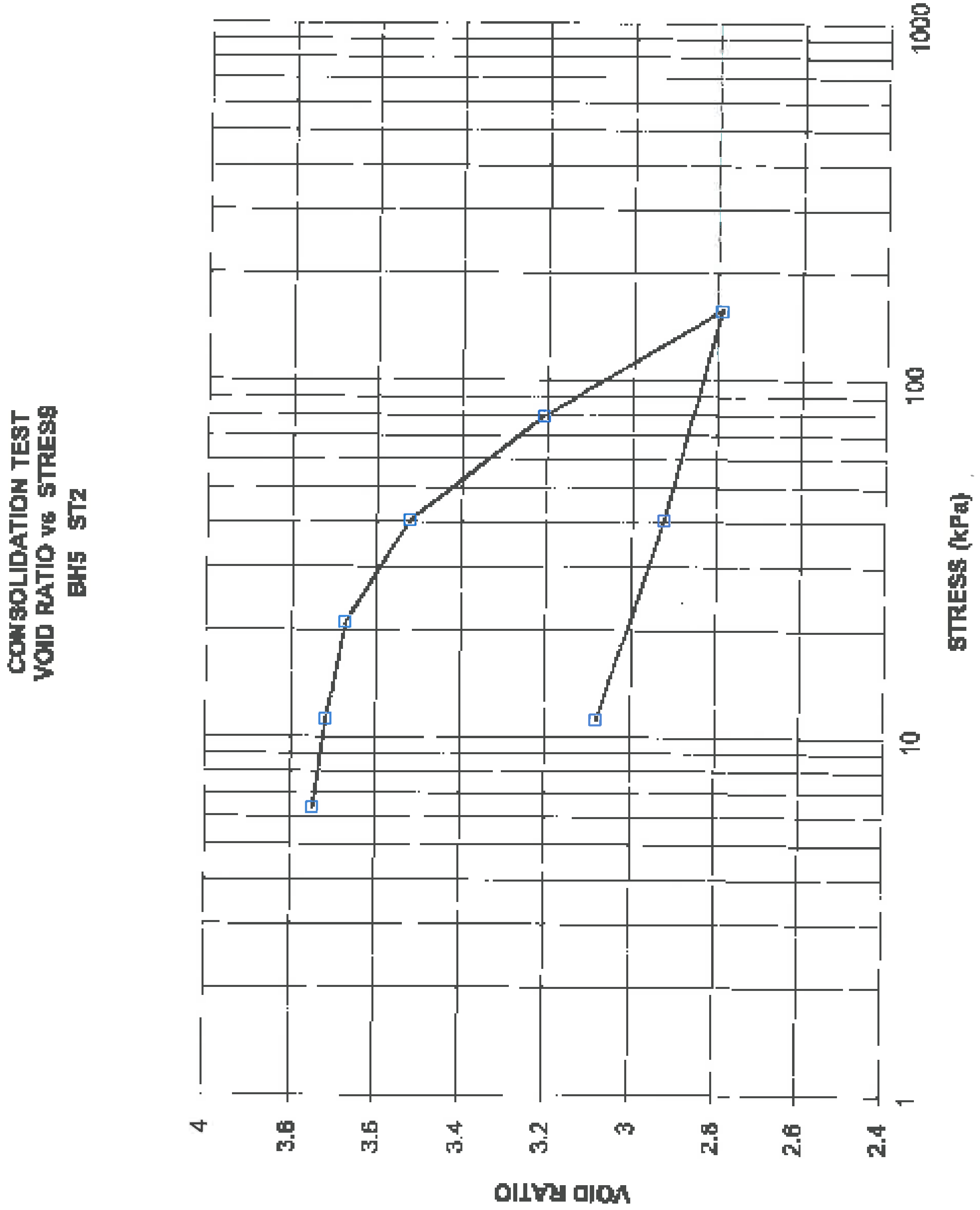
Prepared By: LH

Golder Associates

Checked By:

CONSOLIDATION TEST
VOID RATIO VS LOG STRESS

FIGURE


CONSOLIDATION TEST
VOID RATIO vs STRESS
BH5 ST2

Project No. 1776083(7000)

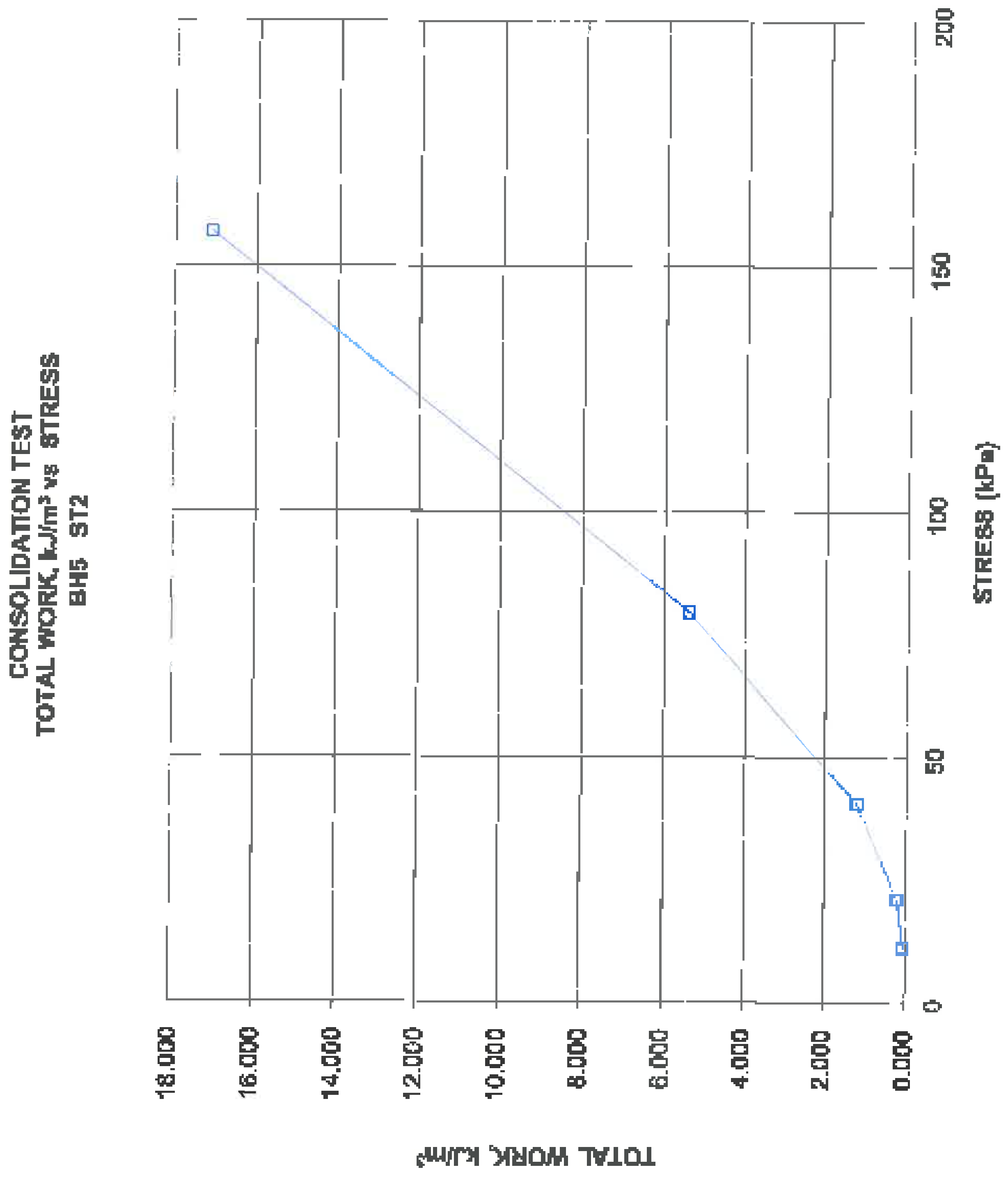
Prepared By: LH

Golder Associates

Checked By:

CONSOLIDATION TEST
TOTAL WORK VS STRESS

FIGURE



Project No. 1775063(7000)

Prepared By: LH

Golder Associates

Checked By:

SPECIFIC GRAVITY TEST RESULTS

ASTM D 854 TEST METHOD B

PROJECT NUMBER	1775083 (7000)
PROJECT NAME	Stantec/LaboratoryTesting/Miss
DATE TESTED	November 21, 2017

Borehole No.	Sample No.	Measured Specific Gravity
5	ST2	1.797

Note: Test carried out on soil particles <4.75mm using kerosene.

Checked By:

Golder Associates

Engtec Consulting Inc.
12-100 Hanlan Road, Vaughan
Ontario, L4L 4V8
Tel: (905) 856-2988
Fax: (905) 856-2989

Project No: ET15-1135A August 25, 2015

Bill Allison, C.E.T., rcca, PEO Lic.
Supervisor, Development Approvals
Engineering and Development Services
City of Brampton
2 Wellington Street West
Brampton, Ontario
L6Y 4R2

Email: bill.allison@brampton.ca

Dear Bill:

Geotechnical Investigation
Proposed New Culvert - Heart Lake Road
Brampton, Ontario

1 Introduction

Engtec Consulting Inc. (Engtec) was retained by City of Brampton (Client), to conduct a geotechnical investigation for the Proposed New Culvert located at Heart Lake Road, Brampton, Ontario. The purpose of this geotechnical investigation was to obtain information on the existing subsurface conditions by means of a limited number of boreholes that would provide the required geotechnical design information for a contemplated Concrete Box Culvert at the project.

The report is prepared with the condition that the proposed culvert design will be in accordance with all applicable standards and codes and applicable regulations and good engineering practice. Further, the recommendations and opinions in this report are applicable only to the proposed project as described above. On-going liaison and communication with Engtec during the design stage and construction phase of the project is strongly recommended to confirm that the recommendations in this report are applicable and/or correctly interpreted and implemented. Any queries concerning the geotechnical aspects of the proposed project shall be directed to Engtec for further elaboration and/or clarification.

This report is provided on the basis of the terms of reference presented in our approved proposal prepared by Engtec and approved by the City of Brampton and based on our understanding of the project. If there are any changes in the design features relevant to the geotechnical analyses, or if any questions arise concerning the geotechnical aspects of the codes and standards, this office should be contacted to review the changes. It may then be necessary to carry out additional borings and investigations, before the recommendations of this report can be relied upon.

This report deals with geotechnical issues only. The geo-environmental (chemical) aspects of the subsurface conditions, including the consequences of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources, were not investigated and were beyond the scope of this assignment.

The site investigation and recommendations follow generally accepted practice for geotechnical consultants in Ontario. This report has been prepared for the Client and Client's engineers. Third party use of this report without Engtec's consent is prohibited. The limitations to the report presented in this report form an integral part of the report and they must be considered in conjunction with the contents of this report.

2 Field Investigation Works

The field work for the geotechnical investigation was carried out on July 29th, 2015, during which time two (2) boreholes (i.e. BH1 and BH2) on the shoulders of the roadway in alignment with the proposed location of the culvert were advanced as shown on the Borehole Location Plan, Drawing No. 1.

The boreholes were advanced using solid stem auger equipment supplied by a drilling specialist subcontracted to Engtec. Samples were retrieved with a 51mm (2in) O.D. split-barrel (split spoon) sampler driven with a hammer weighing 624N with a drop of 762mm (30in) in accordance with the Standard Penetration Test (SPT) method.

The field work for this investigation was monitored by a member of our engineering staff, who also determined the approximate borehole locations in the field, logged the boreholes and cared for the recovered samples. The boreholes were located in the field by Engtec according to the borehole location plan provided by the Client.

The shallow groundwater conditions were noted in the open boreholes during drilling and at the completion of drilling. The boreholes were backfilled and sealed upon completion of drilling. All soil samples obtained during this investigation were brought to our laboratory for further examination.

The ground surface elevations at the as drilled borehole locations were not available at the time of preparing the report. Contractors performing the work should confirm the elevations prior to construction. The borehole locations plotted on the Borehole Location Plan were based on the measurements of the site features and should be considered to be approximate.

3 Site and Subsurface Conditions

The subject site is located at Heart Lake Road, 60 m north of the Heart Lake Conservation entrance in Brampton, Ontario (see Drawing No. 1 for details). Notes on sample descriptions used in the record of borehole are presented on Enclosure No. 1 to this submission. The subsurface conditions in the boreholes (BH1 to BH2) are presented on the borehole logs (Enclosure Nos. 2 to 3 inclusive). The following are the detailed descriptions of the major soil strata encountered in the boreholes.

3.1 Soil Conditions

3.1.1 Granular Base/Subbase

Sand and gravel fill materials were encountered surficially in Boreholes BH1 and BH2. The thickness of granular base/subbase was approximately 690mm.

3.1.2 Fill Materials

Fill materials consisting of sandy silt to silty sand were encountered below the granular base/subbase in Boreholes BH1 and BH2, and extended to the depths ranging from about 2.6m to 3.3m below the existing ground surface. SPT "N" values ranging from 5 to 29 blows per 300 mm penetration indicated a loose to compact relative density.

3.1.3 Peat and Organic Silt

Peat and organic silt deposits were encountered below the fill materials in Boreholes BH1 and BH2, and extended to depths ranging from about 5.6m to 6.5m below the existing ground surface. SPT "N "values ranging from 1 to 2 blows per 300 mm penetration indicated a very loose relative density.

3.1.4 Silty Sand

Silty sand deposits were encountered in Boreholes BH1 and BH2 below the organic silt, and extended to the termination depths of the boreholes. SPT "N "values ranging from 2 to 24 blows per 300mm penetration indicated a very loose to compact relative density.

3.2 Groundwater Conditions

Water was encountered at depths ranging from about 4.6m to 6.4m below the existing ground surface during drilling. Water levels was recorded at depths ranging from about 3.4m to 4.9m below the existing ground surface upon completion of drilling. Borehole BH1 caved at a depth of 4.0m below ground surface upon completion of drilling, Borehole BH2 caved at a depth of 5.5 m below ground surface upon completion of drilling.

It should be noted that the groundwater levels can vary and are subject to seasonal fluctuations in response to weather events subsurface and surface water flow/movement.

4 Discussion and Recommendations

This report contains the findings of Engtec's geotechnical investigation, together with our geotechnical engineering recommendations and any relevant comments. These recommendations and comments are based on factual information and are intended only for the use by the design engineers. Subsurface conditions between and beyond the boreholes may differ from those encountered at the borehole locations, and different conditions may become apparent during construction, which could not be detected or anticipated at the time of the site investigation.

The construction methods described in this report must not be considered as being specifications or direct recommendations to the contractors, or as being the only suitable methods. Construction methods only express Engtec's opinion and are not intended to direct the contractors on how to carry out the construction works and activities. Contractors should also be aware that the data and their interpretation presented in this report may not be sufficient to assess all the factors that may affect the construction works.

Specific design drawings of the project are not available at the time of preparing this report. However Engtec was provided a conceptual drawing of a concrete box culvert with overhand/cantilever extensions, with the objective to determine the suitability of the subsurface conditions to support the concrete box culvert loading (see attachments to this report indicating the type of proposed culvert). As a standard convention, once formal design drawings are generated for this project, it is recommended that Engtec should be consulted on provided any additional or necessary comments relevant to this project.

4.1 Foundation Design Considerations

Based on the results of this investigation, the fill materials, peat and organic silt were encountered in all boreholes at the site and extended to depths ranging from 5.6m to 6.5m below the existing ground surface. The organic soils encountered on this site are highly compressible, and will be subject to long term settlement and potentially to differential settlement should additional loading be applied or any disturbance occurs during the construction or the groundwater tables are significantly lowered. The magnitude of the settlement cannot be predicted. The existing fill materials, peat and organics silt soils are not considered suitable to support the proposed culvert. Completely removing the existing fill materials, peat and organics silt and replacing with engineered fill are also not considered operationally and financially feasible. Therefore, the foundation of the culvert may be considered to be supported in the underlying silty sand soils by installing a deep foundation system.

4.2 Deep Foundation Option – Helical Pile

A deep foundation system may be considered to support the proposed new culvert. Driven piles is not considered for this site due to small size of the culvert and significant cost of mobilizing the pile driving machine as well as for the potential of settlement(s) as a result of heavy piling machines, and as such the proposed new culvert could be supported on a series of helical piles founded in the underlying competent silty sand soils.

The actual design details of the helical piles are typically provided by the piling contractor. Some difficulty may be encountered in advancing the piles through the fill materials due to the potential presence of obstruction such as cobbles and boulders. However, should an obstruction be encountered, the pile may be extracted and reused at an alternate location. Use of helical piles is recommended as it provides a number of advantages when compared to the driven pile option:

1. The effect of the helical pile installation is unlikely to have an adverse impact on the existing paved structure;
2. Helical pile installation requires use of comparatively smaller equipment which is does not generate excessive noise or visible air pollution due to use of diesel engines; and

3. The relatively small size of the helical pile installation equipment would allow easier access to any designer proposed installation locations.

Helical piles, also known as helical piers, are deep foundation underpinning elements constructed using steel shafts with helical flights. The shafts are advanced to bearing depth by twisting them into the soil while monitoring torque to estimate the pile capacity. Helical piles can also act as end bearing piles under certain circumstances. Based on the borehole information, a bearing capacity value of 40kN to 50kN per pile at SLS and 60kN to 75kN at ULS should be available for the helical pile installed into the competent silty sand. The designer should define the depth and type of helical piles according to the soil conditions and the required design loads. A specialized contractor must be retained to design and install helical piles. Bearing capacity and other design details regarding helical piles can be discussed with the specialized contractor. Field load testing of piles is required to confirm the design bearing capacity. The test helical pile should be loaded to at least 2 times the design bearing capacity at ULS.

4.2.1 Subgrade Protection, Frost Protection and Scour Protection

All foundations including the pile caps should be founded at a minimum depth of 1.2 m below the lowest surrounding grade, to provide adequate protection against frost penetration. It should be noted that the scour protection, such as rip-rap and rock blocks should not be considered as earth cover for frost protection purposes.

4.2.1 Sliding Resistance

Resistance to lateral forces/sliding resistance should be carried out by using a battered pile approach, which should be designed by the pile supplier.

4.2.2 Temporary Excavations and Groundwater Control

It is anticipated that foundation excavations at the site will consist of temporary open cuts with side slopes not steeper than 1 horizontal to 1 vertical (1H:1V). However, depending on the construction procedures adopted by the contractor, and weather conditions at the time of construction, some local flattening of the slopes should be required, especially in looser/softer zones (i.e. in fills), or where localized seepage is encountered. All excavations should be carried out in accordance with the Occupational Health and Safety Act and Regulations for Construction Projects. According to the Act, the existing fills would be classified as Type 3 soils above groundwater table and Type 4 below the groundwater table; the native compact silty sand would be classified as Type 4 soils below the groundwater table.

The existing peat and organic soils are highly compressible and are extremely easy to disturb and will not be stable should additional loading (such as construction machines or piled soils) be applied to the peat or organic soils. A layer of mud slab consisting of at least 100 mm lean concrete (10MPa) should be placed on the excavation base to provide a stable platform for the construction. Considering the need to provide a stable subgrade platform for the construction, excavation extending to the depth greater than 2.0m below the existing road surface is not recommended. In addition, care must be taken during excavation to ensure that adequate support is provided for any existing structures and underground services located adjacent to the excavations.

It is expected that the underside of the pile cap should be carried out at a depth not greater than 2.0 m below the existing road surface. Based on the groundwater conditions encountered in the boreholes carried out at the site, foundation excavation not exceeding 2. m below the road surface would extend above the local water tables. Groundwater control during excavation within the fill materials above the prevailing groundwater table can be handled, as required, by pumping from properly constructed and filtered sumps located within the excavations. However, more significant groundwater seepage should be expected from the existing sandy soil or organic soils below the groundwater table. It should be noted that groundwater control measures that extract more than 50,000 L/day of water are subject to a Permit to Take Water (PTTW), as regulated by the MOE.

Pumping discharges should conform to the Ministry of Environments guidelines, City of Brampton, conversation authority and other relevant agencies.

It should be noted that consideration should be given to installing the culvert above the prevailing groundwater table at the level where a stable construction platform can be maintained during the construction since significant settlement will occur should the dewatering be carried out in the peat and/or organic silt, which may in turn cause the instability of the embankment.

Control of the surface flow water, if any, at the base of the excavation from the swap may be necessary at the culvert site in order for foundation construction to be carried out in dry conditions. Depending on the water flow at the time of construction, surface water could flow through the culvert area by means of a temporary pipe, if required.

Surface water should be directed away from the excavation area, to prevent ponding of water that could result in disturbance and weakening of the foundation subgrade.

Depending on the construction staging sequence and schedule, temporary roadway protection may be required along the roadway to facilitate the culvert construction works.

4.2.3 Lateral Earth Pressures for Design

Backfill for the culvert and associated retaining/wing walls should consist of granular fill meeting the requirements of OPSS 1010 Granular A or Granular B Type II. The fill depth during placement should be maintained equal on both sides of the culvert walls, with one side not exceeding the other by more than 500mm. The culverts should be designed for the full overburden pressure and live loads, assuming an embankment fill unit weight of 23kN/m^3 for Granular A, 23kN/m^3 for Granular B Type II, and 22kN/m^3 for earth backfill above and/or surrounding the culverts.

The lateral earth pressures acting on the walls will depend on the type and method of placement of the backfill materials, on the nature of the soils behind the backfill, on the magnitude of surcharge including construction loadings, on the freedom of lateral movement of the structure and on the drainage conditions behind the walls.

The following recommendations are made concerning the design of the walls, assuming that the backfill to the culvert and wing walls consists of free-draining granular fill meeting the requirements of OPSS 1010 Granular A or Granular B Type II. This fill should be compacted in loose lifts not greater than 200 mm in thickness to 95 per cent of the material's Standard Proctor maximum dry density in accordance with OPSS 501. The fill materials should be benched into the existing roadway embankment side slopes. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Other aspects of the granular backfill requirements with respect to sub drains and frost taper should be in accordance with applicable Ontario Provincial Standard Drawings.

a. A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the walls, according to CHBDC Section 6.9.3 and Figure 6.6. Other surcharge loadings should be accounted for in the design as required.
b. The granular fill may be placed either in a zone with width equal to at least 1.2 m behind the back of the wall stem (Case I, Figure C6.20(a) of the Commentary on CHBDC) or within a wedge shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical (1.5H:1V) extending up and back from the rear face of the footing (Case II, Figure C6.20(b) of the Commentary on CHBDC).
c. For Case I, the pressures are based on the existing embankment fill materials and the following parameters (unfactored) may be used:

Soil unit weight:	22kN/m^3
Coefficients of static lateral earth pressure:	
Active, K_a	0.33 (level ground)
At rest, K_o	0.50 (level ground)

d. For Case II, the pressures are based on granular fill (Granular A or Granular B (Type II)) and the following parameters (unfactored) may be assumed:

Soil unit weight:	23kN/m^3
Coefficients of static lateral earth pressure:	
Active, K_a	0.27 (level ground)
At rest, K_o	0.43 (level ground)

e. Where the walls allow lateral yielding of the stem, active earth pressures should be used in the geotechnical design of the structure. Where the wall support does not allow lateral yielding (which we would anticipate would apply for the structure), at rest earth pressures should be assumed for the geotechnical design. The movement to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure, may be taken as follows:

i. Rotation (i.e. ratio of wall movement to wall height) of approximately 0.002 about the base of a vertical wall;
ii. Horizontal translation of 0.001 times the height of the wall; or
iii. A combination of both.

4.3 Corrugate Steel Pipe (C.S.P) Culvert Option

As an alternative to the concrete culvert supported on helical piles, a corrugate steel pipe (CSP) culvert may be considered. Based on the subsoils encountered at the site, existing fills may be considered suitable to support the proposed C.S.P. culvert subject to the inspection during the construction by a qualified geotechnical engineer. Consideration should be given to removing the existing pavement structure, any loosened/softened fill materials at the proposed culvert location to expose the underlying competent fill materials, which have to be inspected and approved by a qualified geotechnical engineer. A layer of concrete mud slab consisting of at least 100 mm lean concrete (10 MPa) should be placed immediately upon the inspection and approval of the subgrade by a qualified geotechnical engineer. The founding depth of the CSP culvert should not extend to more than 2.0 m below the existing road surface due to the concerns of the potential instability of the underlying peat and organic silt caused by the construction machine. The proposed design of the C.S.P. culverts should follow the OPSD 802-010 or 802-014.

It should be noted that the existing road embankment appears to be stable, and there was no obvious signs of settlement observed on the pavement surface. However, the peat and organic silt are extremely easy to disturb. Subject to the workmanship of the contractor, and the weights of the construction machines used for the construction, some disturbances may occur to the underlying peat and organic silt. Should this be the case, excessive settlement might occur to the pavement structure, which may require future repair of the existing pavement structure at the site.

5 Monitoring and Testing

The geotechnical aspects of the final design drawings and specifications should be reviewed by Engtec prior to tendering and construction, to confirm that the intent of this report has been met. During construction, full-time engineered fill monitoring and sufficient foundation inspections, subgrade inspections, in-situ density tests and materials testing should be carried out to confirm that the conditions exposed are consistent with those encountered in the boreholes, and to monitor conformance to the pertinent project specifications. Consequently changes to the above mentioned proposed design primarily in the form of additional excavation and installation of additional granular materials, or increasing the mud slab thickness may be required.

6 Closure

We appreciate the opportunity to be of service to you and trust that this report provides sufficient geotechnical engineering information to facilitate the detail design of proposed culvert for this project. We look forward to providing you with continuing service during the design and construction stage of this project.

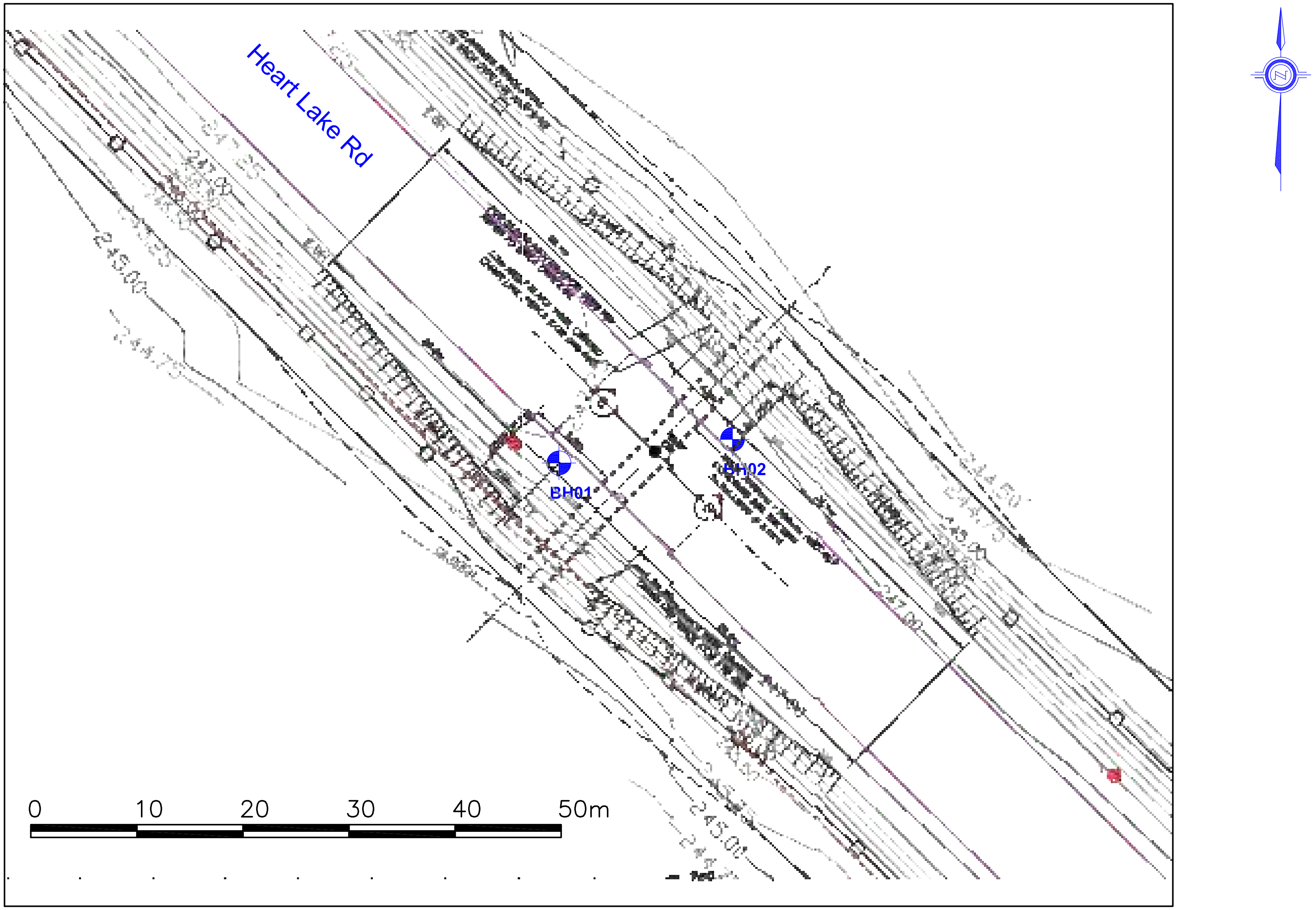
We trust that this submission is satisfactory for your requirements. Should you have any questions, please do not hesitate to contact the undersigned.

Yours truly

David Liu, P.Eng
Senior Geotechnical Consultant

Salman Bhutta, Ph.D., P. Eng.
Principal
Engtec Consulting Inc.

Borehole Location Plan



BH01 **Borehole Location**

Client: City of Brampton		Project No.: 15-1026-01	Drawing No.: 1
Drawn: AC	Approved: DL	Title: Borehole Location Plan	
Date: August 10, 2015	Scale: As shown	Project: Proposal for Geotechnical Investigation Culvert Replacement Heart Lake Rd and Countryside Dr., City of Brampton, Ontario	
Original Size: Letter	Rev: DL	Engtec	

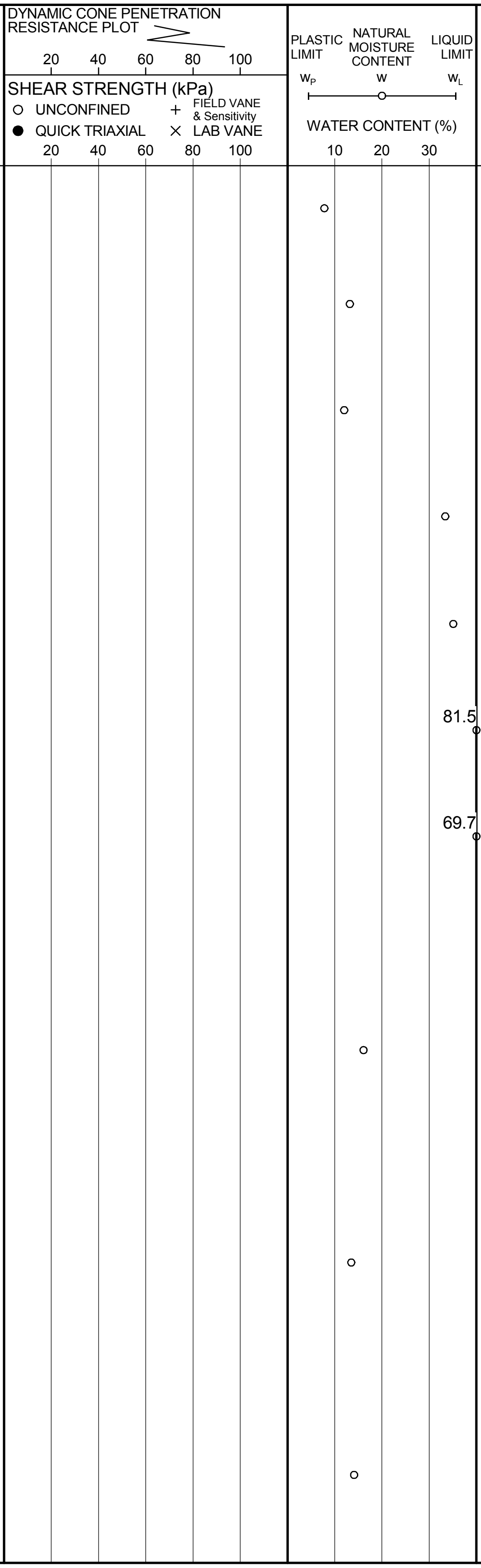
Borehole Logs

LOG OF BOREHOLE BH1

PROJECT: Geotechnical Investigation for Engtec Heart Lake Road Culvert
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Rd. and Countyside Dr., Brampton, Ontario
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Solid Stem Auger
Diameter: 115 mm
Date: Jul/29/2015
REF. NO.: 15-1026-01
ENCL NO.: 2

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
(m) ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" BLOWS 0.3 m					
0.0	**GRANULAR BASE:** sand and gravel, brown, moist.	1	SS	25					
0.7	**FILL:** sandy silt, trace gravel, layer of sand, brown to grey, moist, compact to loose.	2	SS	15					
		3	SS	29					
		4	SS	6					
2.6	**PEAT:** fibrous, trace fine silt, layer of dark grey organic silt, trace shell fragments.	1	AS						
3.6	**ORGANIC SILT:** trace fine sand, trace shell fragments, very loose.	5	SS	2					
		6	SS	1					
5.6	**SILTY SAND:** trace gravel, trace clay, grey, wet, very loose to compact.	7	SS	2					
		2	AS	5					
		8	SS	10					



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GROUNDWATER ELEVATIONS

Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▽ ▼

GRAPH NOTES: $+^3, \times^3$: Numbers refer to Sensitivity

○ ε=3% Strain at Failure

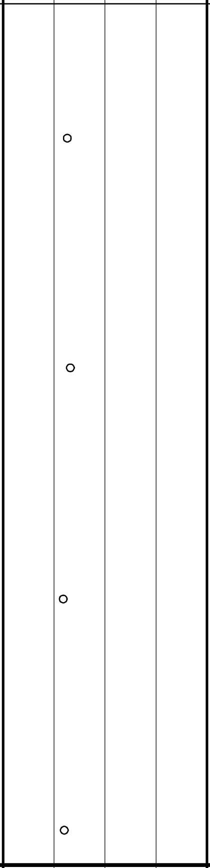
LOG OF BOREHOLE BH1

PROJECT: Geotechnical Investigation for Engtec Heart Lake Road Culvert
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Rd. and Countyside Dr., Brampton, Ontario
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Solid Stem Auger
Diameter: 115 mm
Date: Jul/29/2015

REF. NO.: 15-1026-01
ENCL NO.: 2

SOIL PROFILE			SAMPLES									
(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● 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	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SILTY SAND: trace gravel, trace clay, grey, wet, very loose to compact.(Continued)											
			9	SS	10				○			
			10	SS	10				○			
			11	SS	14				○			
			12	SS	22				○			
15.7	**END OF BOREHOLE** Notes: 1) Water was encountered at a depth of 4.6 m below ground surface during drilling. 2) Water at a depth of 3.35 m below ground surface upon completion of drilling. 3) Borehole caved at a depth of 4.0 m below ground surface upon completion of drilling.											



GROUNDWATER ELEVATIONS

Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▽ ▼

GRAPH NOTES $+^3, \times^3$: Numbers refer to Sensitivity

○ ε=3% Strain at Failure

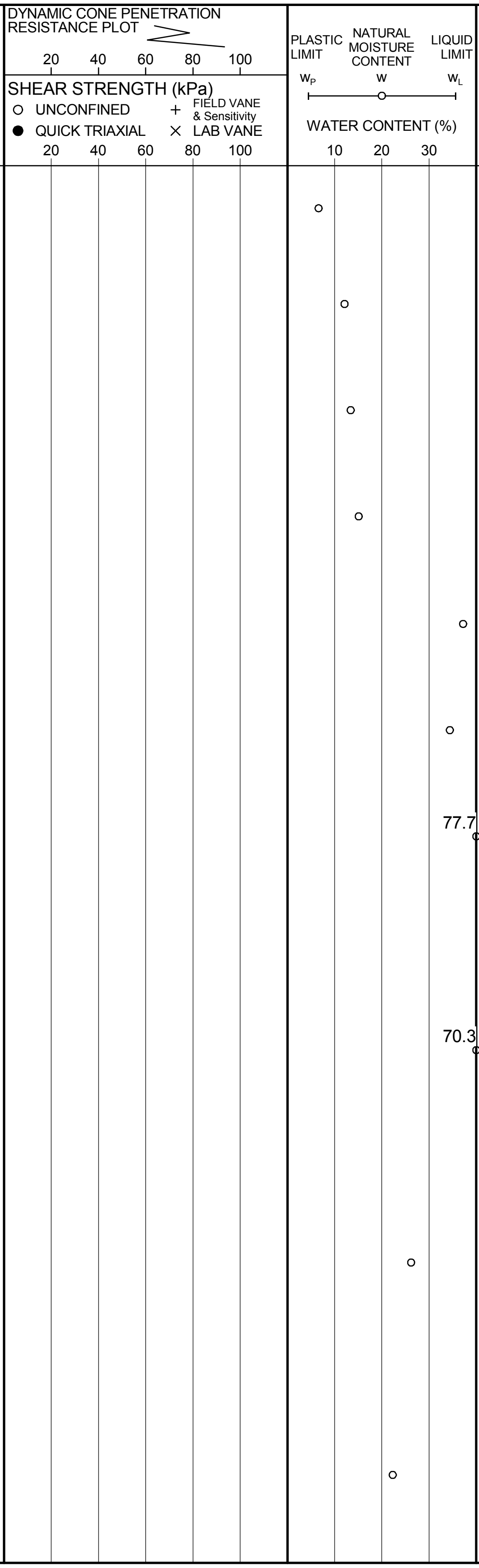
LOG OF BOREHOLE BH2

PROJECT: Geotechnical Investigation for Engtec Heart Lake Road Culvert	**DRILLING DATA**
CLIENT: City of Brampton	Method: Solid Stem Auger
PROJECT LOCATION: Heart Lake Rd. and Countyside Dr., Brampton, Ontario	Diameter: 115 mm
DATUM: Geodetic	Date: Jul/29/2015
BH LOCATION: See Borehole Location Plan	

REF. NO.: 15-1026-01

ENCL NO.: 3

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH (kPa)	WATER CONTENT (%)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS / 0.3 m							
0.0	**GRANULAR BASE:** sand and gravel, brown, moist.		1	SS	21							
0.7	**FILL:** sandy silt to silty sand, trace gravel, trace clay, brown, moist, compact to loose.		2	SS	11							
			3	SS	8							
			4	SS	5							
			5	SS	11							
3.3	**PEAT:** fibrous, trace fine silt, layer of dark grey organic silt, trace shell fragments.		6	SS	2							
4.4	**ORGANIC SILT:** trace fine sand, trace shell fragments, very loose.		7	SS	1				77.7			
			8	SS	2				70.3			
6.5	**SILTY SAND:** trace gravel, trace clay, grey, wet, very loose to compact.		2	SS	4							
			8	SS	10							



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GROUNDWATER ELEVATIONS

Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▽ ▼

GRAPH NOTES: $+^3, \times^3$: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH2

PROJECT: Geotechnical Investigation for Engtec Heart Lake Road Culvert
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Rd. and Countyside Dr., Brampton, Ontario
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SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● 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	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS/0.3 m							
	SILTY SAND: trace gravel, trace clay, grey, wet, very loose to compact.(Continued)		9	SS	9				○			
11.1	**END OF BOREHOLE** Notes: 1) Water was encountered at a depth of 6.4 m below ground surface during drilling. 2) Water at a depth of 4.9 m below ground surface upon completion of drilling. 3) Borehole caved at a depth of 5.5 m below ground surface upon completion of drilling.											

GROUNDWATER ELEVATIONS

Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▼ ▼

GRAPH NOTES $+^3$, $\times^3$: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

Engtec Consulting Inc.
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Project No: ET15-1135A November 19, 2015

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Dear Bill:

Geotechnical Investigation
Proposed New Culvert Locations - Heart Lake Road
Brampton, Ontario

1 Introduction

Engtec Consulting Inc. (Engtec) was retained by City of Brampton (Client), to conduct a supplementary geotechnical investigation at several locations for Proposed New Culvert(s) located at Heart Lake Road, Brampton, Ontario. The purpose of this geotechnical investigation was to obtain information on the existing subsurface conditions by means of a limited number of boreholes that would provide the required geotechnical design information for contemplated Culvert within the project at a geotechnically suitable location.

The report is prepared with the condition that the proposed culvert design will be in accordance with all applicable standards and codes and applicable regulations and good engineering practice. Further, the recommendations and opinions in this report are applicable only to the proposed project as described above. On-going liaison and communication with Engtec during the design stage and construction phase of the project is strongly recommended to confirm that the recommendations in this report are applicable and/or correctly interpreted and implemented. Any queries concerning the geotechnical aspects of the proposed project shall be directed to Engtec for further elaboration and/or clarification.

This report is provided on the basis of the terms of reference presented in our approved proposal prepared by Engtec and approved by the City of Brampton and based on our understanding of the project. If there are any changes in the design features relevant to the geotechnical analyses, or if any questions arise concerning the geotechnical aspects of the codes and standards, this office should be contacted to review the changes. It may then be necessary to carry out additional borings and investigations, before the recommendations of this report can be relied upon.

This report deals with geotechnical issues only. The geo-environmental (chemical) aspects of the subsurface conditions, including the consequences of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources, were not investigated and were beyond the scope of this assignment.

The site investigation and recommendations follow generally accepted practice for geotechnical consultants in Ontario. This report has been prepared for the Client and Client's engineers. Third party use of this report without Engtec's consent is prohibited. The limitations to the report presented in this report form an integral part of the report and they must be considered in conjunction with the contents of this report.

2 Field Investigation Works

The field work for the geotechnical investigation was carried out on November 3rd, 5th, and 6th, 2015, during which time six (6) boreholes (i.e. BH101, BH102, BH201, BH202, BH301 and BH302) on the shoulders of the roadway in alignment with the proposed location of the culvert were advanced as shown on the Borehole Location Plan, Drawing No. 1.

The boreholes were advanced using solid stem auger equipment supplied by a drilling specialist subcontracted to Engtec. Samples were retrieved with a 51mm (2in) O.D. split-barrel (split spoon) sampler driven with a hammer weighing 624N with a drop of 762mm (30in) in accordance with the Standard Penetration Test (SPT) method.

The field work for this investigation was monitored by a member of our engineering staff, who also determined the approximate borehole locations in the field, logged the boreholes and cared for the recovered samples. The boreholes were located in the field by Engtec and the City of Brampton during a site meeting in October 2015.

The shallow groundwater conditions were noted in the open boreholes during drilling and at the completion of drilling. The boreholes were backfilled and sealed upon completion of drilling. All soil samples obtained during this investigation were brought to our laboratory for further examination.

The ground surface elevations at the as drilled borehole locations were not available at the time of preparing the report. Contractors performing the work should confirm the elevations prior to construction. The borehole locations plotted on the Borehole Location Plan were based on the measurements of the site features and should be considered to be approximate.

3 Site and Subsurface Conditions

The investigated locations are located at Heart Lake Road, between the Heart Lake Conservation entrance in Brampton northerly to Countryside Drive, Brampton, Ontario (see Drawing No. 1 for details). Notes on sample descriptions used in the record of borehole are presented on Enclosure No. 1 to this submission. The subsurface conditions in the all boreholes are presented on the borehole logs (Enclosures 2 to 7 inclusive). The following are the detailed descriptions of the major soil strata encountered in the boreholes. The following are the detailed descriptions of the major soil strata encountered in the boreholes.

3.1 Soil Conditions

3.1.1 Pavement

Boreholes BH101 and BH301 were advanced through the existing pavement structure to obtain the information on the thickness of the pavement structure of the existing road at the borehole locations. The asphalt thicknesses encountered in the boreholes were 240mm and 245mm, respectively; the thickness of the granular base/subbase was about 500mm for both boreholes. Boreholes BH102, BH201, BH202, and BH302 were advanced through the shoulder of the existing road. Granular base with thicknesses ranging from about 200mm to 300mm was encountered surficially in Boreholes BH102, BH201, BH202 and BH302.

3.1.2 Fill Materials

Fill materials consisting of sandy silt to silty sand were encountered below the granular base/subbase in all the boreholes, and extended to depths ranging from about 1.1m to 4.7m below the existing ground surface. SPT “N” values ranging from 3 to 17 blows per 300mm penetration indicated a very loose to compact relative density. The in-situ moisture contents of the soil samples ranged from approximately 10% to 15%.

3.1.3 Peat

Peat deposits were encountered below the fill materials in Boreholes BH101, BH102, BH301 and BH302, and extended to depths ranging from about 1.9m to 5.6m below the existing ground surface. SPT “N” values ranging from 3 to 6 blows per 300mm penetration indicated a very loose to loose relative density. The natural moisture contents of the soil samples ranged from approximately 31% to 52%.

3.1.4 Silty Sand

Silty sand deposits were encountered below the peat or clayey silt to silty clay in Boreholes BH101, BH102 and BH302, and extended to the termination depths of the boreholes. SPT “N” values ranging from 6 to 14 blows per 300mm penetration indicated a loose to compact relative density. The natural moisture contents of the soil samples ranged from approximately 18% to 28%.

3.1.5 Clayey Silt Till

Clayey silt till deposits were encountered below the fill materials in Borehole BH201 and extended to a depth of about 5.6m below the existing ground surface. SPT “N” values ranging from 12 to 13 blows per 300mm penetration indicated a stiff consistency. The natural moisture contents of the soil samples ranged from approximately 11% to 12%.

3.1.6 Sandy Silt Till

Sandy silt till deposits were encountered below the fill materials in Borehole BH202 and below the silty clay to clayey silt in Borehole BH301, and extended to depths ranging from about 4.0m to 12.7m below the existing ground surface. Borehole BH301 was terminated in these deposits. SPT “N” values ranging from 13 to 26 blows per 300mm penetration indicated a compact relative density. The natural moisture contents of the soil samples ranged from approximately 14% to 30%.

3.1.7 Silty Fine Sand to Sandy Silt

Silty fine sand to sandy silt deposits were encountered below the till deposits in Boreholes BH201 and BH202, and extended to the termination depths of the boreholes. SPT "N" values ranging from 8 to 20 blows per 300mm penetration indicated a loose to compact relative density. The natural moisture contents of the soil samples ranged from approximately 12% to 23%.

3.1.8 Silty Clay to Clayey Silt

Silty clay to clayey silt deposits were encountered below the peat in Boreholes BH301 and BH302, and extended to a depth of about 12.4m below the existing ground surface. SPT "N" values ranging from 1 to 2 blows per 300mm penetration indicated a very soft consistency. The natural moisture contents of the soil samples ranged from approximately 23% to 32%.

3.2 Groundwater Conditions

Water was encountered during drilling in all of the boreholes at depths ranging from about 1.5m to 5.1m below the existing ground surface. Water was noted in all of the boreholes at depths ranging from about 2.0m to 3.8m below the existing ground surface upon completion of drilling. Cave-in was noted in all of the boreholes at depths ranging from about 2.5m to 3.9m below ground surface upon completion of drilling.

It should be noted that the groundwater levels observed during and after the drilling should not be considered as stable groundwater tables. It should also be noted that the groundwater levels can vary and are subject to seasonal fluctuations in response to weather events.

4 Discussion and Recommendations

This report contains the findings of Engtec's geotechnical investigation, together with our geotechnical engineering recommendations and any relevant comments. These recommendations and comments are based on factual information and are intended only for the use by the design engineers. Subsurface conditions between and beyond the boreholes may differ from those encountered at the borehole locations, and different conditions may become apparent during construction, which could not be detected or anticipated at the time of the site investigation.

The construction methods described in this report must not be considered as being specifications or direct recommendations to the contractors, or as being the only suitable methods. Construction methods only express Engtec's opinion and are not intended to direct the contractors on how to carry out the construction works and activities. Contractors should also be aware that the data and their interpretation presented in this report may not be sufficient to assess all the factors that may affect the construction works.

The design drawings of the project are not available at the time of preparing this report. Once the design drawings and detail site plan are available, this report should be reviewed by Engtec and further recommendations be provided as appropriate.

4.1 Foundation Design Considerations

As discussed with the Client, six boreholes were drilled at three potential culvert locations. It is understood that the culvert will only be constructed at one selected location.

Based on the results of this investigation, fill materials and peat were encountered in Boreholes BH101 and BH102 (Location #1), BH301 and BH302 (Location #3) at the site and extended to depths ranging from 1.9 m to 5.6 m below the existing ground surface. The organic soils, such as peat, are highly compressible and will be subject to long term settlement and potentially to differential settlement should additional loading be applied or any disturbance occurs during the construction or the groundwater tables are significantly lowered. The magnitude of the settlement cannot be predicted. The existing fill materials and peat are not considered suitable to support the proposed culvert. Completely removing the existing fill materials and peat, and replacing with engineered fill are not considered feasible. Therefore, the foundation of the proposed culvert at Location # 1 and Location # 3 may be considered to be supported in the underlying silty/sandy soils by installing a deep foundation system.

Based on the subsoil information encountered at the borehole locations, clayey silt till and sandy silt till deposits encountered in Boreholes BH201 and BH202 (Location #2) are considered to be suitable to support the culvert structure. Any fill materials at the proposed culvert location should be completely removed prior to placing the culvert segments. A geotechnical bearing resistance at Serviceability Limit States (SLS) of 150 kPa and a factored geotechnical bearing resistance at Ultimate Limit States (ULS) of 225 kPa may be used for the design of the culvert bearing on the native, undisturbed, competent soils.

4.2 Shallow Foundation Option (Location #2)

Spread footings are the most feasible and practical alternative for supporting a culvert. The recommended founding depths and geotechnical resistances for spread footings founded on undisturbed competent natural soils at the culvert Location #2 are provided in the following table.

Boreholes	Bearing Resistance at SLS (kPa)	Factored Geotechnical Resistance at ULS (kPa)	Estimated Minimum Excavation Depth (m)	Founding Soil Type
BH201	150	225	2.5	Clayey silt till
BH202	150	225	2.1	Sandy silt till

Any unsuitable materials should be completely sub-excavated within the entire proposed foundation area. Subgrade soils will be easily disturbed when wet. Working mat/skim coat of lean concrete should be poured on subgrade soils after inspection and approval by the geotechnical engineer.

The geotechnical resistances quoted in the preceding table are for concentric, vertical loads only. For eccentric or inclined loading, the geotechnical resistance must be reduced as illustrated in the CHBDC Clause

6.7.3 and Clause 6.7.4. The SLS value quoted in the table corresponds to a settlement of up to 25 mm assuming that the founding soils will be undisturbed during construction.

The sliding resistance of mass concrete poured on the clayey silt and sandy silt till subgrade may be computed based on an ultimate coefficient of friction of 0.4.

Passive earth pressure resistance is generally not considered as a resisting force against sliding for conventional structure design because a structure must deflect significantly to develop the full passive resistance.

A working mat or skim coat of lean concrete is required on all footing bases. Prior to placing foundation concrete, the foundation base must be cleaned of all deleterious materials such as organics, topsoil, fill, softened, disturbed or caved materials, and any standing water. If construction proceeds during freezing weather conditions, adequate temporary frost protection for the founding subgrade and concrete must be provided.

4.3 Deep Foundation Option (Helical Piles) - (Location #1 and Location #3)

A deep foundation system may be considered to support the proposed new culvert at Location #1 and Location #3. Driven piles is not considered for this site due to small size of the culvert and significant cost of mobilizing the pile driving machine as well as for the potential settlement caused by the heavy piling machines, and as such the proposed new culvert could be supported on a series of helical piles founded in the underlying competent silty sand soils.

The actual design details of the helical piles are typically provided by the piling contractor. Some difficulty may be encountered in advancing the piles through the fill materials due to the potential presence of obstruction such as cobbles and boulders. However, should an obstruction be encountered, the pile may be extracted and reused at an alternate location. Use of helical piles is recommended as it provides a number of advantages when compared to the driven pile option:

1. The effect of the helical pile installation is unlikely to have an adverse impact on the existing paved structure.
2. Helical pile installation requires use of comparatively smaller equipment which is not known for generating excessive noise or visible air pollution due to use of diesel engines.
3. The relatively small size of the helical pile installation equipment would allow easier access to locations.

Resistance to lateral forces/sliding resistance should be carried out by battered piles, which should be designed by the pile supplier.

The helical piles are generally designed as end bearing and the friction from the fill, organic soils and native soils must be ignored. Based on the borehole information, a bearing capacity value of 40kN to 50kN per pile at SLS and 60kN to 75kN at ULS should be available for the helical pile installed into the competent silty sand or sandy silt at depths. The designer should define the depth and type of helical piles according to the soil conditions and the required design loads. A specialized contractor must be retained to design and install helical piles. Bearing capacity and other design details regarding helical piles can be discussed with the specialized contractor. Field load testing of piles is required to confirm the design bearing capacity. The test helical pile should be loaded to at least 2 times the design bearing capacity at ULS.

4.3.1 Subgrade Protection, Frost Protection and Scour Protection

It should be noted that the proposed founding level should be at least 1.2 m below the proposed final grade to provide sufficient earth cover for frost protection unless the culvert is designed to withstand the frost pressures. It should be noted that the scour protection, such as rip rap and rock blocks should not be considered as earth cover for frost protection purposes. Frost treatment (i.e. frost taper) should be designed and constructed as per OPSD 803-030 and 803-031.

If the water course flow velocities are sufficiently high, provision should be made for scour and erosion protection for the new culvert. For culvert protection, there are two treatment zones to be considered, namely the embankment and the creek channel. The requirements for design of erosion protection measures for the inlet and outlet of the proposed culvert should be considered by design engineers. As a minimum, rip rap treatment for the outlet of the culvert should be consistent with the standard presented in OPSD 810.010 (Rip-Rap Treatment for Sewer and Culvert Outlets).

4.2.1 Sliding Resistance

Resistance to lateral forces/sliding resistance should be carried out by using a battered pile approach, which should be designed by the pile supplier.

4.2.2 Temporary Excavations and Groundwater Control

It is anticipated that foundation excavations at the site will consist of temporary open cuts with side slopes not steeper than 1 horizontal to 1 vertical (1H:1V). However, depending on the construction procedures adopted by the contractor and weather conditions at the time of construction, some local flattening of the slopes should be required, especially in looser/softer zones (i.e. in fills) or where localized seepage is encountered. All excavations should be carried out in accordance with the Occupational Health and Safety Act and Regulations for Construction Projects. According to the Act, the existing fills would be classified as Type 3 soils above groundwater table and Type 4 below the groundwater table; the native compact silty sand would be classified as Type 4 soils below the groundwater table.

The existing peat and organic soils at Location #1 and Location #3 are highly compressible and are extremely easy to disturb and will not be stable should additional loading (such as construction machines or piled soils) be applied to the peat or organic soils. A layer of mud slab consisting of at least 100 mm lean concrete (10MPa) should be placed on the excavation base to provide a stable platform for the construction. Considering the need to provide a stable subgrade platform for the construction, excavation extending to the depth greater than 1.5 m to 2.5 m below the existing road surface is not recommended.

Based on the groundwater conditions encountered in the boreholes carried out at Location #2, foundation excavation exceeding 3.0 m below the road surface may extend below the local water tables. Considering the need to provide a stable subgrade platform for the construction, excavation extending to the depth greater than 3.0 m below the existing road surface is not recommended.

In addition, care must be taken during excavation to ensure that adequate support is provided for any existing structures and underground services located adjacent to the excavations.

Groundwater control during excavation within the fill materials and native materials at least 0.6 m above the prevailing groundwater table can be handled, as required, by pumping from properly constructed and filtered sumps located within the excavations. However, more significant groundwater seepage should be expected from the existing sandy soil or organic soils below the groundwater table. It should be noted that groundwater control measures that extract more than 50,000 L/day of water are subject to a Permit to Take Water (PTTW), as regulated by the MOE.

Pumping discharges should conform to the Ministry of Environments guidelines, City of Brampton, conversation authority and other relevant agencies.

It should be noted that consideration should be given to installing the culvert above the prevailing groundwater table at the level where a stable construction platform can be maintained during the construction since significant settlement will occur should the dewatering be carried out in the, which may in turn cause the instability of the embankment.

Control of the surface flow water, if any, at the base of the excavation from the swap may be necessary at the culvert site in order for foundation construction to be carried out in dry conditions. Depending on the water flow at the time of construction, surface water could flow through the culvert area by means of a temporary pipe, if required.

Surface water should be directed away from the excavation area, to prevent ponding of water that could result in disturbance and weakening of the foundation subgrade.

Depending on the construction staging sequence and schedule, temporary roadway protection may be required along the roadway to facilitate the culvert construction works.

4.2.3 Lateral Earth Pressures for Design

Backfill for the culvert and associated retaining/wing walls should consist of granular fill meeting the requirements of OPSS 1010 Granular A or Granular B Type II. The fill depth during placement should be maintained equal on both sides of the culvert walls, with one side not exceeding the other by more than 500 mm. The culverts should be designed for the full overburden pressure and live loads, assuming an embankment fill unit weight of 23 kN/m3 for Granular A, 23 kN/m3 for Granular B Type II, and 22 kN/m3 for earth backfill above and/or surrounding the culverts.

The lateral earth pressures acting on the walls will depend on the type and method of placement of the backfill materials, on the nature of the soils behind the backfill, on the magnitude of surcharge including construction loadings, on the freedom of lateral movement of the structure and on the drainage conditions behind the walls.

The following recommendations are made concerning the design of the walls, assuming that the backfill to the culvert and wing walls consists of free-draining granular fill meeting the requirements of OPSS 1010 Granular A or Granular B Type II. This fill should be compacted in loose lifts not greater than 200 mm in thickness to 95 per cent of the material's Standard Proctor maximum dry density in accordance with OPSS 501. The fill materials should be benched into the existing roadway embankment side slopes. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Other aspects of the granular backfill requirements with respect to sub drains and frost taper should be in accordance with applicable Ontario Provincial Standard Drawings.

1. A minimum compaction surcharge of 12kPa should be included in the lateral earth pressures for the structural design of the walls, according to CHBDC Section 6.9.3 and Figure 6.6. Other surcharge loadings should be accounted for in the design as required.
2. The granular fill may be placed either in a zone with width equal to at least 1.2m behind the back of the wall stem (Case I, Figure C6.20(a) of the Commentary on CHBDC) or within a wedge shaped zone defined by a line drawn at 1.5 horizontal to 1 vertical (1.5H:1V) extending up and back from the rear face of the footing (Case II, Figure C6.20(b) of the Commentary on CHBDC).
3. For Case I, the pressures are based on the existing embankment fill materials and the following parameters (unfactored) may be used:

Soil unit weight:	22 kN/m^3
Coefficients of static lateral earth pressure:	
Active, K_a	0.33 (level ground)
At rest, K_o	0.50 (level ground)

4. For Case II, the pressures are based on granular fill (Granular A or Granular B (Type II)) and the following parameters (unfactored) may be assumed:

Soil unit weight:	23 kN/m^3
Coefficients of static lateral earth pressure:	
Active, K_a	0.27 (level ground)
At rest, K_o	0.43 (level ground)

5. Where the walls allow lateral yielding of the stem, active earth pressures should be used in the geotechnical design of the structure. Where the wall support does not allow lateral yielding (which we would anticipate would apply for the structure), at rest earth pressures should be assumed for

the geotechnical design. The movement to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure, may be taken as follows:

- Rotation (i.e. ratio of wall movement to wall height) of approximately 0.002 about the base of a vertical wall;
- Horizontal translation of 0.001 times the height of the wall; or
- A combination of both.

4.4 Corrugate Steel Pipe (C.S.P) Culvert Option

As an alternative to the concrete culvert supported on helical piles, a corrugate steel pipe (CSP) culvert may be considered. Based on the subsoils encountered at the site, existing fills may be considered suitable to support the proposed C.S.P. culvert subject to the inspection during the construction by a qualified geotechnical engineer. Consideration should be given to removing the existing pavement structure, any loosened/softened fill materials at the proposed culvert location to expose the underlying competent fill materials, which have to be inspected and approved by a qualified geotechnical engineer. A layer of concrete mud slab consisting of at least 100 mm lean concrete (10 MPa) should be placed immediately upon the inspection and approval of the subgrade by a qualified geotechnical engineer. The founding depth of the CSP culvert should not extend to more than 2.0 m below the existing road surface due to the concerns of the potential instability of the underlying peat and organic silt caused by the construction machine. The proposed design of the C.S.P. culverts should follow the OPSD 802-010 or 802-014.

It should be noted that the existing road embankment appears to be stable, and there were no obvious signs of settlement observed on the pavement surface. However, the peat and organic silt are extremely easy to disturb. Subject to the workmanship of the contractor, and the weights of the construction machines used for the construction, some disturbances may occur to the underlying peat and organic silt. Should this be the case, excessive settlement might occur to the pavement structure, which may require future repair of the existing pavement structure at the site.

4.5 Pavement Restoration

The traffic data, including the percentage of the commercial traffic, is not available at the time of preparing the report. The following preliminary pavement design is recommended for the pavement restoration, based on the pavement structure revealed from the two boreholes carried out on the site. The pavement structure provided may be further reviewed by the geotechnical engineer once the traffic data is available.

MATERIAL		THICKNESS OF PAVEMENT ELEMENTS (mm)
Asphaltic Material (OPSS 1150)	HL 3	50mm
	HL 8	100mm (two lifts)
Granular Material (OPSS 1010)	Granular A Base	150mm
	Granular B, Type II or Granular A Subbase	450mm
Prepared and Approved Subgrade		

Prior to placing the granular subbase material, the exposed soil subgrade should be proof rolled in conjunction with an inspection by qualified geotechnical personnel. Remedial work (i.e. further sub-excavation and replacement) should be carried out on any disturbed, softened or poorly performing zones, as directed by geotechnical personnel.

The granular subbase and base materials should be uniformly compacted to 100 percent of their standard Proctor maximum dry densities. The asphalt materials should be compacted according to OPSS 310 requirements relative to Marshall Maximum Relative Densities ("MRD").

The above pavement designs should provide serviceable pavements for the anticipated traffic levels over a normal design period of ten (10) to fifteen (15) years with regular maintenance.

Where new pavement abuts existing pavement (e.g. at the construction limits), proper longitudinal lap joints should be constructed to key the new asphalt into the existing pavement. The existing asphalt edges should be provided with a proper sawcut edge prior to keying in the new asphalt. It should be ensured that any undermined or broken edges resulting from the construction activities are removed by sawcut.

5 Monitoring and Testing

The geotechnical aspects of the final design drawings and specifications should be reviewed by Engtec prior to tendering and construction, to confirm that the intent of this report has been met. During construction, full-time engineered fill monitoring and sufficient foundation inspections, subgrade inspections, in-situ density tests and materials testing should be carried out to confirm that the conditions exposed are consistent with those encountered in the boreholes, and to monitor conformance to the pertinent project specifications. Consequently changes to the above mentioned proposed design primarily in the form of additional excavation and installation of additional granular materials, or increasing the mud slab thickness may be required.

6 Closure

We appreciate the opportunity to be of service to you and trust that this report provides sufficient geotechnical engineering information to facilitate the detail design of proposed culvert for this project. We look forward to providing you with continuing service during the design and construction stage of this project.

We trust that this submission is satisfactory for your requirements. Should you have any questions, please do not hesitate to contact the undersigned.

Yours truly

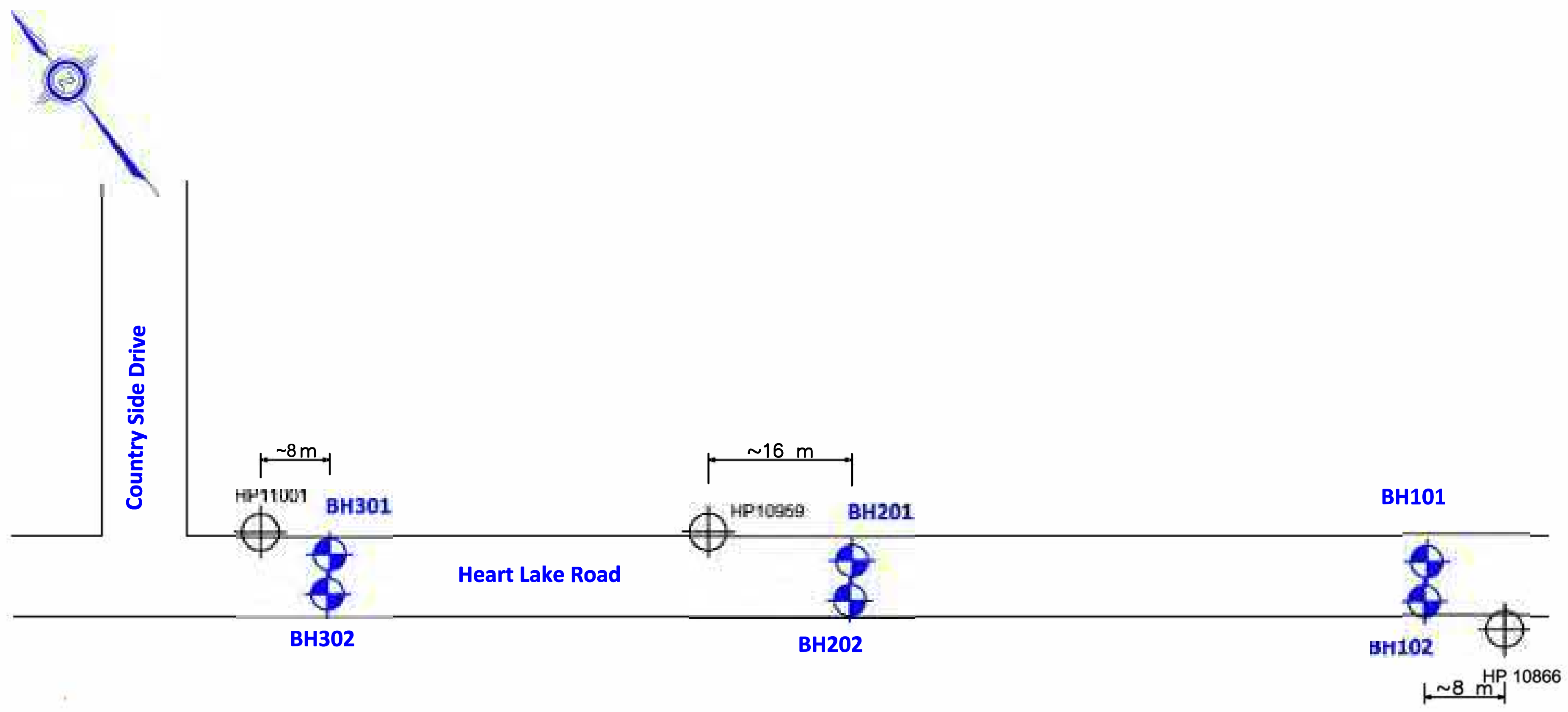
David B. Liu

David Liu, P.Eng
Senior Geotechnical Consultant

Bhutta

Salman Bhutta, Ph.D., P. Eng.
Principal
Engtec Consulting Inc.

Borehole Location Plan



⊕ **BH1** **Proposed Borehole Location**

⊕ **HP11001** **Hydro Pole**

Client:	**City of Brampton**			Project No.: **15-1026B-01**	Drawing No.: **1**
Drawn: **GC**		Approved: **DL**		Title:	**Borehole Location Plan**
Date: **October 2015**		Scale: **N.T.S.**		Project:	**Geotechnical Investigation** **Proposed Culverts** **Heart Lake Road, Brampton, Ontario**
Original Size: **Letter**		Rev: **DL**			Engtec Consulting Inc.

Borehole Logs

Enclosure 1: Notes on Sample Descriptions

1. All sample descriptions included in this report generally follow the Unified Soil Classification. Laboratory grain size analyses provided by GeoPro also follow the same system. Different classification systems may be used by others, such as the Canadian Foundation Engineering Manual soil classification system. Please note that, with the exception of those samples where a grain size analysis and/or Atterberg Limits testing have been made, all samples are classified visually. Visual classification is not sufficiently accurate to provide exact grain sizing or precise differentiation between size classification systems.

2. Fill: Where fill is designated on the borehole log it is defined as indicated by the sample recovered during the boring process. The reader is cautioned that fills are heterogeneous in nature and variable in density or degree of compaction. The borehole description may therefore not be applicable as a general description of site fill materials. All fills should be expected to contain obstruction such as wood, large concrete pieces or subsurface basements, floors, tanks, etc., none of these may have been encountered in the boreholes. Since boreholes cannot accurately define the contents of the fill, test pits are recommended to provide supplementary information. Despite the use of test pits, the heterogeneous nature of fill will leave some ambiguity as to the exact composition of the fill. Most fills contain pockets, seams, or layers of organically contaminated soil. This organic material can result in the generation of methane gas and/or significant ongoing and future settlements. Fill at this site may have been monitored for the presence of methane gas and, if so, the results are given on the borehole logs. The monitoring process does not indicate the volume of gas that can be potentially generated nor does it pinpoint the source of the gas. These readings are to advise of the presence of gas only, and a detailed study is recommended for sites where any explosive gas/methane is detected. Some fill material may be contaminated by toxic/hazardous waste that renders it unacceptable for deposition in any but designated land fill sites; unless specifically stated the fill on this site has not been tested for contaminants that may be considered toxic or hazardous. This testing and a potential hazard study can be undertaken if requested. In most residential/commercial areas undergoing reconstruction, buried oil tanks are common and are generally not detected in a conventional preliminary geotechnical site investigation.

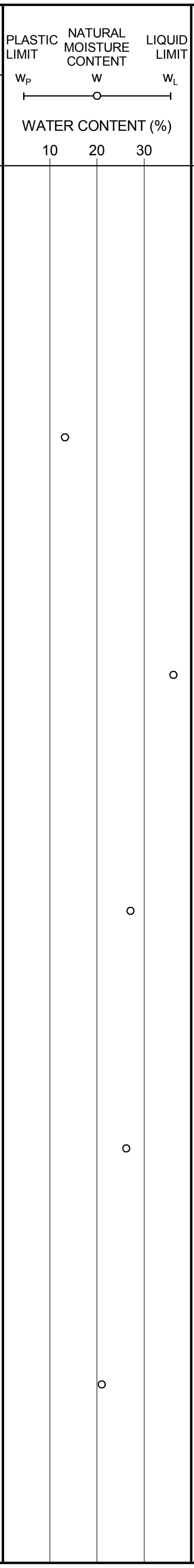
3. Till: The term till on the borehole logs indicates that the material originates from a geological process associated with glaciation. Because of this geological process the till must be considered heterogeneous in composition and as such may contain pockets and/or seams of material such as sand, gravel, silt or clay. Till often contains cobbles (60 to 200 mm) or boulders (over 200 mm). Contractors may therefore encounter cobbles and boulders during excavation, even if they are not indicated by the borings. It should be appreciated that normal sampling equipment cannot differentiate the size or type of any obstruction. Because of the horizontal and vertical variability of till, the sample description may be applicable to a very limited zone; caution is therefore essential when dealing with sensitive excavations or dewatering programs in till materials.

LOG OF BOREHOLE BH101

PROJECT: Geotechnical Investigation for Proposed Culverts
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario
DATUM: N/A
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Continuous Flight Auger - Auto Hammer
Diameter: 115 mm
Date: Nov/06/2015
REF. NO.: 15-1026B-01
ENCL NO.: 2

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● 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	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
(m) ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" BLOWS / 0.3 m							
0.0	**ASPHALT** (240 mm)										
0.2	**GRANULAR BASE:** sand and gravel, brown, moist.										
0.7	**FILL:** sandy silt, trace gravel, trace clay, trace organics, brown to grey, moist, loose.	1	AS								
		2	SS	8							
2.5	**PEAT:** fibrous, trace silt, layer of dark grey organic silt, trace rootlets, dark brown, moist, loose	3	SS	6							
4.0	**SILTY SAND:** trace gravel, trace clay, trace rootlets, grey, wet, loose to compact.	4	SS	7							
		5	SS	6							
		6	SS	9							



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GROUNDWATER ELEVATIONS

Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▼ ▽

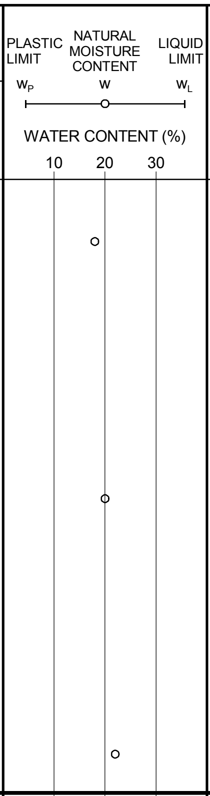
GRAPH NOTES $+^3, \times^3$: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH101

PROJECT: Geotechnical Investigation for Proposed Culverts
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario
DATUM: N/A
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Continuous Flight Auger - Auto Hammer
Diameter: 115 mm
Date: Nov/06/2015
REF. NO.: 15-1026B-01
ENCL NO.: 2

(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS 0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH (kPa)	WATER CONTENT (%)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SILTY SAND: trace gravel, trace clay, trace rootlets, grey, wet, loose to compact.(Continued)		7	SS	13				○			
			8	SS	14				○			
			9	SS	13				○			
12.7	**END OF BOREHOLE** Notes: 1) Water was encountered at a depth of 4.6 m below ground surface during drilling. 2) Water at a depth of 3.35 m below ground surface upon completion of drilling. 3) Borehole caved at a depth of 3.0 m below ground surface upon completion of drilling.											



Shear strength legend: ○ UNCONFINED; + FIELD VANE & Sensitivity; ● QUICK TRIAXIAL; × LAB VANE. Scales: 20 40 60 80 100

GROUNDWATER ELEVATIONS

Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▼ ▼

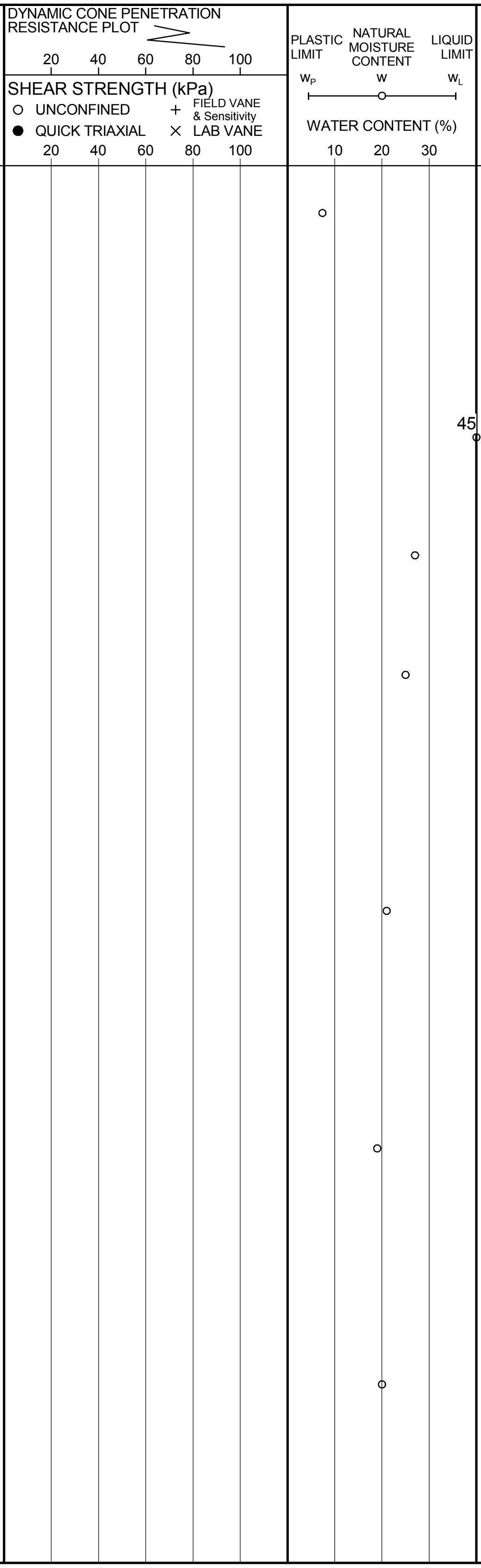
GRAPH NOTES $+^3, \times^3$: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH102

PROJECT: Geotechnical Investigation for Proposed Culverts
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario
DATUM: N/A
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Continuous Flight Auger - Auto Hammer
Diameter: 115 mm
Date: Nov/05/2015
REF. NO.: 15-1026B-01
ENCL NO.: 3

SOIL PROFILE (m) ELEV DEPTH	DESCRIPTION	SAMPLES NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
0.0	**GRANULAR BASE (SHOULDER):** sand and gravel, brown, moist.								
0.3	**FILL:** silty sand, trace gravel, trace clay, brown, moist, compact.	1	SS	13					
1.1	**PEAT:** fibrous, trace silt, layer of dark grey organic silt, trace rootlets, dark brown, moist, loose	2	SS	6					
1.9	**SILTY SAND:** trace gravel,brown to grey, moist to saturated, loose to compact.	3	SS	13					
		4	SS	8					
		5	SS	10					
		6	SS	10					
		7	SS	9					



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GROUNDWATER ELEVATIONS
Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▽ ▼

GRAPH NOTES
$+^3, \times^3$: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

Engtec Consulting Inc

LOG OF BOREHOLE BH102

PROJECT: Geotechnical Investigation for Proposed Culverts
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario
DATUM: N/A
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Continuous Flight Auger - Auto Hammer
Diameter: 115 mm
Date: Nov/05/2015
REF. NO.: 15-1026B-01
ENCL NO.: 3

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● 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			REMARKS AND GRAIN SIZE DISTRIBUTION (%)
(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION			POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m³)	GR SA SI CL
	SILTY SAND: trace gravel,brown to grey, moist to saturated, loose to compact.(Continued)		8	SS	11				○			
9.6	**END OF BOREHOLE** Notes: 1) Water was encountered at a depth of 3.0 m below ground surface during drilling. 2) Water at a depth of 3.35 m below ground surface upon completion of drilling. 3) Borehole caved at a depth of 3.7 m below ground surface upon completion of drilling.											

GROUNDWATER ELEVATIONS

Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▽ ▼

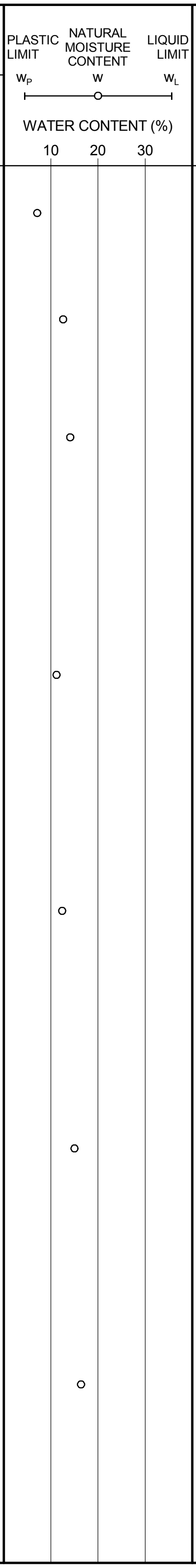
GRAPH NOTES + 3, × 3: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH201

PROJECT: Geotechnical Investigation for Proposed Culverts
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario
DATUM: N/A
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Continuous Flight Auger - Auto Hammer
Diameter: 115 mm
Date: Nov/05/2015
REF. NO.: 15-1026B-01
ENCL NO.: 4

SOIL PROFILE (m) ELEV / DEPTH	DESCRIPTION	SAMPLES NUMBER	TYPE	"N" BLOWS / 0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH (kPa)	WATER CONTENT (%)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
0.0	**GRANULAR BASE (SHOULDER):** sand and gravel, brown, moist.										
0.3	**FILL:** silty sand to sandy silt, trace gravel, trace clay, trace organics, brown to grey, moist, loose to compact.	1	SS	15							
		2	SS	7							
		3	SS	14							
2.5	**CLAYEY SILT TILL:** trace to some gravel, trace sand, grey, moist, stiff.										
		4	SS	13							
		5	SS	12							
5.6	**SILTY FINE SAND TO SANDY SILT:** grey, moist to saturated, compact.										
		6	SS	20							
		7	SS	16							



Shear strength legend: ○ UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE; scale 20 40 60 80 100

Continued Next Page

GROUNDWATER ELEVATIONS
Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▽ ▼

GRAPH NOTES: $+^3$, $\times^3$: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH201

PROJECT: Geotechnical Investigation for Proposed Culverts
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario
DATUM: N/A
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Continuous Flight Auger - Auto Hammer
Diameter: 115 mm
Date: Nov/05/2015
REF. NO.: 15-1026B-01
ENCL NO.: 4

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● 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	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS/0.3 m							
	SILTY FINE SAND TO SANDY SILT: grey, moist to saturated, compact.(Continued)	⁝	8	SS	12				○ (20)			
9.9	**END OF BOREHOLE DUE TO AUGER REFUSAL** Notes: 1) Water was encountered at a depth of 5.1 m below ground surface during drilling. 2) Water at a depth of 3.8 m below ground surface upon completion of drilling. 3) Borehole caved at a depth of 3.9 m below ground surface upon completion of drilling.											

GROUNDWATER ELEVATIONS

Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▼ ▼

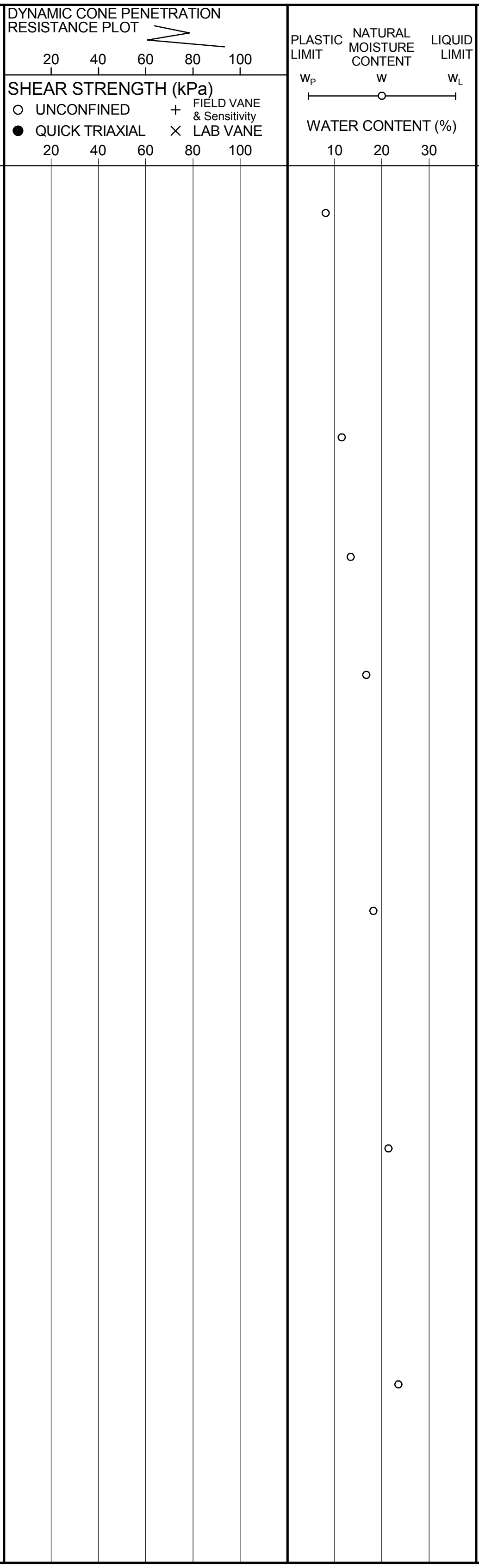
GRAPH NOTES $+^3, \times^3$: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH202

PROJECT: Geotechnical Investigation for Proposed Culverts
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario
DATUM: N/A
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Continuous Flight Auger - Auto Hammer
Diameter: 115 mm
Date: Nov/03/2015
REF. NO.: 15-1026B-01
ENCL NO.: 5

(m) ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
0.0	**GRANULAR BASE (SHOULDER):** sand and gravel, brown, moist.								
0.2	**FILL:** silty sand, trace gravel, trace clay, trace organics, brown to grey, moist, compact.	1	SS	15					
		2	SS	10					
2.1	**SANDY SILT TILL:** trace to some gravel, trace clay, grey, moist, compact.	3	SS	13					
		4	SS	16					
4.0	**SILTY FINE SAND TO SANDY SILT:** grey, moist to saturated, loose to compact.	5	SS	13					
		6	SS	13					
		7	SS	15					



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GROUNDWATER ELEVATIONS
Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▽ ▼

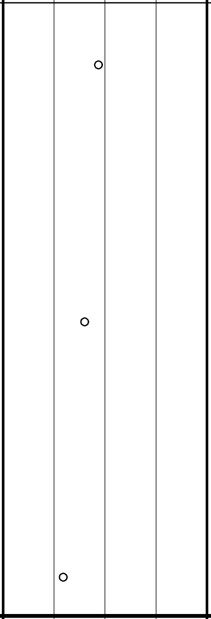
GRAPH NOTES
+³, ×³: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH202

PROJECT: Geotechnical Investigation for Proposed Culverts
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario
DATUM: N/A
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Continuous Flight Auger - Auto Hammer
Diameter: 115 mm
Date: Nov/03/2015
REF. NO.: 15-1026B-01
ENCL NO.: 5

SOIL PROFILE (m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	SAMPLES NUMBER	TYPE	"N" BLOWS / 0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● 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	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SILTY FINE SAND TO SANDY SILT: grey, moist to saturated, loose to compact.(Continued)		8	SS	10				○			
			9	SS	8				○			
			10	SS	14				○			
12.7	**END OF BOREHOLE** Notes: 1) Water was encountered at a depth of 3.1 m below ground surface during drilling. 2) Water at a depth of 3.6 m below ground surface upon completion of drilling. 3) Borehole caved at a depth of 3.7 m below ground surface upon completion of drilling.											



GROUNDWATER ELEVATIONS

Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▽ ▼

GRAPH NOTES $+^3, \times^3$: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH301

PROJECT: Geotechnical Investigation for Proposed Culverts
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario
DATUM: N/A
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Continuous Flight Auger - Auto Hammer
Diameter: 115 mm
Date: Nov/05/2015
REF. NO.: 15-1026B-01
ENCL NO.: 6

SOIL PROFILE			SAMPLES									
(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● 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	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
0.0	**ASPHALT** (245 mm)											
0.2	**GRANULAR BASE:** sand and gravel, brown, moist.											
0.7	**FILL:** sandy silt, trace gravel, pockets of clayey silt brown, moist to wet, compact to very loose.		1	AS								
			2	SS	17							
			3	SS	7							
			4	SS	3							
4.0	**PEAT:** fibrous, trace silt, layer of dark grey organic silt, trace rootlets, dark brown, moist, very loose.											
			5	SS	4				52			
5.6	**SILTY CLAY TO CLAYEY SILT:** trace sand, layer of silt, grey, moist to wet, very soft.											
			6	SS	1							
			7	SS	1							

Continued Next Page

GROUNDWATER ELEVATIONS

Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▽ ▼

GRAPH NOTES $+^3, \times^3$: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH301

PROJECT: Geotechnical Investigation for Proposed Culverts
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario
DATUM: N/A
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Continuous Flight Auger - Auto Hammer
Diameter: 115 mm
Date: Nov/05/2015
REF. NO.: 15-1026B-01
ENCL NO.: 6

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● 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	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS / 0.3 m							
	SILTY CLAY TO CLAYEY SILT: trace sand, layer of silt, grey, moist to wet, very soft.(Continued)		8	SS	2				○			
12.4	**SANDY SILT TILL:** trace gravel, trace clay, grey, moist, compact		9	SS	26				○			
12.7	**END OF BOREHOLE** Notes: 1) Water was encountered at a depth of 1.5 m below ground surface during drilling. 2) Water at a depth of 2.0 m below ground surface upon completion of drilling. 3) Borehole caved at a depth of 2.5 m below ground surface upon completion of drilling.											

GROUNDWATER ELEVATIONS

Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▼ ▼

GRAPH NOTES

$+^3$, $\times^3$: Numbers refer to Sensitivity

○ ε=3% Strain at Failure

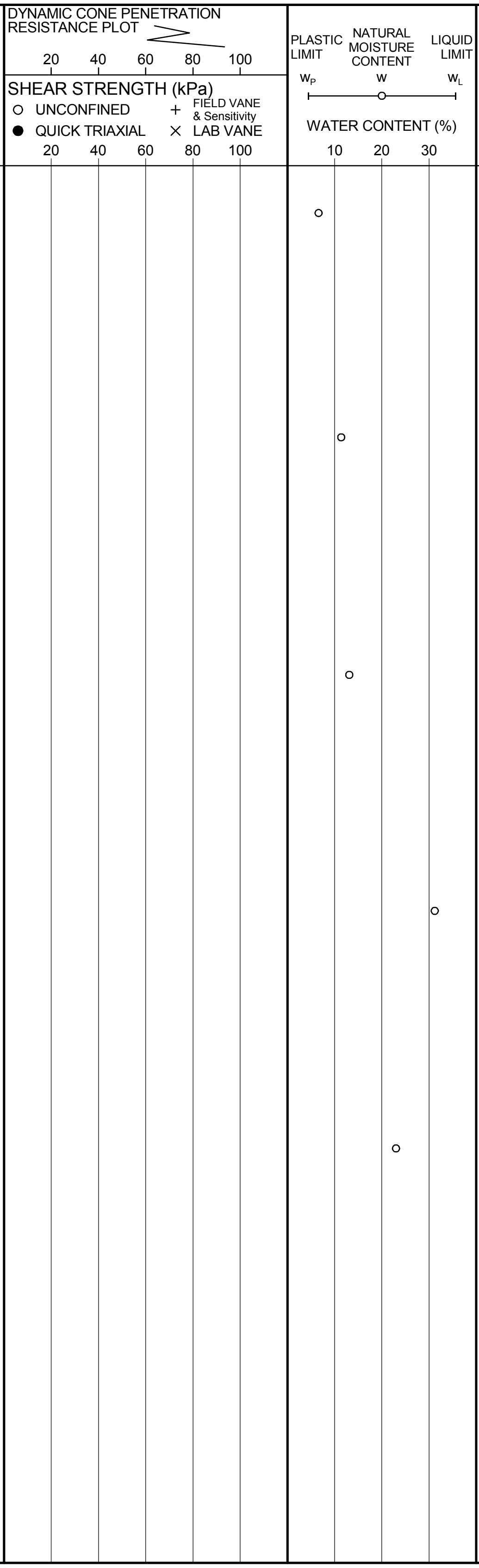
Engtec Consulting Inc.

LOG OF BOREHOLE BH302

PROJECT: Geotechnical Investigation for Proposed Culverts
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario
DATUM: N/A
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Continuous Flight Auger - Auto Hammer
Diameter: 115 mm
Date: Nov/05/2015
REF. NO.: 15-1026B-01
ENCL NO.: 7

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
(m) ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" BLOWS / 0.3 m					
0.0	**GRANULAR BASE (SHOULDER):** sand and gravel, brown, moist.								
0.3	**FILL:** sandy silt, trace gravel, brown, moist to wet, loose to compact.	1	SS	18					
		2	SS	6					
		3	SS	5					
4.7	**PEAT:** fibrous, trace silt, layer of dark grey organic silt, trace rootlets, dark brown, moist, very loose.	4	SS	3					
5.6	**SILTY CLAY TO CLAYEY SILT:** trace sand, layer of silt, grey, moist to wet, very soft.	5	SS	1					



Continued Next Page

GROUNDWATER ELEVATIONS
Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▽ ▼

GRAPH NOTES: $+^3, \times^3$: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH302

PROJECT: Geotechnical Investigation for Proposed Culverts
CLIENT: City of Brampton
PROJECT LOCATION: Heart Lake Road, Brampton, Ontario
DATUM: N/A
BH LOCATION: See Borehole Location Plan

DRILLING DATA
Method: Continuous Flight Auger - Auto Hammer
Diameter: 115 mm
Date: Nov/05/2015
REF. NO.: 15-1026B-01
ENCL NO.: 7

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● 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	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (Mg/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS/0.3 m							
	SILTY CLAY TO CLAYEY SILT: trace sand, layer of silt, grey, moist to wet, very soft.(Continued)		6	SS	1				○			
12.4	**SILTY SAND:** trace gravel, grey, moist, compact.		7	SS	1				○			
			8	SS	13				○			
14.2	**END OF BOREHOLE** Notes: 1) Water was encountered at a depth of 2.8 m below ground surface during drilling. 2) Water at a depth of 3.0 m below ground surface upon completion of drilling. 3) Borehole caved at a depth of 3.1 m below ground surface upon completion of drilling.											

GROUNDWATER ELEVATIONS
Shallow/ Single Installation ▽ ▼ Deep/Dual Installation ▼ ▽

GRAPH NOTES $+^3, \times^3$: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

APPENDIX G

Heart Lake Road Volunteer Ecology Monitoring Project, Phases 1 and 2

A report on findings from the 2011 Heart Lake Road Ecology Monitoring Project.

Heart Lake Road Ecology Volunteer Monitoring Project

The Heart Lake Road Ecology Monitoring Project is a joint initiative delivered by Toronto & Region Conservation Authority in partnership with City of Brampton, Ontario Road Ecology Group, Fleming College and community volunteers.

TORONTO AND REGION Conservation for The Living City

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List of Figures, Maps and Images

Acknowledgements

This study and report was made possible through the generosity of our volunteers, municipality and agency partners and Fleming College. The volunteers concern and commitment towards the protection of wildlife, this sensitive wetland area and efforts to maintain healthy ecosystems is evident by the results obtained. This enthusiastic group contributed a considerable amount of time and effort to this project completing training, making observations (some of which were upsetting due to the nature of the fatality), collecting data and this is undertaken throughout all weather conditions.

Volunteers:

Suzy Attard
Oliver Attard
Sebastian Attard
Leslie Bissegger
Mike Bissegger
Kelly Calovini
Nicole Calovini
Andy Calovini
Gillian Carson
Liz Ceci
Diana Christie
Bette-Anne Goldstein
Colin Grima
Teresa Grima
Janice Hessels
Susan Janhurst
Rosemary Keenan
Jim Laird
Rachel Luck
Sondra Luck
Debby McQuillen
Laura McQuillen
Leah MacSeáin
Mairéad MacSeáin
Damian MacSeáin
Chris McGlynn
Angela Mejury
Elizabeth Morin
Bob Noble
Jason Noro
Leo O'Brien
Shawn Patille
Marilyn Ross
Becky Shields
Bob Shields
Mike Solski
Cooper Solski
Sandhya Singh
Sonam Singh
Pauline Sutherland
Alana Ziobroski
Lyle Ziobroski

HLREMP Volunteers at Heart Lake Conservation Area

The following staff and agency representatives contributed to this project:

Domenic, Mike, Rosanna and Vince Crupi, Lakeside Garden Gallery, 10753 Heart Lake Rd.

Pam Douglas, Brampton Guardian

Susan Jorgenson, Manger, Environmental Planning, City of Brampton
Jessica Skup, Coordinator, City of Brampton

Jessica McEachren, Environmental Planner, City of Guelph

Leo O'Brien, Volunteer Liaison Coordinator, Heart Lake Project Team

Mandy Karch and the Ontario Road Ecology Group, Toronto Zoo

Sara Kelly, Faculty, Fleming College
Laura Baldwick - Ecosystem Management Technology Student, Fleming College
Katie Bigras - Ecosystem Management Technology Student, Fleming College
Carolyn Lobbezoo - Ecosystem Management Technology Student, Fleming College
Ashlea Veldhoen - Ecosystem Management Technology Student, Fleming College

Casey Cook, Project Intern, Toronto and Region Conservation Authority
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Laura Baldwick - Ecosystem Management Technology Student, Fleming College
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Casey Cook, Project Intern, Toronto & Region Conservation Authority
Vince D'Elia, Project Manager, Toronto & Region Conservation Authority

Executive Summary

The Toronto and Region Conservation Authority (TRCA) partnered with the City of Brampton (CoB), Ontario Road Ecology Group (OREG) at the Toronto Zoo and local volunteers to deliver the Heart Lake Rd. Road Ecology Volunteer Monitoring Project (HLREMP). The objective of HLREMP was to better understand which species were being impacted by interactions with vehicles, how many interactions were occurring, and to suggest mitigation measures to protect local biodiversity in the wetland systems adjacent to Heart Lake Road between Sandalwood Parkway and Mayfield Road in Brampton, Ontario. This 2.5 km section of road is adjacent to Heart Lake Conservation Area (HLCA) and bisects a provincially significant wetland complex.

The HLREMP took place between May 9th, 2011 and October 31st, 2011. Data was collected by volunteers with the goal of observing and recording wildlife-vehicle collision sites (WVC's), any notable live wildlife along the road, species proximity to the road, alive/dead status and GPS co-ordinates.

A group of four students through the Sir Sandford Fleming College, Ecosystem Management Technology Program, Credit for Product Course, assisted TRCA with analyzing the data collected through the study to produce a report of the findings. The report provides an overview of the study and study area, outlines the number of monitoring sessions, number of volunteer hours, number of wildlife observed (dead and alive) and also provides recommendations for mitigation.

The wildlife observed over the course of the study period included various frogs, turtles, snakes and avian species. When analyzing the relative number of WVC's, amphibians ranked the highest followed by reptiles then mammals. It is also valuable to note that out of the total number of dead animals observed, there were several unidentified species due to the severity of the kill.

The report and the findings will be shared with TRCA, the Region of Peel, the CoB and the Credit for Product course faculty at Sir Sandford Fleming College in Lindsay, Ontario. It is our hope that the data and recommendations in this submission will be considered a valuable contribution toward implementing mitigation options on Heart Lake Road.

1 Introduction

Road ecology is an emerging field addressing the effects of roads on wildlife populations and the impacts on ecological processes (OREG, 2010). This report focuses on a citizen science study conducted along Heart Lake Road from Sandalwood Parkway travelling north to Mayfield Road, in Brampton Ontario, a distance of approximately 2.5 km. This particular section of road is level to the wetland, adjacent to HLCA and bisects a provincially significant wetland complex.

The wetlands located in and around the Heart Lake Conservation Area, are an example of a complex biodiversity. They contain several species of reptiles and amphibians, aquatic and terrestrial plants and a variety of wildlife, all of them intertwined to support life. The wetland itself acts as a filter for water, catching contaminants and nutrients, thus allowing the groundwater areas to be recharged providing access to clean drinking water. In the spring of 2010, several painted turtles were observed dead along this stretch of Heart Lake Road in a single day. These observations were brought to the attention of TRCA Ecology staff and OREG. Following this observation, TRCA collaborated with OREG and the CoB to create and implement HLREMP over a 25 week period from May to October 2011. The purpose of this project was to determine species being impacted by interactions with vehicles, the number of interactions occurring and suggest mitigation measures to protect biodiversity in the wetland systems of this study area.

Biodiversity encompasses all life and is defined as the variety and genetically different number of species present in each geographic area or habitat. Roads pose risks to wildlife and biodiversity by contributing to increased wildlife mortality and habitat loss, fragment the movement of wildlife from their breeding, feeding and hibernation areas and add increased contamination to the natural environment. The hydrological functions of wetlands include storage of surface water, recharge of groundwater supplies, reduction in peak floodwater flows and erosion prevention (Gabor *et al*., 2004). Wetlands are also important feeding, breeding, and drinking grounds for wildlife (Lillesand *et al*., 2004). Pollution from fertilizers, insecticide, de-icing agents, combustion engine emissions, vehicle debris, illegal dumping activity and motorist litter are all factors of wetland degradation. Noise pollution disrupts normal wildlife behaviours such as mating, migration, predation and nesting (Former & Alexander, 1998). Cutting vegetation as part of regular road maintenance where the road borders a wetland negatively affects the wetland ecosystem by eliminating wildlife habitat, attracting wildlife to the roadside, removing natural buffer zones and encouraging the growth and spread of invasive species (OREG, 2010). Direct mortality due to WVC's is the most common impact roads have on wildlife. These factors can lead to chronic stress on local wildlife, reduced individual fitness and population viability (OREG, 2010). This study will aid in the research of the effects of habitat fragmentation on wildlife behaviour and mortality.

The results outlined in this study attest to the importance of this type of research, as Southern Ontario's dense road networks and human population are expected to intensify each year. Over a period of 60 years (between 1940 and 2000) major roads in southern Ontario increased from 7,133 kilometres to 35,637 kilometres (Fenech et *al*., 2000) and today no area of land is more than 1.5 kilometres from a road (Gunson, 2010). The Ontario Ministry of Transportation reports that there is a vehicle/wildlife collision in Ontario every 38 minutes (MTO 2011)… this is a staggering statistic.

Ontario is blessed with abundant biodiversity but also challenged with having 190 species listed on the Species at Risk Act (Species at Risk Ontario, 2011). Many of these species are negatively affected by roads. Habitat loss and road fatalities are the two major causes of declines in wetland species. The loss of specie numbers is growing and at-risk species are of great concern. Not only are they at risk from accidental kills from vehicles, some studies indicate drivers will intentionally swerve their vehicle to run over reptiles and amphibians. (Ashley EP, Kosloski A, Petrie SA, 2007)This is expected to continue as the population of the Greater Gold Horseshoe area is estimated to increase by over 3 million residents over the next 20 years (Growth Plan for the Greater Golden Horseshoe, 2006).

Increased global population, development, industrialization, overconsumption, pollution and climate change have contributed to a dramatic loss of habitat and threats to species, the natural environment and humans. There is an increased awareness of these threats, and this has led to the United Nations to declare 2011-2020 as the International Decade of Biodiversity (Environment Canada, 2011). This report analyses the data collected through HLREMP, helps raise awareness of the impacts roads are having on biodiversity and provides recommendations for mitigating the impact this section of road is having on the wetland ecosystem.

2 Materials & Methods

2.1 Study Area

The study area lies within the Etobicoke Creek Watershed and focussed on a section of Heart Lake Road that bisects a provincially significant wetland complex in Brampton, Ontario. This section of road is approximately 2.5 km, bordered by Sandalwood Parkway and Mayfield Road. This section of Heart Lake road is a paved and shouldered two-lane road which is level to the wetland complex and adjacent to the HLCA (see Figure 1). Heavy vehicle traffic occurs in the summer months partly due to a garden center located on the east side and people visiting the HLCA.

Figure 1: Study Area

2.2 Volunteer Recruitment

In an effort to recruit volunteers, the project was promoted through local media and various networks of community and volunteer contacts. An article promoting HLREMP was published in the Brampton Guardian on March 23rd, 2011 (see Appendix H) and notices were posted at local community centres outlining the program and invited volunteers to attend an information session at Loafer's Lake Recreation Centre. Volunteers attending the public information session were invited to sign up to participate in the study.

2.3 Surveying and Methods

The study was completed over the course of a twenty-five week period, extending from May 9th, 2011 through to October 31st, 2011. All volunteers received training on the protocol and safety requirements prior to the initiation of the project (see Appendix B). Volunteers worked in pairs and they were scheduled based on their availability. Each monitoring session was approximately two hours in length and these sessions were staggered throughout daylight hours each week (Sunday to Saturday). Each pair was given the opportunity to select from four monitoring time-slots ensuring no two groups were monitoring at the same time but could choose an alternate time to monitor on the same day.

With each monitoring session a field data sheet was completed which included; date and time, volunteer names, length of session, weather conditions (temperature, humidity, precipitation, cloud, wind). When a sighting was observed, volunteers recorded the taxa (mammal, frog/toad, snake, turtle or avian), species (if able to identify), freshness of the kill (dead within the last 24 hours) and alive or dead status. The status could be alive on road (AOR), alive by road (ABR), dead on road (DOR) or dead by road (DBR). Information related to the sighting location was recorded using a GPS unit to obtain UTM coordinates. The proximity of the wildlife observed, in relation to the road, was also recorded (i.e. east side/white line, centre line, or west side/white line). Volunteers were encouraged to take images to provide some visual reference for the data analysis. Dead organisms were moved well off of the road to avoid being counted multiple times. The data sheets and pictures were collected weekly and data was transferred to an excel file.

Image 1: Group Safety Training at HLCA

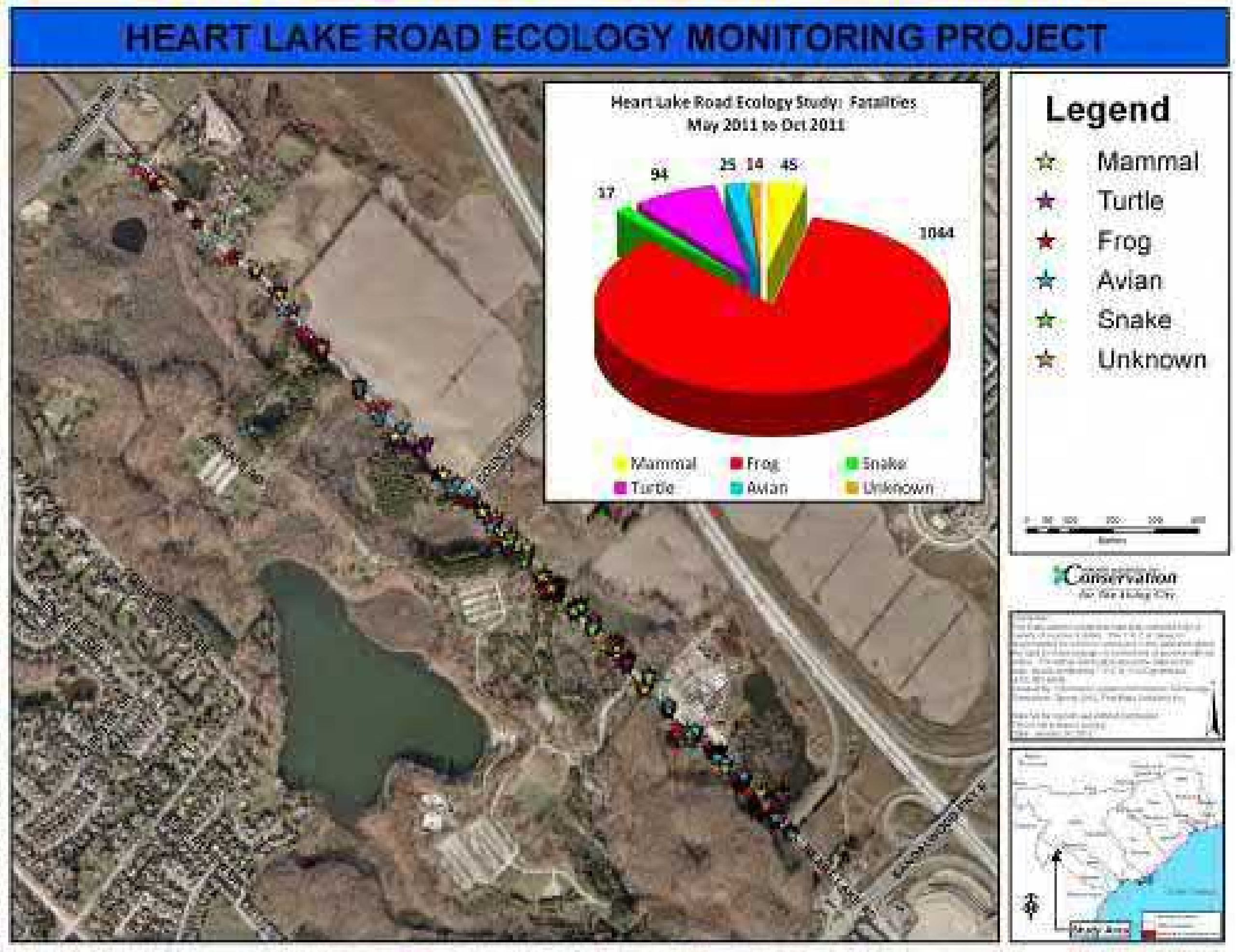
Image 2: Safety Signage

Image 3: Meiraid Mac Seain and Pauline Sutherland along Heart Lake Road

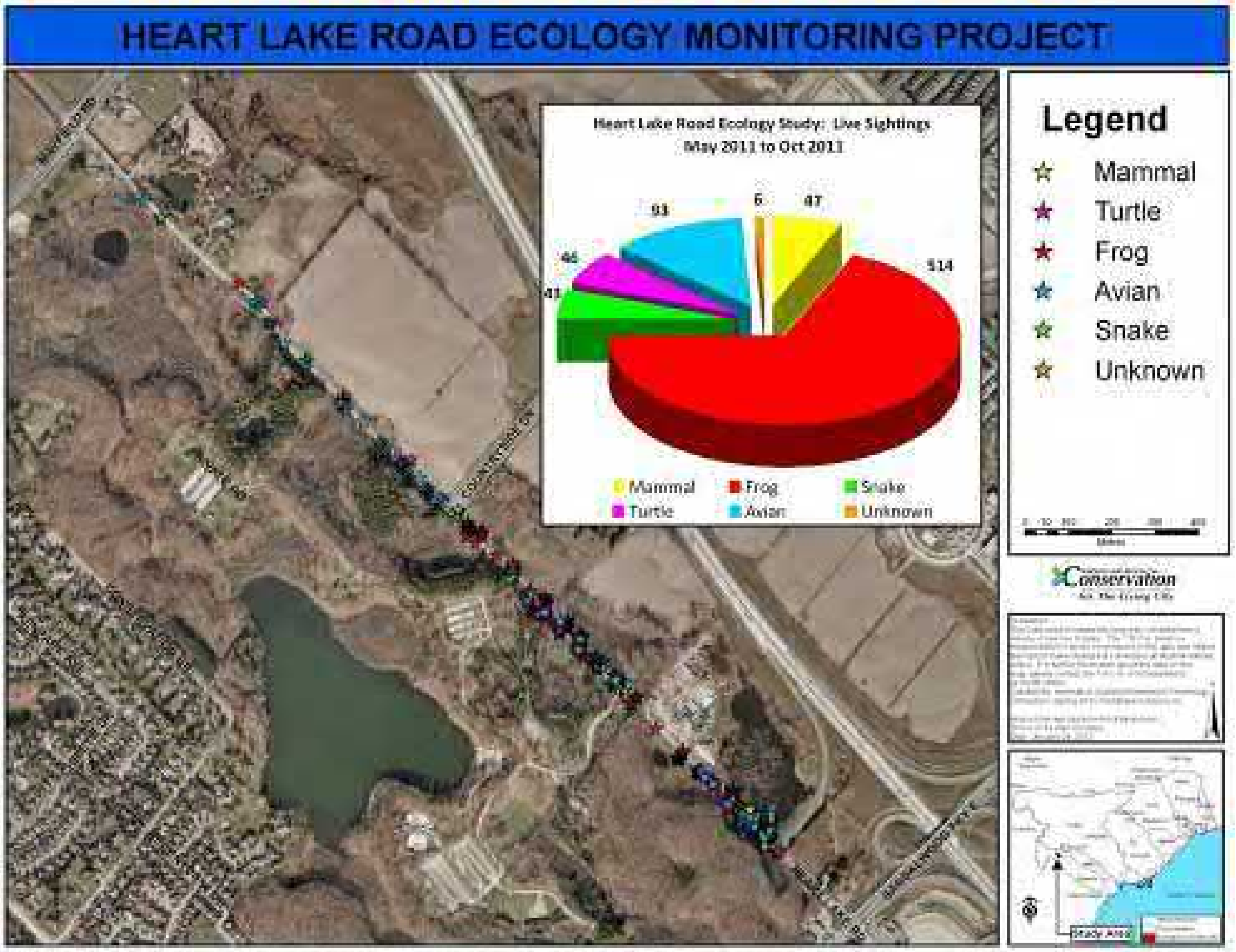
Image 4: Leo O'Brien and Shawn Patille monitoring along Heart Lake Road

2.4 Data Analysis

The data was analyzed to determine the number of monitoring sessions, number of volunteer hours and number and type of wildlife observed. The raw data was compiled to show a list of the observed wildlife by species, their status, the total number observed and using UTM coordinates, GIS maps were created to show these results (See Map 1 to 6).



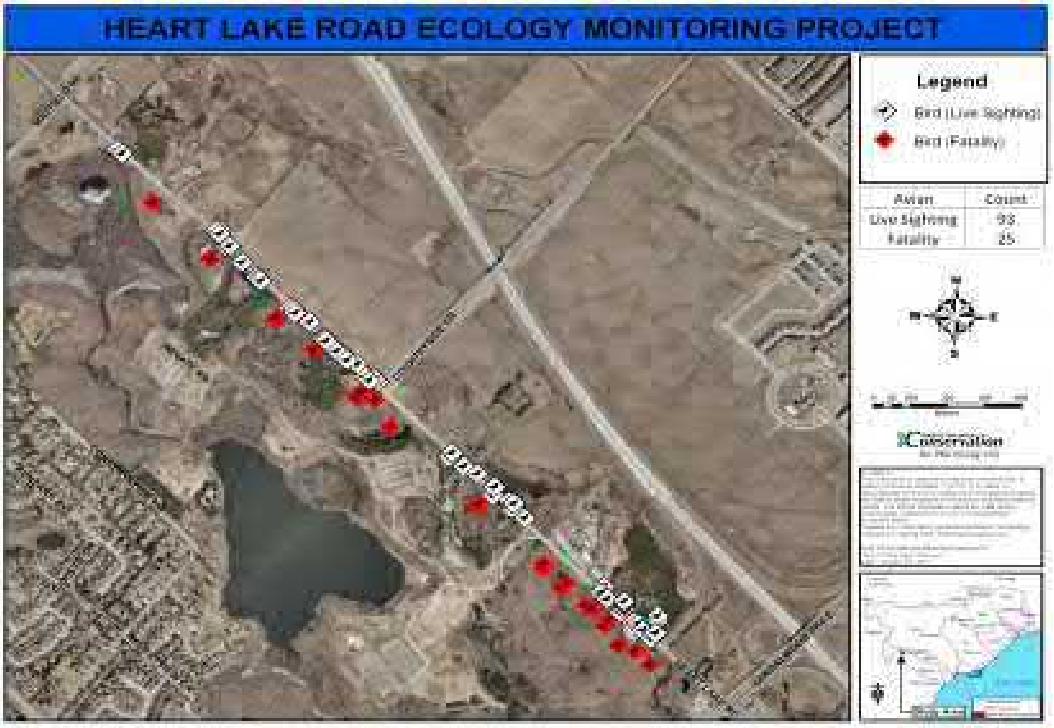
Map 1: Total Fatalities



Map 2: Total Live Sightings

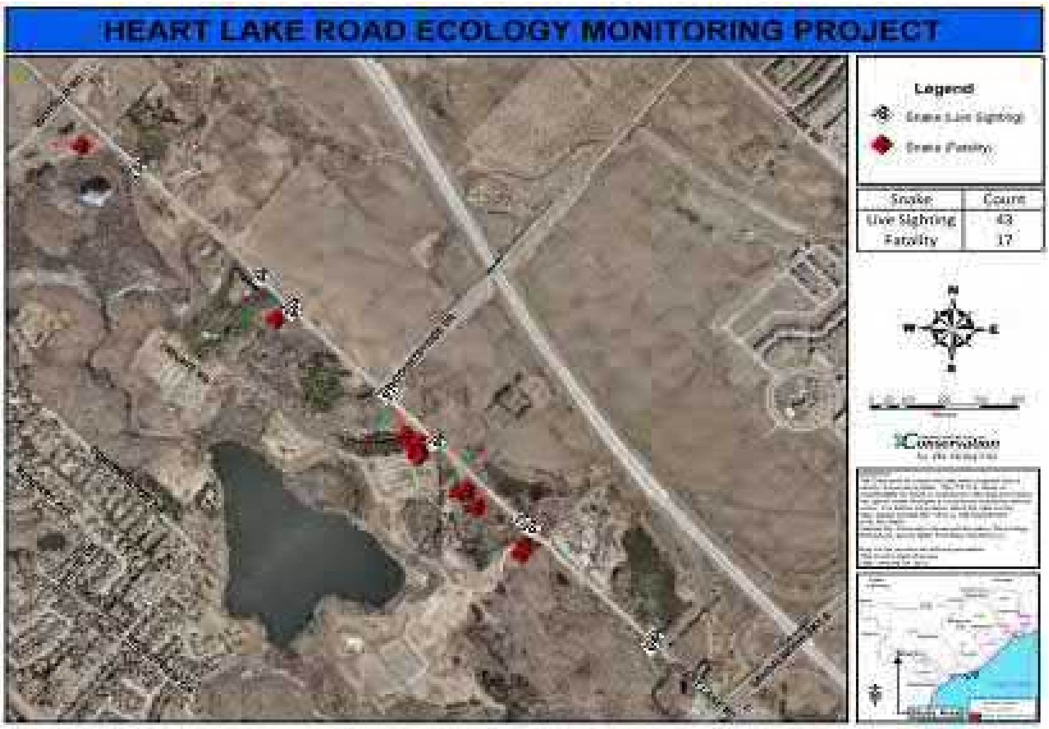
Map 3: Total Frog Sightings

Map 4: Total Turtle Sightings

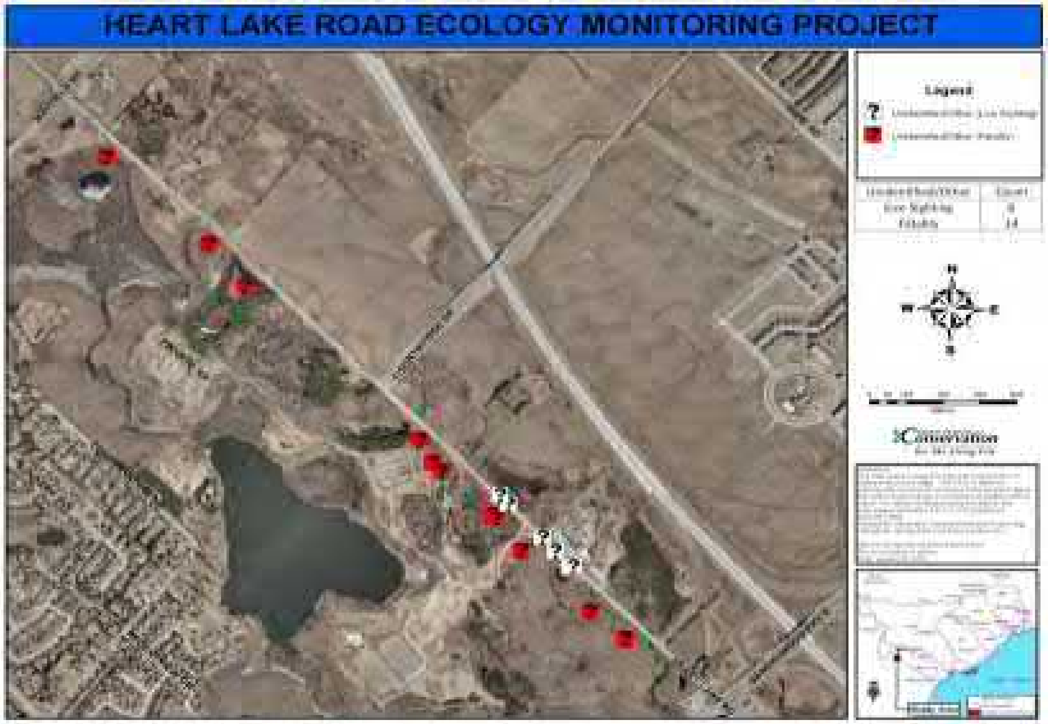


Map 5: Total Avian Sightings

Map 6: Total Mammal Sightings



Map 7: Total Snake Sightings



Map 8: Total Unknown Sightings

3 Results

Over the course of the project, a total of 1988 wildlife were observed. Of the total, 1239 were fatalities and 749 were live sightings. When analyzing the relative number of WVC's, frog/toad ranked the highest with 1044 individuals at 84.26%, followed by 94 turtles at 7.59%, 45 mammals at 3.63%, 25 avian at 2.02%, 17 snakes at 1.37% and 14 unknown at 1.13% (Figure 2 and 3).

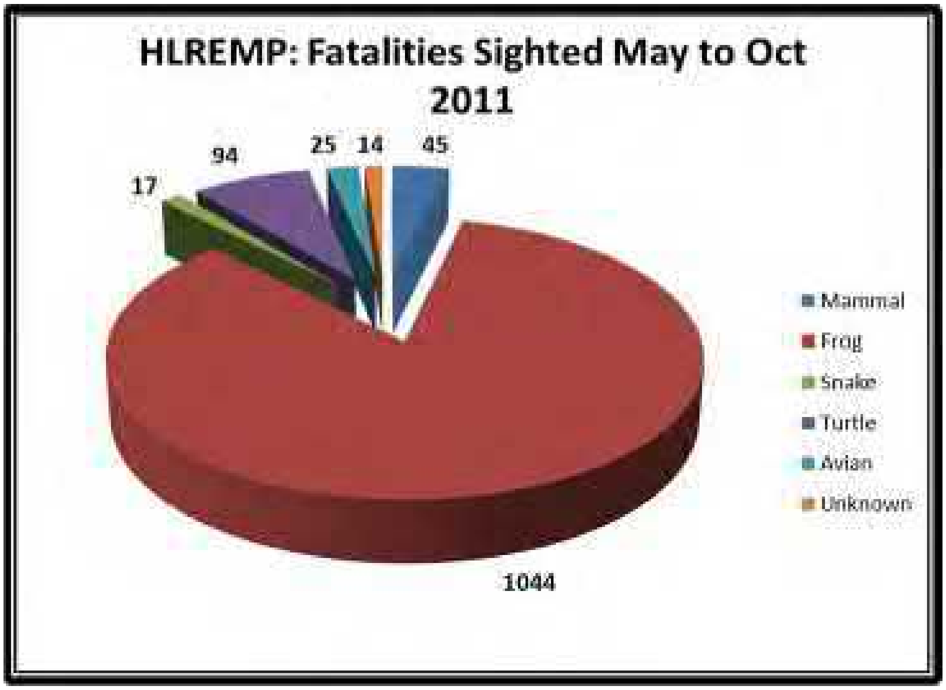


Figure 2: Pie chart showing breakdown of fatalities

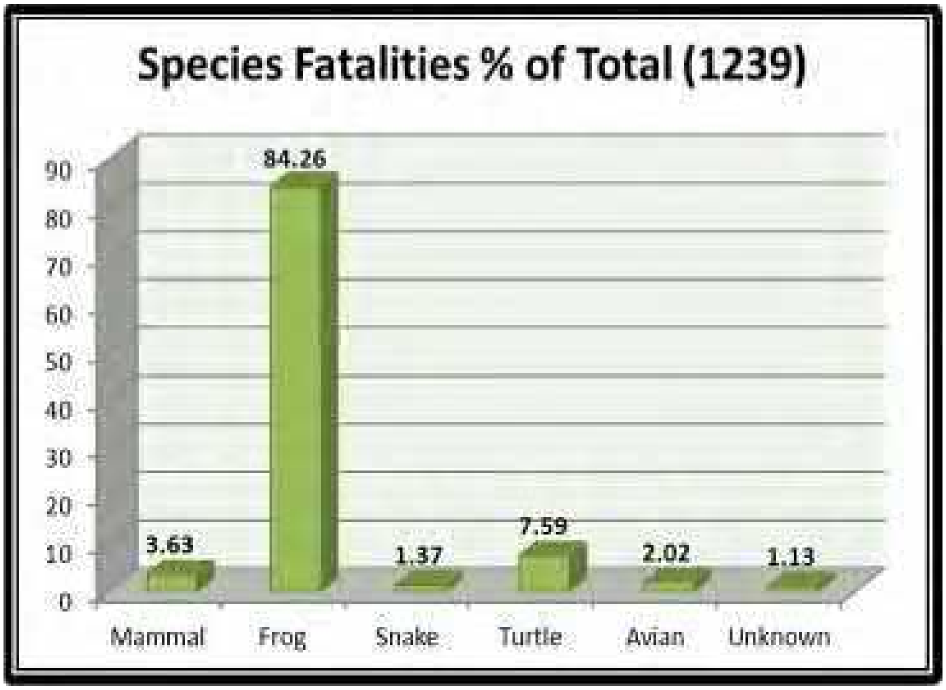


Figure 3: Bar chart showing % of fatalities from total

A total of 749 live wildlife were observed over the same time period with 514 frog/toads at 68.62%, followed by 93 avian at 12.42%, 47 mammals at 6.28%, 46 turtles at 6.14%, 43 snakes at 5.74%, and 6 unknown at 0.80% (Figure 4 and 5).

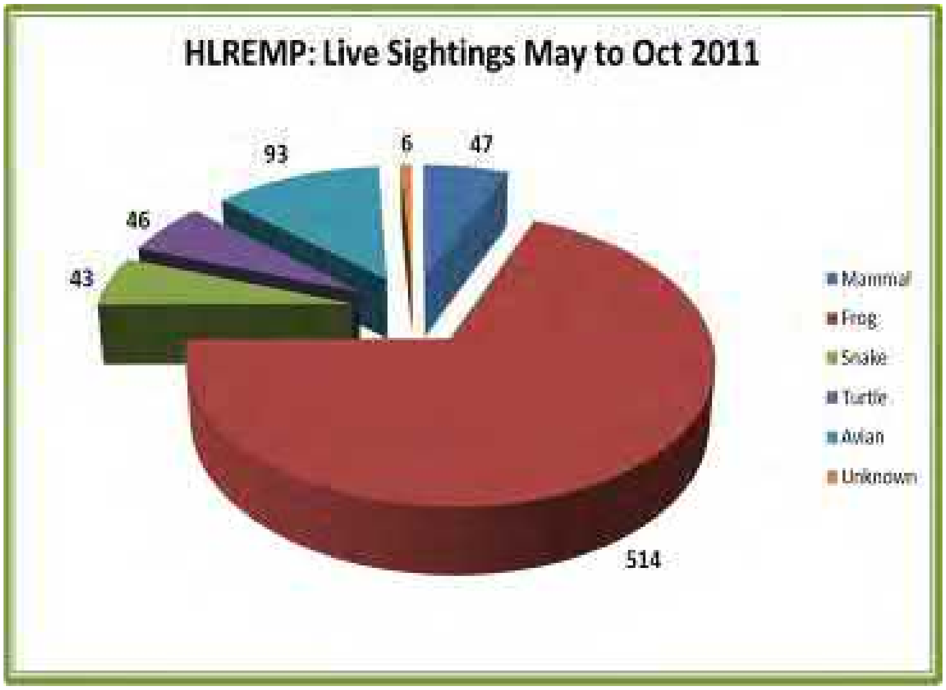


Figure 4: Pie chart showing breakdown of live sightings

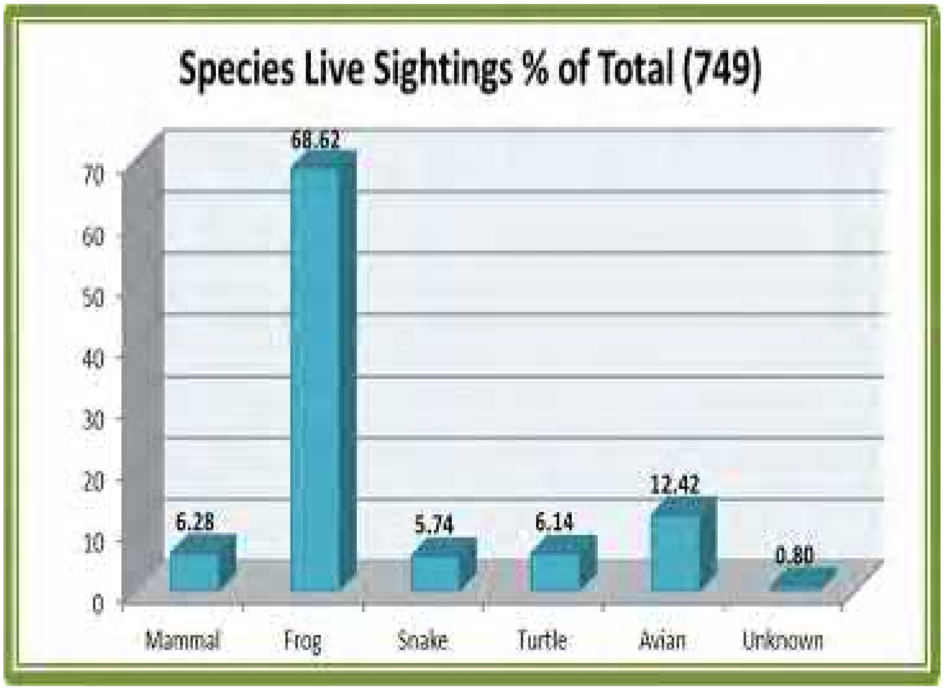


Figure 5: Bar chart showing % of total live sightings

Over the course of the 25 week study period from May 9, 2011 to October 31, 2011, over 40 community volunteers contributed more than 420 hrs to the monitoring project. The actual time spent monitoring only represent approximately 10% of the total available time for monitoring (daylight hours) over the study period. Since volunteers were not monitoring for approximately 90% of the available time and did not monitor after or before daylight, the number of WVC's during the study period is potentially higher than the study results indicate.

The study data indicates that volunteers recorded various uncommon and at-risk species of turtles and frogs. Many of these observations cannot be confirmed due to the lack of photo evidence and/or poor photo quality. Some of these observations, such as the snapping turtles have been confirmed with photos. Volunteers may have also incorrectly identified wildlife or may have been confused with observations of a non-native wildlife (Image 5), likely the result of pet dumping. In addition, there were wildlife observations which were unidentifiable due to the severity of WVC and as a result were placed in the unknown species category.

Image 5: Observation mistaken for native species

4 Discussion

4.1 Data Interpretation

The study area is located in a highly urbanized location but is fortunate to have a relatively high level of species diversity. As Brampton continues to grow the natural spaces and wildlife populations that inhabit them will be exposed to additional stresses. The study findings and observations show the study area has a relatively broad range of species inhabiting the surrounding ecosystem - Appendix B lists observed wildlife species, Appendix C lists avian species observed over the study period.

The majority of reported WVC's involve large wildlife (such as moose, deer etc.), while small wildlife WVC's generally go unreported. Smaller wildlife serves an important role in the ecosystem and some, due to their size and requirements, are confined to local habitat. The findings of this study show local frog, toad, turtle and snakes are the species significantly impacted along this section of road. The following are some facts regarding threats to these species biodiversity in Ontario.

Turtles:

Of the nine species of turtles in Ontario seven are listed on the Species at Risk List, a Regulation under the Endangered Species Act 2007. Depending on the species size, the age of maturity can range between 4 - 36 years (Wyneken, 2008). The number of eggs laid by an adult female varies and less than one percent of those eggs will reach sexual maturity. An adult female is a vital part of the continuation of the species and a loss of 1-2% each year in an area will lead to extirpation in a very short period of time. The habitat of these creatures is declining due to urban development and road extension. With their feeding and breeding grounds divided by roads and highways, it puts them at a higher risk of mortality as they cross over to reach areas to lay eggs and return to feed. As the eggs are dependent on the warmth of the sun to incubate, the female will place them in a non-vegetated area, which exposes them to predation (KTTC, 2011). The sandy-gravel located on the shoulder area of roads provides an ideal location for the turtle to lay her eggs putting her at risk of a WVC, leading to reduced populations and number of eggs laid each year (KTTC, 2011).

The illegal activity of pet trade is another growing concern. In Ontario, the collection and sale of the wood turtle have contributed to its present rating of Endangered on the Species at Risk List and this is verging on Extirpated (Ontario Nature, 2011).

Amphibians:

Nine species of frogs, salamanders and Ontario's only lizard are on the Species at Risk List. Loss of habitat, vehicle mortality from migration across roads and negative impacts caused by contaminants and pollution are all contributors to the decline of this species. Frogs are an essential component of wetlands being both a food source for other wildlife and they consume large amounts of insects and algae. Frogs and salamanders are known as indicator species which means simply by their presence or absence, they indicate the health of an area. They rely on their skin to breathe and transport electrolytes which makes them very sensitive to negative impacts such as pollutants and contaminants in water bodies. Scientists and researchers have discovered frog populations have decreased due to the infectious disease chytridiomycosis, a fungus which is attacking the species on a global scale. This fungus attaches itself to the skin, causes breathing impairment and prevents electrolytes to pass through the body, leading to cardiac arrest. There is global concern regarding the decline of frogs and many studies are currently being conducted to introduce control methods in order to protect these sensitive species (Reptile & Amphibian Ecology, 2011).

Snakes:

Ten of the seventeen species of snakes in Ontario are listed as Species at Risk. Again, snakes play an essential role in maintaining biodiversity of an ecosystem. They are both predator and prey, keeping the rodent population down but are also a food source to several predator species such as hawks. It is believed that human fear of these creatures contributes to their mortality. Many people are afraid of snakes and studies show human attempts to deliberately deplete this species.

The road ecology study has shown this area to be a significantly diverse wetland capable of supporting many varieties of life. There are an alarmingly high number of mortalities along this stretch of Heart Lake Road and the numbers indicate the need for mitigation methods to be put into effect in order to protect their continued existence and ensure a healthy biodiversity.

4.2 Mitigation Recommendations

Reptiles and amphibians are an important component to many ecosystems. Amphibians stay within close proximity of their breeding sites, and most juveniles stay within one kilometer. When a road bisects a seasonal habitat and a breeding site, high levels of amphibian traffic will occur over these roads during peak breeding seasons (Ovaska *et al*., 2005). Research has shown that when comparing mitigation options for reptiles and amphibians, tunnel and fencing systems, culverts, and relocations of breeding sites tend to work best (Ovaska *et al*., 2005). Studies have also found that small to mid-sized mammals will also take advantage of culverts and concrete box structures (Beier *et al*., 2008). For this study, options to decrease WVC's include installing permanent or temporary fencing, utilizing existing culverts, and/or re-construct areas of Heart Lake Road by building concrete-box structures with opening tops at potential crossing hotspots. Extensive research, years of data compilations and studies have proven under-road tunnels to be effective at conserving and sustaining amphibian and reptile populations (Jolivet *et al*., 2008).

Tunnel and fencing systems should be strategically placed at high traffic crossing areas and guidelines of installation and maintenance should be followed. There are a small number of pre-existing culverts along Heart Lake Road which could be modified for use as wildlife pathways. When using culverts for wildlife pathways, it is essential to incorporate as much of the natural habitat as possible by placing substrate on the culvert base versus uncovered steel or concrete (Ovaska et al., 2005). For the mitigation procedure to be effective it is essential that the culvert(s) be relatively close to crossing hotspots (*Bissonette & Cramer,* 2008). If culverts are not pre-existing at wildlife crossing hotspots, concrete box structures should be considered. The concrete box structures are larger, and with the use of overhead openings, it is brighter and therefore more inviting to reptiles, amphibians, and small mammals (McEachren, 2011). For both suggestions, fencing is essential to guiding wildlife to the crossing. Silt fencing can be used (Figure 7), however the fence must be buried a certain depth underground to prevent wildlife from crawling under. This type of barrier should be monitored and maintained on a regular basis. A more permanent solution is a concrete wall (Figure 8) that cannot be dug under, or easily destroyed (Lake Jackson Ecopassage Alliance Inc., 2011).

Image 6: Permanent Concrete Wall Directing Wildlife to Underpass

Image 7: Silt Fencing Mitigation Option

4.3 Prevention

The following recommendations should be considered in an effort to help prevent WVC's prior to construction of a road:

- Conduct monitoring projects prior to road development and expansion adjacent to natural spaces during which monitoring data related to wildlife movement (migration patterns, habitat requirements, species sensitivity, etc.) should be collected, reviewed and considered prior to providing approvals and construction permits.
- For projects related to improving and/or expanding existing roads or for the construction of new roads, wildlife movement data should be reviewed and incorporated into the project design. These types of projects may provide a great opportunity to install a permanent barrier to guide wildlife to the preferred crossing areas, replace undersized culverts, or install new culverts or tunnels at identified crossing hotspots.
- Co-operation between the government and conservation organizations (i.e. OREG, TRCA) to develop policy and legislation in areas of road ecology to aid transportation and planning agencies to design more ecologically-sustainable transportation networks.

4.4 Education and Awareness

The following recommendations should be considered to help raise education and awareness of road ecology:

- Community Level Education – government to work with conservation organizations (i.e. OREG, TRCA) to provide public outreach and education programs to raise awareness about the ecological effects of roads through. Community events, schools, local media, digital media, brochures, and road signage are examples of tools that can be used.
- Staff Level Education – transportation and planning agencies to train and educate staff about the ecological effects of roads and incorporate road ecology into the planning process.
- Construction and Building Community – Employ transportation and planning agencies to educate construction workers about Road ecology and develop certification programs for the installation of the various mitigation options.

5 Conclusion

The objective of HLREMP was to better understand which species were being impacted by interactions with vehicles, how many interactions were occurring, and to suggest mitigation measures to protect local biodiversity in the wetland systems adjacent to Heart Lake Road.

The data analysis from the HLREMP reveals that there is a high numbers of WVC's along this stretch of Heart Lake Road. This report recommends the following options to help mitigate the total number of WVC's including installation of permanent or temporary fencing and utilizing existing culverts, building concrete-box structures with open tops, and/or installing fencing on either side of the road at potential crossing hotspots. In the future, these mitigation options can be employed as prevention strategies to minimize the amount of WVC's that will occur after a road is constructed. The HLREMP will help to provide direction for future studies and stakeholder decisions regarding the construction of roads and development around the study area.

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APPENDIX

Appendix A: HLREMP Articles

BRAMPTON GUARDIAN

Corpse counters needed

Pam Douglas
March 23, 2011

Bramptonians can help protect the many frogs, turtles and snakes that hop, crawl and slither across Heart Lake Road every spring— by documenting the ones that didn't make it.

The Toronto Zoo is looking for volunteer "citizen scientists" in Brampton to help collect data this spring.

A section of Heart Lake Road, between Mayfield Road and Sandalwood Parkway, has been tagged for this first-of-its-kind wildlife monitoring project, being organized by the Ontario Road Ecology Group (OREG) at the Toronto Zoo.

Residents interested in volunteering their time to scientifically collect data on how many frogs, turtles and snakes die on the marsh-flanked roadway are invited to an information meeting Wednesday, March 30, 7 to 9 p.m. at Loafer's Lake Recreation Centre, 30 Loafer's Lake Lane.

The information on just how many are killed and where they are trying to cross will be used to find local solutions, and can even be applied nationally or globally, according to Mandy Karch, OREG co-ordinator.

Because the road bisects conservation land and marshy areas, there is a large number of casualties along that stretch every year. Last spring, six painted turtles were found dead on Heart Lake just in one day, and that fact caught the attention of OREG.

The Toronto and Region Conservation Authority (TRCA) and City of Brampton will supply the equipment needed to do the monitoring, and will work with Karch to train the volunteers and share the collected data.

Karch said similar monitoring projects may be undertaken in other parts of the province if the local project is successful.

"We're hoping to expand this to other municipalities and other local groups," Karch said.

OREG is an organization comprised of government and non-governmental scientists, educators and transportation planners, who work together to raise awareness about the threats of roads to biodiversity in Ontario and to research and apply solutions.

The solutions don't have to be too elaborate, according to Karch.

"A culvert that's already in place for hydrology can be very easily and very inexpensively converted into a crossing for wildlife, so there are very simple solutions," she said.

Culverts under the road are also very easily incorporated into a road resurfacing project or road widening, but the information has to be available to justify a crossing.

"Collecting data is critical," she said.

The monitoring starts in spring when snakes, frogs and turtles start to wake up, and move from their overwintering site to their feeding and reproducing ground, Karch said.

"So that (May) is a real key movement time," Karch said. "For turtles, June again is a key movement time because the females start looking for nesting areas. Species like snapping turtles and blanding's, they'll walk up to 16 kilometres in search of an appropriate nesting site."

In the fall, they are on the move again, moving from their "active" wetlands to an overwintering site.

"Particularly for snakes, October is a very critical movement period when we see a lot of mortality, unfortunately," Karch said.

She said the group is focusing on the species that are becoming extinct because of "road mortality".

With declining habitat availability and climate change, I think globally there's a decline in amphibians, so I think Canada is very lucky to have our population so we should really invest in their protection preemptively before they (are on the endangered species list)," she said.

For more on road ecology, visit the OREG's website is at www.torontozoo.com/conservation/RoadEcologyGroup.asp.

Death Valley. Bramptonians can help protect the many frogs, turtles and snakes that hop, crawl and slither across Heart Lake Road every spring— by documenting the ones that didn't make it. The Toronto Zoo is looking for volunteer "citizen scientists" in Brampton to help collect data this spring. *Submitted photo*

BRAMPTON GUARDIAN

Residents wild about survey

By PAM DOUGLAS
April 16, 2011

Sebastian Attard saw a chance to help some of Brampton's frogs— and he jumped at it.

"Mom, we have to do this. It's our duty," the nine-year-old told his mother, Suzy, when he saw a story in The Guardian about a wildlife monitoring program unique to Brampton that is looking for volunteers.

Sebastian and his mother were just two of the more than 60 residents who attended a meeting recently to find out how they can help protect the many turtles, frogs and snakes that dodge traffic to cross Heart Lake Road every year.

Sebastian is "into any creature and anything to do with science," according to his mom, and she saw the monitoring program as a chance for them to do something together for a great cause.

No special expertise or knowledge is needed, just an interest in helping out. Everything else will be provided by the organizers— the Ontario Road Ecology Group (OREG) at the Toronto Zoo.

The turnout at a recent information meeting exceeded expectations, with a wide range of ages and backgrounds, and that has organizers excited about the interest for the project in Brampton.

A section of Heart Lake Road, between Mayfield Road and Sandalwood Parkway, will be monitored for this first-of-its-kind wildlife monitoring project.

"Citizen scientists" have been asked to volunteer their time to scientifically collect data on how many frogs, turtles and snakes die on the marsh-flanked roadway. The study area is a one kilometre stretch and would take approximately 1 1/2 to two hours to complete a monitoring session. The study will begin in May and run through October.

The information will be used to find local solutions, and can even be applied nationally or globally, according to Mandy Karch, OREG co-ordinator.

The volunteers, who will work in partners, will meet again April 27 for an on-site training session to review safety, data collection methods, and ask questions.

Because that section of road bisects conservation land and marshy areas, there is a large number of wildlife casualties along that stretch every year. Last spring, six painted turtles were found dead on Heart Lake just in one day, and that fact caught the attention of OREG.

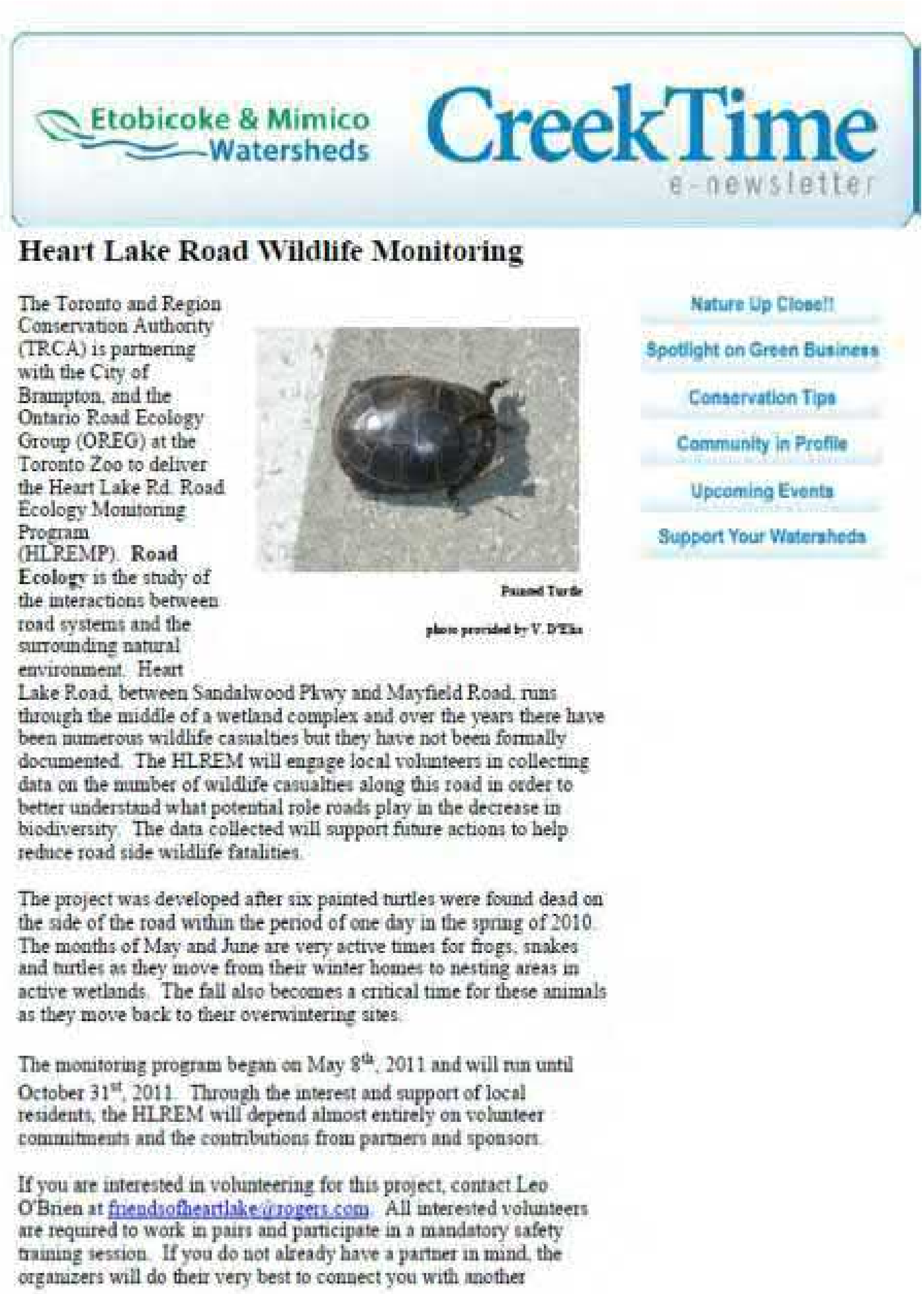
The Toronto and Region Conservation Authority (TRCA) and City of Brampton will supply the equipment needed to do the monitoring, and will work with Karch to train the volunteers and share the collected data. The Heart Lake Project Team first heard about the program one year ago, and many of the volunteers are members of the team.

Karch said similar monitoring projects may be undertaken in other parts of the province if the local project is successful.

"We're hoping to expand this to other municipalities and other local groups," Karch said.

More volunteers are welcome. The group would like to be able to monitor the road two to three times a week, twice a day (morning and evening).

Survey area. Beginning this spring, a section of Heart Lake Road, between Mayfield Road and Sandalwood Parkway, will be monitored in a first-of-its-kind wildlife mortality monitoring project unique to Brampton. *File photo*



Etobicoke & Mimico Watersheds
CreekTime
e-newsletter

Heart Lake Road Wildlife Monitoring

The Toronto and Region Conservation Authority (TRCA) is partnering with the City of Brampton, and the Ontario Road Ecology Group (OREG) at the Toronto Zoo to deliver the Heart Lake Rd. Road Ecology Monitoring Program (HLREMP). **Road Ecology** is the study of the interactions between road systems and the surrounding natural environment. Heart Lake Road, between Sandalwood Pkwy and Mayfield Road, runs through the middle of a wetland complex and over the years there have been numerous wildlife casualties but they have not been formally documented. The HLREM will engage local volunteers in collecting data on the number of wildlife casualties along this road in order to better understand what potential role roads play in the decrease in biodiversity. The data collected will support future actions to help reduce road side wildlife fatalities.

Painted Turtle

photo provided by V. D'Elia

The project was developed after six painted turtles were found dead on the side of the road within the period of one day in the spring of 2010. The months of May and June are very active times for frogs, snakes and turtles as they move from their winter homes to nesting areas in active wetlands. The fall also becomes a critical time for these animals as they move back to their overwintering sites.

The monitoring program began on May 8th, 2011 and will run until October 31st, 2011. Through the interest and support of local residents, the HLREM will depend almost entirely on volunteer commitments and the contributions from partners and sponsors.

If you are interested in volunteering for this project, contact Leo O'Brien at friendsofheartlake@rogers.com. All interested volunteers are required to work in pairs and participate in a mandatory safety training session. If you do not already have a partner in mind, the organizers will do their very best to connect you with another

Etobicoke & Mimico Watersheds
CreekTime
e-newsletter

Heart Lake Road Monitoring - Update

Jan 16, 2012

Written by: Vince D'Elia, Project Manager, TRCA and Casey Cook, TRCA

The Toronto and Region Conservation Authority (TRCA), the City of Brampton and the Toronto Zoo's Ontario Road Ecology Group (OREG) with the help of local volunteers, recently completed the Heart Lake Road Ecology Monitoring Project (HLREMP), which was featured in the article entitled "Heart Lake Road Wildlife Monitoring" in the May edition of CreekTime.

The HLREMP monitored the wildlife vehicle interactions along a section of Heart Lake Road between Sandalwood Parkway and Mayfield Road which runs through the middle of a provincially significant wetland complex. There are significant wetlands on either side of Heart Lake Road which are essential in the process of water recharge and purification and provide habitat to a variety of wildlife including several frogs, turtles, snakes, mammals and avian species.

The HLREMP ran for a 25 week period from May 8th, 2011 to October 31st, 2011. During this time, approximately 40 dedicated local volunteers contributed more than 420 hours towards monitoring this stretch of road. The actual time spent monitoring represents approximately 10% of the total available time for monitoring over the 25 week period, but the data collected was very valuable in allowing us to better understand the types and species of wildlife impacted by Heart Lake Rd., the number of interactions that occur on the road and the wildlife movement activity in this area.

TRCA enlisted a group of four Ecosystem Management Technology students from Sir Sandford Fleming College, School of Environmental and Natural Resource Sciences, to compile the information into a report of findings. These third year students are chosen from the Credit for Product Course which operates in cooperation with various environmental organizations to assist in research, data collection and environmental projects. With the limited funds and staff resources that the TRCA had available for this project, this partnership proved to be very worthwhile for both parties, enabling TRCA to move forward with data analysis and report on findings while providing the students with valuable hands-on experience. The student report also explored mitigation options and provided recommendations to alleviate the number of wildlife and vehicle interactions related to the project area.

The analysis of the data revealed a surprisingly high number of wildlife vehicle interactions along this very short stretch of road (2.5kms). A summary of these findings is represented in the figures below.

Figure 1

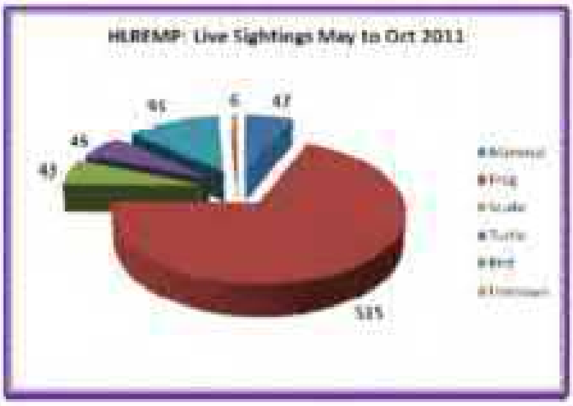
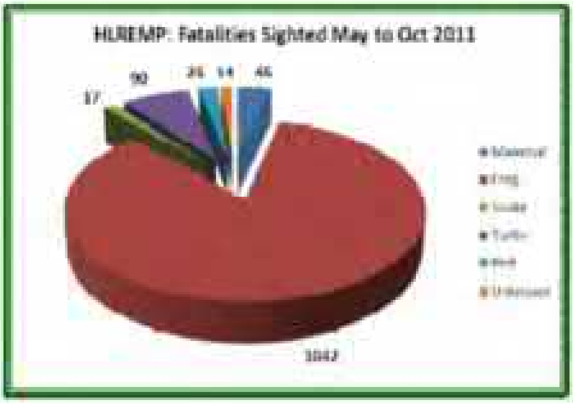


Figure 2



As noted in Figure 1, the number of fatalities is substantial and indicates mitigation is necessary in order to protect the health of both the wetlands and wildlife. These roads pose barriers to the movement of the creatures as they go through the breeding, feeding and hibernation process. Figure 2 represents live sightings, shows potential additional loss and depletion of these important members to a diverse system and are essential to a healthy sustainable ecosystem.

TRCA is in the process of finalizing the 2011 study and plans to share the report with partners and stakeholders in the hope that the report recommendations will be implemented to ensure a healthier, more sustainable future for this area.

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BRAMPTON GUARDIAN

1,000 dead frogs and counting

By PAM DOUGLAS
January 29, 2012

The numbers are in and the picture is grim— traffic on Heart Lake Road is killing local wildlife by the hundreds.

A group of about 40 volunteer citizen scientists devoted their spare time last year to the Heart Lake Road Ecology Monitoring Project (HLREMP), recording the animal death toll along a 2.5 kilometre stretch of road in north Brampton that is level with an extensive marsh.

Between May 8 and Oct. 31 (25 weeks) they monitored Heart Lake Road, between Sandalwood Parkway and Mayfield Road, collecting data on the wildlife they found there— both alive and dead.

What they found in the 420 hours they spent walking the shoulders of that relatively short section of road was a whole lot of dead frogs, turtles, snakes and birds.

In danger. Volunteers monitored Heart Lake Road between May 8 and Oct. 31 (25 weeks) collecting data on the wildlife they found there— both alive and dead. What they found in the 420 hours they spent walking the shoulders of that relatively short section of road was a whole lot of dead frogs, turtles, snakes and birds.

In all, 1,042 dead frogs were recorded, 90 turtles, 45 "mammals" of various types, 25 birds, 17 snakes, and 14 remains that were unidentifiable.

They also spotted plenty of live creatures— 515 frogs, 91 birds, 47 mammals, 45 turtles, 43 snakes and six unidentified animals.

The numbers show the wildlife and wetlands in the area are in need of protection, and ways of reducing the risk to local wildlife need to be found, organizers say.

The busy road is adjacent to Heart Lake Conservation Area, and it bisects a major wetland. Amphibians and reptiles cross to get to the other side frequently. HLREMP was launched to catalogue the impact of those crossings.

The Toronto and Region Conservation Authority (TRCA) teamed up with the City of Brampton and the Toronto Zoo's Ontario Road Ecology Group (OREG), putting together that passionate group of animal-loving volunteers who helped quantify just how deadly the road is for local wildlife.

But it wasn't just an exercise in counting. It is hoped something can be done to improve the deadly situation.

The information was handed over to a group of four Ecosystem Management Technology students from Sir Sandford Fleming College. They analyzed the data, compiled it in a report, and explored mitigation options, offering up recommendations.

That final report was presented to Brampton's Environmental and Planning Advisory Council last month by Vince D'Elia, project manager with the TRCA.

That advisory group has directed city staff to explore ways of reducing the death toll, including such measures as cleaning out the existing culverts and installing some type of fencing to guide wildlife to the culverts.

Also, TRCA planning and ecology staff will use the data when they are reviewing development applications for the area.

While the study was local, it can be seen as a reflection of what is happening all over the province, the report points out. Southern Ontario's road network is growing every year— from 7,133 kilometres in 1940 to 35,637 kilometres in 2000, and the Ontario Ministry of Transportation reports there is a vehicle/wildlife collision in this province every 38 minutes.

It is hoped that more such monitoring projects will be undertaken elsewhere, modelled after the pioneering HLREMP.

The dedicated volunteers were: Suzy Attard, Oliver Attard, Sebastian Attard, Leslie Bissegger, Mike Bissegger, Kelly Caluvini, Nicole Caluvini, Andy Caluvini, Gillian Carson, Liz Ceci, Diana Christie, Bette-Anne Goldstein, Colin Grima, Teresa Grima, Janice Hessels, Susan Janhurst, Rosemary Keenan, Jim Laird, Rachel Luck, Sondra Luck, Debby McQuillen, Laura McQuillen, Leah MacSeáin, Mairéad MacSeáin, Damian MacSeáin, Chris McGlynn, Angela Mejury, Elizabeth Morin, Bob Noble, Jason Noro, Leo O'Brien, Shawn Patille, Marilyn Ross, Mike Solski, Cooper Solski, Sandhya Singh, Sonam Singh, Pauline Sutherland, Alana Ziobroski, Lyle Ziobroski.

To download a copy of the final report, click here.

Appendix B: Observed Wildlife

****note: This table has been created using the raw data from the field data sheet. This data was collected by volunteers and analysis is based at the family level.***

Taxa	Species	Dead	Alive	Total
Bird	Song bird	1	0	**1**
	Humming Bird	1	0	**1**
	Robin	1	0	**1**
	Chickadee	1	0	**1**
	Finch	2	4	**6**
	Canada Goose	2	51	**53**
	Swan	3	20	**23**
	Seagull	1	0	**1**
	Blue Heron	0	2	**2**
	Sharp Shinned Hawk	0	2	**2**
	Red-tailed Hawk	0	6	**6**
	Budge	1	0	**1**
	King Fisher	0	2	**2**
	Crow	1	0	**1**
	Turkey Vulture	0	1	**1**
	Turkey	0	1	**1**
	Mallard	0	2	**2**
	Duck	0	12	**12**
	Unknown	6	4	**10**
TOTAL		**20**	**107**	**127**
Frog/Toad	Leopard frog	226	78	**304**
	Bullfrog	3	4	**7**
	American Toad	2	0	**2**
	northern cricket	12	7	**19**
	Spring Peeper	1	0	**1**
	Western Chorus	5	1	**6**
	Tree Frog	1	0	**1**
	Toad	0	8	**8**
	Pickeral	1	0	**1**
	Green	25	9	**34**
	Grey tree frog	7	0	**7**
	Wood	1	1	**2**
	Unknown	736	93	**829**
TOTAL		**1020**	**201**	**1221**
Mammal	Cat	1	0	**1**
	Racoon	5	4	**9**
	Beaver	0	2	**2**
	Muskrat	3	4	**7**
	Rabbit	4	5	**9**
	Weasel	2	1	**3**

	Groundhog	0	7	**7**
	Mink	1	0	**1**
	Mouse	3	0	**3**
	Skunk	0	1	**1**
	Squirrel	3	6	**9**
	Chipmunk	2	1	**3**
	Rat	1	0	**1**
	Deer	3	9	**12**
	Unknown	4	2	**6**
TOTAL		**32**	**42**	**74**
Snake	Garter snake	10	11	**21**
	Northern Red Bellied	1	1	**2**
	Unknown	10	6	**16**
TOTAL		**21**	**18**	**39**
Turtle	Painted	28	5	**33**
	Wood	1	0	**1**
	Map	0	1	**1**
	Soft shell	2	0	**2**
	Snapping	10	3	**13**
	Unknown	42	39	**81**
TOTAL		**83**	**48**	**131**
Unknown	Unknown	287	9	**296**
TOTAL		**287**	**9**	**296**
Invertebrates	Unknown	1		**1**
TOTAL		**1**	**0**	**1**
OVERALL TOTAL OF INDIVIDUALS		**1233**	**747**	**1980**

Appendix C: List of Birds Identified, Bob Noble

note: This table represents birds observed in the study area by Volunteer Bob Noble over the course of the project.

HLREMP – Observed Bird Species

Row #	Species	Date First Seen
1	Canada Goose	29-May-11
2	Trumpeter Swan	5-Jun-11
3	Wood Duck	5-Jun-11
4	Mallard	29-May-11
5	Pied-billed Grebe	29-May-11
6	Great Blue Heron	29-May-11
7	Green Heron	5-Jun-11
8	Red-tailed Hawk	5-Jun-11
9	Killdeer	29-May-11
10	Ring-billed Gull	29-May-11
11	Rock Pigeon	5-Jun-11
12	Mourning Dove	29-May-11
13	Black-billed Cuckoo	5-Jun-11
14	Common Nighthawk	29-May-11
15	Ruby-throated Hummingbird	5-Jun-11
16	Belted Kingfisher	29-May-11
17	Downy Woodpecker	29-May-11
18	Hairy Woodpecker	29-May-11
19	Northern Flicker	29-May-11
20	Eastern Wood-Pewee	29-May-11
21	Alder Flycatcher	29-May-11
22	Willow Flycatcher	5-Jun-11
23	Eastern Phoebe	5-Jun-11
24	Great Crested Flycatcher	5-Jun-11
25	Eastern Kingbird	29-May-11
26	Warbling Vireo	29-May-11
27	Red-eyed Vireo	29-May-11
28	Blue Jay	29-May-11
29	American Crow	29-May-11
30	Tree Swallow	29-May-11
31	Bank Swallow	5-Jun-11
32	Barn Swallow	29-May-11
33	Black-capped Chickadee	29-May-11

34	White-breasted Nuthatch	5-Jun-11
35	House Wren	29-May-11
36	American Robin	29-May-11
37	Gray Catbird	29-May-11
38	European Starling	29-May-11
39	Cedar Waxwing	29-May-11
40	Yellow Warbler	29-May-11
41	Pine Warbler	29-May-11
42	Blackpoll Warbler	29-May-11
43	American Redstart	29-May-11
44	Common Yellowthroat	29-May-11
45	Chipping Sparrow	29-May-11
46	Savannah Sparrow	29-May-11
47	Song Sparrow	29-May-11
48	Swamp Sparrow	29-May-11
49	Northern Cardinal	29-May-11
50	Indigo Bunting	29-May-11
51	Red-winged Blackbird	29-May-11
52	Common Grackle	29-May-11
53	Brown-headed Cowbird	5-Jun-11
54	Baltimore Oriole	29-May-11
55	American Goldfinch	29-May-11
56	House Sparrow	29-May-11

Appendix D: Feedback from Volunteers and Other Recommendations

October 5th, 2011 Meeting in Brampton

Feedback Discussion from Volunteers

-Data sheet improvements

- Position category: how far from the paved line is the animal? Road boundaries need to be clearly defined.
- Include column indicating animal seen in wetland
- How dead is dead? Ie. turtle with a cracked shell versus flattened turtle. Solution: ensure that volunteers are aware and properly use the 'fresh' column.
- Referring to the LEGEND on the data sheet would help answer most of these questions. Perhaps make legend more visible/ stand out more so its draws attention.

-Photos collected with a measurement (scale) within photo. Create protocol of when to take pictures, and emphasize the importance of getting photos of animal types with small numbers such as turtles and snakes.

-Present to high schools on Road Ecology and recruit volunteers! This creates awareness and participation to a demographic just beginning to drive.

- Partner with Young Drivers of Canada and add Road Ecology to Driver's Manual.

-Inform customers at the Garden Centre. Ask to place a bristol board/ pamphlet with bullet point statistics about turtle mortality percentages, ie. 9% of animal mortality on Heart Lake Road are turtles and 1-2% is sustainable for turtle populations. Nesting females very important.

-Recommendations

- Road closures – generating awareness and notification of this happening prior to.
- Work with institution to find source populations and other significance of species and their interconnectedness. Ie. University studies and other co-op opportunities for university.

-Place all information regarding the project on a website

Other Recommendations

The following are suggestions and feedback given on October 5, 2011 by representatives from the City of Brampton, Peel Region, Toronto Region and Conservation and Associates, and volunteers to improve the HLREMP:

A) Data sheet and Volunteer Communications improvements

- Clearly define what the road boundaries are.
- Include a column for wildlife observed in Wetland.
- Ensure volunteers are properly trained/informed on how to fill in 'fresh' column.
- Improve location and visibility of legend on data sheets.
- Meetings on a bi-weekly basis should be held for both volunteers and community to ask questions.

B) Image Protocols

- Create protocol of when to take images.
- Emphasize the importance of getting images of animal types with small numbers such as turtles and snakes.
- Emphasize the importance of getting images of animals that are unknown.

C) Socio-Economic Recommendations

- Present to high schools on Road Ecology and recruit volunteers, and raise awareness of road ecology.
- Partner with Young Drivers of Canada and add Road Ecology to Driver's Manual.
- Ask the garden centre to place some signage/pamphlets of road ecology and statistics (including lowering speed on Heart Lake Road).
- Work with institutions to find source populations and other significances of species and their interconnectedness. Ie. University studies and other co-op opportunities for university.
- Make Heart Lake Road Ecology Monitoring Program information available to the public by placing information on a website.

D) Ecological Recommendations

- Road Closures are too costly and time consuming and are not a viable method to reduce mortality in this area, therefore it is recommended that future research be completed only during peak migration months. This method will save time, resources, and costs while providing relevant information that can be analyzed statistically to show correlations between time of year, species present, and peak migration times and can be compared against peak wildlife casualties.
- Migration routes for each species should be identified based on the hibernacula, feeding sites and nesting grounds for reptiles and amphibians before the study is carried out. This will provide an idea of the wildlife pathways already in place.
- Knowledge of the seasonal behaviour of the species present at the site will help determine the best times to conduct a study on migration routes and should be applied to future studies to increase the viability of the data and the efficiency with which the data is collected.

Appendix E: Safety and Monitoring Protocol

1. Must work with at least one other person so that one volunteer can complete the work, while the other volunteer can watch for traffic.

2. At least 1 person per monitoring session must have attended a training session.
3. Each volunteer must have signed and submitted a "Volunteer Waiver Form" and registered as a TRCA volunteer on the TRCA website: http://www.trca.on.ca/get-involved/volunteer/sign-in.dot
4. Walk the far edge of the shoulder of the road
5. Walk towards traffic
6. Do not wear ear buds for electronic devices
7. Individuals must wear proper Personal Protective Equipment that consists of safety boots, hard hat, and a safety vest.
8. That two "Road Works" signs be in placed on the side of the roadway prior to the commencement of work. One for northbound traffic just north of Sandalwood Parkway, and one for southbound traffic just south of Mayfield Road. When the work is done the signs must either be taken away or stored on the side of the road face down.
9. Removal of wildlife (dead or alive) from the road is to be done when there is a sufficient gap in traffic to do so as you will not be authorized to stop or direct traffic.
10. Dress weather appropriate
    - Sunscreen
    - Sunglasses
    - Sweater
    - Hat, etc.
11. Drink water
12. Carry a cell phone

I ________________________ have read and understand and agree to comply with the safety protocol.

Contact Information:

Phone: ______________________________

E-mail: ______________________________

Signature: _____________________

Study Site

Heart Lake Road between Sandalwood Pkwy E and Mayfield Rd. (approximately 2.5 km).

Important Contact Information:

Mandy Karch:

Office – (416)-393-6365

Cell - 416-726-9900

E-mail - mkarch@torontozoo.ca

Vince D'Elia:

Office – (416)-661-6600 Ext. 5667

Toronto Wildlife Centre:

Office – (416)-631-0662

Website -
http://www.torontowildlifecentre.com

Local Peel Regional Police Station:

Office – (905)-453-3311

Survey Protocol

1. Set up Road Safety signs at Sandalwood Pkwy. & Heart Lake Rd (NE Corner) and at Mayfield Rd. and Heart Lake Rd (SW Corner). Carefully pull over to the shoulder of the road and set up the signs.
2. Park at Garden Centre Lakeside Garden Gallery or Heart Lake CA
3. Pick up field equipment box at Lakeside Garden Gallery – 10753 Heart Lake Rd.
4. Wear your personal safety equipment
5. Carry with you:
   - Clip board with
     - Data Cards
     - Species ID Guides
     - Emergency Contact #'s
   - GPS Unit – turn on unit and check battery power
   - Camera – turn on camera to check if battery is charged and that there is a memory card in the camera.
   - Cell Phone
   - Gloves
   - Dust pan/stick to remove wildlife remains from study area
6. Walk the far edge of the roadside shoulder towards traffic
7. Complete data sheet (name, date, weather conditions, etc.)

   PLEASE WRITE CLEARLY!!

8. GPS all signs of wildlife/road interactions (e.g. tracks, scat, remains)
9. Photograph unknown species or interesting findings
10. Discard wildlife/road interaction evidence to the side of the road (into the vegetation to avoid double counting a specimen)
11. Check over data cards to ensure all details are included
12. Return ALL equipment to the field box
13. Replace the field equipment box
14. Turn down Road Safety signs (leave them were you found them on the shoulder of the road) at Sandalwood Pkwy. & Heart Lake Rd and at Mayfield Rd. and Sandalwood Pkwy. Carefully pull over to the shoulder of the road and set up the signs.

Appendix F: Supplementary Information on Road Ecology

Ontario Road Ecology Group (OREG) & Toronto Zoo. (2010). A Guide to Road Ecology in Ontario, prepared for the Environment Canada Habitat Stewardship Program for Species at Risk. Scarborough, Ontario: Neo Communications. Retrievable from: *http://www.torontozoo.com/conservation/RoadEcologyGroup.asp*

Appendix G: Species Fact Sheet

List of Reptiles and Amphibians of Ontario – Status Under the Species At Risk in Ontario

Species at Risk in Ontario – Regulation under the Endangered Species Act 2007 (Ministry of Natural Resources, 2011)

Risk Classification

Extirpated	Native Species - Does not exist in Ontario, still exists in other parts of the world
Endangered	Native Species - Faces extirpation or extinction
Threatened	Native Species – At risk of being class as endangered
Special Concern	Native Species – sensitive to human activity, natural events, at risk of being endangered or threatened

Table 1 – Frogs of Ontario

Species Name	Category of Risk	Geographic Location	Facts
American Toad *(Anaxyrus americanus)*	N/A	Most of Ontario	5-9 cm – raised warts on body – kidney-shaped raised gland behind eyes
Blanchard's Cricket Frog *(Acris blanchardi)*	Endangered	Pelee Island [1]	Small, 2.5 cm – dark triangle-shape between eyes on top of head
Boreal Chorus Frog *(Pseudacris maculata)*	N/A	Northern Ontario	Very small, 25-30 mm – dark brown body, dark stripe-like spots – greyish-bronze underside
Bullfrog *(Lithobates catesbeiana)*	N/A	All areas southeast of Lake Superior [2]	Largest, 10-15 cm – green, olive, brown, male has large eardrum behind eye
Fowler's Toad *(Anaxyrus fowleri)*	Endangered	North shores of Lake Erie	50-80 mm – greyish-brown, 3-4 warts in brown areas on body – bony ridge behind eye
Grey Treefrog *(Hyla versacolor)*	N/A	East from Manitoba along shores of Lake Superior to southern Ontario	3-5 cm – Grey, brown or bright green – large toe-disks – inner part of thigh is bright yellow-orange – white squarish patch under eyes
Green Frog *(Lithobates clamitens)*	N/A	Southern Ontario to just north of Lake Superior	6-9 cm – Green with dark brown spots on back – bright green band on upper lip – black bands on hind legs – ridge runs down each side of body
Leopard Frog *(Lithobates pipiens)*	N/A	Most of Ontario	5-9 cm – green, light brown – dark spots lined with yellow on body/legs – white line on upper lip
Mink Frog *(Lithobates septentrionalis)*	N/A	All southern Ontario to just north of Lake Superior	5-7 cm – dark green to gray – dark circular areas on back – musky odour
Pickerel Frog *(Lithobates palustris)*	N/A	Southern Ontario north to Lake Huron	4-7 cm – cream to brown – 2 rows of square-like brown spot on body – 2 lighter ridges along sides of body
Western Chorus Frog *(Psuedacris triseriata)*	N/A	Southern Ontario, south of Sudbury	3 cm – light brown – 3 dark stripes on body, may be broken into splotches – white stripe on upper mouth area – one of 2 chorus frogs in Ontario
Spring Peeper *(Pseudacris crucifer)*	N/A	Most of Ontario	2-3 cm – tan to light brown – dark "X" shape on back – dark stripe between eyes on top of head – small disks on toes
Wood Frog *(Lithobates sylvatica)*	N/A	All of Ontario	3-4 cm – brown, tan or copperish – black triangle on face behind each eye – white line on upper area of mouth extending behind eye

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[1] Confirmed sightings in 1970's, unconfirmed sightings 1990's – suspected not in Canada

[2] Research shows significant decline in recent years

Table 2 – Turtles of Ontario

Species Name	Category of Risk	Geographic Location	Facts
Blanding's Turtle *(Emydoidia blandingii)*	Threatened	Southern Ontario, north to Manitoulin Island	Up to 28 cm – black/grey-brown domed carapace with yellowish dots/streaks – eyes protrude - bright yellow chin and throat
Common Snapping Turtle *(Chelydra serpentina)*	Special Concern	Southern Ontario, north to Wawa , West along Lake Superior to Manitoba border	20-35 cm [3] - light brown, black carapace – yellowish plastron – long tail with triangle scales – large head
Midland Paint Turtle *(Chrysemys picta marginata)*	N/A	Southern Ontario north to Lake Superior	10-15 cm – olive to brownish smooth carapace, orange-red pattern along edge – yellow stripe behind eyes – yellow and red stripes on neck and legs
Northern Map Turtle *(Graptemys geographica)*	Special Concern	Southern Ontario	9-30 cm – olive to brown carapace with fine yellow lines and ridge down centre – head and legs may be lined - yellowish spot behind eyes
Spiny Soft-shelled Turtle *(Apalone spinifera)*	Threatened	South Western Ontario	12-43 cm – olive to brown flat leathery texture carapace, males have black outlined spots, females plain spots - long neck, 2 yellowish stripes outlined in black, distinct tube-like snout
Spotted Turtle *(Clemmys guttata)*	Endangered	Southern Ontario	9-13 cm – carapace smooth, black, yellow or orange dots – head black to grey with yellow marks, inside of legs orange-red
Eastern Musk, aka Stinkpot *(Sternotherus odoratus)*	Threatened	Southern Ontario	5-13 cm – smooth, rounded brown to black carapace – 2 lighter stripes on side of head – musky odour emitted when threatened
Western Painted Turtle *(Chrysemys picta bellii)*	N/A	West of Lake Superior to Manitoba Border	9-18 cm [4] - carapace olive to brown-grey carapace with lighter lines – distinct dark splotch on yellow plastron
Wood Turtle *(Glyptemys insculpta)*	Endangered	Southern Ontario	14-20 cm – carapace brown, sculptured with raised growth rings, may have keel – yellow plastron, black squares – black head, orange or yellow neck and legs

Table 3 - Salamander

Species Name	Category of Risk	Geographic Location	Facts
Mud Puppy *(Necturus maculosus)*	N/A	Southern Ontario	25-30 cm – reddish brown body, black spots – distinct red gills behind head, retained for life – 4 toes
Spotted Salamander *(Ambystoma maculatum)*	N/A	Southern Ontario, north to Lake Superior	15-18 cm – black body with orange or yellow spots
Blue-spotted Salamander *(Ambestoma laterale)*	N/A	Southern Ontario north to Manitoba boarder	7-12 cm – black body, blue spots/flecks
Jefferson Salamander *(Ambesoma jeffersonianum)*	Endangered	Small area around western end of Lake Ontario	12-18 cm – grey-black body, blue-white flecks – lightish-grey belly
Red-spotted Newt *(Notophthalmus viridescens viridescens)*	N/A	Southern Ontario north to shoreline of Lake Superior, along border to Manitoba	7-10 cm – greenish to yellow body, black spots, line on back of red spots outlined in black – 3 life stages, aquatic larvae, terrestrial eft [5], aquatic adult

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[3] 49.4 cm recorded

[4] 25.1 cm recorded

Eastern Red-back Salamander *(Plethodon cinereus)*	N/A	Southern Ontario north to Lake Superior	5-10 cm – dark reddish stripe down body and tail, sides grey – no lungs, respiration through skin
Four-toed Salamander *(Hemidactylium scutatum)*	N/A	Band from Georgian Bay to Ottawa region and Western area of Lake Ontario to Lake Erie	6-8 cm – body reddish-brown, orange tail with groove at rear legs – underside white with black dots –4 toes[6] on all feet
Northern Two-lined Salamander *(Eurycea bilineata)*	N/A	Band East from Georgian Bay to Ottawa region	6 – 9 cm – no lungs – yellow-brown band on back with small back spots, yellow belly, grey sides
Northern Dusky Salamander *(Desmognathus fuscus)*	Endangered	Small area in Niagara Gorge	8-9 cm – grey to brown, line runs from eye to behind mouth – no lungs – young have yellow or red stripe on back, fades with adults

Note: Other Species Salamanders:
Eastern Tiger, Extirpated, Ontario
Allegheny Mountain Dusty – Endangered Provincially, Threatened Nationally
Small-mouthed – Endangered Provincially
Spring Salamander – Extirpated, Ontario– Special Concern Nationally

Table 4 - Lizard

Species Name	Category of Risk	Geographic Location	Facts
Five-lined Skink *(Plestiodon fasciatus)*	Special Concern, Endangered	Eastern Shore Georgian Bay bands out to Southern Canadian Shield and Southwestern Ontario	25-30 cm – brown, grey, olive body, 5 yellowish-white stripes – juvenile brighter stripes, brilliant blue tail – male, reddish-orange jaw

Table 5 - Snakes

Species Name	Category of Risk	Geographic Location	Facts
Blue Racer Snake *(Coluber constrictor foxii)*	Endangered	Pelee Island	90-152 cm - grey or green-blue – dark head, white throat, bluish belly – juvenile is grey, dark spots on back, white/black specks on head
Butler's Garter Snake *(Thamnophis butleri)*	Endangered	Isolated areas, Southwestern of Ontario	35-55 cm – body greenish-brown or black, 3 orange or yellow stripes – small head – yellowish-green belly
DeKay's Brown Snake *(Storeria dekayi)*	N/A	Southern Ontario to Georgian Bay	20-35 cm – body pale grey-brown to red-brown – light stripe with dark spots along back – dark bar angled down on side of head – belly cream-pink
Eastern Fox Snake *(Pantherophis gloydi)*	Threatened Endangered	Isolated area Georgian Bay and Carolinian zone	90-140 cm – body yellowish-brown with black square-like marks on back and roundish marks on side – head may be reddish-brown – belly yellow with black spots
Eastern Garter Snake *(Thamnophis sirtalis sirtalis)*	N/A	Most of Ontario	45-65 cm – black, green, brown with 3 yellowish stripes – belly yellow-greenish
Eastern Hog-nose Snake *(Heterodon platerhinos)*	Threatened	Small band running East from Georgian Bay, Southern Ontario	50-85 cm – grey, brown or black, blotches along back – neck expands when threatened forming triangle shape – flat head, nose turned up
Eastern Milk Snake *(Lampropeltis triangulum)*	Special Concern	Southern Ontario, South of Lake Superior	60-90 cm – grey, cream, tan, dark blotches outlined in black – white belly, black spots

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[5] No eft stage in some populations
[6] Other terrestrial species have 5 toes on back feet

Eastern Rat Snake *(Pantherophis spiloides)*	Threatened Endangered	Isolated areas, Carolinian zone and Eastern Lake Ontario	100-185 cm – black, may have blotch pattern – young are grey, dark blotches – white throat – belly greyish-brown
Eastern Ribbon Snake *(Thamnophis sauritus)*	Special Concern	Southern Ontario	45-70 cm – black, 3 yellow stripes – white crescent-shape in front of eye – belly yellow-green
Eastern Smooth Green Snake *(Opheodrys vernalis)*	N/A	Southern Ontario north to Lake Superior	30-55 cm – bright green body – yellow belly
Lake Erie Water Snake *(Nerodia sipedon insularum)*	Endangered	Isolated areas Lake Erie, Pelee Island	60-110 cm – grey to grey-brown – some bands on body – belly white, yellowish-grey
Massasauga Rattle Snake *(Sisturus catenatus)*	Threatened	Georgian Bay, isolated areas Lake Erie	45-80 cm – grey to brown – blotches down back outlined in white – alternate spots along side – black belly – squarish tail – only venomous snake in Ontario
Northern Water Snake *(Nerodia sipedon sipedon)*	N/A	Southern Ontario to South end of Lake Superior	60-110 cm – brown-dark brown, blackish bands back and sides – creamish belly, reddish crescents shapes
Northern Red-bellied Snake *(Storeria occipitomaculata occipitomaculata)*	N/A	Southern Ontario to Lake Superior, along border to Manitoba	20-25 cm – red to grey brown – neck has 3 light brown or yellow spots – orange-red belly
Queen Snake *(Regina septemvittata*	Endangered	South Western Ontario	35-65 cm – yellow-brown body, yellow stripe on lower area – back may have 3-5 darker stripes
Red-sided Garter Snake *(Thamnophis sirtalis parietalis)*	N/A	Manitoba Border	40-70 cm – black-brown, 3 yellow stripes – reddish on side – green, black belly
Ringneck Snake *(Diadophis punctatus)*	N/A	Southern Ontario to Lake Superior	25-40 cm – shiny, steel-blue, grey or brown body – pale ring on neck – orange-yellow belly

Note: Timber Rattlesnake - Extirpated

Appendix H: Literature Reviews completed by Fleming College Students

G.1 Monitoring roadside ecosystems - The ecological effects of roads on adjacent ecosystems

Ashlea Veldhoen

Introduction

The effects of roads on the ecological systems and processes over which they are paved are numerous. In our study, we will be compiling data collected at Heart lake Road in Brampton, Ontario in efforts to mitigate and promote the conservation of the delicate ecosystems present on either side of the road. Heart Lake Road runs directly through a wetland near Heart Lake Conservation Area and used to be the only road travelling though the area. **Roads fragment natural ecosystems and road ecology is a field borne from this effect. Fragmentation of habitat is often correlated with the decline of biodiversity of species, reduction of wildlife populations, habitat loss, disturbed soils, and increased vehicle–wildlife collisions.** This literature review will be investigating the effects of roads on the biota of local ecological systems.

Annotations

Angold PG. (1997). The Impact of a road upon adjacent heath land vegetation: effects on plant species composition. *Journal of Applied Ecology.* British Ecological Society. 34(2), 409-417.

This study was conducted to investigate the effects of a road on heath land vegetation in New Forest, Hampshire, U.K. The author cites several scientific papers detailing the effects of roads and the fragmentation of ecosystems. The study was conducted on 5 sites adjacent to a major road and nine supplementary sites along 5 minor roads stemming from the major road. Qualitative analysis was done at each of the sites, investigating the height/growth of vascular plants, the abundance and appearance of grass species and the abundance (or lack thereof) of lichen species. It was found that vascular plants were responding positively adjacent to the road, most notable were the grass species – they experience enhanced growth compared to individuals found elsewhere, and there was a “decrease in the abundance and health of lichens beside the road” (Angold, 1997). It was also found that the edge effect in the adjacent communities was linked to the amount of traffic the road experienced and extended up to 200 m on either side of a 2-lane highway. The author hypothesizes that the increased health and growth of vascular plants near the road is due to the increased amounts of nitrous oxides from vehicle exhausts and that the correlation between traffic and edge effect should be taken into account when planning to expand old roads or create new ones. The author suggests building buffer zones on both sides of the road to help minimize its environmental impact and edge effect. The full article could not be accessed and therefore could only provide very limited amounts of information on the ecological effects of roads on adjacent vegetative communities, however enough information could be extracted to be relevant to my study by providing a basic understanding of the study and the impacts that roads have on adjacent vegetative communities.

Clewell A.F., Aronson J. (2007). *Ecological Restoration: principles, values and structure of an emerging profession.* Washington: Island Press. 20-25, 169-179.**

Teaching young ecologists the ecological consequences of impairment in ecosystems by analyzing restoration projects and case studies carried-out globally, with the goal of preparing students to plan, carry-out and follow-up with their own restoration projects is the goal of this book. This book uses cutting-edge data from reputable sources as well as records of real-world projects to demonstrate ecological impairment and the remediation steps that are needed in order to restore an ecosystem to a functional, self-sustaining state. In chapter two, ecological impairment and recovery, the authors give a description of current ecological disasters that are causing entire countries to become poverty stricken. The authors include five sub-chapters describing the eight consequences of reallocating resources and ecological impairment. These eight consequences include: Losses of Specialized Species and Relative or Actual Gains of Generalist Species; Colonization by Invasive Species; Simplification of Community Structure; Changes in Microclimate; Changes in Frequency Distribution of Plant Life Forms; Losses in Beneficial Soil Properties; Reduction in Capacity for Mineral Nutrient Retention and Alteration in the Moisture Regime. All eight of these consequences of ecological impairment can be found at the Heart Lake Road site where the road intersects with a large wetland and virtually splits it into two halves. The overriding message in this book is that systems can never be restored to their past states, but can be readapted to develop a certain way in the future based on the characteristics of the land and the species which are capable of inhabiting it. A site may never be what it once was, the impairments may have caused permanent changes or damages to the ecosystem, but it can be recovered and directed to grow into a functional and self-sustaining system.

This book is an excellent resource and reference for analyzing disturbed sites such as the one on Heart Lake Road, and can be used in such a way to help ecologists understand the methods which must be used to restore a system to a functional state. The book provides a method for creating a restoration plan, defining habitat types using the Ecological Land Classification guide, and how to encourage species to migrate into the newly restored area. This book is relevant to our studies as it will provide us with details about how to mitigate wetland sites to increase their appeal to fauna species and discourage them from crossing the road to find breeding ground or resources – in this way we can provide the Toronto and Region Conservation Authority with mitigation options that are long lasting, self-sustaining and cheaply maintained.

**Coffin AW. (2007). From roadkill to road ecology: A review of the ecological effects of roads. *Journal of Transport Geography.15,* 396-406.

The purpose of Coffin's study (2007) is to provide a review the ecological effects of roads on the abiotic and biotic components of adjacent (or pre-existing) ecosystems. The author is a transportation geographer reporting on the effects of roads on ecological communities.
The source provides great detail on the effects of roads on biotic components of ecosystems, including roads as a way of mortality and as a barrier to fauna in local ecological communities. The source provides examples of how roads change hydrology and water quality and results in erosion and chemical and sediment transfer into hydrological systems. The source fails to provide specific examples where wetland ecosystems are affected but goes into detail mainly about the effects of roads on forest ecosystems. The source is a review of current literature as well as a reflective essay, throughout the document facts are supported by citations from current literature on the subject of road ecology as well as studies concerning the human impacts on global ecosystems. The author goes into detail about a research project on the effects of roads on tropical ecosystems in Belize that used simulation modelling to predict road configuration on animal population persistence. It was found that the effect roads had on populations was dependent on the animals' behaviours when they encountered roads "i.e. to what degree that species avoids crossing roads and the probability of it being killed if it does" (Coffin, 2007). The researchers of the Belize study also concluded that by building roads close together it allowed for greater population persistence in the surrounding areas and measures should be taken to protect the un-fragmented habitat from future road construction. The author notes that "transportation geographers are in a prime position to contribute to emerging science of road ecology in hopes of providing both analytical and theoretical tools to study the landscape scale effects of road networks" (Coffin, 2007). The section named "the effects of roads on biotic components of ecosystems" was very relevant to the subject of this literature review yet it does not provide specific case studies where wetlands are the subject, which would have more helpful to my study.

Eberhardt E. (2009). Current and potential wildlife fatality hotspots along the Thousand Islands Parkway in Eastern Ontario, Canada. Carleton University.

This study was completed to assess the effects of roads on animal mortality. Conducted on the Thousand Islands Parkway near the St. Lawrence Islands National Park, the study analyzed the number of kill sites located along the parkway. Of the 63 species identified along the road, 3 were species of special concern and 2 were threatened as indicated by the Committee on the Status of Wildlife in Canada. The authors used kernel density to identify the "hotspots" where the most kill sites were located, and used a "network K-function" for statistical clustering of data and a "roving window analysis" to investigate the relationships between traffic volume, time of day and other variables and the road kill found along Thousand Islands Parkway. The results showed that traffic volume was negatively correlated with frog and toad kills, which the authors interpreted as an indicator of decreasing populations within the species. The authors suggest that further mitigation efforts should account for habitats that may have been inhabited in the past as wells as accounting for the current mortality hotspots. This article provides key points on the effects of roads on animals but is limited to a single study area that lacks landscape variability, which may add ambiguity to the data in that main population sources may be more difficult to find in a homogenous habitat.

Fahrig, L., and T. Rytwinski. (2009). Effects of roads on animal abundance: an empirical review and synthesis. *Ecology and Society* 14(1): 21. [Online] Retrieved October 11, 2011, from http://www.ecologyandsociety.org/vol14/iss1/art21/

The authors found and compiled the data collected from 79 different studies completed concerning the effects of roads on the abundance of 131 species and 30 species groups, in an attempt to create a complete review on the topic. The review was completed by Fahrig and Rytwinski (2009) and results showed that the negative impacts of wildlife-vehicle interactions (WVCs) on animal abundance outnumbered the positive effects by a factor of 5. From data extracted from the documents used for the study, it was found that the abundance of "amphibians and reptiles were usually negatively affected by roads, birds showed mainly negative or no effects, with a few positive effects for some small birds and for vultures, small mammals were effected either positively or were not affected at all, abundance of mid-sized mammals showed either negative effects or no effect at all, and the abundance of large mammals was predominantly negatively affected. The authors the synthesized the data collected, including species attributes and developed a set of predictions of the circumstances which led to either negative, positive or no effect of roads on animal abundance" Fahrig, L., and T. Rytwinski. (2009). The authors organized their findings on what they named "species type", which categorizes species based on the strength of their affinity or attraction (based on food requirements, movement and their preference concerning traffic or disturbance caused by the roads) to go to the road. The authors recommend further research is done on the mitigation options where species affected by traffic disturbance are concerned, including reducing road and traffic density on the landscape. They also make note that more care be taken during the planning stages of road development to account and consider whether the species of concern is mainly due to road mortality vs. traffic disturbance. This source is very relevant to my research regarding the ecological effects of roads on adjacent communities and provides a comprehensive view on the intensity at which WVCs are occurring.

Findlay CS and Borages J. (2000). Response time of wetland biodiversity to road construction on adjacent lands. *Conservation Biology*. 14(1). 86-94

This study was conducted to investigate the response time of wetland biodiversity to road construction on land adjacent to the road based on the known effects of road construction on biodiversity. The authors documented the lags in wetland diversity loss in response to road construction. Using regression models, the authors set species richness of different taxa as a function of current and historical road densities on adjacent lands (Findlay & Borages, 2000). The study showed that variance in herptile and bird species richness increased when using current density data in multiple regression models. The authors understand this to be an indicator that the full effects of roads on certain taxa may not be noticed for several generations within a community. The authors stress the significance of the lags in response to "changes in anthropogenic stress" on land-use planning and environmental impact assessment. This study is relevant to my topic in that it provides information regarding the historical impacts of roads on species richness and diversity in wetland systems adjacent to roads, and suggests that the historical data is imperative to future land-use planning and when conducting environmental impact assessments.

Forman, Richard T. T. (2004). **Road ecology's promise: what's around the bend?. *Environment*. *46(*4), 8-21.

This document provides information concerning the effects of roads on both the abiotic and biotic components of an ecosystem while using language that can be understood by most people without a background in science or ecology. This document is an informative and motivational piece to inform the lay person about leading edge research and development happening in the newly emerging field of road ecology. It can only be called an informative and motivation piece because no scientific analysis was carried out and a heavy bias against current transportation planning, policy and practices is very apparent throughout the work. The quote below is the author's description of the beginning of road ecology studies in the United States. The author later says that road ecology had been studied in European countries at least 10 years before the U.S. started collecting data.

"In 1991, the U.S. Congress passed its big highway act (ISTEA, the Intermodal Surface Transportation Efficiency Act), which permitted the use of some highway funds for environmental enhancements. In 1997 Congress passed a successor transportation act (TEA-21) to fund highways, including their environmental dimensions. A series of road ecology conferences (ICOET, the International Conference on Ecology and Transportation) began, and the Transportation Research Board of the National Research Council (NRC/TRB) appointed committees that published two books containing chapters highlighting the importance of road ecology." (Forman, 2004).

These events marked the beginning of studies in road ecology monitoring and assessment which can now be applied to transportation planning (within municipalities and provincial lands). With the ecological data in place, the author is mainly concerned with the cultural or human factors in research and development of roads and the newly found interest in ecology within transportation communities and is looking to promote interest in the field of road ecology. With the language being written out in layman's terms, I was able to increase my understanding of the subject without the normal confusion induced by the use of unfamiliar scientific terms. In contrast, I found this work to be biased against the common driver as well as the government. The haughty and alarmist undertones take away from the overall message of the article which is to promote the study of road ecology so that it can be used in transportation planning and development.

Rentch JS, Fortney RH, Stephenson SL, Adams HS, Grafton WN and Anderson JT. (2005). Vegetation–site relationships of roadside plant communities in West Virginia, USA. *Journal of Applied Ecology*. British Ecological Society. Blackwell Publishing, Ltd. 42, 129–138. [Online]. Retrieved October 11, 2011 from http://search.ebscohost.com.rap.ocls.ca/login.aspx?direct=true&db=aph&AN=16187688&site=ehost-live

This study was completed to analyze the relationship between vegetative communities and roads within the mountainous regions located in West Virginia, USA. Data were collected from 13 major 4-lane highways in the state of WV using "analysis of variance (in species), multiresponse permutation procedures and indicator species analysis" (Rentch et al, 2005). The study analyzed nutrient values in the soil shouldering each highway, plant species richness, diversity and evenness. Results showed that mean soil nutrient values varied highway to highway, but when the position of the highway was analyzed, soil nutrients tended to stay relatively the uniform. Species richness, diversity and evenness also remained relatively uniform when highway position was concerned. When the results of the multiresponse permutation were analyzed, they suggested that each highway was associated with different plant species assemblages, and the vegetative communities appeared distinctive to each highway. An indicator species analysis was used to support this hypothesis, its results showed that "54 species showed a statistically significant ($P< 0·05$) affinity to one highway over all others" (Rentch et al 2005). Upon further analysis of these 54 species, more than half were identified as non-native or exotic invasive species, communities tended to stay relatively uniform when highway position was considered, 25 of the 54 species showed a preference to a specific position along the highway, and of those 25, 8 were exotic. The results of the research suggest that despite the high disturbance caused by the construction of roads in mountainous regions, the vegetative communities that propagate and establish themselves tend to stay uniform. The authors recommend that highway agencies manage roadside vegetation using similar methods, while focusing on encouraging the growth of native species to provide erosion control while minimizing the spread of exotic invasive species.

Schipper, P. M., Comans, R. J., Dijkstra, J. J., & Vergouwen, L. L. (2007). Runoff and windblown vehicle spray from road surfaces, risks and measures for soil and water. *Water Science & Technology,* 55(3), 87-96. Retrieved October 11, 2011 from http://search.ebscohost.com.rap.ocls.ca/login.aspx?direct=true&db=eih&AN=24466813&site=ehost-live

This study was completed to investigate the risks and measures for soil and water associated with runoff and vehicle spray from road surfaces. The authors indicated that the primary sources of pollution included polycyclic aromatic hydrocarbons (PAH), mineral oil, heavy metals and salt which originate from vehicles, roadside barriers and salt distributing vehicles during the winter months. The dry deposits combine with rain water and vehicle spray and get distributed into the shoulder of the road anywhere from 50 m to 150 m from the roadway. The study was completed over a period of 13 months along two roads within the Netherlands, and was designed to collect extensive data regarding the risks of the sediment pollution to soils and water quality as well as the geochemical and physical factors that determine those risks. Post-data collection, the results suggested that the pollutants were readily absorbed into natural soils, indicating a possible risk to groundwater quality. The authors suggest that measures be taken to protect the groundwater in vulnerable areas by changing the policy within the Netherlands to allow the removal of contaminated topsoil before the pollution reaches the groundwater. Finally, the authors advise that runoff should not be allowed to reach open water or surface water. This source was essential to gathering an understanding of the chemical and physical effects of runoff and vehicle spray on groundwater resources and hydrological systems. In turn, this knowledge can be applied to my research on the ecological effects of roads on adjacent ecosystems (specifically wetlands), and the species that inhabit them, while acknowledging that further research should be carried out specifically concerning the affects of runoff and vehicle spray on the water quality and chemistry within wetlands adjacent to the road.

Conclusion

The sources collected for this Literature Review provided in-depth information regarding the ecological effecs of roads on adjacent plant and animal communities, especially pertaining to the wetlands. Roads usually have a detrimental effect on ecosystem structure, function and health where the road is constructed through a pre-existing system (i.e. in the case of Heart Lake Road and the surrounding wetland area). However, once the system adapts to the road construction, new communities are able to establish and flourish, as in the case of Rentch JS et al's study of highways in the Virginia mountains in 2005. It can be said however, that wetlands and the species which inhabit them ultimately become more vulnerable to physical stressors as habitat fragmentation due to road construction reduces their mobility between nesting and hibernation sites, as well as feeding and breeding grounds, increases their mortality by exposing species to direct danger due to vehicles, and overall may reduce populations to numbers which may eventually extirpate local populations from the area. Roads also contribute negatively to wetland systems by damaging and in some cases completely removing the riparian zone, degrading the soil, increasing erosion and increases the flow rate of contaminated runoff directly into the system. This contributes to the pollution of the wetland which in most cases is irreversible once particulate matter settles into the peaty soil underneath the water. Pollution of the wetland system will negatively affect the health of the plants and animals living within the system, and may eventually lead bioaccumulation of toxins in ducks and geese, which lead to birth defects and malformation of babies born, as well as an increase illness and disease, within local populations. To conclude this study, mitigation options must take a holistic approach when looking to repair the damaged systems along Heart Lake Road, and must take into account wildlife populations, migration routes, hibernation, nesting, feeding and breeding sites, as well as plant life, riparian zone functionality and health, and water chemistry, soil porosity and chemistry and road size, structure and contaminants found. These factors must all be accounted for when choosing a permanent mitigation solution, and must be provided for at some point in time during the mitigation process in order to truly recreate a healthy and functional wetland ecosystem.

G.2 The Alteration of Abiotic Components from the Development of Road Networks

Laura Baldwick

Introduction

Heart Lake Road located in Brampton, Ontario divides a wetland resulting in wildlife-vehicle interactions. The development of the road has interfered with the wildlife that is living within the wetlands. When a change is made to an ecosystem, it causes changes to other areas within that ecosystem. When roads are developed there are many ecological effects that follow this development. Abiotically speaking, there are alterations to the water quality, erosion of river banks and sediment transportation, effects of chemicals, and noise pollution (Coffin, 1997). These factors all have effects on the wildlife and plant populations that live on the habitats around the roads. The roads affect the biota by being a source of mortality or acting as a barrier (Forman, 1998).

Thesis

The road networks created by human development greatly affect the ecosystem that lines the road. The alteration of the chemical conditions as well as the movement of water and sediment can cause changes within the ecosystem.

Annotations

Boarman, W.I., and Sazaki, M. 2006. A highway's road-effect zone for desert tortoises (*Gopherus agassizii*). *Journal of Arid Environments* 85, 94-101.

Roads and highways affect the wildlife populations surround them. Wildlife is directly affected through road mortality or indirectly by alteration of the habitat like fragmentation or introducing invasive weeds and other plants. The desert tortoise is an endangered species found in the Mojave Desert, California. The researchers of the study were looking to see if the roads affected these populations and if it did what the road-effect zone was. The researchers used 30-m wide strip transects to estimate the tortoise populations along the highway. These transects were located at 0, 400, 800 and 1600 m from the edge of the highway. Mean sign count was 0.2/km at 0m, 4.2/km at 400 m, 5.7/km at 800 m, and 5.4/km at 1600m from the highway edge. The results of the study suggest that tortoises are depressed in a zone at 400 m from the roadways. They measured for a road-effect zone by evaluating the density of animals with the respect to the road edge. The authors speculate that the major cause of death in this zone is road mortality. This article shows how organisms are affected by the roads that run through their habitat. It was interesting to set the road-effect theory in an example and where mitigation should be installed.

*** Coffin, A.W. (1997). From roadkill to road ecology: A review of the ecological effects of roads. *Journal of Transport Geography* 15, 396-406.

Roads affect the biotic and the abiotic components of the environment. The author breaks up the review article into three sections describing abiotic, biotic and ecological effects of roads on the environment. The article assesses the abiotic components giving past examples of changes in water quality, erosion of river banks and sediment transportation, effects of chemicals, and noise pollution. These factors all have effects on the wildlife and plant populations that live on the habitats around the roads. The roads affect the biota by being a source of mortality or acting as a barrier. Saying this, the road systems also act as a habitat for some small mammals and insects as these organisms use the road side for feeding or other activities. The ecological effects discuss the issues with the land such as habitat loss and fragmentation. The author also discusses the road edge effect, and acknowledges that some species thrive on the road side but others avoid the road. The author recommends that transport geographers which have been studying roads specifically, their economical and structural aspects start contributing to the growing science of road ecology. The author explored a variety of topics that discussed each topic clearly through the use of sub headings and a clear and concise sentence structure. The article gives an overview of how road systems affect the natural world around them known as road ecology.

Committee on Ecological Impacts of Road Density and Nation Research Council. 2005. Assessing and managing the ecological impacts of paved roads. The National Academies Home. Washington, D.C. Retrieved from: http://www.nap.edu/openbook.php?record_id=11535&page=62.

Wildlife populations can be reduced by wildlife-vehicle interactions. Although this is not their leading cause of death for a majority of species, the added threat of being killed by vehicles has the potential to cause serious problems for population levels. In extreme cases, it could cause extirpation of species with examples like the Florida panther and grizzly bear. The road-effect zone varies in distance depending on species, location and disturbance type. Wetland species diversity has seen to be negatively correlated when roads are up to two km away. In the case of Heart Lake Road, the road passed through the wetland. Heavy metals and chemical pollution released from cars can degrade the wetland quality as it introduces nitrogen oxides, petroleum, lead, copper, chromium, zinc, and nickel to the area. From the winter maintenance of the road the plant community structure can change as salt-sensitive species are replaced with less-sensitive species, which can cause changes to other wildlife in the area. Ecological indicators are used by planning and construction stages to ensure the quality of the land and the organisms within it. Sometimes using only ecological indicators does not include all the factors. The authors outline many conclusions and recommendations for roads. The recommendations emphasize research, attention and improvements to support the ecosystems that the roads run through.

*** Forman, R.T and Alexander, L.E. (1998). Roads and their major ecological effects. *Annual Review of Ecology and Systematics* 29,201-231

Road ecology is a new area to the scientific community. The authors, Forman and Alexander, provide information to the reader from biological as well as planning views. This review has a section titled water, sediment, chemicals, streams and roads. Within this section, the authors divide it into the specific areas required to give detailed information about each. The use of diagrams helps reinforce their information. The discussion of chemical transport goes into detail providing information about the deicing agent, NaCl, and the damage it can cause on areas adjacent to the roadways. The authors discuss economic development and the question of whether roads cause development or development causes the building of roads. An example of roads built in a forested area led to economic development as well as habitat fragmentation and deforestation. The review is concluded by discussing mitigation options for the animals that live by roads. The best option outlined is to permanently close the road, but a temporary closure during peak periods is also sufficient (ex. Turtle hatchings). The authors outlined the major ecological effects giving examples and providing clear explanation. The information is consistent with other articles written about this topic.

Gabor, S.T., North, A.K., Ross, L.C., Murkin, H.R., Anderson, J.S. and Raven, M. 2004. The importance of wetlands and upland conservation practices in watershed management: functions and values of water quality and quantity. Duck's Unlimited Canada. http://www.ducks.ca/conserve/wetland_values/pdf/nvalue.pdf.

There are five major categories of wetlands in Canada swamps, marshes, fens, and shallow waters. Wetlands can also be classified by their position on the land as lacustrine, riverine, palustrine and isolated. Wetlands have many functions, which benefit humans as well as support the wildlife that lives within them. The hydrological functions of wetlands include storage of surface water, recharge of groundwater supplies, reduction in peak floodwater flows and erosion prevention. Wetlands store surface water, preventing flooding when there is excess water. This function prevents the land from being eroded, movement of sediment and damage to homes. Wetlands recharge groundwater soruces as the wetland slowly percolates underground aquifers. Wetlands act as nutrient sinks. They accumulate everything that is introduced to them including chemicals. Wetlands can convert inorganic nutrients into organic mass. They are capable assimilation by microbes and denitrification. Phosphorus is retained in wetlands by adsorption to peat and clay particles. The range of percent retention for nitrogen in a natural wetland is up to 87% and phosphorus up to 94%. Wetlands are hydrologically, chemically and biologically linked to the landscape where they are found. It is important to understand the habitat and water quality that exists in a wetland. Knowing how a wetland works provides a clearer understanding of how the road can affect the function of the wetland.

Gleason, R.A., and Euliss, N.H. 1998. Sedimentation of prairie wetlands. *Great Plains Research* 8, 97-112.

Sedimentation occurs in all wetlands, it is considered as a water quality benefit in small portions but when there is lots of sedimentation it is harmful to the wetland as it can shorten their life-span or cause the wetland to fill in. Natural processes can cause wetlands to fill with sediment, human interactions accelerate the process of erosion and sedimentation. When wetlands fill with sediments they loss certain functions that usually paired with wetlands. In terms of primary production, sedimentation can suppress them and alter the natural food chain interactions. The increased sediment reduces the depth of the photic zone and this reduces the light available. This in turn affects the aquatic invertebrates of the wetland. The alteration of the vegetative cover affects the wildlife that feed upon the wetland. The authors outline several areas of research that are needed within the field of sedimentation in wetlands. Reduction of sediment inputs, this is more specific to agriculture and their practices. The effects of wetland functions needs more research in the areas of wildlife habitat, groundwater recharge, nutrient cycling, water quality improvement, and production. This paper was more related to prairie wetlands but when roads are built it results with lots of sediment being deposited into the wetland and it changes the composition of the wetland, leading to the alteration of the components discussed above.

Roe, J.H, Gibson, J. And Kingsbury, B.A. 2006. Beyond the wetland border: estimating the impact of roads for two species of water snakes. *Biological Conservations* 130, 161-168.

Roads cover over six million km of the United States. These roads expanding road networks have large volumes of traffic driving on them. Roads are associated with increasing mortality and restricted movement of terrestrial and semi-aquatic wildlife. This study looks at two species of water snakes that differ in vagility, use of terrestrial habitats and conservation status. The researchers are looking at the snake movements across roads in three different areas in Indiana. Using models, the researchers were able to determine the probability of a mortality (road mortality = $1-(1-p_{\text{killed}})^{\text{ncrossing}}$). The researchers suggest that roads that cross over the travel roads of snakes from wetland to wetland can act a mortality trap. The more vagile the species, the greater act first it is. The authors recommend that wetland conservation not just consider the quality of habits, like wetlands but also look into mitigation options like terrestrial corridors between wetlands to offer safe passage for long migrations or dispersal. An interesting aspect for this study is that is was done completely mathematically with models. Through mathematics the authors were able to determine the mortality of the two types of water snakes.

*** Spellerberg, I.F. (1998). Ecological effects of roads and traffic: A literature review. *Global Ecology and Biogeography Letters* 7(5), 317-333.

The subject of the article was to survey the literature on the ecological effect of roads on the environment. The article also looked at the specific habitats and protected areas and the potential mitigation options. The article provides many literature examples that are compiled to form a literature database on the subject. When the article was published there were 388 references in the database. To compile all of the information to create this review and make the database several other database programs were used. Within the discussion section of this review, the author discusses some topics briefly, like deicing solutions, while he goes into depth on topics such as pollution and disturbance effects of biota and ecosystems. The author assesses the risk and impacts of road projects, enforcing how monitoring programs should take place once an environmental impact assessment is completed. A clear section is written on the areas of research in the field of road ecology that needs to be looked at more, such as, the long term effects. This review had tables of literature divided by headings which allows the reader to find more references based on the category in which their looking.

World Bank. 1996. Environmental Assessment Process: Roads and the Environment – the handbook. Washington, DC: World Bank, Environment Department. http://siteresources.worldbank.org/INTTRANSPORT/Resources/336291-1107880869673/chap_1.pdf.

Environmental assessments are important to conduct before road developments as they identify any potential impacts and provide options for minimizing them. For the assessment to be conducted correctly there needs to be many different groups involved in the process such as the road planning people, construction as well as landowners and environmentalists. The handbook is designed for any audience who is looking for information on the topic of road development. It outlines the difference between new, existing, urban and rural projects. New projects consist of building a road for the first time and concentrating on impacts while existing project look into mitigation options. Urban projects involve the displacement of people but rural impacts focus on removal of productive agriculture and other lands involved in harvesting. There are three important steps in environmental assessment screening, scoping and analysis of alternatives. These steps need to integrate biophysical, social and economic considerations, although sometimes others get more attention than others. The environmental assessment can take between six and eighteen months which causes the budget to be higher for the project as the assessment can be greater than five percent of the cost. This roads and environment handbook provided information necessary to realize the amount of effort that goes forth before building a road. It provides evidence that when the Heart Lake Rd was built there was knowledge that wildlife would be living there and had the chance of being struck by a vehicle.

Conclusion

Road networks cause problems for ecosystems, specifically the wildlife that use the road as a passage way. The alteration of the chemical conditions is caused by the vehicles that drive along the roads. Heavy metals and chemical pollution released from cars can degrade the wetland quality as it introduces nitrogen oxides, petroleum, lead, copper, chromium, zinc, and nickel to the area (CEIRD, 2005). A major chemical that ends up in wetlands is deicing solution, NaCl, that is put down in winters to prevent ice build up on the roads (Spellerberg, 1998). Wetlands are natural filters of chemicals but they accumulate everything that is introduced to them and it can become too much (Gabor et *al.*, 2004). Sedimentation is caused by sediment being deposited into the wetland. Wetlands naturally fill with sediment but anthropogenic interactions can cause this process to happen faster. Wetlands lose certain function when this happens; primary producers are suppressed and this alters the food chain (Gleason and Euliss, 1998). The photic zone is suppressed and there is reduced light (Gleason and Euliss, 1998). This affects the aquatic invertebrates which affect the vegetation cover and the wildlife (Gleason and Euliss, 1998)

To try and prevent wildlife-vehicle interactions from happening there are environmental assessments conducted when there is planning for road development. The environmental assessment looks at impacts and provides options for minimizing them (World Bank, 1996). When a road is already in existence mitigation options can be put in place to prevent death of wildlife. Roe et *al.* (2006) conducted a study on water snakes using models to determine the mortalities on the road. From their models it was determined that mitigation options are necessary to prevent deaths of the snakes, one of the species being a threatened species (Roe et *al.*, 2006). A study completed by Boarman and Sazaki (2006) showed that tortoises are depressed in a zone at 400 m from the roadways when looking into the road-effect zone. Information gained from scientific studies enforces the need for a safe method for wildlife to cross over road networks that are in their habitat. Road networks that run through areas bring great stress the ecosystem. The wetlands located on both sides of Heart Lake Road are exposed to chemicals from the vehicles that pass by and sediment from the activities that occurred with the development of the road and the maintenance. The mortalities in this area are tied to the vehicles on the road more so than the alterations of the wetlands.

G.3 The Value of Citizen Science as a Research Approach to Road Ecology

Carolyn Lobbezoo

Introduction

Road ecology is a newly emerging research area that involves environmental monitoring along roadways. A valuable research approach within this study area is citizen science. Citizen science is defined as local citizens participating in the collection of data within a scientific experiment (Lee et al., 2006). The data is not only significant to help researchers understand road ecology but also educates local citizens regarding the threats that road networks pose to species and their habitats (Evans et al., 2004; OREG, 2010). This is also a valuable approach to ecological monitoring because government lacks the resources for continuous monitoring, thus, saving them time and money (Lee et al, 2006). However, to make road ecology research influential on decision-making it needs to be credible and reliable (Hunsberger, 2004; Roedenbeck et al, 2007). Citizen science is extremely relevant to the Heart Lake Road Ecology Monitoring Project because this is the research method in use. The objective of the project is to create a report which analyses the data in hopes of impacting the future decisions made by the City of Brampton and Region of Peel. Therefore, this literature is important for learning how credible data is collected and recorded along with crucial aspects necessary for success of the project, such as strong communication and partnerships.

Thesis

Citizen science is a valuable research approach to ecological monitoring that requires strong partnerships, generates credible and reliable data, and is important to utilize because not only does it raise public education and participation regarding road ecology issues, but it also generates databases that governments do not have the time or money to collect.

Annotated Bibliography

Bissonette, J., & Kassar, C. (2006). Data Issues in Describing Road Mortality Hotspots and Creating Predictive Models. Data Issues in Road Ecology Chapter 3. Retrieved from <http://www.wildlifeandroads.org.>.

This article discusses general problems with generating credible data, specifically the effects of scale resolution and how the data is collected. The case study pertains to four state routes within Utah: 40, 89, 189, and 91. The purpose of the study is to see if there is correlation between traffic volume and/or speed and the number of wildlife-vehicle collisions. This study did not show a relationship between the two variables but the study reveals the importance of how data is collected. Data must be collected and used specifically for its intended purpose. For example, data collected for record-keeping must be kept separate from data that is being collected for analysis of wildlife-vehicle collisions. The study also identifies that if one's objective is to define hotspots of road kill for mitigation action then it is essential to collect data accurately to the mile marker. When the objective of data collection and research is to inform decisions made by government officials the following requirements should be met: 1) road kill data are spatially explicit, 2) data regarding explanatory variables and road kill are recorded at appropriate scale resolutions and extents, 3) data are recorded accurately and completely, 4) the model consider road geometrics and environmental variables, and 5) the model considers both driver behavior and animal behavior. These variables create a credible and reliable model to ecologically monitor the roadways.

Evans, E., Abrams, E., Roux, K., Salmonsen, L., Reitsma, R. and Marra, Peter P. (2004). The Neighborhood Nestwatch Program: Sense of Place and Science Literacy in a Citizen-based Ecological Research Project. *Conservation Biology*, 19: 589-594.

This article reports on a citizen science project called Neighbourhood Nestwatch. The goals of the project are to collect data to help researchers understand ecology of eight bird species in the Washington, D.C. area as well as to educate people about bird biology. The participants are asked to note behaviours and activities that link birds to their habitats, other birds, and to populations of predators which may impact nest success. Data is recorded on sheets provided to the participants. As a result of this program, participants are noticing new species and ninety percent of participants reported learning from their participation. Interestingly, the participants also voiced concerns about the quantity and quality of data and meeting the goals of the project. However, the report outlines success of the project relies heavily on good communication between stakeholders, including staff scientists and participants. Participants can learn a lot from open communication with stakeholders as well as clearing up any uncertainty with data collection. Yet, communication is something all parties need to constantly work on to ensure the project can have full educational potential. Ensuring all participants understand the overall goal is crucial to project success as well as increasing one's education.

Frog Watch Ontario. (2011). Toronto Zoo. Retrieved on 6 October 2011 from <http://torontozoo.com/adoptapond/FrogwatchOntario.asp>.

This informative website encourages people to get involved in ecological monitoring, specifically frog watching. Its main purpose is to generate awareness among multiple communities including schools, families, landowners, agriculture groups, cottagers, and naturalists groups across the province that amphibian monitoring is fun, easy, and important. The program itself is a part of the national initiative, Frogwatch-Canada administered by Environment Canada. Frogwatch-Ontario is a partnership between Adopt-A-Pond, Environment Canada's Ecological Monitoring and Assessment Network (EMAN) and the Natural Heritage Information Centre (NHIC). Becoming involved in the project is simple and involves signing up online to receive a package in the mail. Not only does this project save amphibians in Ontario but it also helps citizens learn how to identify frogs visually and by their calls. The data submitted by volunteer is stored at the Natural Heritage Information Centre (NHIC). The website also highlights reasons why citizens should participate and the reasons include: Frogwatch observations help scientists to track climate change using phenology data, identify positive and negative population trends, and learn about range and distribution of frogs and toads. Evidently, they are stressing the importance of protecting wetland species and habitats. This is also a great example of a current ecological monitoring program in Ontario that citizens can presently get involved and participate in.

Hall, Andrea. (2009). Amphibians Finally Get Some Respect at City Hall. Retrieved on 3 October 2011 from <http://royalcityrag.wordpress.com/2009/09/22/amphibians-finally-get-some-respect-at-city-hall/>.

This article was written by a concerned Guelph citizen to inform other citizens about frog mortality rates on Laird road and the slow actions of City Hall. It is an excellent example of local stewardship and public participation within ecological monitoring. On September 22, 2009, local citizens discovered that more than 1000 frogs were hit by vehicles while trying to migrate to their wintering grounds. The concerned citizens proceeded to collect all the casualties and bring forth the issue to City Hall. The City had been looking into road closure option since the spring when a similar incident happened however nothing had been done. However, after being presented with over 1000 frogs the City closed Laird Road between McWilliams Road and Downey from dusk until dawn the following evening. This is an excellent example revealing that governments act upon evidence. Road ecology studies are important methods of generating data and evidence in hopes to impacting decision making. As a result of the evidence, the City is planning to construct amphibian movement culverts for long term protection of the species.

** Hunsberger, Carol. (2004). Exploring Links between Citizen Environmental Monitoring and Decision Making: Three Canadian Case Examples. Thesis Paper published at the University of Waterloo, Waterloo Ontario. Retrieved on 19 September, 2011 from <http://uwspace.uwaterloo.ca/bitstream/10012/970/1/cahunshe2004.pdf>.

This article provides an in-depth analysis of citizen environmental monitoring programs which involve groups of citizen volunteers gathering environmental data for decision-making purposes. It highlights significant aspects citizen monitoring programs require to function smoothly. Therefore, this paper is a useful tool for researchers collecting data with this method. Hunsberger uses a case study approach to uncover the necessary components of citizen monitoring program and uses three Canadian case studies: Comox Valley, British Columbia, and Hamilton and Muskoka, Ontario. Qualitative interviews are conducted to retrieve information from monitoring programs in each region. The case studies reveal that credibility, data reliability, and strong partnerships between stakeholders are essential to citizen monitoring success. Credibility can be enhanced through receiving support and guidance from scientists, receiving support from the outside community, as well as all stakeholders having a common vision for the program. To collect high quality data quantitative and qualitative observations need to be recorded including who collected the data, dates and locations of observations, and method used. Strong partnerships with governments, businesses, Conservation Authorities and professionals also greatly increase the legitimacy of the project. Specifically, strong partnerships with governments at local, regional, and provincial levels are help to include program results in political agendas. This article explores a new area of study surrounding citizen environmental monitoring in Canada. Many articles have been written based on studies in the United States; however results cannot always be useful because they are case and site specific. Citizen environmental monitoring generates informative data at low costs and thus important resource to impact future local environmental management decisions.

** Lee, T., M. S. Quinn, and D. Duke. (2006). Citizen, science, highways, and wildlife: using a web-based GIS to engage citizens in collecting wildlife information. *Ecology and Society* 11(1): 11.

This article describes what citizen science is, its significance as a research approach, and provides a good example of a citizen science project. Citizen science can be defined as local citizens participating in the collection of data within a scientific experiment. This is a valuable research approach to ecological monitoring because governments lack the resources for on-going monitoring and data collection. Therefore, citizen science is a way to collect data without costing the government large sums of money, time and labour. *Road Watch* is the project discussed and it involves local citizens reporting wildlife observations along 44 kilometres of highway surrounding Crowsnest Pass, Alberta, Canada. Recruitment of participants is crucial and the project was advertized through posters, media announcements, personal communication, and the project website. What is unique about this project is that a web-based tool is used to facilitate the collection, and analysis of the data.

The project website provides access to online GIS mapping tool where the citizens enter their observations along with wildlife identification assistance. The study results include comparison of 11 months of observations and wildlife mortality and demonstrate that the use of citizen science is a useful emerging research approach that increases citizen knowledge and insight surrounding ecological monitoring issues. 56 local citizens participated which is approximately one percent of the local population. This is a significant step towards increased citizen engagement however; it is not enough to assess the success of the project in creating social change. The project also revealed that an average of 109 large mammals are recorded crossing the road or beside the road. Obtaining this data is critical because these facts impact mitigation options. The article provides a good example of the use of citizen science and helps promote this method as a legitimate research approach.

**Ontario Road Ecology Group (OREG) & Toronto Zoo. (2010). A Guide to Road Ecology in Ontario, prepared for the Environment Canada Habitat Stewardship Program for Species at Risk. Scarborough, Ontario: Neo Communications.

This informative booklet discusses the importance of road ecology and focuses on topics such as the threats of roads to the environment and wildlife, wildlife-vehicle collisions (WVC), mitigation options, and how citizens can help. This valuable resource can be a tool for all of society including: citizens, students, government at all levels, and non-government agencies. The main purpose of this booklet is to raise awareness about the threat road networks pose to the natural environment in hopes of generating sustainable solutions. Pages twenty to twenty-seven are specifically useful to educate the public on ways in which they can help reduce WVCs. This section recommends ten ways to avoid WVC and conserve the environment. A few of the recommendations are: drive cautiously, participate in community roadside clean ups and get involved either by attending public information meetings about local road projects or volunteering time to collect data on WVCs. This is an excellent example of a resource accessible to the public that can generate awareness and allow people to learn ways they can reduce their impact on the environment. In addition, beneath several of the recommendations, the authors have placed URLs where the public can find more information on ways to become involved.

Researcher studying ways to improve turtle crossings. *The Brock News*, Top Stories. 14 June 2011. Retrieved on 6 October 2011 from <http://www.brocku.ca/brock-news/?p=10531>.

This online news article discusses an emerging road ecology project that began this past summer. A Brock University professor, John Middleton, is working alongside Kari Gunson, from Eco-Kare International; Fred Schuler, from Bishop Mills Natural History Centre; and the Ontario Road Ecology Group (OREG) to create an inventory of the 700 turtle crossing signs in Ontario. The objective is to determine where and how signs are placed in the landscape in hopes of alleviating some of the mortalities across Ontario. The project is funded by the 2011 Ministry of Transportation Ontario Highway Infrastructure Innovation Funding Program. Included in this project is creating a geographic model to predict hotspots and to determine if these predicted areas are the actual locations of the warning signs. The findings of the study will guide future transportation policy regarding effective signage placement. However, the project cannot succeed without the help from citizen scientists and volunteers to collect the data. Therefore, this is an excellent example of a project that volunteers can participate in right now all across Ontario. This also represents how current these issues are and the importance of having volunteer participation to obtain the data necessary to guide future decisions.

Roedenbeck, I. A., L. Fahrig, C. S. Findlay, J. E. Houlahan, J. A. G. Jaeger, N. Klar, S. Kramer-Schadt, and E. A. Van der Grift. (2007). The Rauischholzhausen agenda for road ecology. *Ecology and Society* 12(1): 11.

This article suggests ways to make road ecology research more relevant and influential on road planning decisions. Specifically, the paper argues that road ecology research needs a framework with five important questions so that research inferences are more relevant to decision-making. The questions are:
(1) Under what circumstances do roads affect population persistence? (2) What is the relative importance of road effects vs. other effects on population persistence? (3) Under what circumstances can road effects be mitigated? (4) What is the relative importance of the different mechanisms by which roads affect population persistence? (5) Under what circumstances do road networks affect population persistence at the landscape scale? The paper also highlights the importance of study design and concludes that Before After Control-Impact (BACI) designs have the greatest inferential strength. This is because data exists from before the development of the road, during the development, and after the development. Therefore, data for the entire process can be analyzed in a prospective manner. The study identifies that this study design is not always feasible and that most studies are Control- Impact designs, meaning that data only exists after the impact. This data is still highly useful but it has a lower inferential strength. Thus, identifying the study design is important and will impact the strength of your inferences.

Conclusion

As evident in the annotations, citizen science is valuable and crucial to use as a research method for several reasons. Building strong partnerships with all stakeholders not only increases the legitimacy of the project but also helps the process to run smoothly (Hunsberger, 2004). In addition, good communication with the local government help to implement program results in future decisions. The design of the study also impacts the quality of data. Literature concludes that Before After Control-Impact (BACI) designs have the greatest inferential strength (Roedenbeck et al., 2007). However, the Heart Lake Road Ecology Monitoring Project does not have data from before the roadway was constructed. Yet, data from after the construction remains highly useful but has lower inferential strength (Roedenbeck et al., 2007). Credibility of data can be enhanced through guidance from scientists and support from the community (Hunsberger, 2004). Also, collecting quantitative and qualitative data ensures that all variables are included in the study, such as volunteers name, weather description and type/number of animals sited.

Citizen science is also valuable for raising public education and participation. Within the annotations, there are five excellent examples of previous and/or current ecological monitoring programs across North America. The prevalence of these projects identifies how important citizen participation is to the completion and success of the programs. Citizens are not only significant components of this research method but the participants are also taking away important knowledge bases. Neighbourhood Nestwatch (Evans et al., 2004), Frogwatch Ontario (2011), road closure on Laird Road, Guelph, Ontario (Hall, 2009), Roadwatch (Lee et al., 2006), and improving turtle crossing are examples of road ecology projects which rely on citizen science to collect data. Without citizen participation, this data would remain unknown.

It is fact that as the human population increases to grow, so too will the number of vehicles on the roads. Thus, since citizen environmental monitoring generates informative data at low costs, it ties into the larger context of impacting future local environmental management decisions (Hunsberger, 2004).

G.4 Road Ecology and Mitigation Options

Katie Bigras

Introduction

Road ecology is a newer field within the environmental sector, and wildlife mitigation practices are beginning to be implemented to avoid destroying wildlife populations. **Tunnel and fencing systems, culverts, and relocations of breeding sites are the best mitigation options for the reptiles, amphibians, and small mammal species.** Heart lake road is a minor roadway that divides wetlands, therefore dividing reptile, and amphibian populations. It has been found that minor roadways have a higher percentage of wildlife death than major highways. Mitigation practices have been proven to be effective at sustaining, and even reviving dwindling reptile and amphibian populations. Many mitigation options are relatively inexpensive, however regular monitoring must be kept to ensure the structures are intact and working. The following annotations are of works that look at different mitigation options, where and how mitigation should occur, and the effectiveness of mitigation practices.

Annotations

Beier, P., Majka, D., Newell, S., Garding, E. (2008).Best Management Practices for Wildlife Corridors. *Northern Arizona University*. Retrieved on Oct 10, 2011 from http://corridor design.org/dl/docs /corridordesign.org_BMPs_for_Corridors.pdf

Roads have different effects on different species. No single road crossing will be effective for all wildlife species. The authors of this paper determine the best practices for different species by means of researching different mitigation options. Wildlife overhead passes are mainly used by large mammals. Wildlife underpasses such as viaducts, bridges, culverts, and pipes are mainly used by reptiles, amphibians, and small mammals but have also been used by large mammals (especially felines). Vegetative cover is a necessity to most small mammals, amphibians, reptiles, and insects, therefore vegetated bridge under crossings usually work best. Because culverts and concrete box structures offer little to no vegetative cover, they are not an ideal crossing for most species, however despite the disadvantages, small and medium sized mammals, frogs/toads, snakes, and turtles do use these crossing when they are available. Ideally multiple crossings should be used at sites with high relative species abundance. Sites should mimic the vegetative community and need to be well maintained and monitored. This study seems to be the first of its kind and is very helpful in determining mitigation options and the practices that need to be applied for both streams and urban development.

* Bissonette, J.A., Cramer, P.C..(2008). Evaluation of the Use and Effectiveness of Wildlife Crossings: Restoring Habitat Networks with Allometrically Scaled Wildlife Crossings. National Cooperative Highway Research Program (p. 86-95). Retrieved Sept 24, 2011 from http://environment. transportation.org/environmental_issues/wildlife_roads/decision_guide/pdf/nchrp_rpt_ 615.pdf

* In this research paper, the purpose and scope was to determine where crossings should be placed in accordance with an animal's home range, and its ability to roam freely over large areas. This study is intended for groups looking to put mitigation options into place. The researchers of this paper used 103 mammals as an example to better understand how far crossings should be placed from one another by using an equation to determine maximum dispersal distance MaxDD = 40 (linear dimension of HR) and median dispersal distance (MedDD). These were related to home range size by the equation: MedDD = 7 (linear dimension of HR). Afterwards, the team compared options for spacing wildlife crossings that were most feasible for large mammals. Due to a variance in home range sizes (from 0.16 miles - >35.00 miles) it was determined that crossings every 6 miles would not work for both large and small mammals. Large and small mammals would have to be split into groups to determine the best mitigation options for them. This argument was very thorough and well done. It has not contradicted any papers I have read in the past and brings to attention the different needs of species that vary in home range sizes.

* Bond, A, Jones, D. (2010). Road barrier effect on small birds removed by vegetated overpass in South East Queensland. *Ecological Management & Restoration* VOL 11 No 1. Retrieved Sept 25, 2011 from http://web.ebscohost.com

* Many bird species are willing to fly over a road structure, which leads most people to believe that over-head road crossings (land bridges) are not valuable for bird species. The authors of this research paper undertook a study to determine whether there was in fact a road barrier effect by observing bird movement on parts of the road with and without a land bridge. The authors did 5 minute stationary intervals at eight intervals, four along the road, and four along a land bridge on the same highway. The study concluded that the relative abundance of birds crossing the road vs. crossing the land bridge had no significant different (6.25/5 minute interval over road) vs. (6.71/5 minute interval over the land bridge). The species however varied significantly. Some bird species were not noted crossing the road whatsoever, using only the land bridge as a means to get across. The authors feel this study and others like it require far more international attention. This study was well done and convincing. The data clearly demonstrates different bird species using only the over-head land bridge. The authors explored new territory that expands on other studies I have read. This study is valuable while determining types of mitigation options available.

Jolivet, R., Antoniazza, M., Strehler-Perrin, C., Gander, A. (2008).Impact of road mitigation measures on amphibian populations: A stage-class population mathematical model. *Cornell University* Retrieved Oct 11, 2011 from http://arxiv.org/PS_cache/arxiv/pdf/0806/0806.4449v1.pdf

It is well known that with urban development, amphibians suffer as a species. With proper roadway mitigation procedures, minimizing the negative impact on amphibians should be relatively easy. The purpose of this study is to determine whether under-road tunnels are in fact effective at conserving/sustaining amphibian populations. The authors of this article look at 2 amphibian populations, (common toad – *Bufo bufo* and common frog - *Ranatemporaria*) before and after mitigation measures were put in place in 1992 in the Cheseaux area. In 1994, data for both species was also collected in an area without roadways in Ostende as a control group. To get the census of migrating adults, bow-nets, drift fences and traps were used to estimate the population. The results did not show any significant trend with the two populations, however years with lower populations were prevalent in both species. A significant transient increase in both populations was found to occur four years after the installation of the tunnels. Although the authors need more data to conclude the increase of population was solely due to the mitigation procedure, it is concluded that the plausible cause of the population increase was attributed to the mitigation options in place. This article was one of the first of its kind. It is important to know that mitigation options are in fact assisting the population of amphibians. Data such as this is needed to prove that mitigation to roads is working.

Kight, C. (2001). Road Ecology: An Often Overlooked Field Of Conservation Research. *Anthrophysis When Humans and nature collide*. Retrieved Oct 9, 2011 from http://www.science20.com/anthrophysis/road_ecology_often_overlooked_field_conservation_research-82715

On approximately 50 million kilometres of road worldwide, and roughly 750 million vehicles on the roads, little is known about road ecology mitigation options, and most people are not even aware of the impacts roads have on wildlife populations. Although roads clearly have a negative impact on both humans and wildlife, they are not regarded as a dangerous habitat feature. Often times simple mitigation options is what it takes to prevent/minimize the death toll of wildlife. Considering different options, it was found that overhead and under-road passes were among the safest options for wildlife. Due to time and money, they also seemed to be among the most affordable. Not only does this help the population of wildlife species, it has been found to increase the overall gene flow of populations as well. The author of this article was slightly brief with the findings. However it is beneficial to prove that mitigation options can be affordable and highly effective.

Lake Jackson Ecopassage Alliance, Inc. (2011).The Lake Jackson Ecopassage Providing a Safe Path for Wildlife. *Lake Jackson Ecopassage Alliance*. Retrieved On Oct 8, 2012 from http://www. lakejacksonturtles.org/#summary

Located in north-western Florida, Lake Jackson is subject to a 4 lane highway built on ¾-mile stretch of the 4000 acre sinkhole lake. Due to the 23,500 vehicles that travel this highway each day, the highway makes crossing for turtles and other wildlife virtually impossible. Over a period of 40 days, 439 turtles were killed. A temporary silt fence measuring 3600 ft and 2600 ft on either side of the highway directing turtles and other wildlife to use an existing culvert was put in place while a more permanent structure was constructed. The silt fence was effective in saving 8,800 turtles while the permanent solution was being constructed. Now that the permanent structure is in place, more species are being saved since they cannot dig under or climb over the barrier, they are all directed to an under-road passage. The permanent structure is the same concept as a silt fence but is secure and higher. This article was very well written, I feel I gained a lot of knowledge about turtle mitigation. The mitigation option they applied, I think will be soon recognized by more road ecology groups and the government as a necessary practice for turtle and other wildlife mitigation.

Ovaska, K., Sopuck, L., Engelstoft, C., Matthias, L., Wind E., MacGarvie, J. (2005) Best Management Practices for Amphibians and Reptiles in Urban and Rural Environments in British Columbia. *Ministry of Water, Land and Air Protection Ecosystem Standards and Planning Biodiversity Branch*. Retrieved Oct 11, 2011 from http://www.env.gov.bc.ca/wld/BMP/herptile/ HerptileBMP_final.pdf.

Reptiles and amphibians are an important component to many ecosystems. Due to their inconspicuous nature, they tend to be overlooked when human development takes place. Amphibians stay within a few 100 metres of their breeding sites, and most juveniles stay within 1 km. When a road is placed in between a seasonal habitat and a breeding site, high levels of amphibian traffic will occur over these roads during peak breeding seasons. The authors of this paper take a look at many mitigation options for reptiles and amphibians including the best road ecology mitigation practices. Although the best management practice would be to avoid putting roads through wetlands in the first place, sometimes it is inevitable and therefore we must provide adequate linkages for reptiles and amphibians to safely cross to the other side. It is found that tunnel and fencing systems, culverts, and relocations of breeding sites tend to work best. Tunnel and fencing systems should be strategically mapped out to accommodate high traffic crossing areas and guidelines given in this paper for proper installation and maintenance of fences and tunnels should be followed. When pre-existing culverts can be used, it is essential to incorporate as much of the natural habitat as possible, if nothing else, natural substrate should be used at the culvert base versus steel. Relocation of breeding grounds is another option when road mortality is very high. In this case permanent fences, and/or enhancement or creation of alternate breeding sites may be created. The authors of this study did a great job on making the public aware of the importance of reptiles and amphibians and why/how mitigation measure should be taken. This is essential to our research when deciding what mitigation options to implement at Heart Lake road.

*Van der Ree, R., Heinze, D., McCarthy, M., and Mansergh, I. (2009). Wildlife tunnel enhances population viability. *Ecology and Society*14(2): 7. Retrieved Sept 20, 2011 from http://www.ecologyand society.org/vol14/iss2/art7/

*The Mountain Pygmy Possum (Burramysparvus) is an endangered small marsupial that lives at high-altitudes in south-eastern Australia. An annual migration takes place between October-December, however due to ski resort development, a major road is separating the male population from the female population. Tunnels have been put in place as a mitigation option, the authors of this study will use population viability modeling to predict what impacts the road and tunnel will have on population size and the probability of decline. The authors used a subset of population data collected before mitigation (1983-1985), and after mitigation (1986-2003) and a set of data from another Mountain Pygmy Possum population unaffected by the road. Using a Ricker function ($[N_{t+1}/N_t] = a + b\times N_t + s\times S_t + \mathrm{norm}(0, \sigma)$) with an addition to account for sex ratio, the future population was predicted. A Bayesian approach was taken. By substituting the pre-tunnel and post-tunnel sex ratio, and the sex ratio of the unaffected population the effect of the tunnel as a mitigation option was predicted. The study found that without any mitigation, the population of B. parvus would have a 40% decline in females in 20 years compared to the population unaffected by a road, and that with the mitigation option in place, there will only be a 15% decline of females compared to the population unaffected by the road. The authors suggest continuing to use population viability as a more accurate way of determining mitigation success then previous studies using only observation to determine if wildlife populations are truly benefiting from mitigation options. This study was well done and convincing because it shows that population sizes are still decreasing even with mitigation options. The authors explored new territory and were amongst the first group to conduct population viability modeling with road ecology. I have not read material such as this and I feel more studies such as this one should be done as mitigation options continue to improve.

Van Langevelde, F., Van Dooremalen, C., Jaarsma, C. F. (2009).Traffic mortality and the role of minor roads. *Journal of Environmental Management* 90, 660-667. Retrieved Oct 10, 2011 from http://www .falw.vu.nl/en/Images/2009-02_tcm24-62140.pdf

There is no doubt that roads have a major impact on wildlife populations. The majority of road kill/mitigation studies however have been done on major roadways (4+ lanes). The authors of this article argue that minor roadways (2 lanes) have a greater impact on wildlife populations. Firstly, the authors took into consideration the road area vs. traffic volume on both major and minor roadways in the Netherlands. In the area of study, major roadways occupy 5600 ha and minor roadways occupy 20,700 ha. Although the area is greater for minor roadways far less traffic travel on minor roadways. On major roadways the traffic is steady and speed limits are on average 100-120km/hr vs. 60-80km/hr on minor roadways. For these reasons it is hypothesised that wildlife is more willing to cross a road with less traffic density than a major roadway that acts as a constant barrier and obvious threat to their well-being. Data collected on road mortality per road type collected from 1990-2005 was used to determine that 64% of deaths occurred on minor roadways and 34% were on major roadways. The authors of this paper would like to see minor roadways taken into consideration for mitigation as well as major roadways. Although this study was conducted in the Neatherlands, it was argued that the data was relevant in most Urban Developments. This study is important to argue that minor roads such as Heart Lake road is as, if not more important to mitigate than major roadways. It was well written and had hard evidence to back up the findings.

Conclusion

There is no doubt that in earlier roadway construction, wildlife had been completely overlooked. The best way to mitigate for wildlife is to build roads around wetlands and wildlife hotspots. When avoidance is un-avoidable, building roads with mitigation in mind is what needs to be done. For existing roads, over-head and under-road crossing are highly effective and becoming more and more popular. When determining what mitigation options we can apply at Heart Lake Road, we must consider the species being killed and the hotspots in which the deaths are taking place. Because of the existing culverts at Heart Lake road, it would be inexpensive and very effective to clean up these culverts and add fencing directing reptiles, amphibians, and small mammals to the culvert crossings.

Heart Lake Volunteer Road Ecology Monitoring Project

Phase II, 2013

Toronto and Region
Conservation
for The Living City

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Executive Summary

The Toronto and Region Conservation Authority (TRCA) partnered with the City of Brampton (CoB), Ontario Road Ecology Group (OREG) and local volunteers to deliver the Heart Lake Road Ecology Volunteer Monitoring Project (HLREMP). The objective of HLREMP was to better understand which species were being impacted by interactions with vehicles, how many interactions were occurring, and to suggest mitigation measures to protect local biodiversity in the Provincially Significant Wetland (PSW) complex adjacent to Heart Lake Road between Sandalwood Parkway and Mayfield Road in Brampton, Ontario.

Phase I of HLREMP took place between May 9, 2011 and October 31, 2011. Data were collected by volunteers with the goal of observing and recording wildlife-vehicle collision sites (WVCs), any notable live wildlife along the road, species proximity to the road, alive/dead status and GPS co-ordinates.

Phase II of HLREMP field data collection of WVCs was undertaken by staff and volunteers between April 8, 2013 and September 30, 2013. The study area was redefined and focused along Heart Lake Road between Sandalwood Parkway and Countryside Drive. Outlined in this report are Phase II data collection and mitigation options which have been investigated to move forward with a strategy to reduce WVCs within this PSW.

The report and the findings will be shared with TRCA, OREG and CoB in order to implement mitigation along Heart Lake Road to reduce WVCs and protect this diverse ecosystem.

Acknowledgements

This project and report was made possible through the generosity of our volunteers, City of Brampton (CoB), Ontario Road Ecology Group (OREG) and project partners. Sincere and heartfelt thanks are extended to all partners and volunteers who have dedicated their time and efforts to the Heart Lake Road Ecology Volunteer Monitoring Project (HLREMP).

Heart Lake Road Ecology volunteers spent time training for safety and efficient data collection protocols to ensure a level of integrity is maintained with information obtained. Field work was conducted in all weather conditions and the devotion and commitment shown by the volunteer members in protecting wildlife in this endeavour, is to be commended.

Special thanks to Bob Noble who spent many hours managing field data and cross referencing images.

Volunteers:

Gillian Carson
Diana Christie
Liz Cici
Ron Fay
Gord Ferguson
Betty-Anne Goldstein
Susan Janhurst
Dayle Laing
David Laing
Jim Laird
Chris McGlynn
Elizabeth Morin
Bob Noble
Leo O'Brien
Shawn Patille
Alana Ziobroski
Lyle Ziobroski

2013 Road Ecology Monitoring Volunteers

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ACO Canada
City of Brampton (CoB)
Ontario Road Ecology Group (OREG)
Region of Peel
Royal Ontario Museum
Toronto and Region Conservation Authority (TRCA)

Report Prepared By:
TRCA - Vince D'Elia, Project Manager
TRCA - Casey Cook, Project Coordinator
OREG - Mandy Karch, Coordinator
Volunteer - Bob Noble, Data Coordinator

1.0 Introduction

Wildlife faces stressors from many fronts throughout their life spans which contribute to regional declines. Stressors include: pollutants, climate change, disease, toxins, invasive species and genetically modified organisms. Wildlife migrates to breed, feed and hibernate throughout their life cycles and roads present notable threats to these migrations. Birds, small and large mammals, insects and fish populations are adversely affected by roads. Sedimentation, spills, pollution and other road-related waterway disturbances are threats representing an important conservation issue – biodiversity loss. Biodiversity is represented by variety of species, their genetics and diversity of ecosystems, along with the resilience, health and interactions of these components. Roads and transportation networks are a primary anthropogenic mark on earth's landscape resulting in habitat loss, fragmentation and degradation. As it becomes more evident that mortality from attempted road crossings is a large threat to wildlife, data collection, research in mitigation design and implementation are important to establish improvements in road network management across the province.

Road ecology is an emerging field of study which examines the effects of roads on wildlife populations and their impacts on ecological processes. In the past sixty years, major roads in southern Ontario have increased from 7,133 kilometres to 35,637 kilometres (Fenech et *al*., 2000). Every 38 minutes there is a wildlife/vehicle collision (WVCs) in Ontario (MTO 2011) and this statistic does not include unreported collisions with smaller species such as amphibians, reptiles and mammals.

Road ecology is the study of interactions between the natural environment and roads. The four main threats roads pose to biodiversity are:

1. Habitat loss;
2. Direct mortality caused by WVCs;
3. Population subdivision, less gene flow and increased vulnerability to environmental stochasticity (eg: extreme weather events, disease, etc.); and
4. Inaccessibility to critical resources such as mates, food and habitat.

Together these four threats result in smaller populations which are less likely to persist. (Jaeger, et al, 2005)

Locations where roads act as barriers to habitat connectivity and cause concentrated wildlife road mortality are termed "hotspots", making them critical areas to research and mitigate. Herpetofauna is a classification which includes reptiles and amphibians and some taxa in this grouping are at risk of becoming extirpated (i.e. locally extinct). Herpetofauna are slow-moving and have not evolved to avoid roads or vehicles making them particularly vulnerable to WVCs. Unlike other issues plaguing these taxa, threats created by roads can be mitigated to relieve survival pressures these groups encounter. Provincial legislation acknowledges this threat and through the Endangered Species Act (ESA) and recovery strategies, mitigating road mortality is recognized and supported as a priority to help protect and recover most Species at Risk (SAR) herpetofauna. The revised implementation strategy of ESA supports herpetofauna road mitigation and under the Standard Condition approach requires proponents to proceed with "road improvement activities with the protection of reptiles and amphibians and benefits provided through the installation of fencing and improved passage".

(http://www.e-laws.gov.on.ca/html/regs/english/elaws_regs_080242_e.htm)

Region of Peel is committed to road ecology and is working with its partners to achieve the following goal; "to assist transportation managers make informed decisions to proactively protect and enhance wildlife connectivity when designing new and expanded road projects."

In 2011, Phase I of Heart Lake Volunteer Road Monitoring Project (HLREMP) was delivered in partnership with Toronto and Region Conservation Authority (TRCA), City of Brampton (CoB), Ontario Road Ecology Group (OREG) and local volunteers. The objective of HLREMP was to better understand which species were being impacted by interactions with vehicles, how many interactions were occurring, and to suggest mitigation measures to protect local biodiversity. The study area (Figure 1) is a Provincially Significant Wetland (PSW) complex bisected by Heart Lake Road between Sandalwood Parkway and Mayfield Road in Brampton, Ontario.

Figure 1. HLREMP Study Area - Heart Lake Road from Sandalwood Parkway to Mayfield Road, including Heart Lake CA.

Data collection in 2011, (online report at: http://www.trca.on.ca/dotAsset/151730.pdf) resulted in a total of 1,988 wildlife observations. Of the total, 1,239 were fatalities and 749 were live sightings. When analyzing the relative number of WVCs, frog/toad ranked the highest with 1,044 individuals, followed by 94 turtles, 45 mammals, 25 birds, 17 snakes and 14 unknown. This was shared with CoB staff and project partners leading to further consultation and exploration of options for mitigation. Existing culverts were located in 2012, and considered as a possibility for facilitation of wildlife movement between habitats fragmented within the study area. Options for directional fencing to guide wildlife toward the existing culverts for safer passage were also considered as part of the mitigation strategy.

In an effort to better understand “hotspots” (key areas of fatalities) identified from data in Phase I, it was decided to conduct Phase II. Based on findings from Phase I, Phase II study area (SA) was redefined to focus data collection in areas with high levels of WVCs. Phase II site boundaries extended along Heart Lake Road from Sandalwood Parkway to Countryside Drive (Figure 2).

Monitoring was scheduled to begin at peak amphibian breeding season which occurs when temperatures are conducive to their emergence from hibernation and continued through to early fall in an effort to capture primary movement of resident populations of reptiles, amphibians, mammals and birds.

Volunteer monitoring protocols were better defined to reduce errors and ensure accuracy of data with respect to species identification and location.

Figure 2. HLREMP Phase II Site Boundaries– Heart Lake Road from Sandalwood Parkway to Countryside Drive.

In addition to the volunteer monitoring component of Phase II, a study (Appendix G) included directional fencing and three "mock culverts" being placed at the wetland on the west side of Heart Lake Road just north of HLCA entrance (Figure 3). This was undertaken in order to determine variation in efficacy in attracting and passing of three culvert types; a corrugated steel pipe (CSP), a concrete pipe and a dedicated wildlife culvert produced by ACO Systems Ltd.

Figure 3. Directional Fencing & Culvert Study Location, west side Heart Lake Road.

The following report analyzes data collected within the SA, helps raise awareness and provides insight of impacts Heart Lake Road has on local biodiversity. It outlines results of data collected in order to better inform decision makers to develop and implement mitigation strategies at this designated PSW complex.

2.0 Materials and Methods

2.1 Phase II Site Boundaries

The study was conducted on a 1 km segment of Heart Lake Road between Sandalwood Parkway and Countryside Drive in Brampton, Ontario (Figure 4). Heart Lake Road is a municipal two-lane, paved road with gravel shoulders between 0.5 m and 1.5 m in width. At the SA, Heart Lake Road bisects a Provincially Significant Wetland (PSW) complex.

Figure 4. HLREMP Phase II Site Boundaries and wetland areas– Heart Lake Road from Sandalwood Parkway to Countryside Drive.

The water in Wetland A is almost level with the road. Wetland B, C, and D, water levels sit at a lower elevation with an approximate 2.5 m sloped berm leading to a gravel shoulder. The surrounding roadside habitat is a mix of wetland, woodlot, field and commercial property. The land bordering the study sites west side is Heart Lake Conservation Area (HLCA) which is owned by TRCA. HLCA occupies 169 hectares and its diverse ecosystem includes two kettle lakes, the headwaters for Spring Creek and a wetland complex. It has one of the largest individual blocks of forest in Etobicoke Creek watershed and surficial geology of glacial till and riverine deposits. Also found within HLCA are sections of the PSW, an Environmentally Significant Woodland area and a bog of Natural and Scientific Interest. This area provides nesting opportunities for at least seventy-five species of birds, including a regionally significant heronry and is home to thriving populations of several herpetofauna and mammal species including two species that are listed as SAR (snapping turtle, *Chelydra serpentina* and the milk snake, *Lampropeltis triangulum*).

2.2 Personnel:

Staff:
TRCA’s Etobicoke and Mimico Creek Watersheds project manager and project coordinator, as well as OREG coordinator and field researcher oversaw the study. Staff coordinated project permits from City of Brampton and Ministry of Natural Resources, volunteer recruiting, scheduling, communications, data management and reporting. Arrangements were made at a local veterinarian clinic to receive wildlife in need of care (including euthanasia) prior to commencing road survey and data collection. Dedicated field staff was required in order to deliver this program and maintain consistency throughout the duration of this study.

Volunteers:
Volunteers were recruited in 2011, for Phase I of HLREMP through TRCA’s Environmental Volunteer Network, articles in the Brampton Guardian local newspaper and by word of mouth. Phase II volunteers were recruited using the list from Phase I. A group of seventeen people committed to Phase II, and received training in accordance with TRCA’s health and safety guidelines, permit requirements and monitoring protocols.

Project Data Manager
A project volunteer with data analysis expertise and species identification skills managed and summarized field data and images. After each monitoring session, field data sheets were placed in a waterproof folder within the equipment field box. At least once per week, field data sheets and digital camera memory cards were collected from the field box. Data were entered and recorded using Microsoft Excel and image management was conducted using Adobe Photoshop Lightroom software.

2.3 Field Equipment

A field equipment box was kept at HLCA for staff and volunteers to conduct surveys. The box was chained to a tree and hidden from public view with only project staff and volunteers having an access code. The locked box contained the following equipment and resources:

- safety vests;
- hard hats;
- safety glasses;
- nitrile gloves;
- leather work gloves (to handle live snapping turtles, etc.);
- hand sanitizer (for use after monitoring);
- UV Protectant;
- clip boards;
- copy of permits (Appendix A);
- data sheets (regular and waterproof paper), (Appendix B);
- copy of volunteer waiver form (Appendix B);
- monitoring protocol guidelines, (Appendix B);
- safety protocols (Appendix B);
- emergency contact information (volunteer and TRCA contact information);
- wildlife identification sheets (Appendix C);
- wildlife acronyms (Appendix C);
- writing utensils appropriate for weather conditions ;
- FujiFilm FinePIX XP150 Waterproof Digital Camera;
- rechargeable batteries for camera ***;**
- additional memory cards for camera ***;**
- REED Digital Psychrometer (Model No. 8726)*;
- thermometer ***;**
- plastic box with perforated lid to be used for small, injured animal transport (i.e. a turtle);

- terry cloth towels, (for animal transport);
- carpet (primarily used for live transport across road for snapping turtle);
- shovel;
- dust pans; and
- replacement orange survey flags for fixed Global Positioning System (GPS) points ***;**
  (***** Indicates: as shown in Figure 1)

Figure 5. Field Equipment as indicated by asterisk in list above.

City of Brampton Works and Transportation Department provided orange ‘caution people at work’ signs (Figure 6) during the field season that were kept in-situ at the north and south limits of study area.   Numbered orange survey flags were placed at pre-determined GPS locations as set by TRCA staff.

Figure 6. City of Brampton signage.

2.4 Safety Protocol:

A safety training session was held by TRCA staff on April 30, 2013, prior to volunteers commencing monitoring sessions. All volunteers were required to attend safety training including proper use of safety equipment, road safety protocols, personal protection during inclement weather conditions (i.e. heat, rain, storm events) and wildlife interactions. Volunteers were also trained in a standard protocol (Appendix B) for field data collection in order to maintain consistency and repeatability. This protocol was made available in written form and kept in the material supply bin on site. Volunteers were required to sign liability waivers indicating they would respect and follow protocols prior to participating (parents/legal guardians signed for volunteers under age eighteen).

Participants were required to monitor in groups of no fewer than two people in order to ensure vehicle/road safety was followed in accordance to permit and TRCA protocols. Personal protective equipment was required to be worn during each survey which included: safety vest, hard hat, safety glasses, nitrile and/or leather work gloves and close-toed shoes. Volunteers were responsible to come prepared and protected against weather conditions during their scheduled survey period (e.g. sunscreen, drinking water, sunglasses, insect repellent, rain gear, etc.). Each volunteer carried a cell phone, was provided with emergency contact information and project staff contacts (e.g. project coordinator, local veterinarian, emergency contacts, etc.).

Volunteers (Figure 7 and 8) did not wear ear-buds and did not engage with electronic devices (e.g. no texting, etc.) to avoid distractions (e.g. hear and see approaching vehicles) while on road right-of-way's to ensure personal safety and allow for awareness of environment and traffic conditions.

Figure 7. Volunteer at south east Heart Lake Road.

Figure 8. Volunteers on west side of Heart Lake Road.

2.5 Survey Protocol, Data Collection and Management:

At onset of study and field monitoring (March 2013), TRCA staff established 30 fixed GPS points using orange survey flags which were labelled and staggered at a distance of approximately 25m increments, within the SA. These markers were placed at a safe distance from paved surfaces. Points #1 - #15 were on the west side of Heart Lake Road commencing slightly north of Sandalwood Parkway. Points #16 - #30 were on the east side commencing on the south side of Countryside Drive ending slightly north of Sandalwood Parkway (Figure 10). Dividing the study site into 25m increments allowed for increased sighting accuracy during data collection for the volunteers.

Data collection commenced on April 8, 2013 by TRCA staff and continued through peak herpetofauna breeding season (June) and beyond. During breeding season, monitoring and data collection was conducted primarily in late afternoon and evening (Figure 9) when species movement is more frequent (at night in warm/moist conditions). In addition to the road surveys, two Marsh Monitoring stations were installed to assess the status of frog/toad populations on either side of Heart Lake Rd. This frog monitoring project was conducted following Marsh Monitoring Program (MMP) initiated by Bird Studies Canada in the 1990s.

Figure 9. Staff night monitoring (Photo Credit: Vanessa Hussey).

MMP Protocol provides a convenient method for conducting long term monitoring of both birds and frogs in marshes of a wide variety of size and quality (BSC 2008). Two locations were chosen at Wetland Area C (Figure 4), on both east and west sides of Heart Lake Road and marked with reinforced bar posts and geo-referenced using a GPS unit. Observations and counts were undertaken in a 100m semi-circle from the station marker since in general, stations are located at the edge of the wetland. It was important to ensure orientation of the semicircle was constant for repeatability. Orientation was documented using a compass (Appendix D).

Surveys were conducted on relatively warm and moist nights that have little to no wind (based on the Beaufort Wind Scale) and began a half hour after sunset and ended before midnight. To report and map the frogs, a point was mapped on the field sheet representing the position of separate choruses' audible from the station. These choruses were mapped both within and beyond the count semi-circle (Appendix D).

The intensity of each chorus is indicated by a number-code associated with each observation:

- 0 - None heard;
- 1 - Individuals can be counted, calls not overlapping;
- 2 - Calls overlapping but individuals can still be distinguished and;
- 3 - Full chorus, calls continuous and overlapping, individuals not distinguishable.

Once volunteer monitoring started (May 1, 2013), volunteers set up "people at work signs", informed HLCA staff that monitoring would be taking place and left appropriate signage on their vehicle dashboard indicating volunteer activities were taking place.

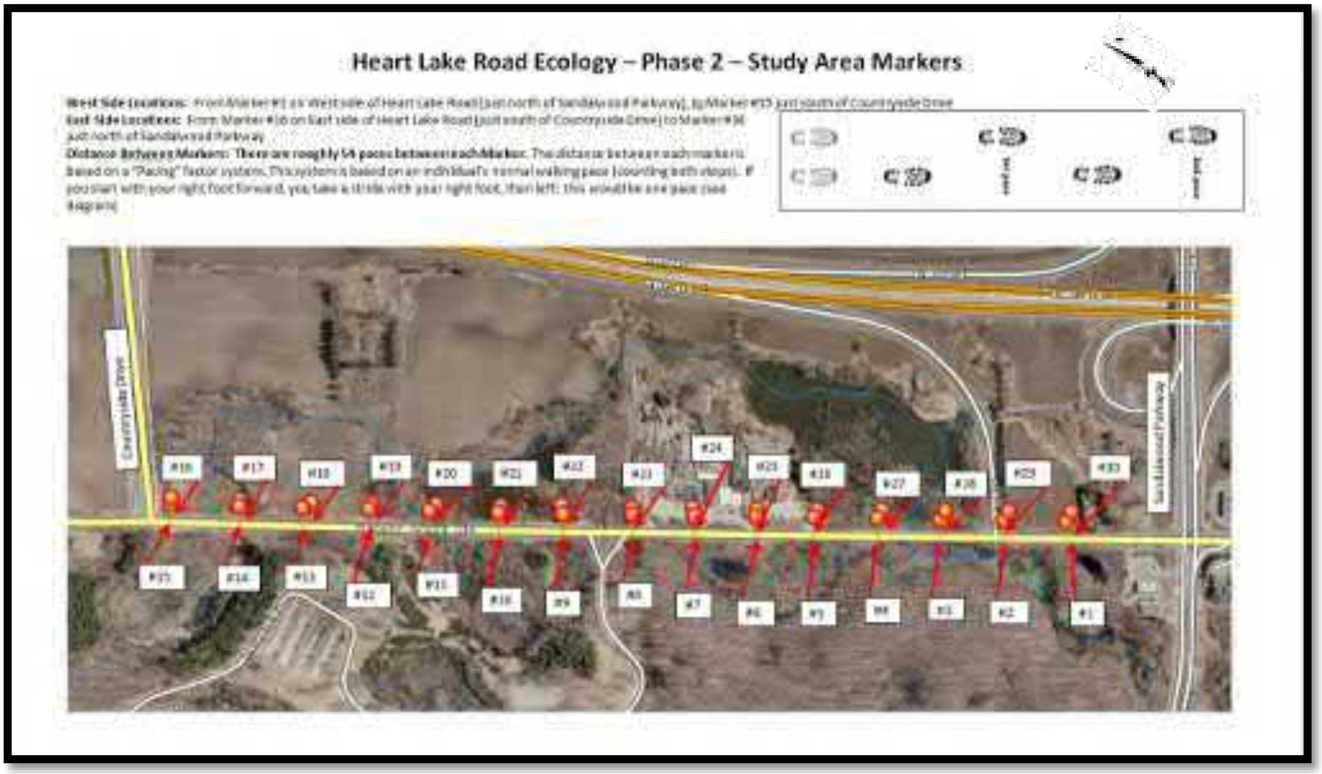

Figure 10. GPS Locations – labelled and numbered orange survey flags.

Volunteers used the fixed orange survey flag numbers to record sighting locations, as opposed to obtaining GPS coordinates for each sighting. Prior to commencing each monitoring session, temperature and moisture readings were obtained using a REED Digital Psychrometer (Model No. 8726). Environmental data including percent cloud cover (0%, 25%, 50%, 75%, 100%), precipitation (none, light, moderate, heavy) and wind strength (approximate km/hr or obtained online at Environment Canada) were also recorded.

The road was divided using the middle yellow line as a centre point to approximately 1.5m into roadside habitat, or further as conditions allowed. Parking for volunteer vehicles was provided at HLCA which was located between Point #8 and #9. Monitoring started at Point #9, where participants walked in a northerly direction, in pairs, facing traffic on the gravel shoulder keeping as far from traffic as possible. At Point #15, participants carefully crossed the road and continued monitoring the east side in a southerly direction from Points #16 - #30. After carefully crossing back to the west side of Heart Lake Rd, they monitored north from Points #1 - #8, completing the monitoring route.

These areas were monitored for evidence of wildlife/road interactions (e.g. carcass remains, scat, tracks, etc.) and live sightings. Observations were recorded using the following criteria:

Status:	Dead on Road (DOR), Dead Beside Road (DBR), Alive on Road (AOR), Alive Beside Road (ABR).
Position:	Shoulder, White Line, Middle of Lane or Yellow Line
Proximity:	(from edge of pavement) 0.25 m, 0.5 m, 1 m or > 1 m
Behaviour (alive):	Foraging, Basking, Crossing, etc.,
Side of Road:	N, S, E, W

Location observations of WVCs were documented on field data sheets provided (Appendix B). Upon encountering an observation, sighting location was recorded using closest fixed orange survey flag numbers as a reference. All sightings were photographed and documented using a FujiFilm waterproof digital camera and the numbering sequence recorded as a cross-reference to the wildlife sighting number on field data sheets. To ensure images corresponded to individual field data sheet sets, an image of field data sheet page(s) were photographed at the end of each monitoring session. It is to be noted that by cross referencing each sighting on individual data sheets with a corresponding numbered image, duplications of fatalities were able to be detected by the volunteer managing data input. This allowed for an increased accuracy of data reporting. Completed field data sheets were stored in a waterproof folder within the equipment box.

Wildlife remains of each recorded observation were discarded into roadside habitat to avoid recounting data by subsequent volunteers in future monitoring sessions. Observations of DOR species such as: worms, ants, flies, snails, slugs and other common invertebrates were not documented. Observations of dragonflies, bees and butterflies were recorded in the comment box of field data sheets. While there are presently no road mitigation options for these latter invertebrates, there are conservation issues for these taxa and data may prove beneficial in the future.

2.6 Monitoring Schedule

Volunteers began monitoring May 1, 2013 and ended on September 30, 2013. A monitoring schedule was set up each month using Doodle Poll free online scheduling software and monitored by staff. Monitoring times were set up starting at 0800 hrs. (8:00 a.m.), ending prior to sunset and divided into two hour segments. Each volunteer accessed Doodle online and entered their name to a preferred time slot on a first-come-first-serve basis with the understanding monitoring was to be conducted with a minimum of two people.

A summer student was hired by OREG and TRCA to:

- conduct monitoring sessions as needed;
- aide volunteers during monitoring sessions;
- maintain a log of activities and sightings;
- ensure volunteer supplies and resources were available; and
- participate in Stewardship activities to raise awareness of road ecology.

3.0 Results

Data from Phase II were collected, analyzed and evaluated in an effort to:

- determine actual time spent collecting field data relative to total time available through project duration;
- better understand and document population and wildlife diversity via Marsh Monitoring Protocols and live sightings;
- compile raw data – grouping taxa and species where possible;
- group taxa as either adult or juvenile;
- plot WVC locations using Geographic Information System Software (GIS) and Ortho imagery;
- compile total fatalities by species during total study time period; and
- determine hot spot(s) of concentrated WVCs within SA.

Over the course of Phase II which was a twenty five week study period from April 8, 2013 to September 30, 2013, project staff and 17 volunteers contributed 404 hours to field data collection. Total time spent collecting field data was 202 hours based on volunteers working in pairs (Figure 11). Total monitoring sessions for the time period was 134 (Figure 12). The duration of each session varied each day/week due to amount of WVCs encountered and recorded. The actual time spent monitoring represents approximately 2.4 % of total available time based on 12 daylight hours (Figure 13). Since volunteers were not monitoring for approximately 97% of the available time and did not monitor before or after daylight, the number of WVCs during the study period is potentially higher than study results indicate.

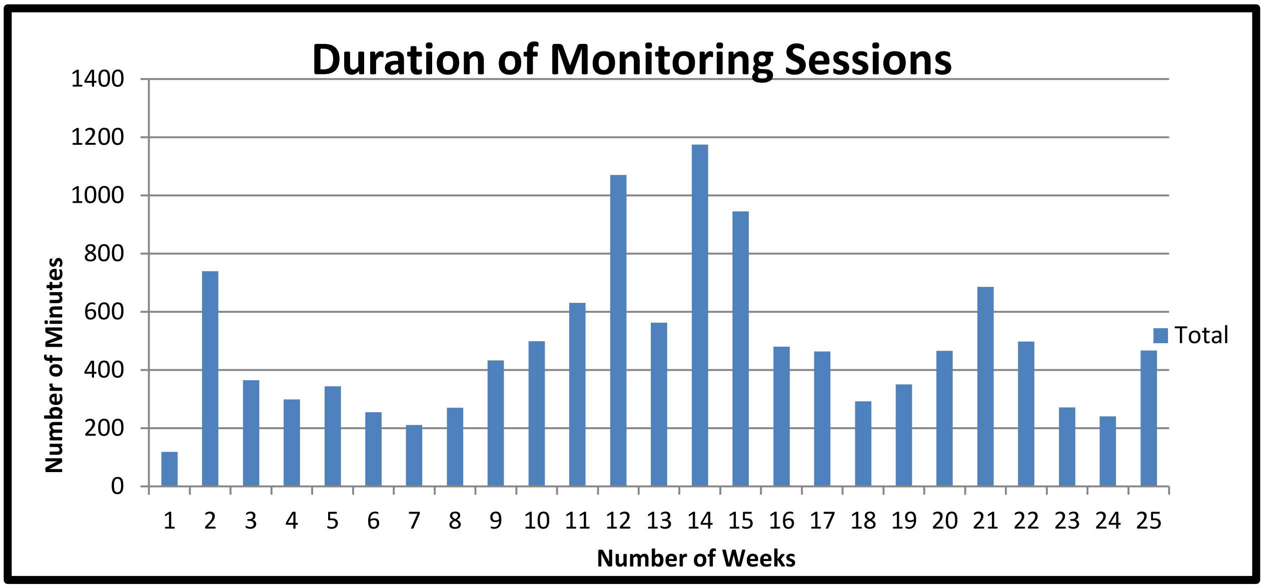

Figure 11. Breakdown of monitoring efforts - 202 hours.

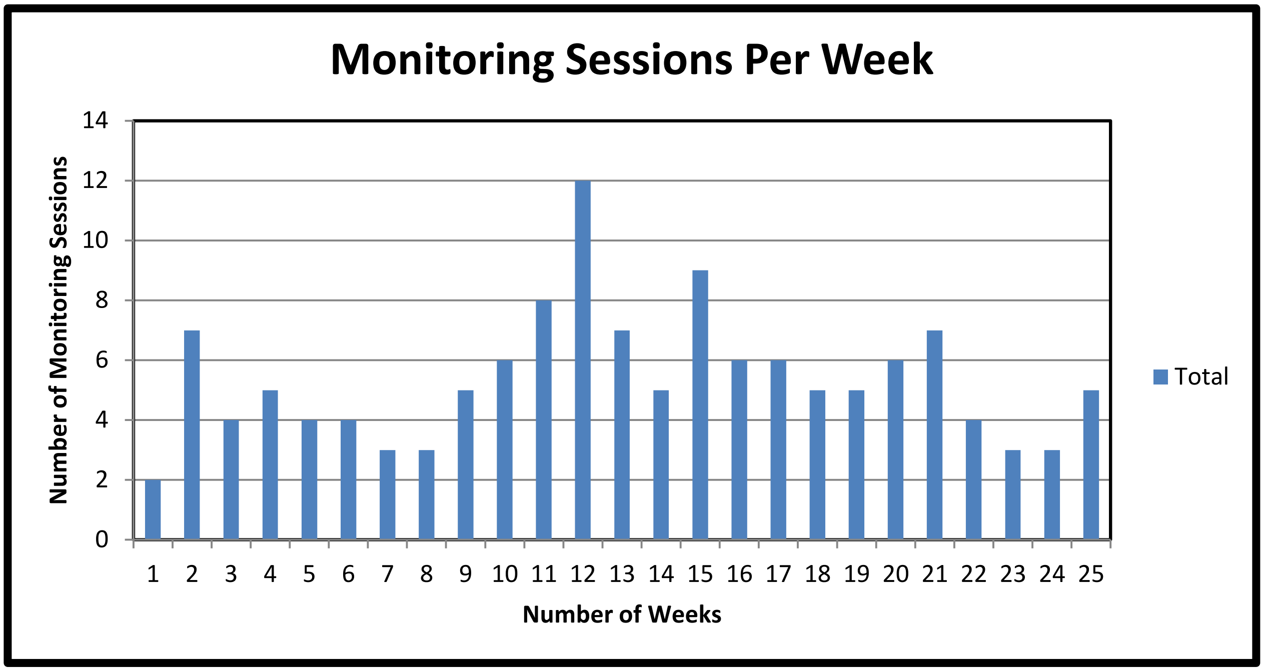

Figure 12. Total Monitoring Sessions - 134.

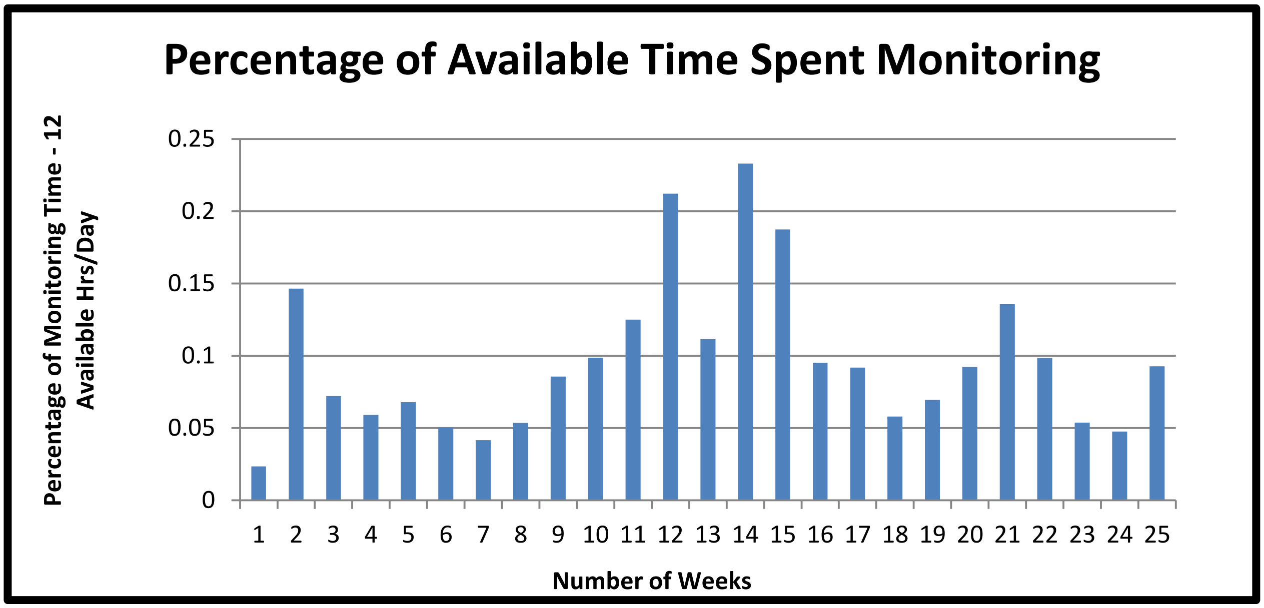

Figure 13. Actual Time Spent Monitoring Based on a 12 Hour Day (2.4%).

Over the course of Phase II, a total of 2,078 WVCs were observed. When analyzing the relative number of WVCs, frog/toad ranked the highest with 1,773 individuals at 85%, followed by 101 turtles at 5%, 77 mammals at 4%, 60 birds at 3%, 37 snakes at 2%, 28 unidentified at 1% and 2 salamander/newt (Figure 14).

Efforts were made to accurately identify each observation on field data sheets with corresponding digital image(s). Where required, images were reviewed by TRCA and partner ecologists and biologists to confirm identification. Some WVCs were difficult to identify due to extent carcass damage.

Wildlife population information for the study area was not available; therefore it cannot be determined whether the numbers of DOR constitute a significant proportion of the resident populations.

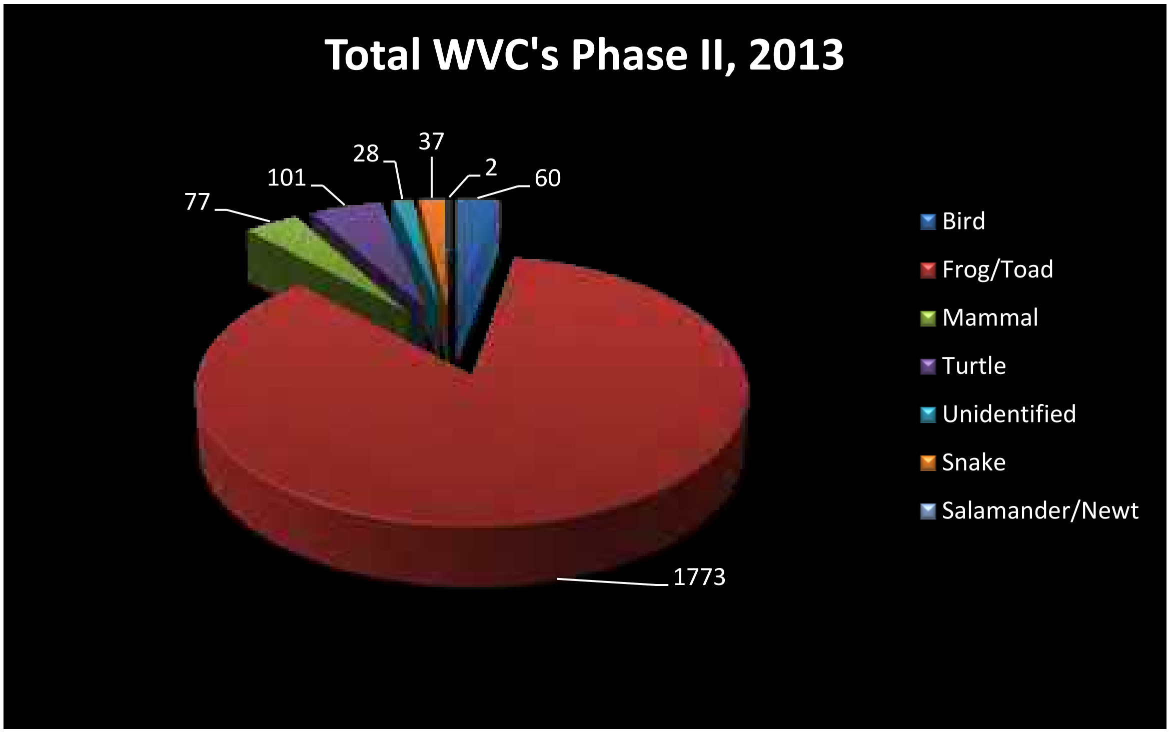

Figure 14. Total WVCs, Phase II, 2013.

WVCs were plotted by taxa and species using GIS and ortho imagery. The following map indicates total number of WVCs (2,078). The total WVC numbers are presented as points indicating multiple fatalities in specific locations within the study area (Figure 15).

Figure 15. Total WVCs in study area (2,078).

The following sequence of maps (Figures 16 to 21) indicates total number of WVCs broken into species fatalities within the SA. These numbers are presented as points indicating multiple fatalities in specific locations.

Figure 16. Frog Mortalities in SA (1,773).

Figure 17. Turtle Fatalities (101).

Figure 18. Mammal Fatalities (77).

Figure 19. Bird Fatalities (60).

Figure 20. Snake Fatalities (37).

Figure 21. Salamander/Newt Fatalities (2).

3.1 Nest protectors

Snapping turtles were observed nesting (Figure 22) at three gravel shoulder locations within the SA. In order to protect the nests against predation, cages were installed on July 3, 2013, at two locations in the north section of the SA and on July 7, 2013, at a mid-section location of the SA. Cages were constructed by staff using 2 cm hex wire netting and held in place with 15 cm plastic stakes (Figure 23). On July 15, 2013, cages were discovered missing from the two north locations and subsequently replaced. When discovering missing cages, volunteers were not able to see signs of predation or damage to nest site. City of Brampton was notified of these protective cages to prevent disturbance during regular road maintenance works. The cages were monitored by volunteers for predation, disturbances and remained in place until September 2, 2013. It was decided to remove cages at this time for hatching season.

Figure 22. Nesting Snapping Turtle.

Figure 23. Turtle Nest Protector – west side of Heart Lake Rd.

4.0 Data Interpretation

Other variables influencing data collection related to this study are briefly explained in the following sub-sections.

4.1 Monitoring Sessions and Observations

The SA was monitored on an opportunistic basis dependent upon volunteer and staff availability. Efforts were made during the twenty five weeks to conduct monitoring sessions at an earliest start time of 0800 hrs (8:00 a.m.), making it possible to collect fresh data before it was unidentifiable or lost to traffic volume and scavengers. Additional opportunistic surveys were conducted by project staff when weather conditions would support mass amphibian movements (e.g. warm, moist nights). Attempts were made to accurately identify each observation on field data sheets with corresponding digital image(s). Where required, images were reviewed by TRCA and partner ecologists and biologists to confirm identification. Some WVCs were difficult to identify due to extent of carcass damage (Figure 24 and 25).

Figure 24. Unidentified carcass.

Figure 25. Unidentified carcass.

4.2 Traffic Data:

There are no existing CoB traffic count stations within the SA and therefore a request was submitted to CoB Works Department staff and a station was positioned covering both north and south traffic. Counters were located slightly south of Countryside Drive and slightly north of Hwy #410/Sandalwood Parkway off-ramp. CoB Works Department provided in-kind traffic data collection at the SA between June 7 and June 13, 2013, (See Appendix F). Vehicle volume totals are listed below:

Weekday: (Friday June 7th and Monday June 10th to Thursday June 13, 2013)
Average Daily Traffic was 5,435 vehicles/day

Weekend: (Saturday June 8th and Sunday June 9, 2013)
Average Daily Traffic was 7,073 vehicles/day

Speed: 85% of vehicles were travelling at an estimated rate of speed of 78.1 km/hr or < (posted speed limit; 60 km/hr)

The traffic survey indicates high volumes of vehicles along this section of Heart Lake Road during this seven day period. Although above traffic count numbers represent a specific and short time period (including the 25 week study period), throughout the year local residents and project volunteers have expressed concerns of high volumes of traffic and speed along Heart Lake Road.

These volumes of traffic may be impacting data collection as some specimens may be run over multiple times by vehicles which could impact WVC counts by (Figure 26 and 27):

- Displacing and/or crushing the body making it difficult/impossible to identify through visual observation; and
- Removing the carcass from study area (body sticking to tire or thrown into surrounding habitat).

Figure 26. Midland painted turtle remains,

Figure 27. Midland painted turtle, remains collected for identification.

4.3 Scavenging

Fatalities of species along roads leave them highly visible to both diurnal and nocturnal scavengers. A scavenging related study in Florida using birds and snakes resulted in 60% to 97% of carcasses being removed within 36 hours (Antworth RL, *et al,* 2005*)*.

When collecting data of wildlife fatalities, accurate numbers may be affected by scavenging and therefore needs to be considered (Antworth RL, *et al*. 2005). Additional information regarding scavenging is available in Appendix E of this report.

5.0 Discussion

This PSW complex adjacent to HLCA has valuable habitat which is home to an abundance of wildlife and species diversity. Within this system, certain species require distinct, separate habitats (i.e. wetland and terrestrial) at different points in their life cycle to breed, forage and hibernate. The surrounding area is highly urbanized with a growing residential population, increasing traffic volume and new development is ongoing. These are contributing factors to high frequency of WVCs within SA.

5.1 Amphibians:

Twenty-six of Ontario's herpetofauna (including eight salamander species) are SAR. The majority of these species are restricted to the southern portion of Ontario, an area which holds the vast majority of human population, and by extension, the highest density of roads. Loss of habitat, vehicle mortality from migration across roads and negative impacts caused by contaminants and pollution are all contributors to the decline of Ontario's herpetofauna.

Frogs are an essential component of wetlands, consuming large numbers of invertebrates and larvae, and are a significant food source for other wildlife. Frogs and salamanders are indicator species and their presence or absence indicates the health of an area. They rely on their skin to breathe and transport electrolytes which makes them very sensitive to negative impacts such as pollutants and contaminants in water bodies. There is global concern regarding the decline of frogs and many studies are currently being conducted to introduce control methods in order to protect these sensitive species (Reptile & Amphibian Ecology, 2011).

Phase II data collection began early April in order to capture peak movement of amphibians as they migrated from hibernation to breeding areas. Data collection ended on September 30, 2013 and temperatures remained warm which may have resulted in additional WVCs not captured in this study. It should be noted that due to the late start date, two species in particular which are well-represented within the HLCA area are likely to be very much under-represented in these results: wood frog (*Lithobates sylvaticus*) and spring peeper (*Pseudacris crucifer*) both emerge as early as late March and undergo synchronised mass migrations from overwintering habitat in upland forests to wetland breeding habitats.

The frog populations at HLCA are especially significant within the Etobicoke watershed context since they represent the most southerly location for several of these species in the watershed. Wood frog, spring peeper and grey tree frog (*Hyla versicolor*) have not been reported in the past decade anywhere south of Sandalwood Parkway. The leopard frog is likewise absent in the watershed below Sandalwood Parkway except for a small population persisting near the lakeshore at Marie Curtis Park.

Phase II data collection revealed 1,773 frog and toad fatalities within the study area. Results for individual species are as follows:

- Unknown - 1016
- Leopard Frog - 460 (Figure 28 and 29)
- Green Frog – 180 (Figure 34 and 35)
- American Toad - 61
- Spring Peeper - 38 (Figure 30 and 31)
- Wood Frog - 9 (Figure 32 and 33)
- Gray Tree Frog - 9

Figure 28. Leopard Frog, Heart Lake Road.

Figure 29. Leopard Frog fatality, Heart Lake Road.

Figure 30. Spring Peeper, Heart Lake Road.

Figure 31. Spring Peeper Fatality.

Figure 32. Wood Frog (egg sack visible), Heart Lake Road.

Figure 33. Wood Frog fatality, Heart Lake Road.

Figure 34. Green Frog, Heart Lake Road.

Figure 35. Green Frog fatality, Heart Lake Road.

5.2 Turtles:

Of the nine species of turtles in Ontario seven are listed as SAR, a Regulation under the Endangered Species Act 2007. Depending on species size, age of maturity can range between 4 to 36 years (Wyneken, 2008). The number of eggs laid by an adult female varies and less than 1% of those eggs will reach sexual maturity. An adult female is a vital part of species continuation and a loss of 1% to 2% percent each year in an area will lead to extirpation in a very short period of time. The habitat of these creatures is declining due to urban development and road development, both of which create fragmentation. This puts them at a higher risk of mortality as they migrate to feeding, breeding and hibernation habitats. Turtle eggs are dependent upon specific conditions to incubate. The exposed, sandy-gravel conditions located on the shoulder of roads provide an ideal location for the turtle to lay her eggs putting her, as well as hatchlings, at risk of WVCs, leading to reduced populations and number of eggs laid each year (KTTC, 2011).

Phase II data collection captured peak movement of turtles in spring migration from hibernation to breeding areas. Data collection ended on September 30, 2013 and although some hatchling movement was captured, temperatures remained warm which may have resulted in additional hatchling movement and WVCs not captured in this study.

Turtle populations at HLCA are of great significance at the watershed level. There have been no reports of midland painted turtles (*Chrysemys picta marginata*) at any wetland south of this location in the Etobicoke Watershed, and only one location is known for snapping turtle. The particularly high number of painted turtles killed on the road during the course of the survey suggests that the local population is thriving, but also begs the question: just how much more of this level of mortality can the population withstand? This question is even more pertinent in the case of the snapping turtles. Although this latter species is dying in lower numbers on this stretch of road than its smaller cousin, snapping turtles are extremely long-lived and take many years to reach sexual maturity; therefore the loss of even a small number of adult snapping turtles (particularly mature females) is potentially devastating for a local population (this was one of the reasons for the species' listing as SAR).

Phase II data collection revealed 101 turtle fatalities within SA. Results for individual species are as follows:

- Midland Painted Turtle - 76 (Figure 36 and 37)
- Snapping Turtle - 15 (Figure 38 and 39)
- Unknown - 10

Figure 36. Midland painted turtle basking, east wetland Heart Lake Road.

Figure 37. Midland painted turtle fatality, Heart Lake Road.

Figure 38. Snapping turtle, Heart Lake Road.

Figure 39. Snapping turtle fatality, Heart Lake Road.

5.3 Mammals

Unlike amphibians and reptiles, many mammals remain active year round. Phase II data collection from April to September captured many mammal fatalities but additional WVCs occurring before and after the study would not be captured.

There are a variety of mammals ranging in size found within the study area. Larger mammal fatalities such as deer and coyote receive more attention due to size and impacts related to human and vehicle damage. Small mammal WVCs, much like amphibians and reptile WVCs, often go unnoticed and unreported. Populations of these small mammals are an extremely significant prey item for predators across several taxa (e.g. for milk snake, SAR) and therefore any local decline in small mammal populations will likely have repercussions for the status of many other local species.

Phase II data collection revealed 77 mammal fatalities within SA. Results for individual species are as follows:

- Unknown - 34
- Raccoon - 13 (Figure 40)
- Muskrat - 7 (Figure 41)
- Gray Squirrel - 6
- Virginia Opossum – 3
- Deer Mouse - 2
- Red Squirrel - 2
- Star-nosed Mole - 2
- Striped Skunk - 2
- Eastern Chipmunk - 2
- Eastern Cottontail - 2
- American Mink - 1 (Figure 42)
- Domesticated Cat – 1

Figure 40. Raccoon fatality, gravel shoulder Heart Lake Road.

Figure 41. Muskrat fatality, Heart Lake Road.

Figure 42. American Mink fatality, Heart Lake Road.

5.4 Birds

The wetlands surrounding this study area provide resting and feeding areas for migratory birds, nesting habitat, nurseries for fledglings (Figure 50) and attract a variety of common and locally significant bird species year round.

Aquatic habitat proximity within SA contributes to bird WVCs due to minimum buffer zones between vehicle traffic and preferred habitat. One theory of high rates of bird fatalities is the inability to reach clearance height from trees closely bordering roadways and subsequently being hit by passing vehicles (Jaeger JAG, 2012).

In North America at least 20 species previously categorized as common have declined more than 50% in the last forty years. One likely contributor is the expansion of paved roads, mostly in terms of widening, and corresponding increases in the speed and volume of vehicles on those roads. It is difficult to measure the true extent of vehicle induced mortality because estimates are typically far lower than the actual number of birds killed; estimation accuracy is reduced by variation in researcher efficiency, scavenger bias, and incorrect attribution of cause of death (Kociolek et al, 2010).

Phase II data collection revealed 60 bird fatalities within the study area. Results of individual species are as follows:

- Unknown - 15
- American Goldfinch - 13
- Cedar Waxwing - 8
- Canada Goose - 5 (Figure 47 & 48)
- American Redstart - 2 (Figure 43)
- Black-billed Cuckoo - 2
- Hooded Merganser - 2
- Northern Cardinal - 2
- American Robin - 1
- Grey Catbird - 1
- Mourning Dove - 1
- Northern Flicker - 1
- Northern Rough-winged Swallow - 1
- Pie-billed Grebe - 1 (Figure 49 & 50)
- Red Winged Blackbird - 1
- Song Sparrow - 1 (Figure 44)
- Tree Swallow - 1 (Figure 46)
- Wilson's Warbler - 1 (Figure 45)
- Yellow Warbler – 1

Figure 43. American Redstart fatality, Heart Lake Rd.

Figure 44. Song Sparrow fatality, Heart Lake Rd.

Figure 45. Wilson's Warbler fatality, Heart Lake Rd.

Figure 46. Tree Swallow fatality, Heart Lake Rd.

Figure 47. Canada Goose fatality, Heart Lake Rd.

Figure 48. Canada Goose and gosling, Heart Lake Rd.

Figure 49. Adult male Pied-billed Grebe fatality, Heart Lake Rd.

Figure 50. Pied-billed Grebe fledglings, Heart Lake Rd.

5.5 Snakes:

Ontario snake migration to hibernacula typically occurs in the fall when temperatures start to drop. Phase II data collection, ended on September 30, 2013 and temperatures were still relatively warm which may have been prior to peak migration activities. As temperatures continued to drop, additional snake movement may have occurred resulting in additional WVCs not captured in this study.

Ten of the seventeen species of snakes in Ontario are listed as SAR. Again, snakes play an essential role in maintaining biodiversity of an ecosystem. They are both predator and prey, keeping the rodent population down but are also a food source to several predator species such as hawks. It is believed that human fear of these creatures contributes to their mortality. Many people are afraid of snakes and studies show humans attempt to deliberately deplete these species.

Phase II data collection revealed 37 snake fatalities within the study area. Results of individual species are as follows:

- Eastern Garter snake - 16 (Figure 52 & 53)
- Unknown - 17
- Eastern Milk snake (SAR) - 2 (Figure 51)
- Northern Red-bellied Snake – 2

Figure 51. Eastern milk snake fatality (SAR), Heart Lake Rd.

Figure 52. Garter snake, Heart Lake Rd.

Figure 53. Garter snake fatality, Heart Lake Rd.

5.6 Salamander & Newts

Salamanders and newts are an important component of local ecosystems, as they consume large quantities of insects and are a food source for other wildlife. As with other amphibians, these creatures are very sensitive to changes in the environment and are recognized as indicator species. Ontario's SAR lists four types of salamanders as endangered and two are extirpated, meaning they no longer exist in Ontario.

Phase II data collection revealed 2 salamander/newt (Figure 54) fatalities within the study area, both of which were unidentifiable due to condition of the remains.

Figure 54. Eastern Newt, Heart Lake Rd.

5.7 Unidentified

It is important to consider when analysing results of these WVCs, many smaller species particularly among the amphibians (e.g. spring peepers, and any yearling frogs), disappear very quickly after being involved in a WVC especially in wet weather. Most amphibians move at night resulting in greater number of WVCs occurring in the evening. If the road becomes wet shortly after the fatality, carcases rapidly deteriorate and will likely be completely gone by the following day. This suggests that frog WVC totals presented in the preceding text will be a fraction of the actual number of fatalities. Furthermore, many carcasses are scavenged in early morning hours by foraging birds and mammals, and it becomes clear that despite large numbers of WVCs presented in this study, they may only represent a portion to total WVCs during the study period.

Phase II data collection revealed 28 fatalities which were unidentifiable (Figure 55) within SA. Despite efforts to accurately collect and identify data through images and outreach to biologists, some fatalities could not be identified. In some cases deterioration of the carcass was so extreme that identification could not even be made to class – mammal, bird, reptile or amphibian.

Figure 55. Unidentified fatality (28 total) – Heart Lake Rd.

6.0 Mitigation Recommendations

The designation of a PSW complex within this highly urbanized area along Heart Lake Road provides both unique challenges and opportunities. Moving forward with mitigation to reduce WVCs will require a strategy that integrates or incorporates a variety of techniques.

High volumes of WVCs in Phase I (2011) and Phase II (2013) as indicated in the charts below (Figures 56 and 57) provide rationale to move forward with mitigation. Hotspots (Figure 58) confirmed by data collection indicate areas to target mitigation and reduce WVCs and help protect local wildlife populations.

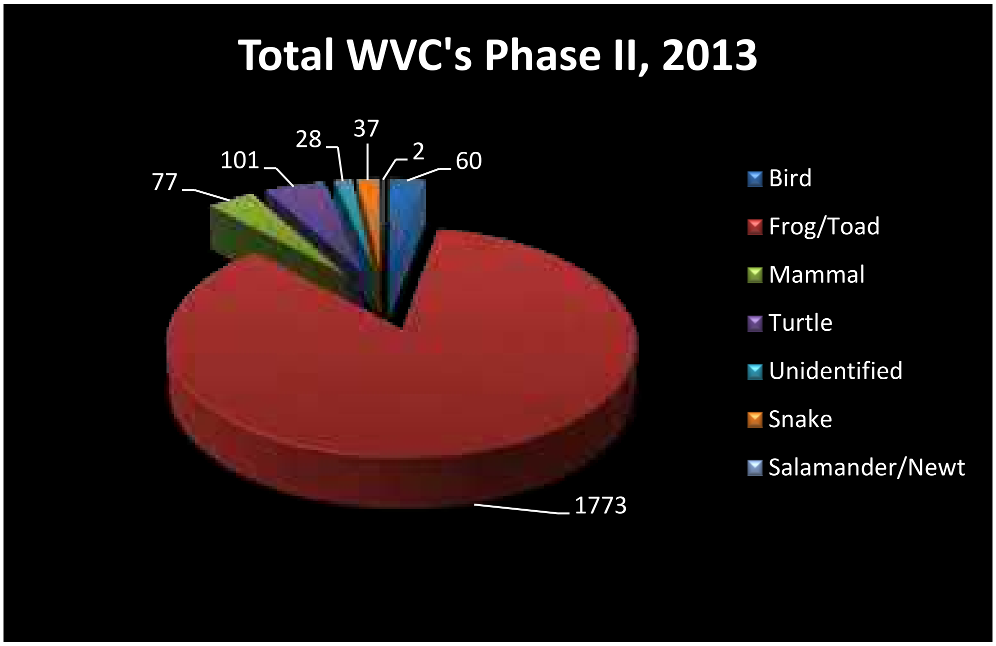

Figure 56. Phase II, HLREMP fatalities 2013.

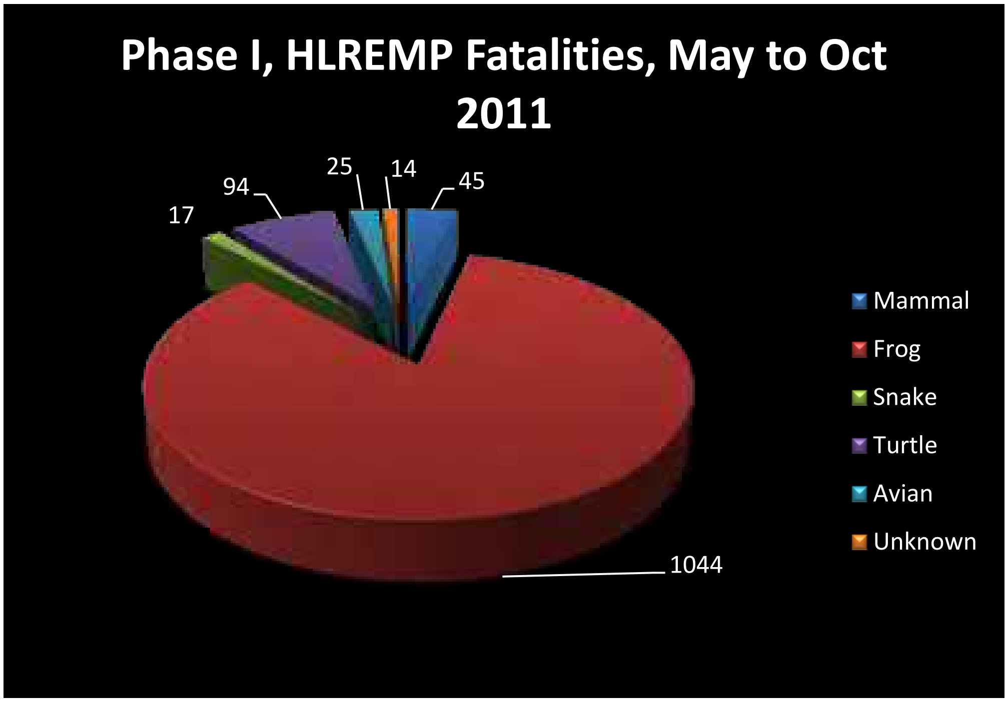

Figure 57. Phase I, HLREMP fatalities 2011.

Data from Phase I and II show fatalities occurring along the entire length of SA(s). Phase II data interpretation grouped fatalities at fixed GPS points within SA represented by the following:

- Yellow = 1
- Light pink = 2 to 42
- Dark pink = 43 to 54
- Red = 55 to 71
- Burgundy = 72 to 114

Figure 58. WVC Hotspots, Phase II SA.

From these data sets, staff determined that hotspots are represented by red and burgundy icons are areas which experience largest number of fatalities ranging from 55 to 114 at a fixed GPS location. As indicated, there are seven (7) red icons and seven (7) burgundy icons. These are grouped into three (3) sections to help divide SA into manageable areas in order to move forward with implementing mitigation techniques to reduce WVCs.

There are effective and affordable mitigation strategies to assist with protection of biodiversity and recovery of SAR. Mitigation is feasible within SA but there are ecological and engineering complications as decades ago this road was built through a wetland complex and as a result, poses challenges to any construction upgrades. Construction timing and methods will have to be sensitive to the PSW and there are unique engineering considerations to be integrated. SAR are found in the study area and road mortality mitigation for these taxa is referenced in ESA (http://www.e-laws.gov.on.ca/html/regs/english/elaws_regs_080242_e.htm).

Mitigation involves taking advantage of existing land elevations and contours and includes overpasses, underpasses, fencing and raised roads. When considering these options in species conservation, assessment of existing habitat is essential. It may not be feasible and/or possible to restore heavily fragmented areas due to existing depletion and/or extinction of species (Jaeger JAG, 2012).

The following sections provide an overview of mitigation considerations that can be implemented within SA to help protect local wildlife populations and reduce WVCs. This would include physical changes to infrastructure, planning policy changes, habitat and breeding area enhancement, community education and continued monitoring to track success of mitigation

6.1 Wildlife Culverts and Directional Fencing

Reptiles and amphibians are an important component to ecosystems. Amphibians stay within close proximity of their breeding sites, and most juveniles stay within one kilometer. When a road bisects seasonal habitat and breeding sites, high levels of amphibian traffic will occur over these roads during peak breeding seasons (Ovaska *et al*., 2005). Research has shown that when comparing mitigation options for reptiles and amphibians, culverts, concrete box structures, wildlife directional fencing systems and relocation of breeding sites tend to work best (Ovaska *et al*., 2005). Studies have also found that small to mid-sized mammals will also take advantage of culverts and concrete box structures (Beier *et al*., 2008).

Oversize culverts and wildlife directional fencing systems should be strategically placed at wildlife crossing hotspots with proper installation and post-project monitoring and maintenance programs in place. Following completion of 2011 study, results were shared with CoB staff and Brampton Environmental Planning and Advisory Council (BEPAC) which led to recommendations to locate existing culverts and determine if their conditions were suitable to safely facilitate wildlife movement across the road. Field investigations revealed a small number of pre-existing culverts along Heart Lake Road which were located by CoB and TRCA in 2012. Staff found these culverts to have the following limitations for wildlife passage:

- Not in ideal locations for wildlife crossing;
- Undersized;
- Blocked with debris;
- Below water level;
- Serve primarily as a hydrological function to allow water flow between bisected wetlands; and
- Limited airflow and light penetration.

When using culverts for wildlife passage, it is essential to incorporate as much of the natural habitat as possible by placing substrate on the culvert base versus uncovered steel or concrete (Ovaska et al., 2005). For the mitigation procedure to be effective the culvert(s) should be placed relatively close to crossing hotspots (*Bissonette & Cramer,* 2008). Since existing culverts are not suitable for wildlife passage at hotspots, installing new structures should be considered. Specialized wildlife tunnels (Figure 59) are preferred where they can be installed, as they provide air flow and lighting resulting in improved interior conditions. An alternative suitable option is oversized concrete box structures or CSPs (diameter = 1.2 m or greater) (Figure 60 and 61). These units are larger and combined with overhead grate-type road surface openings (minimum 0.6 x 0.6 m) similar to catch basins with covers (Figure 62) provide greater air flow and lighting which is more inviting to reptiles, amphibians, and small mammals.

For this study, options to decrease WVCs include installing oversize culverts with road surface grate-type openings to allow air-flow and lighting and permanent directional fencing. Extensive research, years of data compilations and studies have proven under-road tunnels to be effective at conserving and sustaining amphibian and reptile populations (Jolivet *et al*., 2008).

Depending on site conditions, perched oversized CSPs for dry passage of small wildlife can be installed or partially submerged swim-through oversized CSPs can be used for passage of aquatic small wildlife (Figure 63).

Figure 59. ACO Wildlife passage.

Figure 60. Oversized concrete box culvert.

Figure 61. Oversized CSP culvert (Photo Credit: Great Wall Co).

Figure 62. Overhead grate-type road surface covering.

Figure 63. Oversized CSP culvert, partially submerged.

In addition to oversized culverts, permanent wildlife directional fencing is necessary to guide wildlife to culverts. There are several permanent directional fencing options that can be considered (Figure 64 to 67). Wildlife directional fencing requirements need to be installed as part of a long-term solution. Features of fencing include;

having no gaps along/under fencing preventing smaller wildlife access to road, have an angled top to prevent wildlife climbing over, be of durable materials, UV resistant, able to withstand weather conditions and winter road maintenance impacts, easy to maintain and not interfere with road safety. Additionally this fencing is targeted to smaller wildlife and does not restrict movement of larger wildlife. Fencing specific for managing WVCs for larger wildlife can also be considered as part of a strategy in applicable locations (Figure 68), while still protecting smaller species.

Figure 64. Directional wildlife fence, buried guardrail (Photo Credit: Aresco MJ).

Figure 65. Directional wildlife fence, steel piling (Photo Credit: Aresco MJ).

Figure 66. Directional wildlife fence, ACO one-way wildlife fence.

Figure 67. Directional fencing, partially buried hardware cloth fence with rail (MNR, 2013).

Figure 68. Directional fencing, chain link with hardware cloth, one-way entry from road.

6.2 Turtle Beaches for Nesting

Disturbances from human activities can change behaviour patterns of wildlife migration, nesting and breeding activities. Gravel shoulders of roads provide ideal nesting sites for turtles which was observed by volunteers in both Phase I and Phase II of this study. During 2013 data collection, a total of three female snapping turtles (SAR) were observed nesting at Countryside Drive and Heart Lake Road on both east and west gravel shoulders, as well as the west side of Heart Lake Rd across from Lakeside Garden Gallery Nursery. This does not represent all potential nesting sites in gravel shoulders along Heart Lake Road. All three nest sites were protected by placing wire cages over each site and monitored by staff.

Additional mitigation options for this site include installation of turtle nesting and basking beaches (Figure 69) providing a safer alternative to gravel shoulders. Installing turtle beaches in areas away from Heart Lake Rd will provide safer habitat for females to nest and protect emerging hatchlings. Installation (Figure 70) involves choosing a site with south facing exposure to provide direct sunlight, allow ample drainage and being positioned in an area where there is low risk of flooding. Steps include, removing approximately 15 cm (6 inches) of existing vegetation and soil from surface, placing landscape fabric on prepped site and applying a mix of pea gravel and sand evenly over area to a depth of 40 cm (15 inches). It is recommended to construct nesting/basking beaches in fall after existing nests have hatched. Although this mitigation option will not prevent turtles from using gravel shoulders to nest, it provides a plausible alternative. Combined with other mitigation techniques as outlined in this report turtle beaches are an important component of an overall mitigation strategy for this SA.

Figure 69. Turtle Beach, Rouge Park Ontario (Adopt-A-Pond 2012).

Figure 70. Steps to install turtle nesting/basking beach (Adopt-A-Pond 2012).

6.3 Traffic Speeds and Volumes

Based on feedback from project volunteers and staff, along with traffic study results, this section of Heart Lake Road is subject to high volumes of vehicle traffic and excessive speeds. Another mitigation option to be explored for SA is implementing a three-way stop at the intersection of Countryside Drive and Heart Lake Road. The existing stop sign located on Countryside Drive for westbound traffic would be augmented by two additional stop signs for both north and south bound traffic on Heart Lake Road (Figure 71). Installing additional stop signs will help reduce speeds, preventing WVCs with certain sized wildlife by increasing motorist's chances of seeing the animal prior to collision and reduce chances of vehicle and collision related injuries. Slowing down traffic volume along this road will also provide the opportunity to reinforce the following messages:

- additional signage to reinforce messages related to the sensitivity and significance of this area;
- various wildlife vulnerable to WVCs; and
- efforts being made by CoB to reduce wildlife fatalities.

CoB currently posts turtle crossing signs on Heart Lake Road just south of Mayfield Road for southbound traffic and north of Sandalwood Parkway for northbound traffic. These signs are installed and removed to correspond with turtle movement. Examples of additional signage are shown in Figures 72 to 76. Consideration should also be given to signs, both graphic and electronic, being installed and removed at specific times throughout the year. This would help motorists acknowledge signs and raise awareness of species diversity.

Figure 71. Intersection, Heart Lake Rd and Countryside Dr (north view).

Figure 72. Wildlife crossing sign (Photo Credit: University of Guelph).

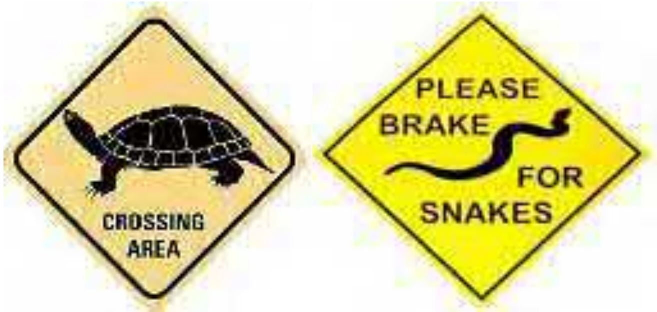

Figure 73. Wildlife crossing sign (Photo Credit: Toronto Zoo, OREG).

Figure 74. Wildlife crossing sign (Photo Credit: Nature Conservancy).

Figure 75. Wildlife sign (Photo Credit: Photo Gallery).

Figure 76. Road sign, Provincially Significant Wetland, (Photo Credit: Kawartha Naturalists).

Additional traffic surveys should also be conducted along Heart Lake Road to better understand traffic volumes and patterns to assist planners with managing and reducing traffic volumes. Lower traffic volumes, reduced speeds and wildlife signage are additional components of an effective mitigation strategy for this SA.

The Ministry of Transportation of Ontario (MTO) is developing a Wildlife Mitigation Strategy to undertake short (e.g. signage) and long-term (e.g. fencing and dedicated wildlife passages) mitigation for small and large animals. The key elements of the strategy include:

- gather available data on wildlife populations and habitats intersected by roads (including SAR) as well as road mortality and wildlife/vehicle collision data;
- perform geospatial analyses on these data to map and prioritize the areas of greatest need for wildlife mitigation from a conservation and safety perspective;
- collaborate with municipal, regulatory and non-government partners (including OREG and academia) to establish a coordinated strategy for effective siting of mitigation measures; and
- identify and review tools to assist in related areas such as public awareness, education and standardized collision data collection.

As Brampton moves forward to reduce WVCs along Heart Lake Road, consultation with MTO would provide additional guidance and resources for the development of their mitigation strategy and implementation of mitigation projects.

6.4 Education and Awareness

There is a need to raise awareness amongst decision makers, various levels of government and the public. The following recommendations should be considered to help with education and awareness of road ecology:

- Community Level Education – government to work with conservation organizations (i.e. OREG, TRCA) to provide public outreach and education programs to raise awareness related to ecological effects of roads. Community events, schools, local media, digital media, brochures, and road signage are examples of tools that can be used;
- Staff Level Education – transportation and planning agencies to train and educate staff about the ecological effects of roads and incorporate road ecology into the planning process; and
- Construction and Building Community – collaborate with transportation and planning agencies and local Conservation Authorities to educate developers on Road ecology and develop certification programs for the installation of various mitigation options.

Additionally, city planning and developers should work together to better understand and integrate road ecology into urban development process. This can be accomplished by:

- Conducting monitoring projects prior to road development and expansion adjacent to natural spaces during which monitoring data related to wildlife movement (migration patterns, habitat requirements, species sensitivity, etc.) should be collected, reviewed and considered prior to providing approvals and construction permits;
- Reviewing and incorporating wildlife movement data into project designs prior to improving and/or expanding existing roads or for new road construction. These types of projects may provide a greater opportunity to install a permanent barrier to guide wildlife toward preferred crossing areas, replace undersized culverts, or install new culverts or tunnels at identified crossing hotspots; and
- Co-operation between government and conservation organizations (i.e. OREG, TRCA) to develop policy and legislation in areas of road ecology to aid transportation and planning agencies in designing more ecologically-sustainable transportation networks.

7.0 Conclusion and Next Steps

The objective of Phase I was to better understand which species were being impacted by interactions with vehicles, how many interactions were occurring, and to suggest mitigation measures to protect local biodiversity in the wetland systems adjacent to Heart Lake Road. Phase II provided an opportunity to further investigate WVCs, determine hotspots and provide a solid mitigation strategy.

Data analysis from Phase II reveals continued high volumes of WVCs along this stretch of Heart Lake Road and evidence of diverse wildlife including SAR. Mitigation options have been outlined in greater detail to allow decision makers the opportunity of implementing a solution.

Staff and partners working on this project have recognized mitigation is necessary and strongly support moving forward with implementation of mitigation within SA. Understanding there are challenges with respect to infrastructure and site conditions, implementing a mitigation strategy to address all WVCs in the SA will require a significant amount of time, effort and financial commitment. It is imperative that CoB take the initial step to move forward by targeting at least one of the identified hotspots and implementing one or more of the techniques outlined in this report.

All project partners are committed to moving forward and assisting CoB with this initial step as well as the development of a long term mitigation strategy.

Based on discussions and field observations between TRCA and CoB staff in 2012, the preferred initial target area is located in hot spot Area #2 (Figure 58), slightly north of the entrance to HLCA. Staff recognized this area as being more conducive to supporting the installation of an oversized culvert and permanent directional wildlife fencing. Once a decision is made, project partners will work together to assist with design details, location and pre and post monitoring to evaluate the success of mitigation.

The Heart Lake Provincially Significant Wetland complex is not only a unique feature in an urban setting but is a valuable asset to local wildlife and Brampton residents. CoB has indicated their commitment through support of this project and will be leaders in the GTA and local municipal champions in the field of Road Ecology by implementing ground-breaking mitigation measures to decrease WVCs and wildlife protection (including SAR).

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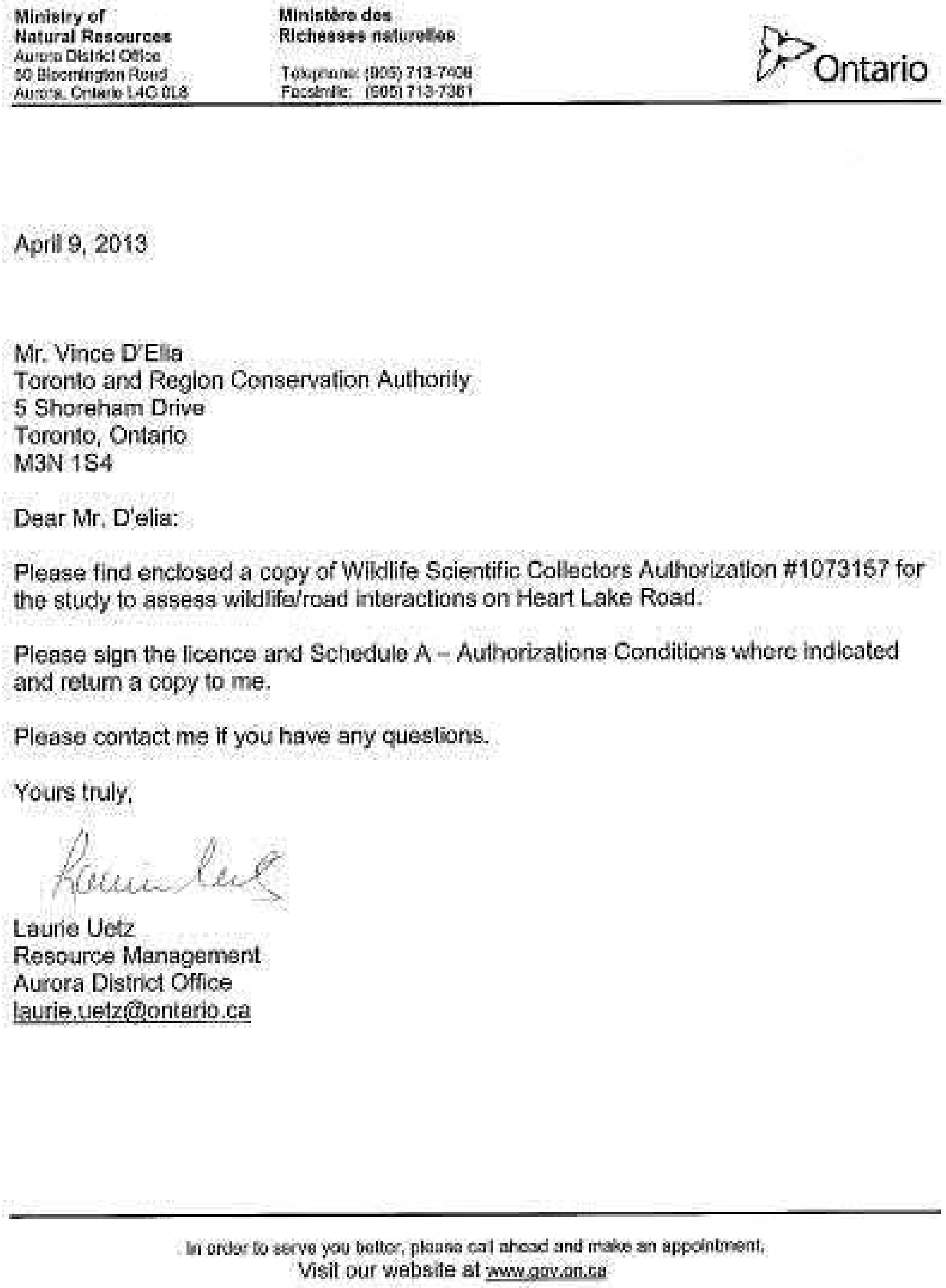
APPENDIX A

MNR Wildlife Handling Permits



Ministry of
Natural Resources
Aurora District Office
50 Bloomington Road
Aurora, Ontario L4G 0L8

Ministère des
Richesses naturelles

Téléphone: (905) 713-7400
Facsimile: (905) 713-7361

Ontario

April 9, 2013

Mr. Vince D'Elia
Toronto and Region Conservation Authority
5 Shoreham Drive
Toronto, Ontario
M3N 1S4

Dear Mr. D'elia:

Please find enclosed a copy of Wildlife Scientific Collectors Authorization #1073157 for the study to assess wildlife/road interactions on Heart Lake Road.

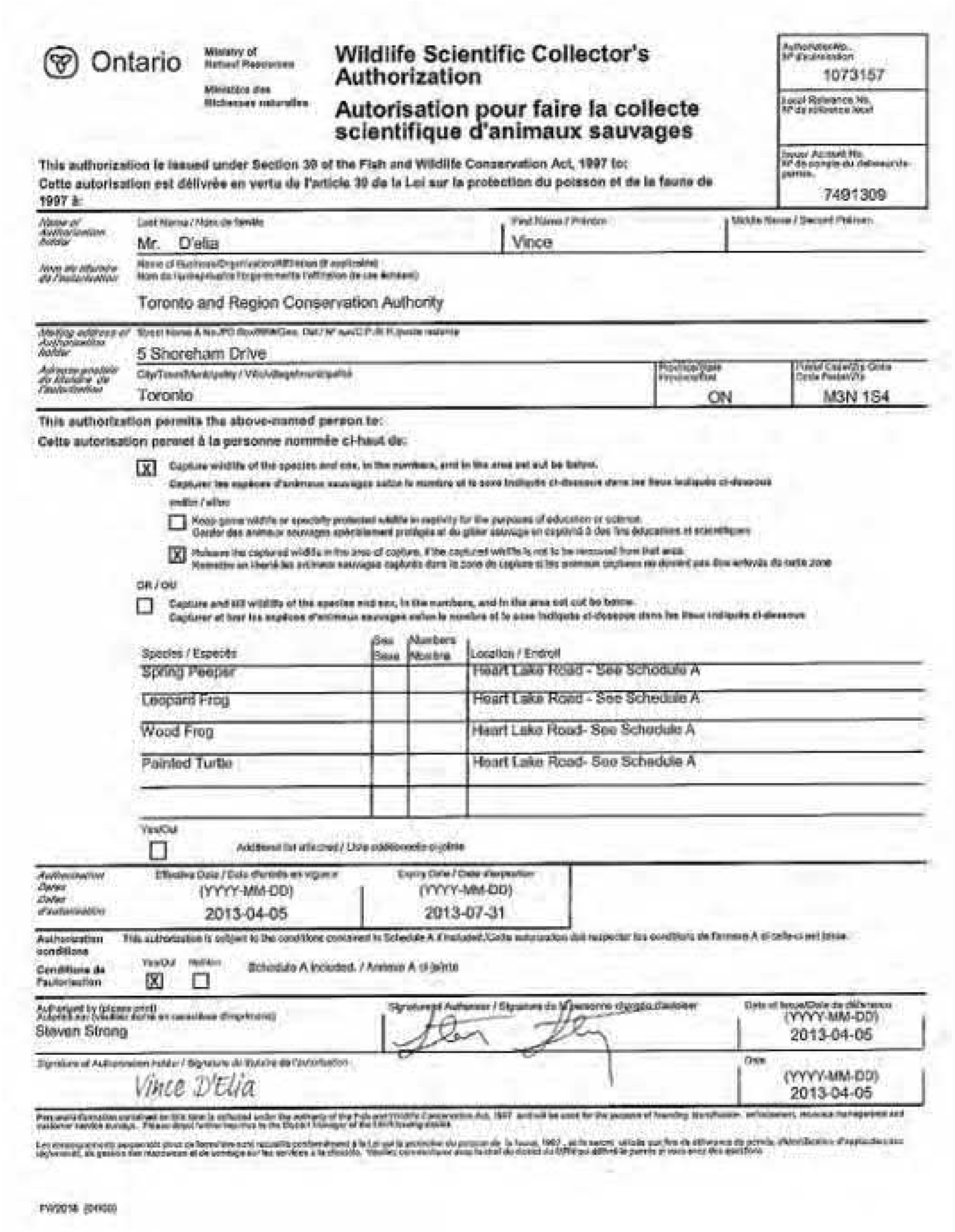
Please sign the licence and Schedule A – Authorizations Conditions where indicated and return a copy to me.

Please contact me if you have any questions.

Yours truly,

Laurie Uetz
Resource Management
Aurora District Office
laurie.uetz@ontario.ca

In order to serve you better, please call ahead and make an appointment.
Visit our website at www.gov.on.ca



Ontario

Ministry of Natural Resources

Ministère des Richesses naturelles

Wildlife Scientific Collector's Authorization

Autorisation pour faire la collecte scientifique d'animaux sauvages

Authorization No. / Nº d'autorisation
1073157

Local Reference No. / Nº de référence local

Issuer Account No. / Nº de compte du délivreur de permis
7491309

This authorization is issued under Section 30 of the Fish and Wildlife Conservation Act, 1997 to:
Cette autorisation est délivrée en vertu de l'article 30 de la Loi sur la protection du poisson et de la faune de 1997 à:

Name of Authorization holder / Nom du titulaire de l'autorisation

Last Name / Nom de famille: Mr. D'elia
First Name / Prénom: Vince
Middle Name / Second Prénom:

Name of Business/Organization/Affiliation (if applicable) / Nom de l'entreprise/de l'organisme/de l'affiliation (le cas échéant)
Toronto and Region Conservation Authority

Mailing address of Authorization holder / Adresse postale du titulaire de l'autorisation

Street Name & No./PO Box/RR#/Gen. Del. / Nº rue/C.P./R.R./poste restante
5 Shoreham Drive

City/Town/Municipality / Ville/village/municipalité: Toronto
Province/State / Province/État: ON
Postal Code/Zip Code / Code Postal/Zip: M3N 1S4

This authorization permits the above-named person to:
Cette autorisation permet à la personne nommée ci-haut de:

☒ Capture wildlife of the species and sex, in the numbers, and in the area set out below.
Capturer les espèces d'animaux sauvages selon le nombre et le sexe indiqués ci-dessous dans les lieux indiqués ci-dessous

and/or / et/ou

☐ Keep game wildlife or specially protected wildlife in captivity for the purposes of education or science.
Garder des animaux sauvages spécialement protégés et du gibier sauvage en captivité à des fins éducatives et scientifiques

☒ Release the captured wildlife in the area of capture, if the captured wildlife is not to be removed from that area.
Remettre en liberté les animaux sauvages capturés dans la zone de capture si les animaux capturés ne doivent pas être enlevés de cette zone

OR / OU

☐ Capture and kill wildlife of the species and sex, in the numbers, and in the area set out below.
Capturer et tuer les espèces d'animaux sauvages selon le nombre et le sexe indiqués ci-dessous dans les lieux indiqués ci-dessous

Species / Espèce	Sex / Sexe	Numbers / Nombre	Location / Endroit
Spring Peeper			Heart Lake Road - See Schedule A
Leopard Frog			Heart Lake Road - See Schedule A
Wood Frog			Heart Lake Road- See Schedule A
Painted Turtle			Heart Lake Road- See Schedule A

Yes/Oui
☐ Additional list attached / Liste additionnelle ci-jointe

Authorization Dates / Dates d'autorisation

Effective Date / Date d'entrée en vigueur (YYYY-MM-DD)	Expiry Date / Date d'expiration (YYYY-MM-DD)
2013-04-05	2013-07-31

Authorization conditions / Conditions de l'autorisation

This authorization is subject to the conditions contained in Schedule A if included./Cette autorisation doit respecter les conditions de l'annexe A si celle-ci est jointe.

Yes/Oui ☒ No/Non ☐ Schedule A included. / Annexe A ci-jointe

Authorized by (please print) / Autorisé par (veuillez écrire en caractères d'imprimerie)
Steven Strong

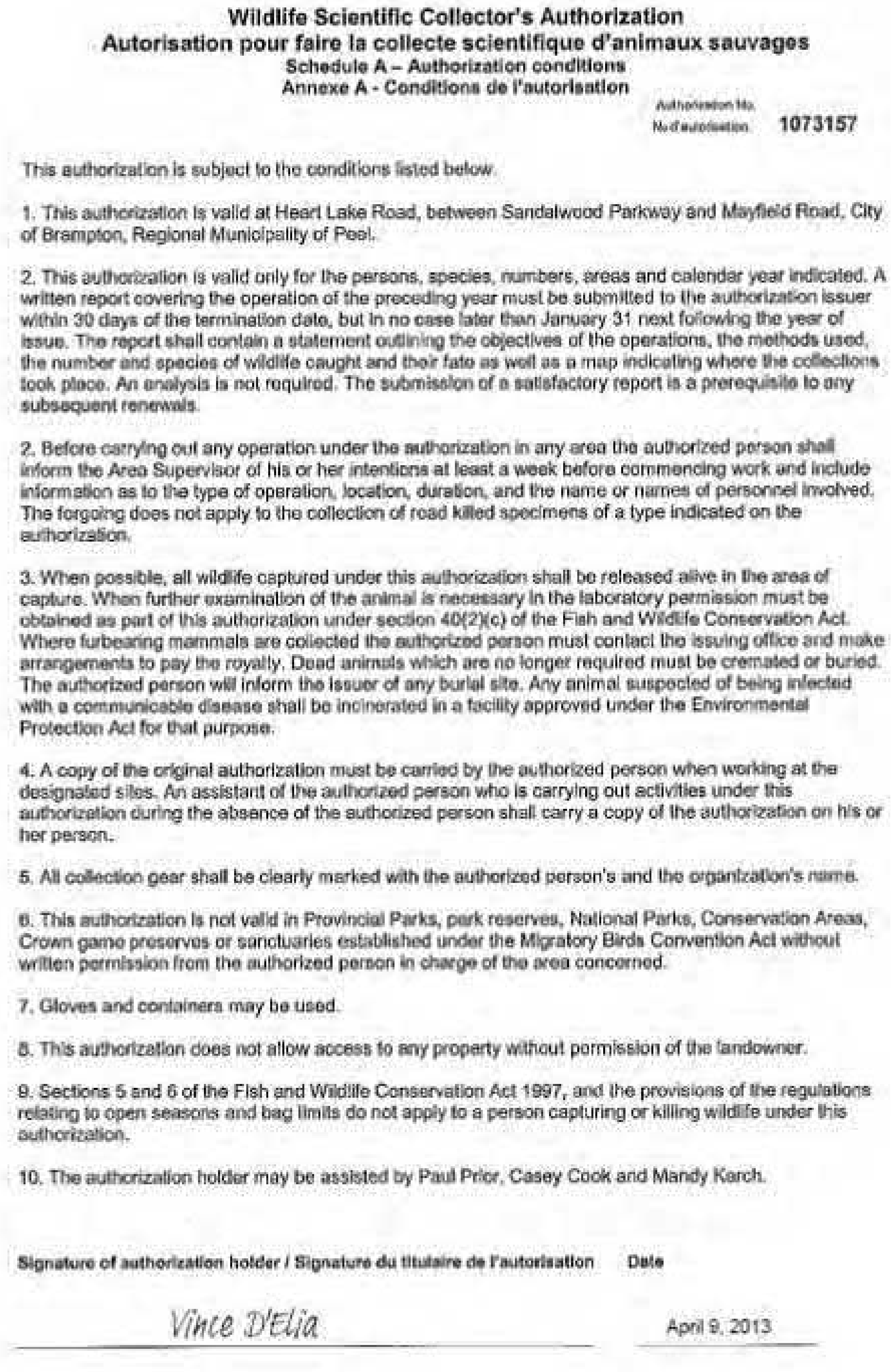
Signature of Authorizer / Signature de la personne qui a délivré

Date of Issue/Date de délivrance (YYYY-MM-DD)
2013-04-05

Signature of Authorization holder / Signature du titulaire de l'autorisation
Vince D'Elia

Date (YYYY-MM-DD)
2013-04-05

FW2016 (04/00)



Wildlife Scientific Collector's Authorization
Autorisation pour faire la collecte scientifique d'animaux sauvages
Schedule A – Authorization conditions
Annexe A - Conditions de l'autorisation

Authorization No.
No d'autorisation **1073157**

This authorization is subject to the conditions listed below.

1. This authorization is valid at Heart Lake Road, between Sandalwood Parkway and Mayfield Road, City of Brampton, Regional Municipality of Peel.

2. This authorization is valid only for the persons, species, numbers, areas and calendar year indicated. A written report covering the operation of the preceding year must be submitted to the authorization issuer within 30 days of the termination date, but in no case later than January 31 next following the year of issue. The report shall contain a statement outlining the objectives of the operations, the methods used, the number and species of wildlife caught and their fate as well as a map indicating where the collections took place. An analysis is not required. The submission of a satisfactory report is a prerequisite to any subsequent renewals.

2. Before carrying out any operation under the authorization in any area the authorized person shall inform the Area Supervisor of his or her intentions at least a week before commencing work and include information as to the type of operation, location, duration, and the name or names of personnel involved. The forgoing does not apply to the collection of road killed specimens of a type indicated on the authorization.

3. When possible, all wildlife captured under this authorization shall be released alive in the area of capture. When further examination of the animal is necessary in the laboratory permission must be obtained as part of this authorization under section 40(2)(c) of the Fish and Wildlife Conservation Act. Where furbearing mammals are collected the authorized person must contact the issuing office and make arrangements to pay the royalty. Dead animals which are no longer required must be cremated or buried. The authorized person will inform the issuer of any burial site. Any animal suspected of being infected with a communicable disease shall be incinerated in a facility approved under the Environmental Protection Act for that purpose.

4. A copy of the original authorization must be carried by the authorized person when working at the designated sites. An assistant of the authorized person who is carrying out activities under this authorization during the absence of the authorized person shall carry a copy of the authorization on his or her person.

5. All collection gear shall be clearly marked with the authorized person's and the organization's name.

6. This authorization is not valid in Provincial Parks, park reserves, National Parks, Conservation Areas, Crown game preserves or sanctuaries established under the Migratory Birds Convention Act without written permission from the authorized person in charge of the area concerned.

7. Gloves and containers may be used.

8. This authorization does not allow access to any property without permission of the landowner.

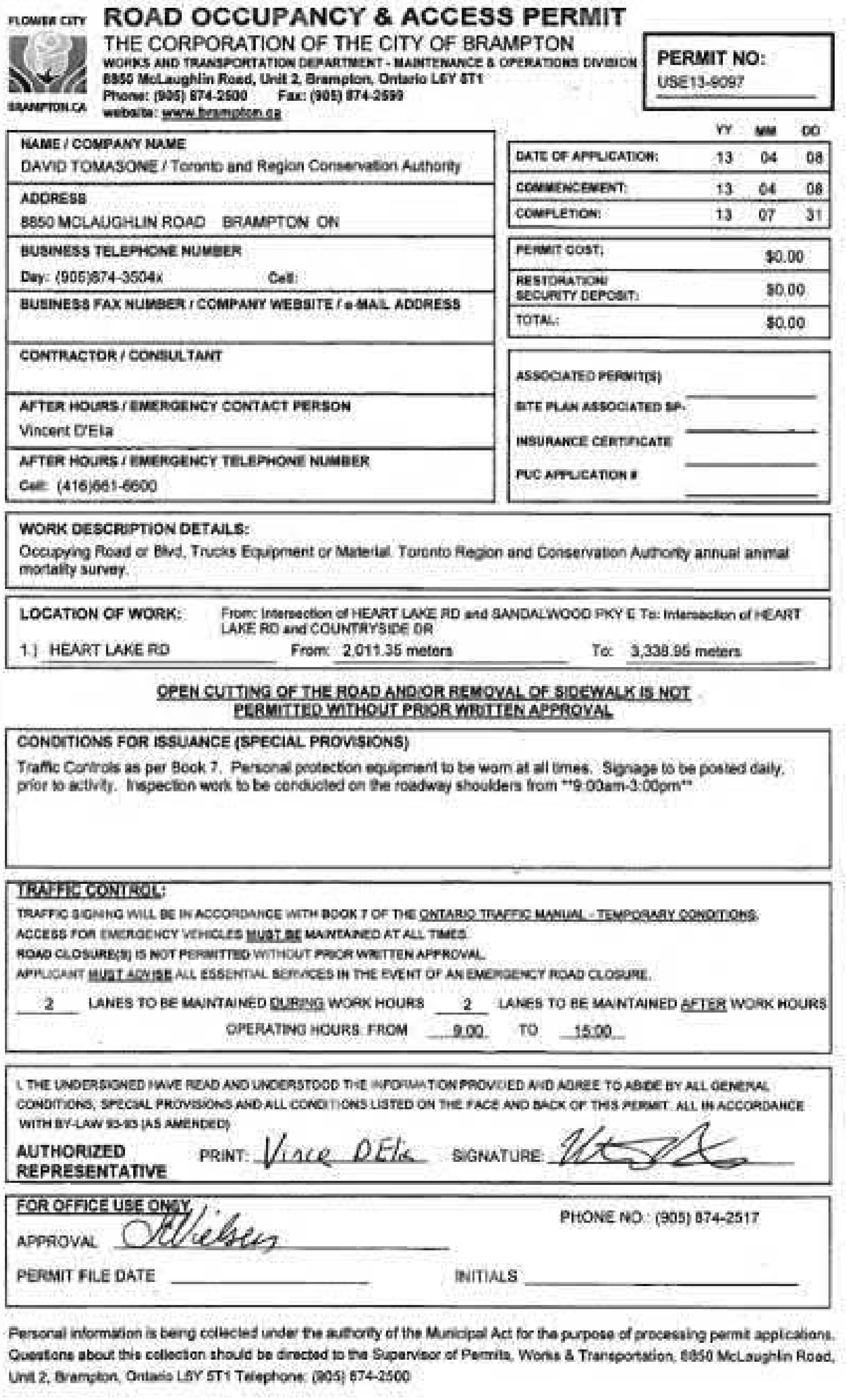
9. Sections 5 and 6 of the Fish and Wildlife Conservation Act 1997, and the provisions of the regulations relating to open seasons and bag limits do not apply to a person capturing or killing wildlife under this authorization.

10. The authorization holder may be assisted by Paul Prior, Casey Cook and Mandy Karch.

Signature of authorization holder / Signature du titulaire de l'autorisation **Date**

Vince D'Elia April 9, 2013

City of Brampton Road Permit



FLOWER CITY
BRAMPTON.CA

ROAD OCCUPANCY & ACCESS PERMIT

THE CORPORATION OF THE CITY OF BRAMPTON
WORKS AND TRANSPORTATION DEPARTMENT - MAINTENANCE & OPERATIONS DIVISION
8850 McLaughlin Road, Unit 2, Brampton, Ontario L6Y 5T1
Phone: (905) 874-2500 Fax: (905) 874-2599
website: www.brampton.ca

PERMIT NO: USE13-9097

NAME / COMPANY NAME
DAVID TOMASONE / Toronto and Region Conservation Authority

ADDRESS
8850 MCLAUGHLIN ROAD BRAMPTON ON

BUSINESS TELEPHONE NUMBER
Day: (905)874-3504x Cell:

BUSINESS FAX NUMBER / COMPANY WEBSITE / e-MAIL ADDRESS

CONTRACTOR / CONSULTANT

AFTER HOURS / EMERGENCY CONTACT PERSON
Vincent D'Elia

AFTER HOURS / EMERGENCY TELEPHONE NUMBER
Cell: (416)661-6600

	YY	MM	DD
DATE OF APPLICATION:	13	04	08
COMMENCEMENT:	13	04	08
COMPLETION:	13	07	31

PERMIT COST:	$0.00
RESTORATION/ SECURITY DEPOSIT:	$0.00
TOTAL:	$0.00

ASSOCIATED PERMIT(S) ________
SITE PLAN ASSOCIATED SP- ________
INSURANCE CERTIFICATE ________
PUC APPLICATION # ________

WORK DESCRIPTION DETAILS:
Occupying Road or Blvd, Trucks Equipment or Material. Toronto Region and Conservation Authority annual animal mortality survey.

LOCATION OF WORK: From: Intersection of HEART LAKE RD and SANDALWOOD PKY E To: Intersection of HEART LAKE RD and COUNTRYSIDE DR
1.) HEART LAKE RD From: 2,011.35 meters To: 3,338.95 meters

OPEN CUTTING OF THE ROAD AND/OR REMOVAL OF SIDEWALK IS NOT PERMITTED WITHOUT PRIOR WRITTEN APPROVAL

CONDITIONS FOR ISSUANCE (SPECIAL PROVISIONS)
Traffic Controls as per Book 7. Personal protection equipment to be worn at all times. Signage to be posted daily, prior to activity. Inspection work to be conducted on the roadway shoulders from **9:00am-3:00pm**

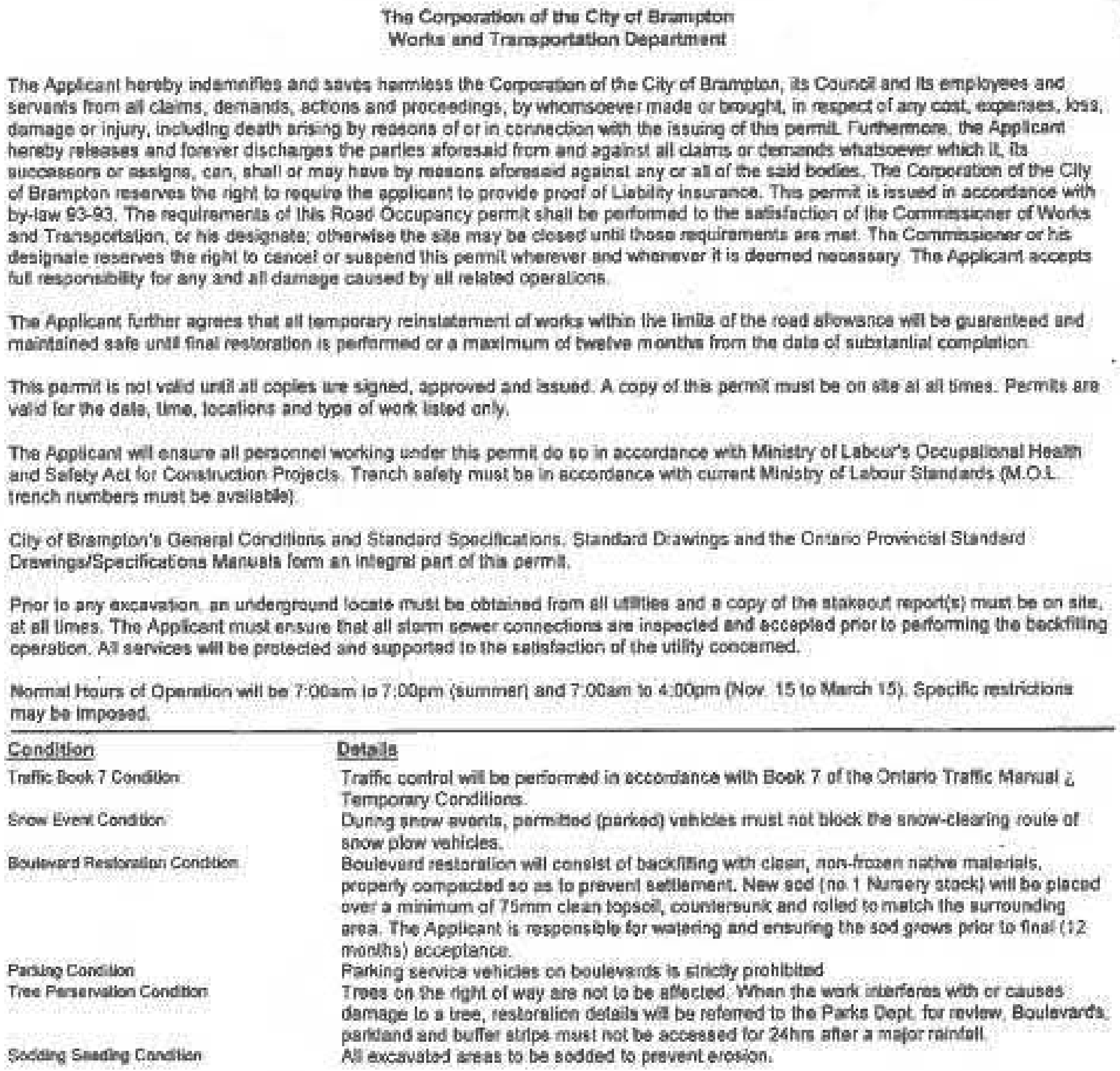
TRAFFIC CONTROL:
TRAFFIC SIGNING WILL BE IN ACCORDANCE WITH BOOK 7 OF THE ONTARIO TRAFFIC MANUAL - TEMPORARY CONDITIONS.
ACCESS FOR EMERGENCY VEHICLES MUST BE MAINTAINED AT ALL TIMES.
ROAD CLOSURE(S) IS NOT PERMITTED WITHOUT PRIOR WRITTEN APPROVAL.
APPLICANT MUST ADVISE ALL ESSENTIAL SERVICES IN THE EVENT OF AN EMERGENCY ROAD CLOSURE.
2 LANES TO BE MAINTAINED DURING WORK HOURS 2 LANES TO BE MAINTAINED AFTER WORK HOURS
OPERATING HOURS: FROM 9:00 TO 15:00

I, THE UNDERSIGNED HAVE READ AND UNDERSTOOD THE INFORMATION PROVIDED AND AGREE TO ABIDE BY ALL GENERAL CONDITIONS, SPECIAL PROVISIONS AND ALL CONDITIONS LISTED ON THE FACE AND BACK OF THIS PERMIT. ALL IN ACCORDANCE WITH BY-LAW 93-93 (AS AMENDED)

AUTHORIZED REPRESENTATIVE PRINT: Vince D'Elia SIGNATURE:

FOR OFFICE USE ONLY
APPROVAL
PHONE NO.: (905) 874-2517
PERMIT FILE DATE ________ INITIALS ________

Personal information is being collected under the authority of the Municipal Act for the purpose of processing permit applications. Questions about this collection should be directed to the Supervisor of Permits, Works & Transportation, 8850 McLaughlin Road, Unit 2, Brampton, Ontario L6Y 5T1 Telephone: (905) 874-2500



The Corporation of the City of Brampton
Works and Transportation Department

The Applicant hereby indemnifies and saves harmless the Corporation of the City of Brampton, its Council and its employees and servants from all claims, demands, actions and proceedings, by whomsoever made or brought, in respect of any cost, expenses, loss, damage or injury, including death arising by reasons of or in connection with the issuing of this permit. Furthermore, the Applicant hereby releases and forever discharges the parties aforesaid from and against all claims or demands whatsoever which it, its successors or assigns, can, shall or may have by reasons aforesaid against any or all of the said bodies. The Corporation of the City of Brampton reserves the right to require the applicant to provide proof of Liability insurance. This permit is issued in accordance with by-law 93-93. The requirements of this Road Occupancy permit shall be performed to the satisfaction of the Commissioner of Works and Transportation, or his designate; otherwise the site may be closed until those requirements are met. The Commissioner or his designate reserves the right to cancel or suspend this permit wherever and whenever it is deemed necessary. The Applicant accepts full responsibility for any and all damage caused by all related operations.

The Applicant further agrees that all temporary reinstatement of works within the limits of the road allowance will be guaranteed and maintained safe until final restoration is performed or a maximum of twelve months from the date of substantial completion.

This permit is not valid until all copies are signed, approved and issued. A copy of this permit must be on site at all times. Permits are valid for the date, time, locations and type of work listed only.

The Applicant will ensure all personnel working under this permit do so in accordance with Ministry of Labour's Occupational Health and Safety Act for Construction Projects. Trench safety must be in accordance with current Ministry of Labour Standards (M.O.L. trench numbers must be available).

City of Brampton's General Conditions and Standard Specifications, Standard Drawings and the Ontario Provincial Standard Drawings/Specifications Manuals form an integral part of this permit.

Prior to any excavation, an underground locate must be obtained from all utilities and a copy of the stakeout report(s) must be on site, at all times. The Applicant must ensure that all storm sewer connections are inspected and accepted prior to performing the backfilling operation. All services will be protected and supported to the satisfaction of the utility concerned.

Normal Hours of Operation will be 7:00am to 7:00pm (summer) and 7:00am to 4:00pm (Nov. 15 to March 15). Specific restrictions may be imposed.

Condition	Details
Traffic Book 7 Condition	Traffic control will be performed in accordance with Book 7 of the Ontario Traffic Manual ¿ Temporary Conditions.
Snow Event Condition	During snow events, permitted (parked) vehicles must not block the snow-clearing route of snow plow vehicles.
Boulevard Restoration Condition	Boulevard restoration will consist of backfilling with clean, non-frozen native materials, properly compacted so as to prevent settlement. New sod (no.1 Nursery stock) will be placed over a minimum of 75mm clean topsoil, countersunk and rolled to match the surrounding area. The Applicant is responsible for watering and ensuring the sod grows prior to final (12 months) acceptance.
Parking Condition	Parking service vehicles on boulevards is strictly prohibited
Tree Perservation Condition	Trees on the right of way are not to be affected. When the work interferes with or causes damage to a tree, restoration details will be referred to the Parks Dept. for review. Boulevards, parkland and buffer strips must not be accessed for 24hrs after a major rainfall.
Sodding Seeding Condition	All excavated areas to be sodded to prevent erosion.

APPENDIX B

TRCA Waiver Form

TORONTO AND REGION CONSERVATION AUTHORITY (TRCA)
Environmental Volunteer Network (EVN)

WAIVER OF LIABILITY

Task / Role: **Road Ecology Data Collection Volunteer**
(volunteer job title)

In consideration of the acceptance of my application and permission to participate as a(n) **Road Ecology Data Collection Volunteer**, starting April 30th, 2013, at which time I will begin working on the following tasks:

- walking a pre designated study area and following safety & data collection protocols as outlined by TRCA (see attached Safety Protocol)
- that you are confident in performing the data collection and if uncertain obtain clarification from TRCA staff

I agree that Toronto and Region Conservation Authority (hereinafter referred to as "TRCA"), which term includes its members, officers, officials, employees, agents, servants and contractors, will not be liable to me for any accident, injury, damage, loss or other claim for death, bodily injury, personal injury or property damage, including income loss replacement and/or health care costs, resulting from my participation in the Environmental Volunteer Network.

I agree to perform my duties as a volunteer in a safe manner at all times; to act in a responsible and reasonable manner as a representative of TRCA; to treat all internal matters of TRCA as strictly confidential; to perform my duties in a professional manner and to treat others with respect.

I further agree to follow all policies, procedures and instructions as set out by the organizers of the Environmental Volunteer Network and further understand that if I do not adhere to these requirements I will not be able to participate/volunteer in the project and I will be asked to leave the premises.

I acknowledge that I have read, understood and agree to the above waiver.

IN WITNESS THEREOF, this waiver has been duly executed at Brampton,

on this 30th day of April, 2013

SIGNED IN THE PRESENCE OF:

____ ____
(witness name) (witness signature)

____ ____
(volunteer name) (volunteer signature)

____ ____
(volunteer's supervisor name) (volunteer's supervisor signature)

In case of emergency, please provide contact information:

Name: Relationship to Volunteer:
Address:
Phone (primary):
Phone (secondary):

____

Consent by Parent or Guardian if Volunteer is under the age of 18:

I, ____________________________, am the _____________________ of __________________________________ (hereafter known as "the volunteer")
(your name here) (parent/guardian) (the volunteer's name here)

and hereby give permission to participate in the Environmental Volunteer Network. I confirm that I have advised the volunteer of:
1. the obligation to act in a responsible manner as a representative of the TRCA
2. to treat all matters of the TRCA as strictly confidential
3. to follow all the rules and regulations as set out by the organizers of the Environmental Volunteer Network
4. that by not adhering to the rules and regulations, the volunteer may endanger himself/herself and permission for the volunteer to continue to participate in the project may or will be revoked, and the volunteer will be asked to leave the premises.

IN WITNESS THEREOF, this consent has been duly executed at ____
(municipality)
on this __________________ day of ____,
20____________________.
(day) (month) (year)

SIGNED IN THE PRESENCE OF:

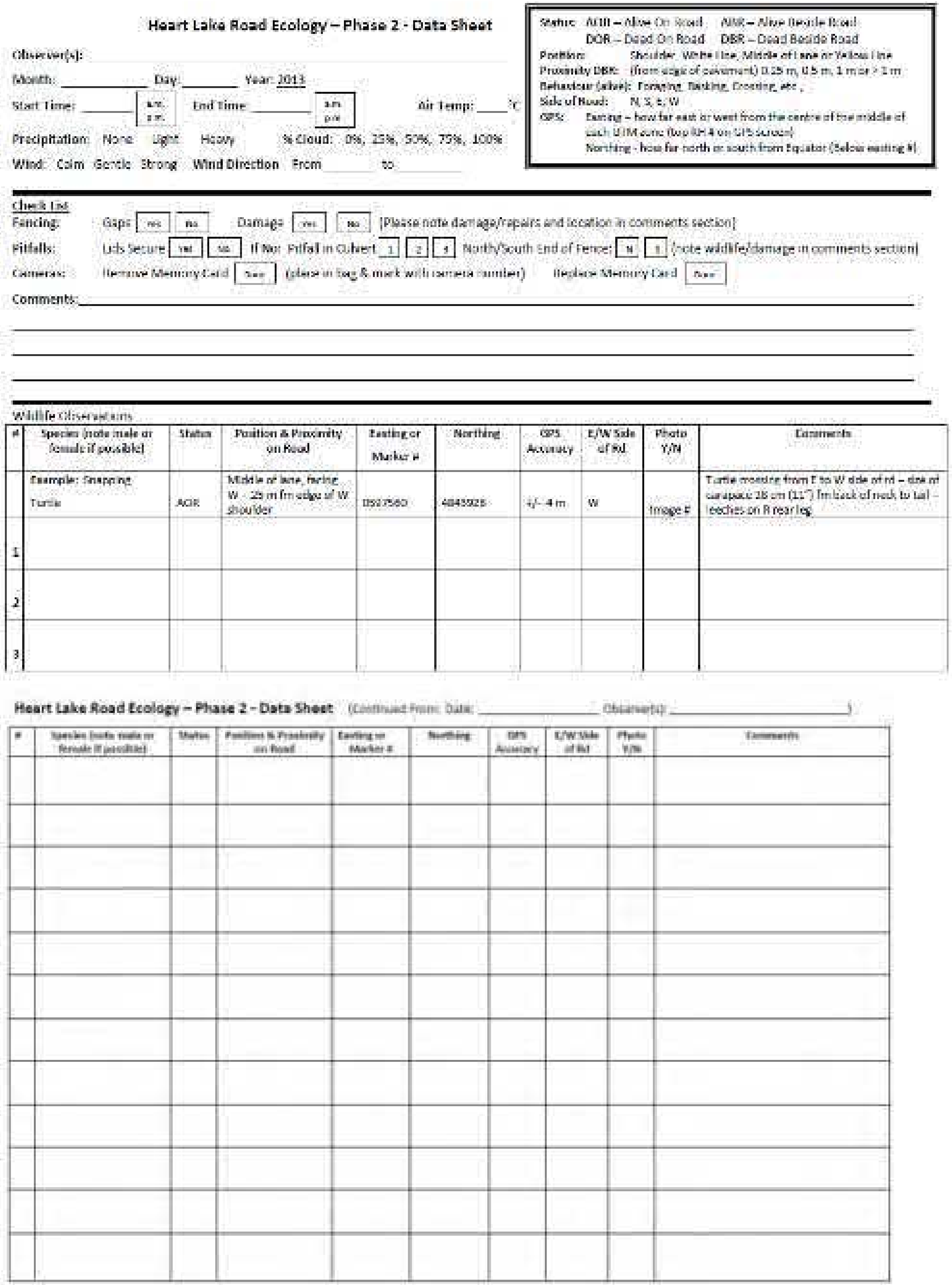
____ ____
(witness name) (witness signature)

____ ____
(parent/guardian name) (parent/guardian signature)

____ ____
(volunteer's supervisor name) (volunteer's supervisor signature)

In case of emergency, please contact me:
Name:
Address:
Phone (primary):
Phone (secondary):

Field Data Sheet



Heart Lake Road Ecology – Phase 2 - Data Sheet

Observer(s):

Month: ____________ Day: ________ Year: 2013

Start Time: ________ a.m. p.m. End Time ________ a.m. p.m. Air Temp: ____°C

Precipitation: None Light Heavy % Cloud: 0%, 25%, 50%, 75%, 100%

Wind: Calm Gentle Strong Wind Direction From ________ to ________

Status: AOR – Alive On Road ABR – Alive Beside Road
DOR – Dead On Road DBR – Dead Beside Road
Position: Shoulder, White Line, Middle of Lane or Yellow Line
Proximity DBR: (from edge of pavement) 0.25 m, 0.5 m, 1 m or > 1 m
Behaviour (alive): Foraging, Basking, Crossing, etc.,
Side of Road: N, S, E, W
GPS: Easting – how far east or west from the centre of the middle of each UTM zone (top RH # on GPS screen)
Northing - how far north or south from Equator (Below easting #)

Check List
Fencing: Gaps: Yes No Damage: Yes No [Please note damage/repairs and location in comments section]
Pitfalls: Lids Secure Yes No If No: Pitfall in Culvert 1 2 3 North/South End of Fence: N S (note wildlife/damage in comments section)
Cameras: Remove Memory Card Done (place in bag & mark with camera number) Replace Memory Card Done

Comments:____

Wildlife Observations

#	Species (note male or female if possible)	Status	Position & Proximity on Road	Easting or Marker #	Northing	GPS Accuracy	E/W Side of Rd	Photo Y/N	Comments
	Example: Snapping Turtle	AOR	Middle of lane, facing W – 25 m fm edge of W shoulder	0597560	4845928	+/- 4 m	W	Image #	Turtle moving from E to W side of rd – size of carapace 28 cm (11") fm back of neck to tail – leeches on R rear leg
1									
2									
3									

Heart Lake Road Ecology – Phase 2 - Data Sheet (Continued From: Date: ____________ Observer(s): ____________)

#	Species (note male or female if possible)	Status	Position & Proximity on Road	Easting or Marker #	Northing	GPS Accuracy	E/W Side of Rd	Photo Y/N	Comments

Safety Protocol

Heart Lake Rd. Wildlife/Road Interaction Study

1. Must work with at least one other person so that one volunteer can complete the work, while the other volunteer can watch for traffic.
2. At least 1 person per monitoring session must have attended a training session.
3. Each volunteer must have signed and submitted a "Volunteer Waiver Form" and registered as a TRCA volunteer on the TRCA website: http://www.trca.on.ca/get-involved/volunteer/sign-in.dot
4. Walk the far edge of the shoulder of the road
5. Walk towards traffic
6. Do not wear ear buds for electronic devices
7. Individuals must wear proper Personal Protective Equipment that consists of safety boots, hard hat, and a safety vest.
8. That two "Road Works" signs be in placed on the side of the roadway prior to the commencement of work. One for northbound traffic just north of Sandalwood Parkway, and one for southbound traffic just south of Mayfield Road. When the work is done the signs must either be taken away or stored on the side of the road face down.
9. Removal of wildlife (dead or alive) from the road is to be done when there is a sufficient gap in traffic to do so as you will not be authorized to stop or direct traffic.
10. Dress weather appropriate
    - Sunscreen
    - Sunglasses
    - Sweater
    - Hat, etc.
11. Drink water
12. Carry a cell phone

Ontario Road Ecology Group
www.torontozoo.com/conservation

FLOWER CITY
BRAMPTON.CA

Toronto and Region
Conservation
for The Living City

Heart Lake Rd. Wildlife/Road Interaction Study

Study Site & Survey Protocol

Study Site

Heart Lake Road between Sandalwood Pkwy E and Countryside Dr.
(approximately 2.5 km).

Mandy Karch:

Office – (416)-393-6365

Cell - 416-726-9900

E-mail - mkarch@torontozoo.ca

Vince D'Elia:

Office – (416)-661-6600 Ext. 5667

Toronto Wildlife Centre:

Office – (416)-631-0662

Website - http://www.torontowildlifecentre.com

Local Peel Regional Police Station:

Office – (905)-453-3311

Volunteer Monitoring Protocols

TO: **Data Collection Volunteers**

RE: **Heart Lake Road Ecology Monitoring STEP BY STEP Procedures for Monitoring Sessions**

The following are some steps to assist with following protocols currently being used for Phase 2 of Road Ecology Monitoring.

- Put up signs at both north and south locations – sign for northbound traffic is on the east side, just north of Sandalwood Parkway – sign for the southbound traffic is located on the west side (past Countryside Drive) attached to the hydro pole with road sign (just south of the guard rail)
- Enter through **first set of green gates** and immediately park car to the right (north) side of the lot (ie: along cedar fence, as far away from the Gate-house as possible) Please do not park along the driveway entrances to Heart Lake
- Notify staff in Gate-house at entrance to Heart Lake you are commencing a monitoring session for TRCA Road Ecology Study.
- Extract key from lock box (code: 3131) located at back of Heart Lake Admission Building at parking lot and open equipment bin **NOTE: please return the key to the lock-box immediately** – do not take with you during monitoring.

Commencing Study:

Safety and monitoring equipment to take from supply bin:

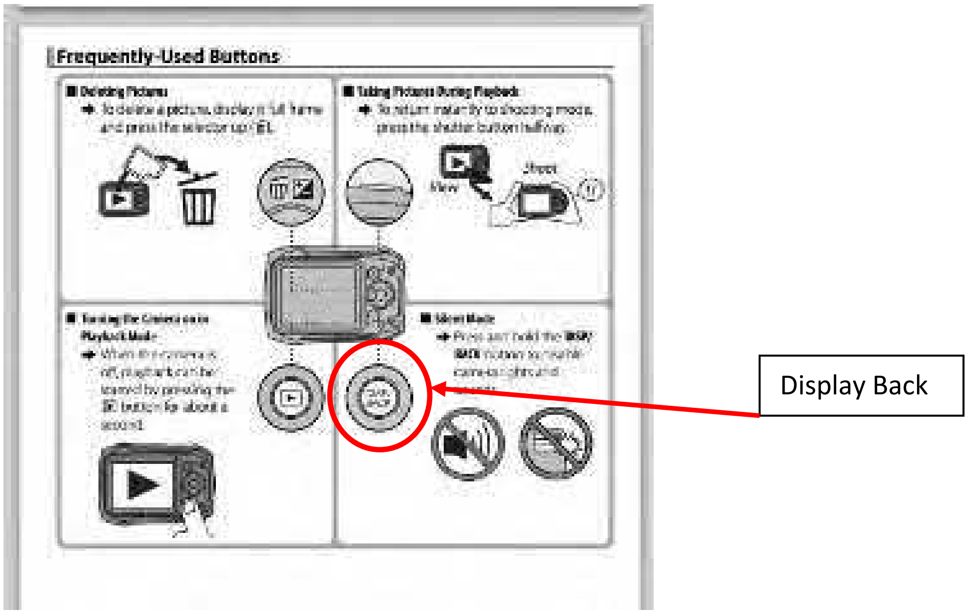
- Place laminated "permission to park" sign in dash board of vehicle
- Review safety sheet
- Close-toed shoes - CSA approved boots if possible
- Safety hard hat
- Safety vest
- Safety glasses (these are provided for your protection to prevent injury from flying debris from vehicles)
- Thermometer (take temperature and return to box)
- Pencils, pens (no **red** please) and clip board and data sheet from binder - **IMPORTANT:** please put **date and names** of volunteers on **ALL** pages of the monitoring sheets (front and back) and number the sheets. ie: 1 of 3, 2 of 3, 3 of 3 – if the sheets get separated and do not have names and dates, it will be very difficult to match them and record the data
- Camera - please take note of the image number you are starting with. The previous group will have taken their images and followed with a final image of their data sheets
- Dust pan and shovel
- Non-latex gloves and work gloves
- Lock equipment bin

Personal Safety

- Sunscreen and bug spray. Do not apply to palms of hands, especially if handling wildlife. Use back of hand to smear onto exposed skin (This is very important, as the chemicals are extremely harmful to wildlife especially amphibians)
- Keep hydrated (carry water bottle)
- Monitor weather – do not stay out if there is any thunder or lightning, stop monitoring immediately

Monitoring Protocols – We ask that you follow the route outlined below to remain consistent with existing monitoring protocols.

- **IMPORTANT:** please put **date and names** of volunteers on **ALL** pages of the monitoring sheets (front and back) and number the sheets. ie: 1 of 3, 2 of 3, 3 of 3 – if the sheets get separated and do not have names and dates, it will be very difficult to match them and record the data
- **Start** monitoring at **Marker #1** - south-west location – this is located just north of Sandalwood Parkway on the west side of Heart Lake Road (Pole with "Right Hand Turn Lane" sign).
- Proceed north (facing traffic) to Marker #15 (located at Countryside Drive).
- Walking in pairs, use the yellow center line as your monitoring guide-line and sweep across the road, across the gravel shoulder and into the ditch. As mentioned, many animals may be hit on the road and be thrown or make their way off the road into the ditch. One scans road, other scans shoulder, switch places to avoid monotony
- Live Sightings: (PLEASE NOTE: Wear gloves - do not handle species is you have any lotions, perfumes, bug repellant, etc., on your hands)
- If alive, note location, gently pick up and move the species in direction they are heading – please ensure they are moved well off the road to edge of wetland
- Please record sightings that have either full or partial remains and take images of remains. Please make sure you take images of both sides of the remains, it may give clues as to identity – if you are unable to ID the specimen, a TRCA staff may be able to ID from image. If it is just a stain on the road with no tissue/bones/flesh, please do not make a recording as this will alleviate duplicate records.
- If you see a fresh stain (blood is evident) but no remains of the animal are present, mark this in the comments section, referencing the marker number and location on the road (if the next group comes along and makes the same observation, we can cross-reference when compiling the statistical data to ensure it only gets recorded once)
- **NOTE:** To extend battery life, turn camera off after taking your image: Take an image(s) of each sighting even if it is un-identifiable or looks to be only partial remains (these may be able to be identified by other members of TRCA) – make note of the image # (or numbers if more than one) in the appropriate column – to view the image number press and hold the display back button until image appears in viewfinder If unidentified remains are found, take 2-3 photos from different angles to allow for identification later. These photos can be emailed to each other to view on larger computer screen



- Remove or scrape the remains from the road and place in ditch well away from the site in order to avoid duplication. **PLEASE NOTE**: When photographing and scraping up animals, one person always looks out for traffic and informs partner of oncoming vehicles. **VERY IMPORTANT**
- Continue north to Marker #15, crossing over to the east side of the road and continue south to Marker #30.

- Make note of any wildlife sightings as you are able: ie: pair of Turkey Vultures circling for 30 minutes just north of Heart Lake CA, at wetland located on west side where mock culverts are positioned, frogs calling and if able, which species . Note down in comments in ‘Check List’ section
- Remember: All information is valuable and can contribute to the final report

Completion of Study:

- Obtain “permission to park” sign from vehicle and return to equipment bin
- Return all monitoring equipment to bin: safety hard hat, safety vest, safety glasses, shovel, dust pan
- Photograph data sheet and make note of number on your data sheet, return camera to box
- Place data sheet in main binder behind tab labeled “Completed Data Sheets”
- Lock equipment bin, you are in separate vehicles, ensure both start and safely depart.
- Take down construction signs.

APPENDIX C

Species ID Sheet - Frog & Toad


Grey Tree Frog

Spring Peeper


Key ID: "X" on back


Spring Peeper

Leopard Frog


Key ID:
Brown or black spots on back, side, legs
White line on upper lip

Leopard Frog

Leopard Frog

American Toad


Green Frog


Green Frog

Key ID:
Ridge extend fm eye along back on both sides
bright green above upper lip
Larger tympanum (ear drum) than Leopard Frog

Wood Frog


Key ID:
Distinct black triangle-shape mask around eye


Bull Frog

Key ID:
Ridge extends fm eye around large tympanum (ear drum)

Species ID Sheet – Turtle, Snake & Newt


Garter Snake


De'Kays Brown Snake


Red-bellied Snake

(Photo Credit: JD Wilson)


Milk Snake


Paint Turtle


Snapping Turtle

Key ID: triangle scales on tail


Red-eared Slider

(Photo Credit: Toronto Zoo)

NOTE: Can be mistaken for Paint Turtle


Eastern Newt


Blanding's Turtle

Key ID: Bright yellow under chin

Species Names and Codes

Common Name Frogs/Toads	CODE
American Toad	AMTO
Bullfrog	BUFR
Western Chorus Frog	CHFR
Green Frog	GRFR
Leopard Frog	LEFR
Wood Frog	WOFR
Pickerel Frog	PIFR
Spring Peeper	SPPE
Gray Treefrog	TGTF

Common Name Turtle	CODE
Red-Eared Slider*	SLID
Midland Painted Turtle	MPTU
Snapping Turtle	SNTU

Common Name Snake	CODE
Brown Snake (Dekay's)	BRSN
Eastern Garter Snake	EAGA
Eastern Milk Snake	EMSN
Eastern Ribbon Snake	ERSN
Northern Red-bellied Snake	NRBS
Northern Water Snake	NWSN
Smooth Green Snake	SGSN

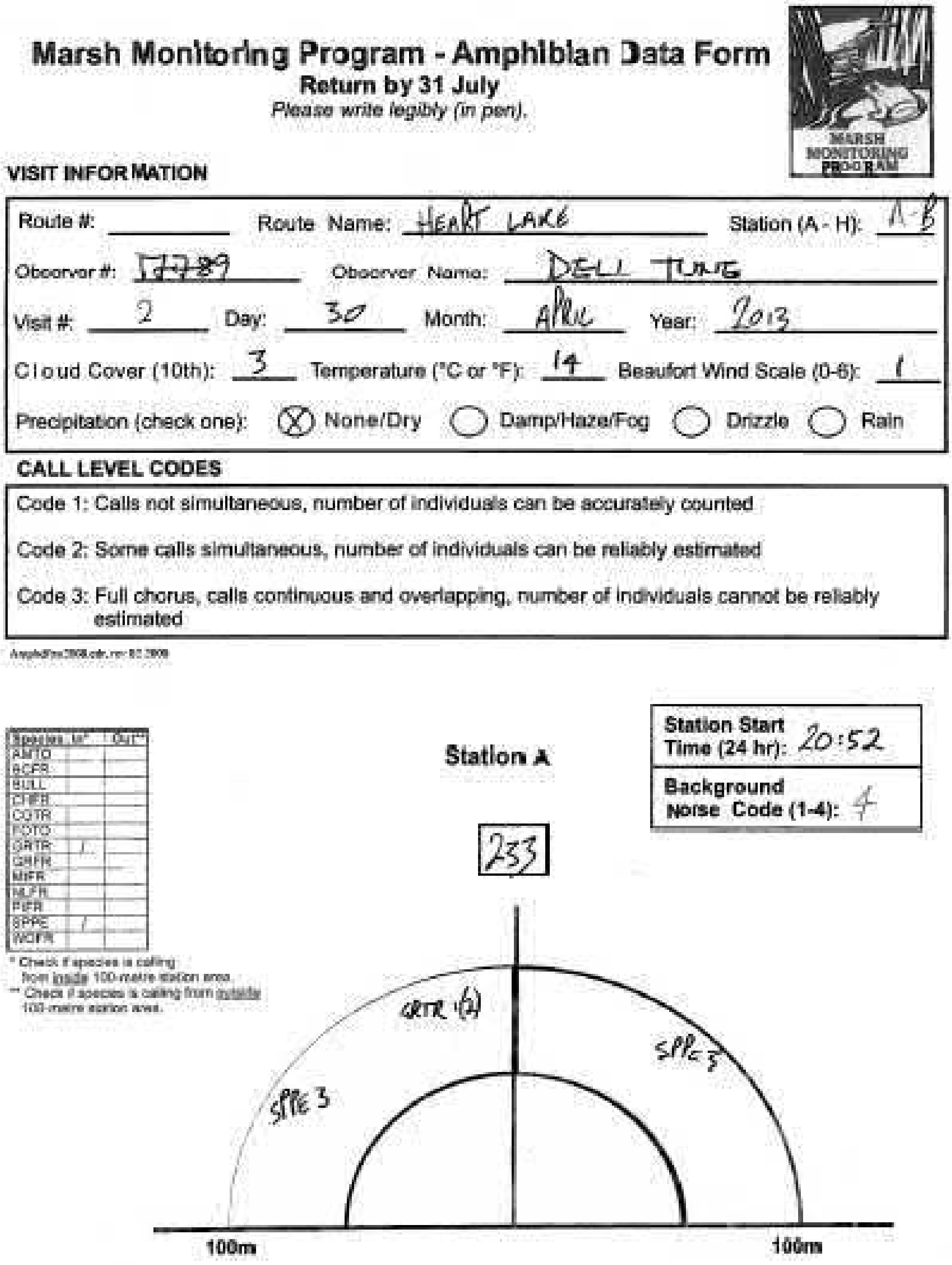
Common Name Mammal	CODE
American Mink	AMMI
Beaver	BEAV
Coyote	COYO
Eastern Chipmunk	EACH
Eastern Cottontail	EACO
Deer Mouse	DEMO
Gray Squirrel	GRSQ
Meadow Vole	MEVO
Norway Rat	NORA
Muskrat	MUSK
Raccoon	RACC
Red Fox	REFO
Striped Skunk	STSK
Woodchuck (Groundhog)	WOOD
Virginia opossum	VIOP
White-tailed Deer	WTDE

Common Name Avian	CODE
Alder Flycatcher	ALFL
American Crow	AMCR
American Robin	AMRO
Bank Swallow	BANS
Baltimore Oriole	BAOR
Barn Swallow	BARS
Black-billed Cuckoo	BBCU
Black-capped Chickadee	BCCH
Belted Kingfisher	BEKI
Brown-headed Cowbird	BHCO
Blue Jay	BLJA
Blackpoll Warbler	BLPW
Canada Goose	CANG
Chipping Sparrow	CHSP
Common Grackle	COGR
Cooper's Hawk	COHA
Common Nighthawk	CONI
Common Yellowthroat	COYE
Downy Woodpecker	DOWO
Eastern Bluebird	EABL
Eastern Kingbird	EAKI
Eastern Phoebe	EAPH
Eastern Screech-owl	EASO
Eastern Wood-peewee	EAWP
European Starling	EUST
Great Blue Heron	GBHE
Great-crested Flycatcher	GCFL
Great horned Owl	GHOW
Green Heron	GRHE
Hairy Woodpecker	HAWO
House Sparrow	HOSP
House Wren	HOWR
Indigo Bunting	INBU
Killdeer	KILL
Mourning Dove	MODO
Mallard	MALL
Mute Swan	MUSW
Northern Cardinal	NOCA
Northern Flicker	NOFL
Pied-billed Grebe	PBGR
Pine Warbler	PIWA
Pileated Woodpecker	PIWO
Red-breasted Nuthatch	RBNU
Red-eyed Vireo	REVI
Red-tailed Hawk	RTHA
Red-winged Blackbird	RWBL
Rose-breasted Grosbeak	RBGR
Ring-billed Gull	RBGU

Common Name Avian	**Code**
Rock Dove	ROPI
Ruby-throated Hummingbird	RTHU
Savannah Sparrow	SAVS
Sharp-shinned Hawk	SSHA
Song Sparrow	SOSP
Swamp Sparrow	SWSP
Turkey Vulture	TUVU
Trumpeter Swan	TRUS
Tree Swallow	TRES
Warbling Vireo	WAVI
White-breasted Nuthatch	WBNU
Willow Flycatcher	WIFL
Winter Wren	WIWR
Wood Duck	WODU
Yellow-bellied Sapsucker	YBSA

APPENDIX D

Marsh Monitoring Report – Station A & B



Marsh Monitoring Program - Amphibian Data Form

Return by 31 July

Please write legibly (in pen).

VISIT INFORMATION

Route #: ______ Route Name: HEART LAKE Station (A - H): A-B

Observer #: 17789 Observer Name: DELL TUNG

Visit #: 2 Day: 30 Month: APRIL Year: 2013

Cloud Cover (10th): 3 Temperature (°C or °F): 14 Beaufort Wind Scale (0-6): 1

Precipitation (check one): ☒ None/Dry ○ Damp/Haze/Fog ○ Drizzle ○ Rain

CALL LEVEL CODES

Code 1: Calls not simultaneous, number of individuals can be accurately counted

Code 2: Some calls simultaneous, number of individuals can be reliably estimated

Code 3: Full chorus, calls continuous and overlapping, number of individuals cannot be reliably estimated

AmphibFm2008.cdr, rev 02.2008

Species	In*	Out**
AMTO		
BCFR		
BULL		
CHFR		
COTR		
FOTO		
GRTR	/	
GRFR		
MIFR		
NLFR		
PIFR		
SPPE	/	
WOFR		

* Check if species is calling from inside 100-metre station area.

** Check if species is calling from outside 100-metre station area.

Station A

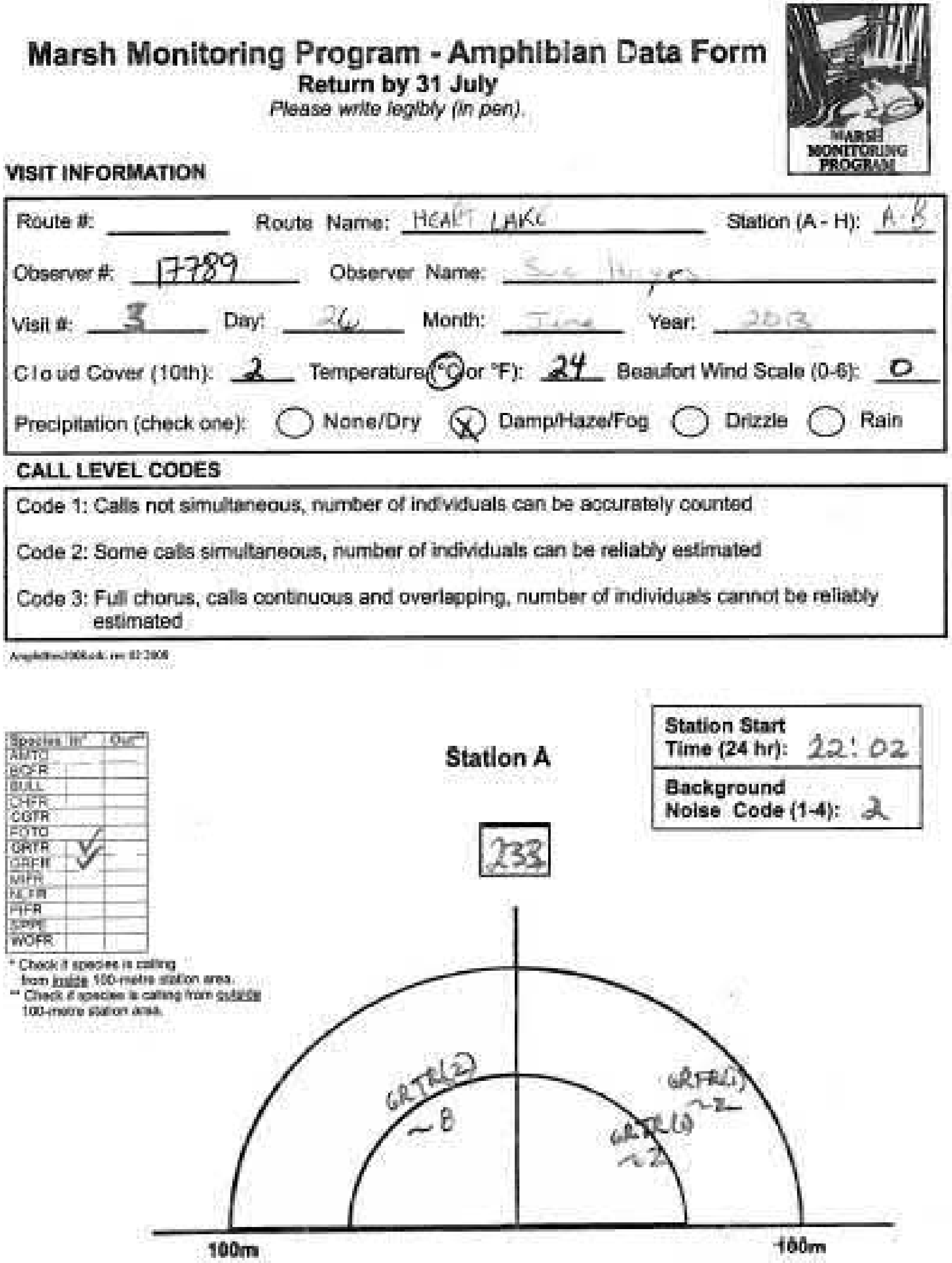
Station Start Time (24 hr):	20:52
Background Noise Code (1-4):	4

233

GRTR (2)

SPPE 3

SPPE 3



Marsh Monitoring Program - Amphibian Data Form

Return by 31 July

Please write legibly (in pen).

MARSH MONITORING PROGRAM

VISIT INFORMATION

Route #: ______ Route Name: HEART LAKE Station (A - H): A-B

Observer #: 17789 Observer Name: Sue Hayes

Visit #: 3 Day: 26 Month: June Year: 2013

Cloud Cover (10th): 2 Temperature([✓ °C] or °F): 24 Beaufort Wind Scale (0-6): 0

Precipitation (check one): ○ None/Dry ☒ Damp/Haze/Fog ○ Drizzle ○ Rain

CALL LEVEL CODES

Code 1: Calls not simultaneous, number of individuals can be accurately counted

Code 2: Some calls simultaneous, number of individuals can be reliably estimated

Code 3: Full chorus, calls continuous and overlapping, number of individuals cannot be reliably estimated

Amphibian2008.xls rev 01/2008

Station A

Station Start Time (24 hr): 22:02

Background Noise Code (1-4): 2

233

Species	In*	Out**
ABTO		
BCFR		
BULL		
CHFR		
CGTR		
FOTO		
GRTR	✓	
GRFR	✓	
MIFR		
NLFR		
PIFR		
SPPE		
WOFR		

* Check if species is calling from inside 100-metre station area.

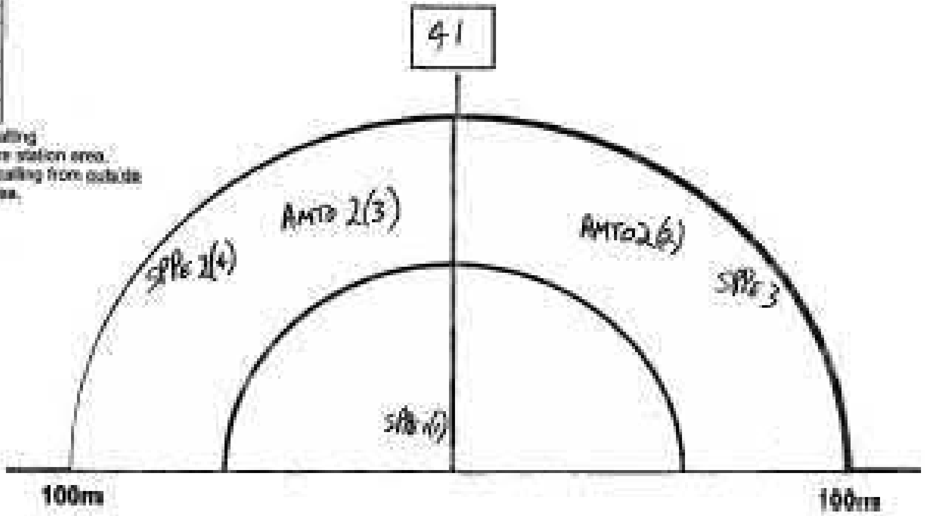
** Check if species is calling from outside 100-metre station area.

Station B

Station Start Time (24 hr):	20:58
Background Noise Code (1-4):	3

Species	In*	Out**
AMTO	✓	
SCFR		
BULL		
CHFR		
CGTR		
FOTO		
GRTR		
GRFR		
MIFR		
NLFR		
PIFR		
SPPE	✓	
WOFR		

* Check if species is calling from inside 100-metre station area.
** Check if species is calling from outside 100-metre station area.

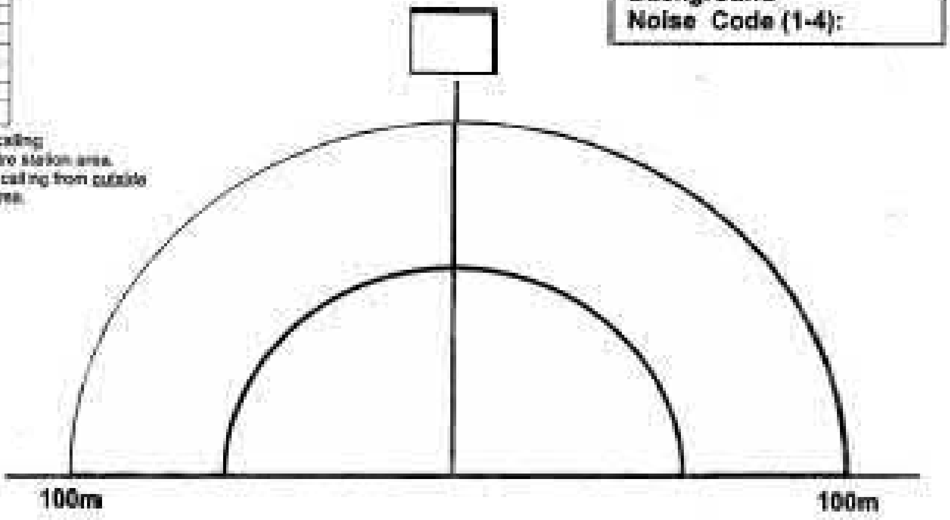


Station C

Station Start Time (24 hr):	
Background Noise Code (1-4):	

Species	In*	Out**
AMTO		
SCFR		
BULL		
CHFR		
CGTR		
FOTO		
GRTR		
GRFR		
MIFR		
NLFR		
PIFR		
SPPE		
WOFR		

* Check if species is calling from inside 100-metre station area.
** Check if species is calling from outside 100-metre station area.



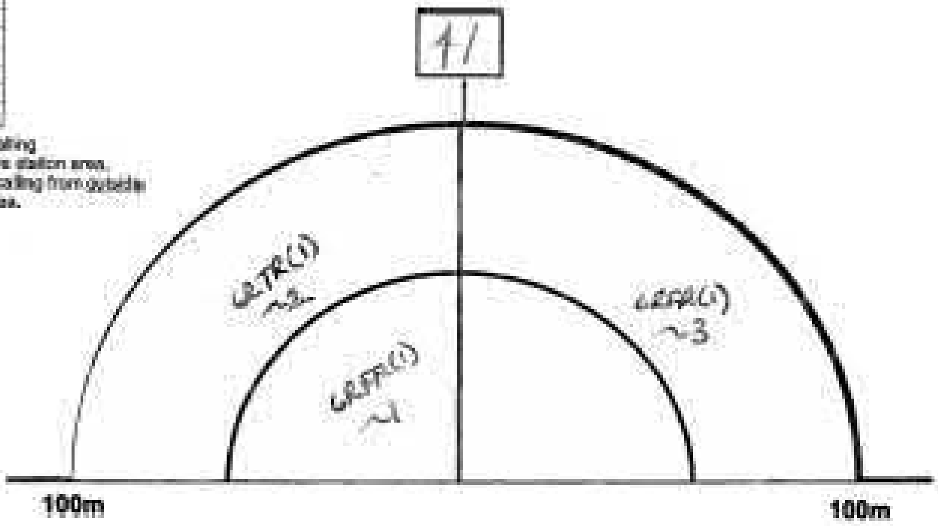
Station Start Time (24 hr):	22:07
Background Noise Code (1-4):	2

Station B

Species	In*	Out**
AMTO		
BCFR		
BULL		
CHFR		
CGTR		
FOTO		
GRTR	✓	
GRFR	✓	
MIFR		
NLFR		
PIFR		
SPPE		
WOFR		

* Check if species is calling from inside 100-metre station area.

** Check if species is calling from outside 100-metre station area.



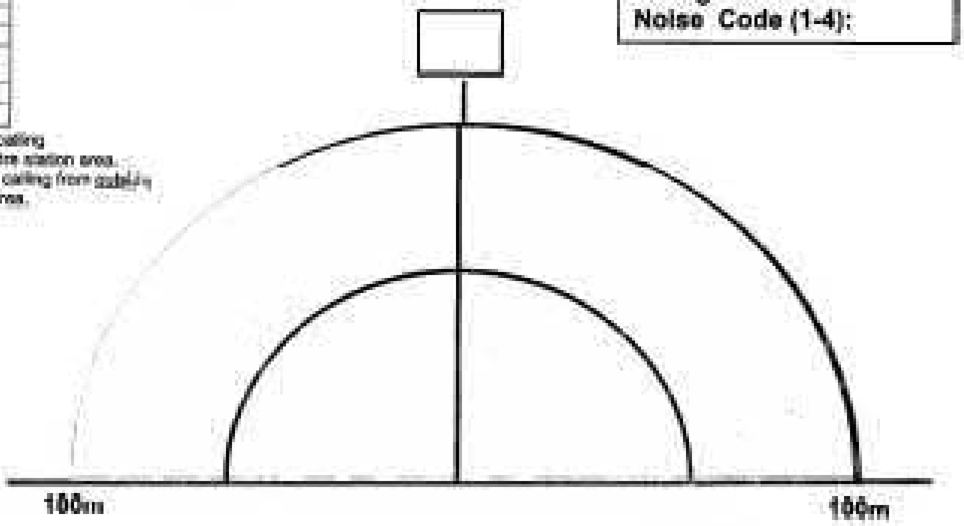
Station C

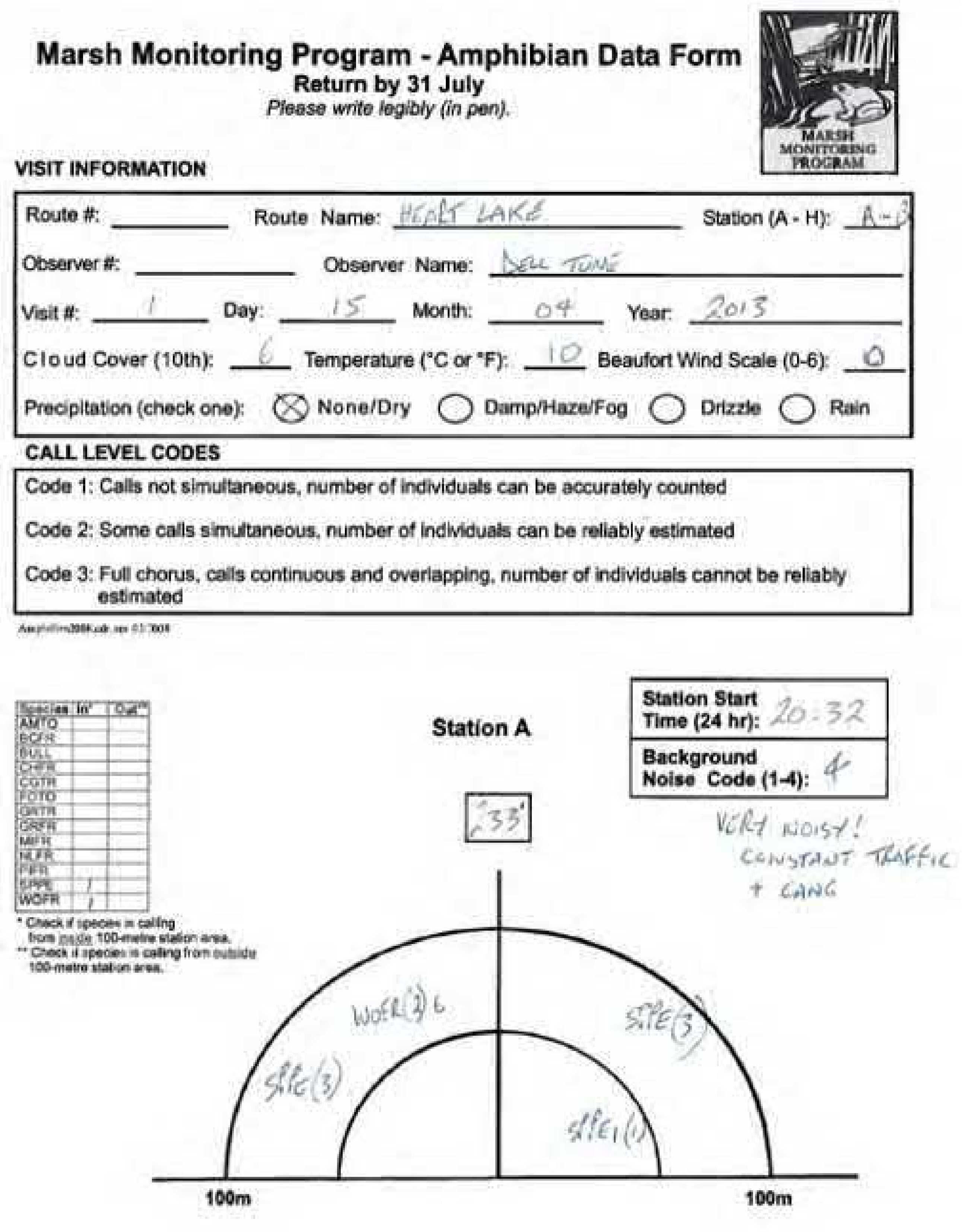
Species	In*	Out**
AMTO		
BCFR		
BULL		
CHFR		
CGTR		
FOTO		
GRTR		
GRFR		
MIFR		
NLFR		
PIFR		
SPPE		
WOFR		

* Check if species is calling from inside 100-metre station area.

** Check if species is calling from outside 100-metre station area.

Station Start Time (24 hr):	
Background Noise Code (1-4):	





Marsh Monitoring Program - Amphibian Data Form

Return by 31 July

Please write legibly (in pen).

MARSH MONITORING PROGRAM

VISIT INFORMATION

Route #: ______ Route Name: HEART LAKE Station (A - H): A-

Observer #: ______ Observer Name: DELL TONE

Visit #: 1 Day: 15 Month: 04 Year: 2013

Cloud Cover (10th): 6 Temperature (°C or °F): 10 Beaufort Wind Scale (0-6): 0

Precipitation (check one): ☒ None/Dry ○ Damp/Haze/Fog ○ Drizzle ○ Rain

CALL LEVEL CODES

Code 1: Calls not simultaneous, number of individuals can be accurately counted

Code 2: Some calls simultaneous, number of individuals can be reliably estimated

Code 3: Full chorus, calls continuous and overlapping, number of individuals cannot be reliably estimated

Species	In*	Out**
AMTO		
BCFR		
BULL		
CHFR		
CGTR		
FOTO		
GRTR		
ORFR		
MIFR		
NLFR		
PIFR		
SPPE	/	
WOFR	/	

* Check if species is calling from inside 100-metre station area.

** Check if species is calling from outside 100-metre station area.

Station A

Station Start Time (24 hr):	20:32
Background Noise Code (1-4):	4

VERY NOISY!
CONSTANT TRAFFIC
+ CANG

33°

WOFR(3) 6

SPPE(3)

SPPE(3)

SPPE,(1)

100m

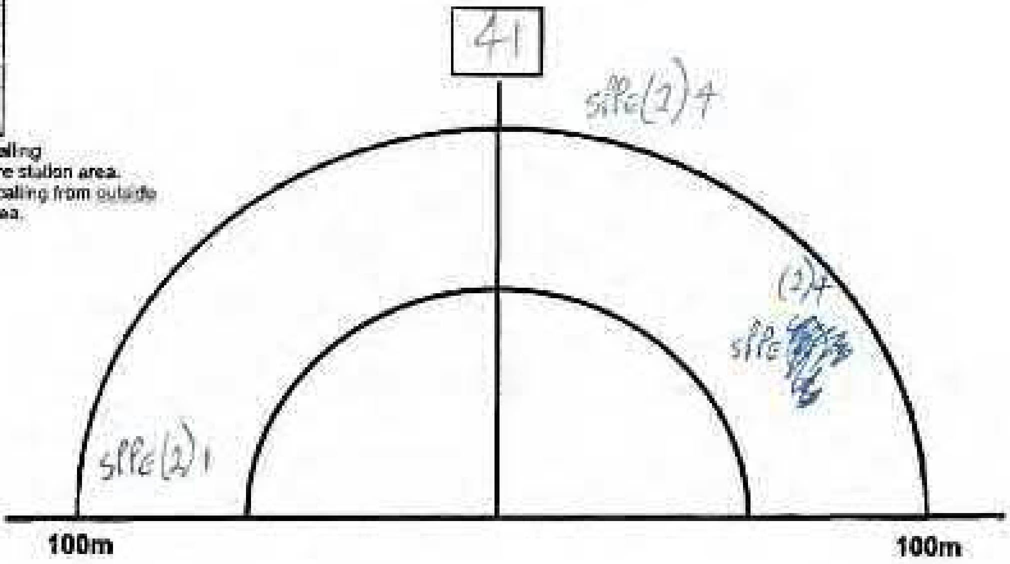
100m

Species	In*	Out**
AMTO		
BCFR		
BULL		
CHFR		
CGTR		
FOTO		
GRTR		
GRFR		
MIFR		
NLFR		
PIFR		
SPPE	I	
WOFR		

* Check if species is calling from inside 100-metre station area.
** Check if species is calling from outside 100-metre station area.

Station B

Station Start Time (24 hr):	20:39
Background Noise Code (1-4):	4

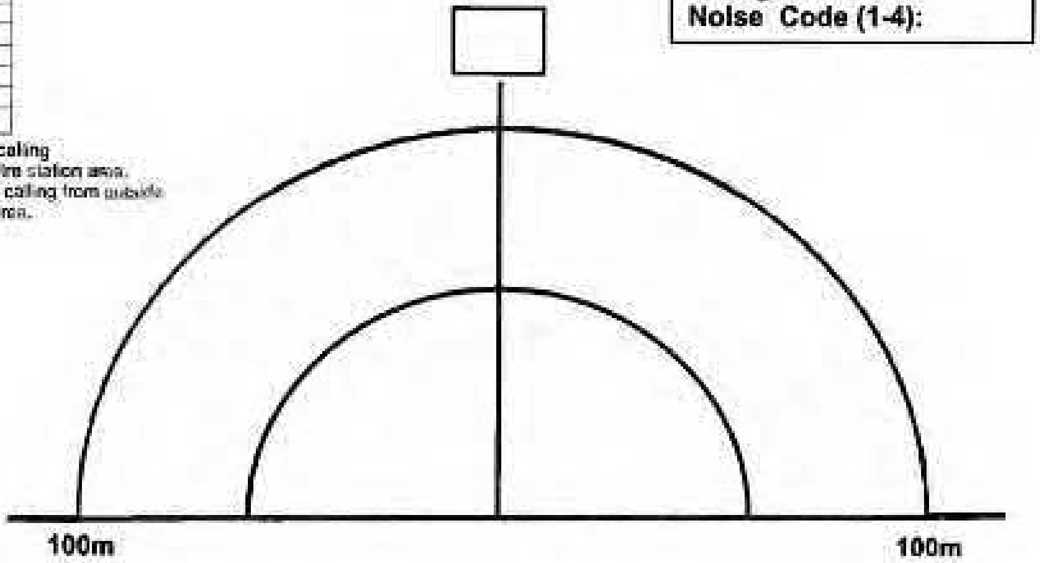


Species	In*	Out**
AMTO		
BCFR		
BULL		
CHFR		
CGTR		
FOTO		
GRTR		
GRFR		
MIFR		
NLFR		
PIFR		
SPPE		
WOFR		

* Check if species is calling from inside 100-metre station area.
** Check if species is calling from outside 100-metre station area.

Station C

Station Start Time (24 hr):	
Background Noise Code (1-4):	



APPENDIX E

Research Summary

Evaluating the effectiveness of road mitigation measures.
Van der Grift EA, Van der Ree R, Fahrig L, Findlay S, Houlahan J, Jaeger JAG, Klar N, Madrinan LF, Olsen L. July 2012. Available online at: Springer http://link.springer.com/article/10.1007/s10531-012-0421-0 **Biology Conservation. Volume 22, Issue 2, 2013, pp 425-448.**

Summary: the overall points of this paper highlight why/how to initiate a monitoring study, how it affects humans/wildlife and steps to consider in setting up the study. There are excellent tables outlining questions and possible outcomes and insight to endpoints. Ie: wildlife populations over time after mitigation.

Highlights: In the past two decades, there has been an increase in efforts to study and understand measures and methods of vehicle/wildlife fatalities. Although crossing structures have been implemented in areas of North America, more research is required to evaluate their effectiveness. It is essential to have collaboration between policy makers, road agencies, engineers and scientists in order to effectively use financial resources for road expansion and protection of wildlife and habitat.

Historically indicators to warn motorists of wildlife include; warning signs, reduced speed postings, animal detection systems, fencing and modifications to roads and overpasses. Globally, more research and funds are being allocated to road and wildlife interaction. Between 1992 and 2008 the US spent more than 90 million dollars on mitigation measures.

Although studies have shown success that wildlife will use crossing structures, more study is needed to determine if populations have in increased or if there are gene flow alterations in species populations.

It is important to set up guidelines of mitigation including a monitoring plan to determine if a wildlife crossing will be effective. Criteria such as;

1. Target species and mitigation method
2. Variables to measure ie: study design, sampling scheme
3. Study site and survey methods
4. Costs of evaluation and feasibility of monitoring

Some factors related to a study include;

- human safety; example: moose/vehicle collision
- animal welfare; loss of animal changes local populations but not regional populations and
- wildlife conservation; loss of species leads to its status of protection (endangered, threatened, etc)

Effects of roads and traffic on wildlife populations and landscape function; Road ecology is moving toward larger scales.
Van der Ree R, Jaeger JAG, Van der Grift EA, Clevenger AP. Ecology and Science 2011 Vol 16, Art 48.

Summary: Special issue of Ecology and Society focusing on 17 papers related to road ecology. This overview of all submissions and the reasons for this special edition, points out the lack of research on ecosystem level effects. No papers were submitted on this topic despite it being a criterion. All submissions; Canada, Australia, Netherlands and US, primarily focused on populations and community effects. This paper highlights the need to establish communication between scientific research, regions and road agencies.

Highlights: Humans are the primary reason of biodiversity decrease through habitat loss, fragmentation, climate change and pollution. Globally, an approximate 750 million vehicles are on apx. 50 km of roads and the numbers increase annually. One of the first documentations of road ecology was in 1925 by Dayton Stoner who recorded 225 vertebrate fatalities (29 species) over 632 miles in Iowa.

Term “Road Ecology” originally a German term “Straßenökologie” in 1981, was translated to English by Richard Forman (*et al*) author of the book “Road Ecology; Science and Solutions”. The 1990’s showed increased interest via research, leading to present where there are now dedicated organizations and conferences on this topic.

The goal of road ecology is to determine what effects roads have ecologically and help to lessen negative impacts such as habitat fragmentation, wildlife mortality, changes related to light, moisture and wind on habitat, various pollutants (noise, chemical, light), changes due to invasive vegetation and feral animals.

It is important that we not only count and realize wildlife fatalities related to roads but how they affect the area beyond. How they affect populations, genetics and extended areas these species use for hibernation, feeding and breeding.

It is therefore important to open lines of communication between researchers, road managers, developers and the general public to gain a better understanding of the importance of planning roads effectively. Most regions have the phrase “environmentally sustainable” in their mission statement. Valid and viable research is needed to help obtain this goal as it relates to development or alteration of roads and their effects to wildlife and surrounding habitat.

As populations rise and vehicles increase, more roads are required to handle the volume. Secondary routes are being used more frequently to handle overflow on main throughways in urban settings.

Quantify the road effect zone; Threshold effects of a motorway on Anuran populations in Ontario Canada.
Eigenbrod F, Hecnar SJ, Fahrig L. 2009. Ecology and Society, Volume 14, Article 24.

Summary: Study of road effects on 7 species; wood frog, spring peeper, western chorus frog, northern leopard frog, American toad, grey tree frog and green frog. Study took place along Hwy 401, eastern Ontario.

Highlights: Purpose was to quantify how far from the road do vehicles effect the richness and population numbers of these species.

Based on a previous study, ponds located 500 m from the road side were identified as showing the highest effects.

- 34 ponds, 17 from 68 m to 500 m and 17 from 500 m to 3,262 m, from the edge of the road,
- covering 48 km along Hwy 401 in Eastern Ontario
- All ponds were sampled in 2006 and 22 (subset) sampled in 2007
- Traffic volume (average) = 18,300 vehicles/day (Sept 2006)
- 8 auditory night surveys (Apr 1 to Jul 12), 4 routes, random order – 4 visual day surveys Apr 2 – Jul 12
- 9 of 14 frog species noted: wood, western chorus, spring peeper, northern leopard, grey tree, green, mink and bull
- Variables measured: pH, conductivity, pond area, % emergent & floating vegetation (2 m from pond), overhang, forest vegetation (w/in 100 m pond edge), degree of sun exposure,
- Generalized linear regression and general piecewise linear regression model for species and richness.

Results:

- Significant difference in slope parameter
- Piecewise regression models gave at least as good a fit to data as linear models for richness
- Richness breakpoint; 450 m to 800 m from road
  - 200 m to 300 m for spring peeper, American toad, grey tree frog
  - 600 m to 1,000 m for wood frog
  - 1,100 m to 2,400 for chorus frog
- Statistically significant relationship for richness of wood frog and spring peeper with distance to highway to threshold
- Leopard frog and green frog abundance higher when further away from highway

Results: road effect zones exist for species richness extending from 250 m to 1,000 m from highway. All species negatively affected by road. Wetlands within 250 m, show low populations due to negative effects.

Behavioural responses of Northern leopard frogs (*Rana pipiens)* to roads and traffic: implications for population persistence.

Bouchard J, Ford AT, Eigenbrod FE, Fahrig L, 2009. Ecology and Society, Volume 14, Issue 2, Article 23.

Summary: General objective of road ecology is to study negative effects of roads to wildlife. This study focuses on Northern Leopard Frog which, by previous studies, shows their population persistence are affected by roads.

Highlights: How species react to roads and related obstacles ie: barriers, habitat loss and inability to access habitat, can be a factor in understanding if populations of species can remain stable. This is difficult to determine and would require research on avoidance behaviour of a number of species.

Purpose: do migrating leopard frogs respond to roads, (ie: avoid them) - do they avoid them in heavier traffic - what is the probability of them getting killed and does it depend on traffic volume.

- Study area: Ottawa and Kemptville ON
- Spring migration from Rideau River to breeding ponds
- Sites were; 10 x 20 m habitat bands set up as a Cartesian plane – (2) adjacent to low traffic, (2) adjacent to high traffic and (2) >100 m distance
- Frogs captures as they approached road, placed in bucket, bucket then inverted at origin, left to rest for 2 minutes, bucket removed
- All frogs moved in the direction they were facing, observer (5 m away from origin) visually followed movement with red filter flashlight – each hop landing coordinates recorded
- Frogs stopped moving with un-filtered light (red light did not alter movement)
- Recorded fate of each frog after 10 m habitat band and arrival at road
- Dates: April 13th to 21st 2004 – 2 to 4 sites visited each night\
- Sites visited 3 to 4 times at same time of frog observations to count traffic in both directions over 30 minute period
- To determine if frogs slowed and if it was traffic related, time to cross 10 m bands analyzed with ANOVA – variables: high traffic, low traffic & no road and temperature (frog activity changes with temperature)

Results:

- 193 frogs captured and released – (60) control sites, (66) low traffic sites, (67) high traffic sites
- Significant interaction between distance to road, traffic level and frog direction of movement – tended to deviate from straight course to road and distance to road decreased
- Results support assumption they do not avoid roads which results in fatalities
- Movements were slower near roads than non-road areas and slower near high traffic roads
- Changed from straight line path at 3.3 m from road
- All frogs released near road attempted to cross

- 28% in high traffic were killed – this is high in relation to 1 car passing per minute
- Behaviour near roads changes, tend to be immobile, slows movement (Mazerolle et al 2005)
- Pauses between hops longer on roads (personal observation Bouchard)
- Did human presence influence movement? Frogs did not attempt to flee when observers in area with flashlights, did not alter direction when released – indicates urge to cross road stronger than flee response
- Road mortality affects breeding population, reduces genetic exchanges (Jaeger et al 2005)

Conservation of frogs; deterrent methods be put in place to reduce mortality.

Hit and Run: Effects of Scavenging on Estimates of Road killed Vertebrates.
Antworth RL, Pike DA, Stevens EE, 2005. Southeastern Naturalist Dec 2005. Vol 4, Issue 4, pp 647-656.
Published By: Humboldt Field Research Institute.

Summary:
Along a coastal road in Central Florida, researchers used both bird and snake carcasses to investigate the rates at which they scavenged from the road.

Highlights:
Researchers discovered that 60-97% of the carcasses disappeared within 36 hours of being placed on the road. Regardless of the carcass size, there was a higher rate of removal for snakes than birds. Researchers also noticed that there was a quicker removal rate for birds carcasses placed in the centre of the road than at the sides of the road.

Purpose:
Road ecology studies on vertebrates involves collecting information on populations, life cycles and habitats; and also needs to include examining scavenging, as studies may not accurately reflect what is happening on the road.

Avian Study:
Trail Time: Mid-March, Mid-May and Mid-June 2004
Trail Length: 36 hour period on the weekend
Study Site: 19.6 km two-lane coastal high way, with a variety of vegetation along the edges
Speed Limit: 56-80 km/h
Bird Carcass: Commercially purchased domestic chicken chicks, weighing approximately 30 grams
Placement: Chick carcasses were randomly placed both in the centre and at the edge of the road
0.4km apart

Study:

- On the first day chick carcasses were placed at 9:00am
- Flags were placed 10m off the road to mark the placement of the chick carcasses
- On the first day chick carcasses were checked every 2 hours until sunset
- During the 2 hour checks, vehicles and vultures were also counted and recorded; and road sides were checked for missing chick carcasses
- On the first day before sunset, the remaining chick carcasses were placed on a 0.5m2 board covered with moist sand to identify animal tracks during the night
- On the second day, the boards were examined for chick carcasses and animal tracks
- On the second day, chick carcasses were placed again at 9:00am, and checked every 2 hours until sunset
- Study ended at sunset on second day, and all remaining chick carcasses were collected and disposed of

Snake Study:
Trail Time: August 2004
Trial Length: 36 hour period
Study Site: 14.4 km two-lane coastal high way, with a variety of vegetation along the edges; different stretch of road was used than in the avian study
Speed Limit: 56-80 km/h
Snake Species: Yellow-bellied racer snake, Eastern indigo snake, Western coachwhip snake, Banded water snake, Rough green snake, Eastern ribbon snake, and Common garter snake were the snake species used in the study.
Snake Carcass: Collected 36 snakes of 7 species from March – July 2004 on Cape Canaveral Air Force Station, Canaveral national Seashore and Merritt Island National Wildlife Refuge, Florida.
All snake carcasses were kept frozen and thawed before using in the study. All snake carcasses were identified, measured and condition recorded.
Placement: Snake carcasses were placed 0.4km apart on either side of the road.

Study:

- On the first day snake carcasses were placed at 9:00am
- Flags were placed 10m off the road to mark the placement of the snake carcasses
- On the first day snake carcasses were checked every 2 hours until sunset
- During the 2 hour checks, vehicles and vultures were also counted and recorded, and road sides were checked for missing snake carcasses
- Study ended after 36 hours, and all remaining snake carcasses were collected and disposed of

Results for Avian and Snake Studies:
The snake carcasses were taken from the road at a faster rate than the chick carcasses. Snake carcasses remained on the road within a 2-26 hours range. Chick carcasses remained on the road within a 2-32 hours range. 97.2% of the snake carcasses were scavenged from during the 36 hours study. 90% of the chick carcasses were scavenged from the centre of the road, 67% were scavenged from the east side of the road, and 61% were scavenged from the west side of the road. The snakes may have been easier to recognize by their shape, and due to previous road-kill wounds may have been easier to sense by aerial scavengers, like vultures. Vultures, raccoons, skunks and fire ants were the scavengers of all the carcasses identified both on the track boards and sighted in the area. Road ecology studies need to include scavenging when examining populations of wildlife residing near roads.

Questions arise with the use of commercially purchased chicks versus the wild snakes collected for the scavenging research, as it does not appear to be consistent, as scavengers no doubt have a dietary preference based on what is usually available in the area. And why did the researchers not feel the need to use the board at night during the snake study?

**How quickly are road-killed snakes scavenged? Implications for Underestimates of Road Mortality.
Degregorio BA, Hancock TE, Kurz DJ, Yue S, 2011. Journal of the North Carolina Academy of Science, 127(2), 2011, pp 184-188.**

Summary:
Along a coastal road on Bald Head Island, North Carolina, researchers used snake carcasses to investigate the rates at which they scavenged from the road.

Highlights:
Researchers discovered that habitat type did have an impact on the length of time that a snake carcass was removed.

Purpose:

Examining the timing, speed, and intensity of carcass removal is essential for studies attempting to understand road mortality rates as these factors can conceivably misrepresent the results.

Trail Time: July 20 – August 1, 2010
Trial Length: Ten trials happened over a separate 24 hour period
Study Site: 35 km of paved road on Bald Head Island, North Carolina. Road is two lanes often divided by a median of dune or maritime forest vegetation. Traffic on the road is restricted to electric golf carts, and the occasional gas-powered emergency and contractor vehicles.
Speed Limit: Does not exceed 29 km/h
Snake Species: Rough green snake and Black racer snake were the species used in early afternoon; Yellow rat snake and Scarlet snake were the species used at sundown.
Snake Carcass: Collected road-killed snake species during May 1 – June 29, 2010. All snake species were kept frozen and thawed before using in the study. Snake carcasses with open wounds were not used in the study. All snake carcasses were identified and measured; and carcasses of similar sizes were placed together on the road.
Placement: Two snake species were randomly placed at the side of the road along a 2km stretch of the forest section of the road, and along a 2km stretch of the dune section of the road.

Study:

- Snake carcasses were checked every hour for the first three hours after placed on the side of the road
- Then snake carcasses were checked every four hours afterwards for a 24 hour period.
- After the 24 hour period, all remaining snake carcasses were removed

Results:
In this study the snake carcasses placed in the forest section of the road were scavenged more quickly and frequently than those carcasses placed in the dune section of the road. Red fox and sow bugs were the scavengers of the carcasses identified by the researchers. Half of the snake carcasses were removed within the first 8 hours of being placed on the road, and all were removed at night. Removal of carcasses can be influenced by time of day, weather, temperature, species and condition of carcass, traffic density, topography season, and species of predators (Bumann and Stauffer 2002; Slater 2002). A scavenging analysis piece must be part of any road ecology and road mortality study to truly reflect the carcass removal in the area.

Effects of Road Networks on Bird Populations. Kociolek AV, Clevenger AP, St. Clair CC, Proppe DS, 2010. Conservation Biology, Vol 25, No. 2, 2011, pp 241-249.

Summary: In North America the abundances of at least 20 species previously categorized as common have declined more than 50% in the last 40 years. One likely contributor is the expansion of paved roads, mostly in terms of widening, and corresponding increases in the speed and volume of vehicles on those roads. Many of the negative effects of roads on other vertebrates (e.g., mortality, habitat fragmentation, and audiovisual disturbance, chemical pollution) also apply to birds.

Highlights: It is difficult to measure the true extent of vehicle induced mortality because estimates are typically far lower than the actual number of birds killed; estimation accuracy is reduced by variation in researcher efficiency, scavenger bias, and incorrect attribution of cause of death.

Purpose: Examining the direct and indirect threats posed to birds by roads and traffic.

Results:

- Birds are more likely to collide with vehicles if they forage, roost, or nest near roads
- Collisions with birds are more likely to occur at lower elevations and in open areas than in forests

- For many bird species, vehicle induced mortality increases during breeding and migration, but for other species it increases during winter
- Collisions can increase or decrease as roadside lighting increases
- Roadside trees, hedgerows, and other features that cause birds to fly higher across roads, typically decrease collision frequency, but they can also increase it
- Birds also vary in their responses to roads; some individuals appear to learn to avoid vehicles, whereas others do not
- Road salt is a common deicing agent that attracts birds; its ingestion can lead to death among birds
- Despite the ubiquity of road contaminants from vehicles and maintenance activities, toxic effects of roads appear to be rare, even in areas with high traffic volumes, and pollution appears to have fewer effects on birds than other road-related effects
- For birds, road avoidance appears to be associated with the physical barrier to movement roads present, noise, artificial light, and edge effects
- Noise likely causes reductions in population densities that have been reported for several bird species that are present near roads
- In grasslands the effects of noise appear to extend farther from roads than in forests, perhaps because grasslands have less vegetation to absorb sound
- Chronic industrial noise can reduce species richness, alter population age structure, and change avian predator–prey dynamics
- Several urban-dwelling songbird species appear to counteract the masking effects of traffic noise by singing at a higher pitch, increasing song amplitude, or singing during periods of low traffic noise
- Some lighting structures attract migrating bird species, which increases the probability they will be preyed on or collide with structures and often causes them to redirect flight paths and thus deplete energy stores
- Artificial lighting can also affect avian patterns of nestling development, singing, breeding, molting, and migration
- Changing roadway lighting may also benefit both birds and people through reductions in energy consumption and increases in safety
- The edge effects of roads may be particularly acute when introduced species, such as rats, prey on ground nesting birds or parasitic species, such as Brown-headed Cowbirds, target the nests of species of conservation concern
- The unvegetated area created by light-rail train tracks is more permeable to bird movement than roads of equivalent sizes, perhaps because they are quieter

* * *

Diet composition of common ravens across the urban-wildland interface of the West Mojave Desert
Kristan III WB, Boarman WI, Crayon JJ, 2004. Wildlife Society Bulletin 2004, 32(1), pp 244-253.

Summary: The importance of human-provided resources to raven population growth is supported by the observation that proximity to human developments, such as housing, landfills, sewage treatment ponds, and roads, augments raven reproductive success.

Highlights: Ravens are generalists in foraging ecology and diet and are capable of exploiting a variety of anthropogenic resources.

Purpose: Evaluate the effects of human developments on the relative composition of food items that can be detected in raven pellets

Results:

- The rapid increase in raven populations has become a management concern because large raven populations may harm species such as the threatened desert tortoise

- The primary study area was within the western half of Edwards Air Force Base (EAFB) and on lands immediately surrounding the base in the West Mojave Desert of California
- During springs 1999 and 2000 collected pellets from beneath known raven nests
- Nest locations were known from concomitant studies of raven breeding biology
- Nest searching was conducted each year from 1996 to 2000;by 1999 observed 261 nests (of which 150 exhibited some degree of breeding activity), and by 2000 observed 341 nests (of which 168 exhibited some degree of breeding activity)
- Nests were distributed throughout the study area
- Collected pellets opportunistically during reproductive monitoring, and made collections from 42 nests in 1999 and from 72 nests in 2000; because collections were made from some of the same nests in both years, made collections from 98 different nests over the 2 years, distributed throughout the study area
- The number of pellets from a nest ranged from 1–44, and analyzed 1,142 items from 560 pellets
- Identified plant and animal remains to species when possible
- Interpreted the presence of pieces of paper or plastic or other artificial, nonfood items in a pellet as consumption of trash
- Measured distance between each nest and the nearest paved road and nearest point subsidy using Geographic Information System (GIS) maps
- “Point subsidies” consisted of any potential source of food found on the study area that could be represented by a point or polygon on a map and included housing developments, landfills, and artificial water bodies (e.g., sewage ponds, artificial wetlands, permanent artificial ponds)
- Found mammals in 76.5% of pellets, arthropods at 81.6% of nests and in 37.4% of pellets. Trash was present at 57.1% of nests and in 24.2% of pellets
- Nests from which pellet collections were obtained were found up to 8 km from the nearest road and up to12 km from the nearest point subsidy
- Nests close to both subsidies and roads had more birds and amphibians
- Nests close to roads and far from subsidies had greater numbers of mammals and reptiles
- Pellets from nests far from both roads and subsidies had greater amounts of plant material and more arthropods
- Pairs with more anthropogenically enhanced diets fledged more chicks
- Known biases in pellet-based diet studies, since pellets contain indigestible components of food such as bone, feather, and fur, the highly digestible foods such as muscle tissue are underestimated by pellet analysis
- Reducing the availability of food subsidies to ravens may reduce predation pressure on the threatened desert tortoise population, thereby aiding in its recovery

Results: suggest that ravens forage opportunistically on foods available near their nests, and different kinds of human developments contribute different foods. Improved management of landfills and highway fencing to reduce road-kills may help slow the growth of raven populations in the Mojave.

How long do the dead survive on the road? Carcass Persistence Probability and Implications for Road-Kill Monitoring Surveys. Santos SM, Carvalho F, Mira A, 2011. PLoS One, Online Publication. Sep 2011, Vol. 6, Issue 9, e25383.

Summary: Daily surveys of road-killed vertebrates were conducted over one year along four road sections with different traffic volumes. Survival analysis was then used to i) describe carcass persistence timings for overall and for specific animal groups; ii) assess optimal sampling designs according to research objectives; and iii) model the influence of road, animal and weather factors on carcass persistence probabilities. Most animal carcasses persisted on the road for the first day only, with some groups disappearing at very high rates. The advisable periodicity of road monitoring that minimizes bias in road mortality estimates is daily monitoring for bats (in the morning) and lizards (in the afternoon), daily monitoring for toads, small birds, small mammals, snakes, salamanders, and lagomorphs; 1 day-interval (alternate days) for large birds, birds of prey, hedgehogs, and freshwater turtles; and 2 day-interval for carnivores. Multiple factors influenced the persistence probabilities of vertebrate carcasses on the road. Overall, the persistence was much lower for small animals, on roads with lower traffic volumes, for carcasses located on road lanes, and during humid conditions and high temperatures during the wet season and dry seasons, respectively.

Highlights: The guidance given here on monitoring frequencies is particularly relevant to provide conservation and transportation agencies with accurate numbers of road-kills, realistic mitigation measures, and detailed designs for road monitoring programs.

Purpose: The study aims to describe and model carcass persistence variability on the road for different taxonomic groups under different environmental conditions throughout the year; and also to assess the effect of sampling frequency on the relative variation in road-kill estimates registered within a survey.

Results:

- Roads can exert severe impacts upon the long-term viability of animal populations, either through direct killings that decrease the number of individuals (road mortality), or through habitat loss and fragmentation, and barrier effects increasing isolation of populations
- Road mortality is one of the best known and visible impacts of roads on animal populations, with millions of individuals from a wide range of taxonomic groups being killed every year
- The need for effective mitigation measures to minimize impacts of existing and future roads on wildlife populations has thus lead to an increasing body of research relating the spatial patterns of road-kills with both ecological and road features
- Several factors have been referred to affect the accuracy of road mortality estimates, including the rate at which the carcasses decompose, the time interval between the occurrence of mortality and road monitoring, the number of vehicles that pass over the carcass, the visibility of carcasses, the abundance and diversity of scavengers, the weather, and the accuracy and precision of the search method
- Most animal carcasses on roads are quickly dismembered by passing vehicles, eaten or removed by scavengers and predators, or reduced to skeletons by ants and other decomposers
- In the present study, most carcasses remained on the road for the first day only, with some groups disappearing at high rates over this first day
- Animals that are covered by fur, spines or scales are more resistant to vehicles passing over them than amphibians, though some species of amphibian (e.g. Salamandra, salamandra) may remain longer on the road due to their tough skin and unpalatability
- A few situations during field work suggest that, occasionally, persons remove carcasses from the road: intact lagomorphs and partridges recently road-killed (for eating), and carnivores and birds of prey (for taxidermy and scientific studies)
- Suggest monitoring with 2-day intervals for carnivores; alternate days for large birds, birds of prey, hedgehogs, and freshwater turtles; and daily for all other groups
- There are several species that include carrion in their diet. The most common are corvids, birds of prey, and mammalian carnivores; but communities of invertebrate decomposers also are very relevant, due to their abundance and diversity; and hedgehogs and rats also are occasional consumers
- Carcass persistence is lower in summer months than in spring or autumn, due to increased temperatures and the diversity of insect communities, or scavenger activity
- Elevated temperatures during summer increase the formation of volatile and smelly chemicals that can attract scavengers and predators to the carcasses
- Predator and scavenging activity by vertebrates can increase during the dry season due to the greater energy needs of seasonal offspring and the later abundance of juveniles

- Other explanatory variables were: classes of traffic volume for each road section, mean body mass and length of each species, and average meteorological conditions during the period of carcass persistence (proportion of days with rainfall, amount of rainfall, mean daily temperature, minimum daily temperature and maximum daily temperature)
- The carcass removal by scavengers and predators should be studied further in different regions and landscape contexts because, besides differences in population abundances, scavengers and predators with different sizes, periods of activity or food preferences must affect differently the probabilities of carcass persistence

* * *

Road Ecology. Jaeger, J.A.G., 2012. Invited contribution to the Encyclopedia of Sustainability. Vol. 5; Ecosystem Management and Sustainability. Berkshire Publishing Group, Great Barrington MA, pp. 344-350.

Summary: Dr. Jaeger was invited to contribute a section on road ecology in a book publication of Ecosystem Management and Sustainability. It is an overview on roads and traffic effects on; biodiversity, wildlife fatalities, habitat isolation, wildlife genetics and ability to recolonize areas. It provides information for planners to consider impacts and long term effects on future development and improvements to existing roads.

Highlights: Along with being a threat to wildlife in respect to fatalities, roads also fragment and overtake habitat and create edge effects. This edge zone is explained as how far into the landscape do roads effect wildlife. It has been estimated that wildlife is affected from road edge, up to:

- 40 – 2,800 meters for birds
- 250 – 1,000 (+) for amphibians
- 17 km for mammals (Forman et al. 2003; Benitez-Lopez, Alkemade, Verweij, 2010)

Other research has indicated annual global wildlife fatalities number from 100 thousand to several 100 million in various countries. In Europe fatalities reached 500,000 of hoofed animals and more than 8 million birds in Sweden (Seiler, 2003). A theory of the high rate of avian fatalities is they are not able to reach clearance height from trees bordering roadways and are subsequently hit by passing vehicles.

Wildlife has the ability to adapt to changes however ongoing research is required to study long-term changes to population numbers and habitat (ie: food chain) in order to obtain a clear picture of effects. The term *extinction debt* has been applied by ecologists (Tilman et al. 1994) to help planners strategize road implementation and its effects to biodiversity. This includes assessing existing impacted areas and implementing mitigation plans for surrounding landscape development.

Mitigation involves taking advantage of existing land elevations and contours and includes overpasses, underpasses, fencing and raised roads. When considering these options in the capacity of species conservation, assessment of existing habitat is essential. It may not be possible to restore heavily fragmented areas.

* * *

APPENDIX F

City of Brampton Road Traffic Survey

MetroCount Traffic Executive
Weekly Vehicle Counts

WeeklyVehicle-460 -- English (ENC)

Datasets:

Site: **[FQ37D7NE] MCSetup factory setup**
Direction: 1 - North bound, A hit first. **Lane:** 0
Survey Duration: 5:16 2013/06/07 => 3:55 2013/06/14
Zone:
File: FQ37D7NE14Jun2013Heart Lake Rd N of #410 Exit TURTLE NS.eco (Plus)
Identifier: FQ37D7NE MC56-L5 [MC55] (c)Microcom 19Oct04
Algorithm: Factory default (v3.21 - 15315)
Data type: Axle sensors - Paired (Class/Speed/Count)

Profile:

Filter time: **5:17 2013/06/07 => 3:55 2013/06/14**
Included classes: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
Speed range: 10 - 160 km/h.
Direction: North, East, South, West (bound)
Separation: All - (Headway)
Name: Default Profile
Scheme: Vehicle classification (Scheme F2)
Units: Metric (meter, kilometer, m/s, km/h, kg, tonne)
In profile: Vehicles = 41613 / 41683 (99.83%)

Weekly Vehicle Counts

WeeklyVehicle **-460**
Site: FQ37D7NE.0.0N
Description: **MCSetup factory setup**
Filter time: **5:17 2013/06/07 => 3:55 2013/06/14**
Scheme: Vehicle classification (Scheme F2)
Filter: Cls(1 2 3 4 5 6 7 8 9 10 11 12 13) Dir(NESW) Sp(10,160) Headway(>0)

```
                 Mon       Tue       Wed       Thu       Fri       Sat       Sun     Averages
              03 Jun    04 Jun    05 Jun    06 Jun    07 Jun    08 Jun    09 Jun     1 - 5     1 - 7
Hour                                                                              |
0000-0100          *         *         *         *         *        73        52 |       *      62.5
0100-0200          *         *         *         *         *        37        26 |       *      31.5
0200-0300          *         *         *         *         *        22        22 |       *      22.0
0300-0400          *         *         *         *         *        17         9 |       *      13.0
0400-0500          *         *         *         *         *        17         7 |       *      12.0
0500-0600          *         *         *         *        44        29        16 |    44.0      29.7
0600-0700          *         *         *         *       183        89        34 |   183.0     102.0
0700-0800          *         *         *         *       366       132        86 |   366.0     194.7
0800-0900          *         *         *         *       349       241       199 |   349.0     263.0
0900-1000          *         *         *         *       239       307       318 |   239.0     288.0
1000-1100          *         *         *         *       270       401       447 |   270.0     372.7
1100-1200          *         *         *         *       274       525<      540<|   274.0     446.3<
1200-1300          *         *         *         *       306       558       547 |   306.0     470.3
1300-1400          *         *         *         *       329       538      1108 |   329.0     658.3
1400-1500          *         *         *         *       344       512      1275<|   344.0     710.3<
1500-1600          *         *         *         *       475       628<      871 |   475.0     658.0
1600-1700          *         *         *         *       522<      565       630 |   522.0<    572.3
1700-1800          *         *         *         *       479       454       519 |   479.0     484.0
1800-1900          *         *         *         *       424       375       360 |   424.0     386.3
1900-2000          *         *         *         *       387       266       274 |   387.0     309.0
2000-2100          *         *         *         *       254       188       235 |   254.0     225.7
2100-2200          *         *         *         *       201       147       141 |   201.0     163.0
2200-2300          *         *         *         *       151        93        89 |   151.0     111.0
2300-2400          *         *         *         *        85        77        49 |    85.0      70.3
                                                                                  |
Totals      ______________________________________________________________________|__________________
                                                                                  |
0700-1900          *         *         *         *      4377      5236      6900 |  4377.0    5504.3
0600-2200          *         *         *         *      5402      5926      7584 |  5402.0    6304.0
0600-0000          *         *         *         *      5638      6096      7722 |  5638.0    6485.3
0000-0000          *         *         *         *         *      6291      7854 |       *    6656.0
                                                                                  |
AM Peak            *         *         *         *         *      1100      1100 |
                   *         *         *         *         *       525       540 |
                                                                                  |
PM Peak            *         *         *         *      1600      1500      1400 |
                   *         *         *         *       522       628      1275 |

* - No data.
```

Weekly Vehicle Counts

WeeklyVehicle **-460**
Site: FQ37D7NE.0.0N
Description: **MCSetup factory setup**
Filter time: **5:17 2013/06/07 => 3:55 2013/06/14**
Scheme: Vehicle classification (Scheme F2)
Filter: Cls(1 2 3 4 5 6 7 8 9 10 11 12 13) Dir(NESW) Sp(10,160) Headway(>0)

```
                 Mon      Tue      Wed      Thu      Fri      Sat      Sun    Averages
              10 Jun   11 Jun   12 Jun   13 Jun   14 Jun   15 Jun   16 Jun    1 - 5    1 - 7
Hour                                                                       |
0000-0100         27       19       40       32        1        *        * |   23.8     23.8
0100-0200          9        8       11       18        0        *        * |    9.2      9.2
0200-0300          9        7        8        5        0        *        * |    5.8      5.8
0300-0400          9        7        6        6        0        *        * |    5.6      5.6
0400-0500         17       17       18       25        *        *        * |   19.3     19.3
0500-0600         77       72       80       72        *        *        * |   75.3     75.3
0600-0700        205      198      215      215        *        *        * |  208.3    208.3
0700-0800        407     432<     400<      411        *        *        * | 412.5<   412.5<
0800-0900       435<      388      399     417<        *        *        * |  409.8    409.8
0900-1000        295      250      263      263        *        *        * |  267.8    267.8
1000-1100        205      232      261      245        *        *        * |  235.8    235.8
1100-1200        230      248      311      259        *        *        * |  262.0    262.0
1200-1300        250      256      335      303        *        *        * |  286.0    286.0
1300-1400        275      304      323      310        *        *        * |  303.0    303.0
1400-1500        326      358      351      355        *        *        * |  347.5    347.5
1500-1600        329      360      401      373        *        *        * |  365.8    365.8
1600-1700        343      477      458      428        *        *        * |  426.5    426.5
1700-1800       360<     503<     560<     474<        *        *        * | 474.3<   474.3<
1800-1900        304      469      471      438        *        *        * |  420.5    420.5
1900-2000        225      351      364      316        *        *        * |  314.0    314.0
2000-2100        163      279      230      299        *        *        * |  242.8    242.8
2100-2200         98      178      206      214        *        *        * |  174.0    174.0
2200-2300         49      108       89      109        *        *        * |   88.8     88.8
2300-2400         46       53       69       62        *        *        * |   57.5     57.5
                                                                           |
Totals    _________________________________________________________________|________________
                                                                           |
0700-1900       3759     4277     4533     4276        *        *        * | 4211.3   4211.3
0600-2200       4450     5283     5548     5320        *        *        * | 5150.3   5150.3
0600-0000       4545     5444     5706     5491        *        *        * | 5296.5   5296.5
0000-0000       4693     5574     5869     5649        *        *        * | 5435.4   5435.4
                                                                           |
AM Peak         0800     0700     0700     0800        *        *        * |
                 435      432      400      417        *        *        * |
                                                                           |
PM Peak         1700     1700     1700     1700        *        *        * |
                 360      503      560      474        *        *        * |

* - No data.
```

APPENDIX G

Mock Culvert and Wildlife Directional Fencing Study

Studies are being undertaken globally to understand methods to address WVCs and implement mitigation. This mock culvert pilot study was undertaken to assist with addressing mitigation strategies at the Heart Lake Road Provincially Significant Wetland (PSW) complex and make an effort to reduce WVCs.

Following 2011 Phase I study, project partners agreed to pursue a project to determine suitable mitigation for SA. The pilot project location (Figure 1 and 2) is north of HLCA on the west side of Heart Lake Road. This area was chosen from data collected in 2011, examining existing historical wildlife data collected by TRCA and consultations with TRCA Ecology staff. To determine what type of mitigation would work best, TRCA and OREG chose three wildlife passage designs. Three pieces of culvert were chosen consisting of a DIMENSIONS corrugated steel pipe (CSP) , a DIMENSIONS concrete box culvert, a 500 mm ACO Amphibian Tunnel and ACO one-way wildlife directional fencing. CoB donated the CSP and box culvert, ACO Systems Ltd donated the ACO Amphibian Tunnel and TRCA purchased 80 meters of ACO wildlife directional fencing. ACO one-way fencing was chosen because of its permanent and durable features and inside curve design. This curved design along the inside allows wildlife (small mammals, reptiles and amphibians) to be directed towards a specific area of passage. In addition, the outside slope allows wildlife on the road access to wetland habitat.

Figure 1 –Pilot project location west side, Mar 25-13

Figure 2 - Pilot project location west side, Jun 18-13

On March 26, 2013, a crew of 2 field staff 5 days (total of 60 man-hours), began installing 80 meters of ACO one-way wildlife fence (Figure 3). Installation was targeted to ensure equipment was in place to monitor and assess early spring emerging amphibians moving to breeding areas. The edges of ACO fence curve inward (Figure 4) to guide target species towards three mock culverts, each two (2) metres in length. Any vegetation that facilitated wildlife from crossing over the inside portion of fencing was cut back. The pilot project site is an existing natural area with abundant existing vegetation, woody debris, wet areas and uneven ground which proved to be a challenge during installation. To properly anchor fencing, ground conditions must be relatively level for each section of fence to connect and prevent gaps along each section and lower edge of this product. Smaller wildlife are capable of navigating through very small areas therefore effectively sealing seams of fencing is essential for animals to reach passages. A large portion of man-hours were spent clearing vegetation, cutting woody debris and levelling the ground. Additional challenges were efforts made to collect vegetation and surrounding soils to create a “natural” ramp leading up the outside edge of fencing. This ramp would allow wildlife access to wetlands from the road (Figure 5 and 6).

As this is a sensitive area (PSW), staff were prohibited from using heavy machinery to clear debris, downed wood and level the ground. All work related to the 1m wide, 80m long fencing was accomplished using hand tools. In sites where heavy equipment is used, installation time is considerably shorter (approximately 2 days). Examples of installing the same length of product with machinery in a newly constructed or level site with minimal vegetation would take considerably less time. Additional time would be required to create the ramp on the back side of fencing and time allotted would depend on source and location of materials being used. Although not experts with this ACO product, valuable lessons were learned throughout installation.

Figure 3 –Staff installing ACO directional fence

Figure 4 – Inside edge of ACO directional fence

Figure 5 – ACO fence banked material

Figure 6 – ACO fence with banked natural material

All safety measures were in place and permits were obtained prior to installation and on March 29, 2013, three mock culverts were put into place via crane (Figure 7 and 8). They were placed at a central point of the two sections of fencing allowing species passage between wetlands in a west to east direction. Once in place, textile fencing was extended from the edge of the ACO fencing to the edge of the culverts to create a "landing area" to culvert entrances (Figure 9 and 10).

Figure 7 – Crane positioning culverts

Figure 8 – Culverts in place

Figure 9 Textile fabric extension

Figure 10 – Textile fabric at culverts

Additional fabric fencing was added to the far north and south ends of the ACO fencing extending into forested areas. This allowed additional guidance for wildlife from woodland areas to access mock-culverts. On April 5, 2013, pitfalls with drainage holes (Figure 11) and secure lids (Figure 12) were placed at each end of directional fencing (Figure 13), as well as exits of each culvert (Figure 14). These pitfalls allowed monitoring staff to safely transport wildlife across the road during breeding season. Lids were tightly secured and covered with woody debris to prevent wildlife entering between monitoring sessions.

Figure 11 – Pitfall with drainage

Figure 12 – Securing pitfall lid

Figure 13 – South pitfall

Figure 14 – Pitfall at culvert exit

Figure 15 – Mock culverts and ACO wildlife directional fencing in place

Although effective data related to wildlife passage was not able to be determined, valuable lessons were learned related to specific aspects of material used.

ACO directional wildlife fencing is most conducive to new construction sites with level ground, where the product can be installed with minimal chance of wildlife escaping through gaps in each section and where the base meets ground surface.

Challenges associated with installation and use of this product, in areas adjacent to Heart Lake Road includes:

- Non-level surface grade which created gaps in fence sections and base;
- insufficient natural debris available on site to create ramp on outside of fence;
- permits required to transport remote fill material into the PSW;
- amount of fill required to create ramp along entire stretch of directional fencing; and
- high water levels resulting in product shifting

Precipitation and high water levels of the wetland throughout the season of 2013, created additional challenges associated with initiating monitoring such as:

- culvert water levels allowed species to swim through;
- pitfalls were below water level and ineffective;
- water levels extended beyond culvert exits;
- wildlife cameras were unable to be installed at entrance and exit areas; and
- sections of fencing became submersed.

Following outcomes of 2013 pilot study efforts TRCA staff and project partners are considering several options to address challenges encountered during this study. TRCA has outreached to engage a graduate student to assist with leading monitoring studies related to this project. It is intended to readdress dynamics of the location of culverts and associated factors to ensure a non-biased study can be conducted. Consideration will be given to relocate the culverts to higher ground providing a buffer from potentially high water levels. Additionally staff will conduct further research to reduce bias associated with the study.

It is the intention of TRCA and partners to move forward in 2014, pending on adequate staff and funding to support completion of the study and share results with CoB to better inform them for future mitigation.

APPENDIX H

Cost Estimates

Class D Cost Estimate for Short-Term Improvement | Trail Connection through HLCA

No.	Description	Quantity	Unit	Total Cost
1	Inititation and Start-Up	1	L.S.	$ 15,000.00
2	Meetings	1	L.S.	$ 5,000.00
3	Reports	2	L.S.	$ 10,000.00
4	Planning	1	L.S.	$ 30,000.00
5	30% Design Submission	16	Drawing	$ 15,000.00
	60% Design Submission	16	Drawing	$ 20,000.00
	90% Design Submission	16	Drawing	$ 25,000.00
	100% Design Submission	16	Drawing	$ 30,000.00
6	IFC Submission	16	Drawing	$ 30,000.00
Total				$ 180,000.00

No.	Description	Quantity	Unit	Total Cost
1	Earth Excavation and Grading	760	m^3	$ 50,000.00
2	Gravel Pathway (3.0 m Multi-Use Path)	2280	m^2	$ 100,000.00
3	Landscaping	1	L.S.	$ 80,000.00
4	Misc (50%)	1	L.S.	$ 115,000.00
Total				$ 345,000.00

Grand Total (Planning, Detailed Design, and Construction Costs) **$ 525,000.00**

Cost Estimate - Long Term
Heart Lake Road

Item Description	QUANTITY	Unit	Unit rate	TOTAL (without taxes)	Bicycle Pathway	Countryside Drive Roundabout	Mini Roundabout	Culvert 0+800	Culvert 0+300
Pavement removal	75626	m^2	10.00 $	75,626.00		42,500.00 $	16,330.00 $	1,564.00 $	15,232.00 $
Fill	0	m^3	18.00 $	0.00		0.00 $	0.00 $	0.00 $	0.00 $
Earth Borrow	81486	m^3	18.00 $	81,486.00		37,800.00 $	6,300.00 $	1,350.00 $	36,036.00 $
Excavation	146970	m^3	18.00 $	146,970.00		64,656.00 $	39,600.00 $	34,650.00 $	8,064.00 $
Proposed CB, Ø915mm, Grate included	56100	Unit	3,300.00 $	56,100.00		39,600.00 $	16,500.00 $	0.00 $	0.00 $
Mainhole, Ø1200mm, Cover included	14715	Unit	4,905.00 $	14,715.00		9,810.00 $	4,905.00 $	0.00 $	0.00 $
Conduits, Storm Drainage, PVC, Ø250mm	99000	m	225.00 $	99,000.00		81,000.00 $	18,000.00 $	0.00 $	0.00 $
Excavating, Backfilling, Cutting and Repairing Coatings for electrical trench	124000	m	200.00 $	40,000.00		84,000.00 $	40,000.00 $	0.00 $	0.00 $
Concrete sidewalk	1500	m^2	100.00 $	1,500.00		1,500.00 $	0.00 $	0.00 $	0.00 $
Concrete curbs	65715	m	65.00 $	65,715.00		52,455.00 $	13,260.00 $	0.00 $	0.00 $
Concrete median	54240	m^2	160.00 $	54,240.00		52,800.00 $	1,440.00 $	0.00 $	0.00 $
Bicycle Pathway	**0**	m^2	50.00 $	0.00	382,500.00 $	0.00 $	0.00 $	0.00 $	0.00 $
Flexible Bollards	**520**	unit	30.00 $	0.00	15,600.00 $				
Stormtech Culvert plus installation	16000	Unit	8,000.00 $	16,000.00		0.00 $	0.00 $	8,000.00 $	8,000.00 $
Heart Lake Rumble Strips	8400	m	1.50 $	8,400.00		600.00 $	7,800.00 $	0.00 $	0.00 $
Roadway pavement	307940	t	89.00 $	307,940.00		144,180.00 $	59,630.00 $	6,230.00 $	97,900.00 $
Granular A, 200mm	69792	m^3	50.00 $	69,792.00		37,500.00 $	15,500.00 $	1,560.00 $	15,232.00 $
Granular B, 500mm	72738	m^3	30.00 $	72,738.00		24,300.00 $	23,250.00 $	2,340.00 $	22,848.00 $
Concrete guardrail	0	m	500.00 $	0.00		0.00 $	0.00 $	0.00 $	0.00 $
Turtel Fence	54000	m	45.00 $	54,000.00		0.00 $	54,000.00 $	0.00 $	0.00 $
Pavement Marking 120mm	4678	m	2.00 $	4,678.00		1,640.00 $	2,518.00 $	70.00 $	450.00 $
Stop Line 400mm	0	m	50.00 $	0.00		0.00 $	0.00 $	0.00 $	0.00 $
Hatch 400mm	0	m	10.00 $	0.00		0.00 $	0.00 $	0.00 $	0.00 $
Arrows for lane slection	0	Unit	75.00 $	0.00		0.00 $	0.00 $	0.00 $	0.00 $
Pavement marking removal	625	m	2.50 $	625.00		0.00 $	625.00 $	0.00 $	0.00 $
Roadside Signalisation Installation	6000	Unit	1,000.00 $	6,000.00		3,000.00 $	3,000.00 $	0.00 $	0.00 $
Lighting	228000	m	400.00 $	228,000.00		168,000.00 $	60,000.00 $	0.00 $	0.00 $
Grass by plate, Type P-1	36750	m^2	5.00 $	36,750.00		17,500.00 $	12,500.00 $	1,250.00 $	5,500.00 $
Topsoil, 150mm	36750	m^2	5.00 $	36,750.00		17,500.00 $	12,500.00 $	1,250.00 $	5,500.00 $
Surface Ditch profiling	24000	m	40.00 $	24,000.00		16,800.00 $	7,200.00 $	0.00 $	0.00 $
Lighting Pole Displacement	0	Unit	7,000.00 $	0.00		0.00 $	0.00 $	0.00 $	0.00 $
Hydro Pole Displacement	50000	Unit	10,000.00 $	50,000.00		50,000.00 $	0.00 $	0.00 $	0.00 $
				1,551,025.00	**398,100.00**	**947,141.00**	**414,858.00**	**58,264.00**	**214,762.00**
		30%	Contingency	465,307.50	119,430.00	284,142.30			
			Total :	**2,016,332.50**	**517,530.00**	**1,231,283.30**			
		5,000 $		**2,015,000 $**	**520,000 $**	**1,230,000 $**			

Cost Estimate - Short Term
Heart Lake Road

Item Description	QUANTITY	Unit	Unit rate	TOTAL (without taxes)	HLR	Mini Roundabout	Culvert 0+800	Culvert 0+300
Pavement removal	33126	m^{2}	10.00 $	33,126.00		16,330.00 $	1,564.00 $	15,232.00 $
Fill	0	m^{3}	18.00 $	0.00		0.00 $	0.00 $	0.00 $
Earth Borrow	43686	m^{3}	18.00 $	43,686.00		6,300.00 $	1,350.00 $	36,036.00 $
Excavation	82314	m^{3}	18.00 $	82,314.00		39,600.00 $	34,650.00 $	8,064.00 $
Proposed CB, Ø915mm, Grate included	16500	Unit	3,300.00 $	16,500.00		16,500.00 $	0.00 $	0.00 $
Mainhole, Ø1200mm, Cover included	4905	Unit	4,905.00 $	4,905.00		4,905.00 $	0.00 $	0.00 $
Conduits, Storm Drainage, PVC, Ø250mm	18000	m	225.00 $	18,000.00		18,000.00 $	0.00 $	0.00 $
Excavating, Backfilling, Cutting and Repairing Coatings for electrical trench	40000	m	200.00 $	40,000.00		40,000.00 $	0.00 $	0.00 $
Concrete sidewalk	0	m^{2}	100.00 $	0.00		0.00 $	0.00 $	0.00 $
Concrete curbs	13260	m	65.00 $	13,260.00		13,260.00 $	0.00 $	0.00 $
Concrete median	1440	m^{2}	160.00 $	1,440.00		1,440.00 $	0.00 $	0.00 $
Bicycle Pathway	0	m^{2}	50.00 $	0.00		0.00 $	0.00 $	0.00 $
Stormtech Culvert plus installation	16000	Unit	8,000.00 $	16,000.00		0.00 $	8,000.00 $	8,000.00 $
Heart Lake Rumble Strips	0	m	1.50 $	7,800.00	7,800.00 $	0.00 $	0.00 $	0.00 $
Roadway pavement	163760	t	89.00 $	163,760.00		59,630.00 $	6,230.00 $	97,900.00 $
Granular A, 200mm	32292	m^{3}	50.00 $	32,292.00		15,500.00 $	1,560.00 $	15,232.00 $
Granular B, 500mm	48438	m^{3}	30.00 $	48,438.00		23,250.00 $	2,340.00 $	22,848.00 $
Concrete guardrail	0	m	500.00 $	0.00		0.00 $	0.00 $	0.00 $
Turtel Fence	54000	m	45.00 $	54,000.00		54,000.00 $	0.00 $	0.00 $
Pavement Marking 120mm	520	m	2.00 $	3,038.00	2,518.00 $	0.00 $	70.00 $	450.00 $
Stop Line 400mm	0	m	50.00 $	0.00		0.00 $	0.00 $	0.00 $
Hatch 400mm	0	m	10.00 $	0.00		0.00 $	0.00 $	0.00 $
Arrows for lane slection	0	Unit	75.00 $	0.00		0.00 $	0.00 $	0.00 $
Pavement marking removal	0	m	2.50 $	625.00	625.00 $	0.00 $	0.00 $	0.00 $
Roadside Signalisation Installation	3000	Unit	1,000.00 $	3,000.00		3,000.00 $	0.00 $	0.00 $
Lighting	60000	m	400.00 $	60,000.00		60,000.00 $	0.00 $	0.00 $
Grass by plate, Type P-1	19250	m^{2}	5.00 $	19,250.00		12,500.00 $	1,250.00 $	5,500.00 $
Topsoil, 150mm	19250	m^{2}	5.00 $	19,250.00		12,500.00 $	1,250.00 $	5,500.00 $
Surface Ditch profiling	7200	m	40.00 $	7,200.00		7,200.00 $	0.00 $	0.00 $
Lighting Pole Displacement	0	Unit	7,000.00 $	0.00		0.00 $	0.00 $	0.00 $
Hydro Pole Displacement	0	Unit	10,000.00 $	0.00		0.00 $	0.00 $	0.00 $
Speed Cushions				2,500.00	2,500.00 $			
				690,384.00	**13,443.00**	**403,915.00**	**58,264.00**	**214,762.00**
		30%	Contingency	207,115.20	4,032.90	121,174.50	17,479.20	64,428.60
			Total :	**897,499.20**	**17,476**	**525,090**	**75,743**	**279,191**
		2,500 $		**897,500 $**	**17,500 $**	**525,000 $**	**75,000 $**	**280,000 $**

Figure 49: Roundabout at Countryside Option 1 (with encroachment on TRCA lands)

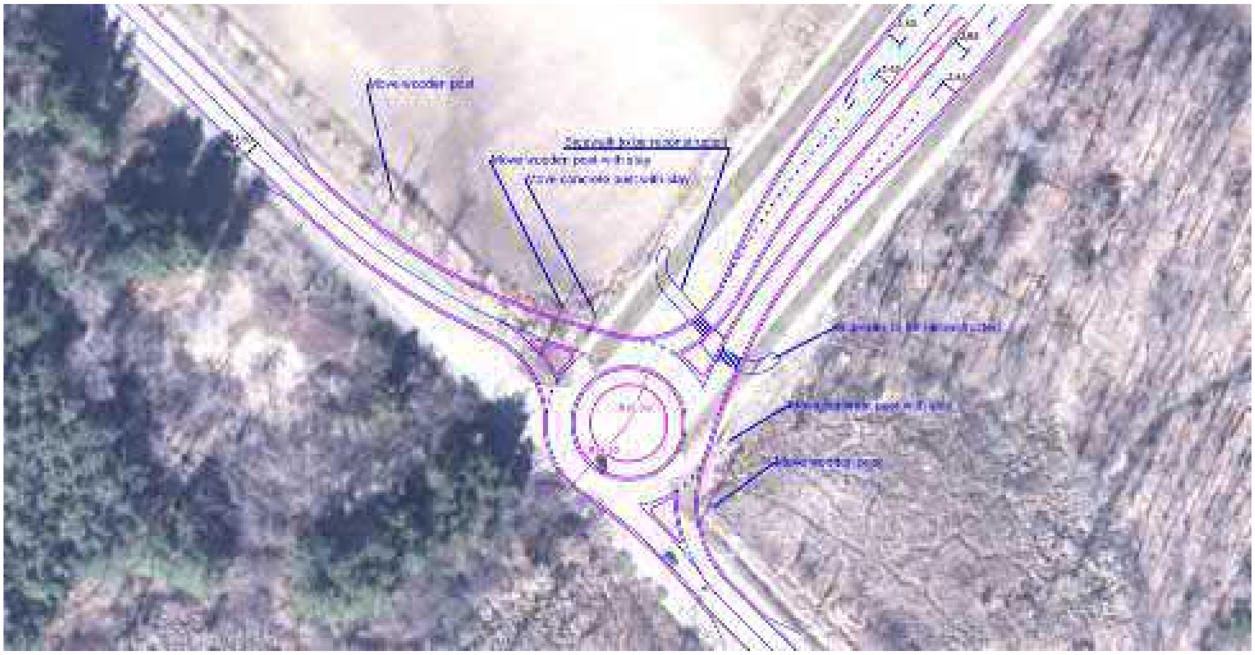


Figure 50: Roundabout at Countryside Option 2 (without encroachment on TRCA lands)